P_14

HERITAGE AND CARBON ZERO

Responding to the Climate Emergency

Lancaster City Council Heritage and Design Team

May 2021

LANCASTER CITY COUNCIL
Promoting City, Coast & Countryside

List of Abbreviations

ASHP	Air Source Heat Pump
BRE	Building Research Establishment
CPRE	The Campaign for the Protection of Rural England
EPC	Energy Performance Certificate
GSHP	Ground Source Heat Pump
HEET	Oxford Heritage Energy Efficiency Tool
IGU	Insulated Glass Unit
IHBC	Institute of Historic Building Conservation
LCA	Life Cycle Assessment
PV Panels	Photovoltaic Panels
RICS	Royal Institute of Chartered Surveyors
SAP/RdSAP	Standard Assessment Procedure
SPAB	Society for the Protection of Ancient Buildings
STBA	Sustainable Traditional Buildings Alliance
WSHP	Water Source Heat Pump

Cover: *The Chapter House, Cockersand Abbey – Grade I*

Summary

The IPCC Special Report *Global Warming of 1.5^{o}C* (IPCC 2018) has made it clear that immediate and profound changes are now necessary in order to slow the progress and mitigate the effects of the climate crisis. On 30th January 2019, Lancaster City Council voted to declare a Climate Emergency (Lancaster City Council 2019). This action has made it necessary for all aspects of Local Authority functions and policies to be reviewed in light of the new target of carbon zero by 2030. The purpose of this report is therefore to appraise current Conservation policies and practice, and to offer options for how they might adapt in light of the Climate Emergency. These options may be used as background evidence for the Climate Emergency Review of the Local Plan (2020-2031).

Contents

Introduction

Background

The practice of heritage conservation occupies a complex position in the current context of environmental crisis. In many ways, the philosophy of maintenance and re-use which underpins it is consistent with the task of achieving carbon zero. The energy expended in material extraction, construction, operation, maintenance, repair and demolition are all aspects of the built environment which must now be taken into serious consideration, and a preference for the retention and re-use of existing buildings over new construction will be logical and necessary moving forward. Nevertheless, many of the commonly adopted principles for reducing environmental impact are not applicable to historic buildings, where they can be harmful to building fabric, occupant health and heritage value.

Responsible Retrofit of historic buildings offers a solution. Intelligent adaptations based on a growing repository of research will allow the district to progress towards carbon neutrality while simultaneously continuing to reap the benefits of its diverse heritage.

The Climate Crisis

This document sets out Lancaster City Council's conservation response to the goal of reaching carbon zero by 2030. It will mean working with historic buildings in new and creative ways in order to ensure that their environmental impact is minimised.

It is vital to remember, however, that the climate crisis is also posing an increasing risk to our district's heritage itself, and that the Conservation Team faces unprecedented challenges in protecting it. It is likely that increasing frequency and severity of floods; increasing frequency and volume of rainfall; rapid variations and extremes of temperature; and coastal change will pose a serious risk which it is our responsibility to understand and address.

The Conservation Team has adopted the following objectives to guide our activities moving forward:

O1. Understanding the nature and value of our district's heritage
O2. Monitoring and assessing the capacity for change
O3. Responsibly adapting to environmental and climate changes
O4. Monitoring the effects of the changing climate on our district's heritage
O5. Recording heritage where it is threatened to be lost

Our activities under O4 have led us to begin a process of evaluating all Heritage Assets in the district in light of their vulnerability to climate change. We have developed a Climate Change Vulnerability Index in order to do so, which is now incorporated into our routine Heritage At Risk surveys. The initial survey results have revealed some of the district's most significant Heritage Assets to be at risk of total loss due to flooding and coastal change.

Therefore, while this document sets out adaptation recommendations according to O2 and O3, it is only one side of the colossal problem posed by the climate crisis which conservation practice in Lancaster must now try to address.

Adaptation and Mitigation: Opportunities and Risks

The options available for adaptation of historic buildings must seek to strike a balance between environmental impact, heritage significance, and user health and comfort. Many of the district's historic buildings were constructed before the industrial revolution, and can offer valuable information about the ways in which everyday life was conducted before reliance on carbon-based energy sources.

Lancaster City Council has a duty in the context of national legislation and local policy to protect the significance of heritage assets in its district. This is a difficult task which is complicated further in light of the climate crisis. The National Planning Policy Framework stipulates that the significance of all heritage assets, designated and non-designated, must be given consideration in planning decisions. In the case of Listed Buildings and Conservation Areas, this is a statutory duty under the Planning (Listed Buildings and Conservation Areas) Act (1990). In most instances, much of a heritage asset's significance lies in its physical fabric. This may mean, for example, that removing historic single glazed windows, or replacing a historic roof covering, would conflict with our duties to ensure that significance is not harmed as these elements may hold evidential, illustrative or aesthetic value. The overall appearance of a heritage asset may also be a factor, especially where its value lies in its architectural design, or where it is part of a homogenous designed landscape or building group. This may mean that to install solar panels on the roof of the building, for example, is impossible from a conservation perspective. There is a risk of harm with every adaptation measure. What is essential is that we are able to continue to maintain whatever it is which lends significance to each particular building, structure and area.

The overwhelming majority of heritage assets in the district are buildings of traditional construction, with solid masonry walls and no integrated moisture barriers. For this reason, the factors and recommendations discussed in this document are largely applicable to buildings built before 1919. Such buildings are designed to perform differently to modern buildings of cavity wall construction. While modern buildings depend on barriers which ensure that the structure is watertight, traditional solid walled buildings cyclically absorb and release moisture through their fabric. This process depends on maintaining an equilibrium of heating and ventilation, which can easily upset by changes to the building.

Generally speaking, energy expended in building operation - through heating, lighting and powering of appliances - is higher for traditional buildings than it is for newly constructed buildings which meet the current standards for energy efficiency. It is from this that many of the concerns in relation to the Climate Emergency stem. However, the comparatively long refurbishment and replacement cycles of traditionally constructed buildings, and the means of production of replacement elements, is such that they may outperform newly constructed buildings in Life Cycle Analysis (LCA).

Historic Scotland (now Historic Environment Scotland) Technical Paper 13, *Embodied energy considerations for existing buildings*, explored the issue of expended energy over the entire life cycle of buildings (Menzies 2011). It concluded that while the embodied energy of existing buildings is not of relevance to the current carbon emissions targets, the comparative potential embodied energy of newly constructed alternatives is. Replacing a building requires significant energy in both demolition and new construction. A comparative case study assessment of LCA by Vaclav et.al. in August 2019 has shown a 53-75% reduction in major environmental impacts for retrofit and renovation of existing buildings compared with construction of new buildings (Vaclav, et al. 2019).

These findings demonstrate that without introducing the potentially damaging retrofit measures which have been routinely recommended in the past, historic buildings do not have the negative environmental impact it was previously presumed they had.

The focus of most retrofit is on improving thermal efficiency. Thermal efficiency of buildings is usually calculated in terms of U-value – that is, the rate of heat transfer through a structure. It has historically been assumed that traditionally-constructed buildings can not be as thermally efficient as cavity wall buildings. However, a growing body of research has proven this assumption too to be incorrect.

Historic Environment Scotland commissioned a series of research papers in 2007-10 which demonstrated that the U-values of typical solid-walled structures in situ are lower than previously assumed (Baker 2008) (Baker 2010). The key finding of the study was that standard software for U-value calculations tended to overestimate U-values of traditional building elements when compared with results from in situ measurements, and that traditional building elements tend to perform better thermally than would be expected from the U-value calculations. This was consolidated by SPAB-commissioned research in 2013, which concluded that U-values are not fit-for-purpose in evaluating the thermal efficiency of traditionally constructed buildings, and advocated for a revised approach to be implemented in such cases (SPAB 2014). These results have been reproduced and refined in the years following (SPAB 2017). The BRE has amended the U-value figures used for their SAP to reflect the findings, so that the current U-value for stone/solid brick walls with 200mm external or internal insulation is listed at 0.18, while filled cavity walls with 200mm external or internal insulation are listed at 0.16 (Building Research Establishment 2016). The possibility must also be anticipated that the emphasis of UK Building Regulations, which is currently on insulation and minimisation of draughts in order to optimise internal building warmth, may be refocussed in future as the effects of the climate crisis make cooling of the internal environment a new priority (Chappells and Shove 2007).

The need for extensive thermal upgrades of traditional buildings is therefore not as great as is often thought. Nevertheless, it will be necessary. The fundamental issue is how buildings of solid-wall construction can be made thermally efficient in a manner appropriate to their designed permeability and heritage value.

Adaptation measures must be based on a sound understanding of the significance of the building, and how it has been constructed. However, there is a general lack of knowledge and understanding of how to determine the significance of historic buildings, and even less of how traditionally constructed buildings react to interventions designed for buildings of modern cavity wall construction. The biggest risk in introducing retrofit measures is their effect on permeability. The measures detailed below may be safely introduced individually, but a combination of several may have a harmful effect. For this reason decisions related to retrofit will have to be made on an individual basis according to the specific requirements of each building, as there is no rule which could be applied as a blanket standard to all buildings in the district. Inadequate permeability poses a risk to building fabric, and occupant health (Bone, et al. 2010). There may also be a risk of overheating in future as temperatures rise. Therefore while the primary focus of this document is addressing thermal efficiency and comfort for occupants – explicitly in keeping warm – the reverse may be true in the future. This should be borne in mind, and the SPAB principle of reversibility should be applied as far as possible in decision-making.

There is currently a lack of specialist contractors and engineers with the ability and experience to successfully implement many of the retrofit measures outlined here. It is anticipated that this will soon be remedied following the introduction of PAS2035:2019, *Retrofitting Dwellings for Improved Energy Efficiency – Specification and Guidance* and PAS2030:2019 *Specification for the Installation of Energy Efficiency Measures (EEM), in existing dwellings and insulation in residential park homes,* which requires a competent ‘retrofit advisor’ to act in a supervisory role for retrofit projects. The retrofit advisor will usually hold a CITB Level 3 Award in the Energy Efficiency and Retrofit of Traditional Buildings. Nevertheless, the industry continues to be dominated by standardised solutions and systems which are not fit for purpose in the case of traditional buildings.

Recommendations

As both the understanding of the nature of the climate crisis and the technologies and processes available to mitigate it are constantly developing, the specifics of adaptation will continue to change in response. The most realistic approach is to establish an overriding strategy for application of the most current information to retrofit in the historic environment.

This strategy must allow some degree of discretion on a case-by-case basis, as the relevant considerations will vary for each heritage asset according to its individual characteristics and heritage significance, as well as the type and number of proposed measures, and how these are likely to interact.

Responsible Retrofit is an approach which provides an appropriate model for such a strategy because it allows this balance to be struck. The approach is governed by the following principles (STBA 2015):

1. Consideration of the balance between Energy and Environment; Building Health; and Heritage and Community
2. Adoption of a Whole Building Approach
3. Adoption of a ‘Joined-up Process’

In practice, it means taking a fully holistic information- and evidence-led approach to policy forming and decision-making. A thorough understanding based on specialist input and up to date research is used to assess the balance between the various harms and benefits to the whole building and wider context. Retrofit measures can be recommended when an appropriate balance has been reached.

For each of the following measures, therefore, the responsible retrofit approach could be adopted when considering their appropriateness in each case.

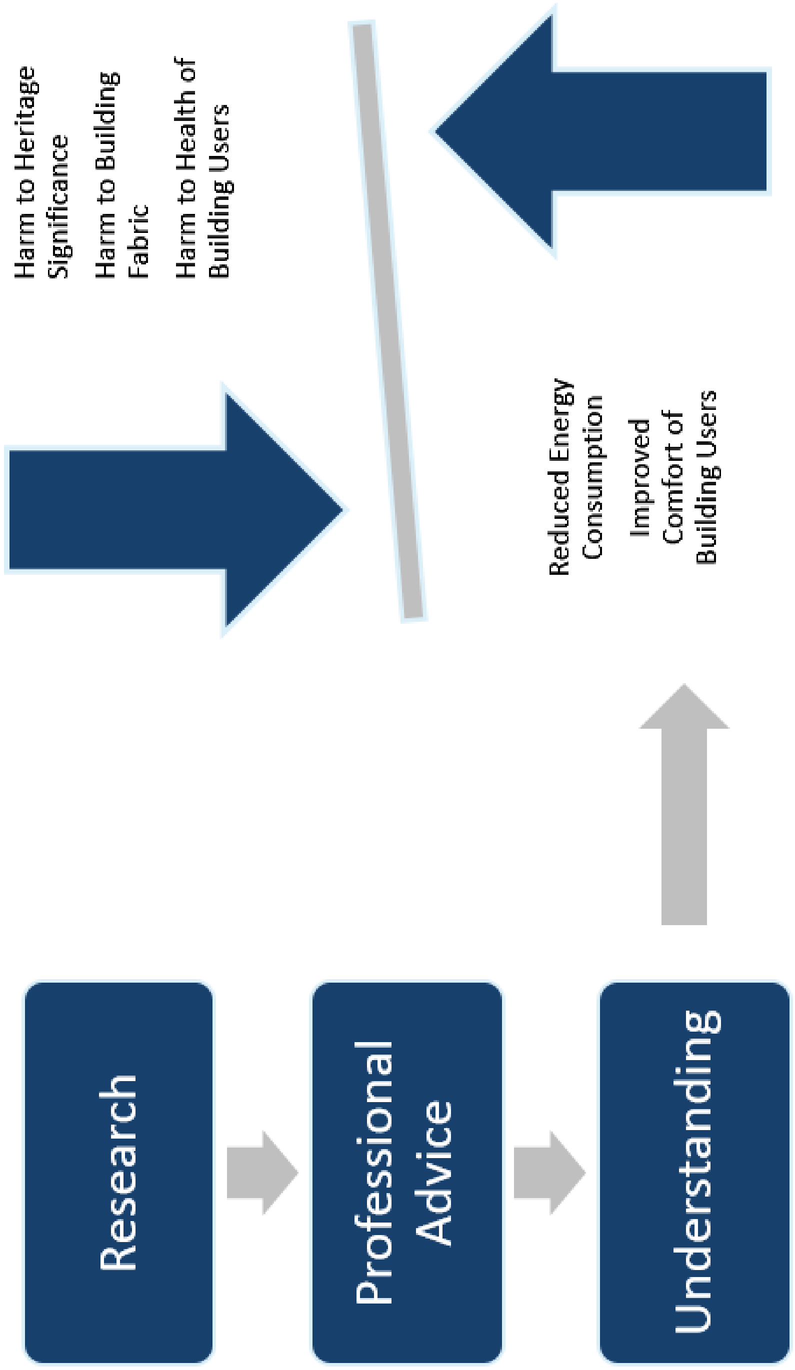


FIGURE 1. THE RESPONSIBLE RETROFIT APPROACH

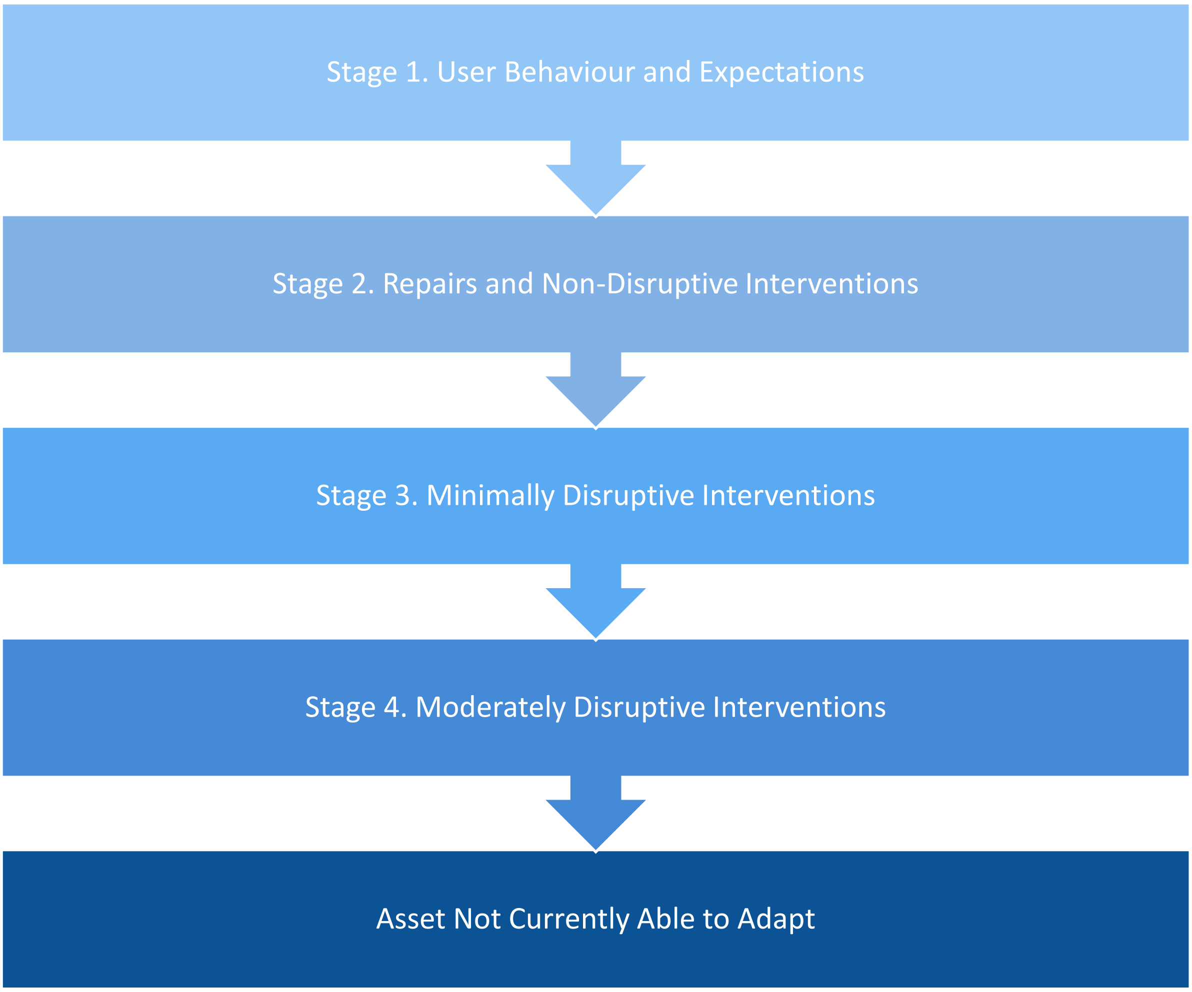
Hierarchy of Adaptation Measures

As a priority, a policy specifically relating to retrofit is recommended for introduction in the revised Development Management DPD.

Following Historic England's guidance for local authorities (Centre for Sustainable Energy 2017), it is recommended that a Hierarchy of Measures for improving energy efficiency (as illustrated overleaf) is adopted to go alongside this policy, and to inform decision-making. The measures listed are progressively higher in potential either to harm heritage significance or impact on carbon emissions and should therefore only be implemented where preceding measures are impossible or ineffective: i.e. stage 3 and 4 measures should be introduced only where stage 1 and 2 measures are ineffective and the potential harm to the building's significance does not outweigh the benefit of implementation. The proposed Hierarchy of Measures is consistent with the energy hierarchy, which prioritises changes in user behaviour to reduce energy usage. The Hierarchy should be used alongside a continued requisite understanding of the particular significance of the Heritage Asset.

Mitigation and adaptation measures must take into account the relative benefit to the climate, health of building users, and harm to the heritage asset. In making decisions weighed against the significance of heritage assets, there will be cases where measures cannot be accommodated without resulting in substantial harm. However, with creativity of design and a good understanding of traditional construction, it is expected that in most cases a compromise can be reached.

FIGURE 2. THE HIERARCHY OF ADAPTATION AND MITIGATION MEASURES



The Hierarchy of Measures in Practice

The following section provides a more detailed analysis of the recommended course of action for adaptation measures in the historic environment of the Lancaster District. It gives an explanation of the Hierarchy of Measures, the associated opportunities and risks, and how these can be implemented in practice. This is not a comprehensive survey of all available measures, but covers those most readily available and commonly employed at the time of writing.

Hierarchy stage	How could it be managed?
1. User Behaviour and Expectations	Guidance Documents
2. Repairs and Non-Disruptive Interventions	Guidance Documents Planning Policy Development Management
3. Minimally Disruptive Interventions	Planning Policy Development Management
4. Moderately Disruptive Interventions	Planning Policy Development Management

Stage 1. Options: User Behaviour and Expectations

The first logical step in reducing the environmental impact of traditional buildings is to alter the ways buildings are used and the internal environment expected of them (Janda 2011). This may prove to be a long term goal, as building user behaviour is driven by societal norms. While awareness of environmental issues is high, there is a general inertia to forgo aspects of daily comfort and convenience. However, it presents the simplest, least intrusive and most cost-effective means of improving efficiency. In implementing the hierarchy of means, the following steps should be the first port of call in reducing the energy impact of historic buildings.

a) Alter daily lifestyle and reduce use of energy intensive appliances

It is important to consider firstly the extent to which the routines and activities of building users reflect daily and seasonal changes in temperature. The question should be one of how users can work with the building, not only how can the building work for its users. Solid stone walls have a high thermal capacity, meaning that once warmed they will retain heat. As a result, acceptable comfort conditions can be achieved with lower air temperatures than in a modern house where heat is not stored by the structure (West Oxfordshire District Council 2016). The solar orientation of buildings should be taken into consideration when planning the use of rooms. This was commonplace in some historic buildings, where the use of rooms would vary in summer and winter, and in morning and evening. The 'morning room' in a middle class house of a century ago was so called because of the time of day it was in use: its orientation meant that it was warmer and lighter in the mornings.

Secondly, it should be determined whether energy consumption can be reduced through lifestyle measures. We are all creatures of habit, and it is difficult to adjust daily routines. However, there are some simple measure which could be introduced as tools or reminders. Real-time energy displays can be effective in alerting building users to the extent of their energy usage and assisting in habit formation (Anderson and Robinson 2011) (Shove, et al. 2013). Smart metres are increasingly free to install, and can help reduce energy consumption with minimal effort.

Patterns of Use

Before any change to a historic building is considered, the following should be encouraged:

i. That the daily lifestyle of building users makes optimum use of its solar orientation
ii. That every reasonable opportunity to reduce energy usage in the daily lifestyle of building users is taken

It is recommended that guidance is produced for owners and users of traditional buildings in the district which would promote this approach.

b) Alter expectations of thermal comfort

It is often assumed that historic buildings are cool and draughty because the expertise and technology was unavailable at the time to make them otherwise. While this is partially true, it is equally the case that they are product of a society which had radically different expectations of thermal comfort (Shove, et al. 2013) (Nicol and Roaf 2017). Even in the past fifty years, indoor temperature standards have become much higher. A study of mean indoor temperatures of UK houses in 1970 showed that rooms were 12^{o}C on average. While this may sound chilly to the modern reader, the climate crisis will necessitate a return to cooler homes as the energy cost of maintaining the currently expected levels of internal comfort are unsustainable.

The approach we take towards keeping warm has also shifted over time - from a person-centred approach (e.g. 'put on a jumper') to a space-centred approach (e.g. 'turn on the radiator'). This has undoubtedly resulted in much lower levels of energy efficiency. In the past, not every room in a building would be heated. During the winter, activities took place in one or two heated rooms where the whole family would gather (Kuijer and de Jong 2010). The idea that a hallway or bathroom would be centrally heated would have seemed very decadent. Building users also wore thicker clothes indoors, and warmed themselves with portable means such as bedpans, and later, hot water bottles.

Person-centred means of achieving thermal comfort are likely to see a revival in coming years, and may be helpful in improving energy efficiency in traditional homes. Studies are being conducted on cultural differences in expectation of and means of achieving thermal comfort, with Japan presenting a particular area of interest. In Japan, the person-centred approach predominates, with local radiant heating sources such as heated dining tables being the preferred method of keeping warm at home. The findings of timely research such as this may help to inform future strategies for achieving thermal comfort without measures which harm the fabric and significance of historic buildings.

Stage 2. Options: Repairs and Non-Disruptive Interventions

Repairs and non-disruptive measures should be considered as a priority, and in practice could be carried out alongside all of the Stage 1 measures as well as isolated Stage 3 measures.

a) Repairs and Maintenance

Building users should be encouraged to undertake regular inspections and carry out routine maintenance. This is not only because well maintained buildings are more efficient, but also because if a building is not watertight, retrofit efficiency measures are likely to cause further moisture damage. Aspects such as regular repair of pointing and render, and regular bleeding of radiators can make a notable difference to the thermal performance of a building. Drainage and rainwater goods should kept clear in order to ensure that walls do not become damp. Special attention should be paid to windows and doors, with simple maintenance to mend cracks and eliminate gaps carried out regularly in order to reduce air infiltration or draughts. In tests carried out by Historic England and Historic Environment Scotland, air infiltration was reduced by more than 33% through repairs to cracks in windows (Historic England 2017). Standardised inspection and maintenance checklists may be helpful for building users to have as a prompt when carrying out routine checks.

b) Upgraded Services

Building services should be up to date in order to ensure that they are functioning optimally. This may mean replacing an entire heating system, but is more likely to entail simple interventions, such as upgraded timer controls, thermostatic radiator valves so each can be controlled individually, and smart meters. Where the decision is taken to replace systems, the potential for physical harm to the building which could result from removing the old system as well as installing the new system must be considered.

c) 'Functional Furniture'

In the past, buildings were furnished to withstand the effects of climate as much as for decoration. Many solutions for improving the insulation of windows, such as blinds, timber shutters and awnings were commonplace in the past and only abandoned when energy became cheap and readily available. There are lessons to be learned from the way homes were furnished in the past which might be revived in a more energy-conservative world.

There has been some research which demonstrates that thermal comfort is to a large extent a psychological phenomenon (Rohles 2007). Frederick Rohles has conducted a number of studies which demonstrate this, including that indoor furnishings which are associated with warmth – carpeted floors, timber panelled walls, soft chairs and warm lighting - actually caused subjects to feel warmer.

i. Curtains, Blinds and Shutters

Heavy curtains reduce heat loss by conduction, and are extremely effective in preventing draughts. Thermal lined curtains are readily available and have an even greater effect. Thermal blinds, such as honeycombed roller blinds, have been shown to cut thermal losses by more than 50% and roller blinds with reflective surfaces on the window side have been found to cut losses by as much as 57%. Well-fitted external or internal wooden shutters can decrease heat loss from both draughts and conduction by around 60% (Historic England 2017).

ii. Rugs and Carpets

Rugs and carpets can have a similar effect in reducing thermal loss through historic floors, and do not carry the risk of reduced ventilation that retrofit insulation does. Thermal carpet underlay can augment the effect at a low cost, and is available in materials such as natural wool felt which maintain effective permeability.

d) Draught-Proofing

Draught-proofing measures can be extremely effective at improving thermal efficiency in buildings, and even more so at improving levels of perceived thermal comfort for building users. This is achieved by removing sources of unwanted air infiltration (Historic England 2016).

i. Windows and doors

It has been demonstrated that draught-proofing measures can reduce unwanted air infiltration by over 90%. Draught-proofing strips can be discreetly fitted to the perimeters of historic windows and doors in order to exclude superfluous air infiltration. The most common types are compression seals and wiper seals. The product chosen should be of a colour which will not adversely affect the appearance of the building. It should be ensured that adequate ventilation is maintained – this may mean that some windows need to be left untreated.

ii. Disused chimneys

Where a chimney is not in use, it will usually cause unnecessary heat loss which outweighs its contribution to ventilation in the building (Historic England 2016). Chimney caps, vents or balloons should be introduced in order to exclude draughts from disused chimneys and flues (Anderson and Robinson 2011).

iii. Functioning Chimneys

Where a chimney is still in use, an adjustable baffle can be installed to allow manual control of ventilation and to exclude draughts when not in use.

Stage 3. Options: Minimally disruptive interventions

In most cases there will be a number of interventions which can be introduced without harm to the significance of the heritage asset. These should be encouraged before more disruptive measures are considered.

Key Principles for Installing Insulation

The only possible approach to insulating traditional buildings is for a conservation professional to consider each case on an individual basis.. Nevertheless, it is recommended that the following factors are considered:

i. Ensure permeability of material and adequate ventilation around timbers is maintained
ii. Ensure thickness of insulating material does not impede permeability
iii. Ensure detailing at eaves does not impact upon aesthetic or illustrative values
iv. Ensure appearance of roof vents does not impact upon aesthetic or illustrative values

a) Roof Insulation

Insulating roofs will be possible but comes with a risk of impeding permeability of the building fabric.

There are a number of roof insulation materials now readily available which offer a suitable level of permeability. Being naturally sourced, these materials often have the added benefit of having lower embodied carbon than their synthetic counterparts.

The most common options are:

i. Sheep's wool
Sheep's wool offers a locally available solution for insulating historic buildings in the district which will be highly compatible with their fabric in most cases (Korjenic, et al. 2015). The wool must have been treated to minimise the risk of fire and insect infestation.

ii. Hemp fibre
Hemp fibre 'wool' is a plant-based alternative to sheep's wool which operates in the same way. Hemp insulation is not commonly produced in the UK. Hemp consequently often has a higher embodied energy than wool, as it may have been imported.

iii. <u>Fibreboard</u>

Hemp or wood fibreboard is easily accessible, but does not offer the same standard of thermal improvement as the above materials due to its inflexible nature, which increases the likelihood of thermal bridging which used for roof insulation.

iv. <u>Loose Cellulose</u>

A cellulose insulating material is available, which is produced from recycled paper. While this is a permeable option which would be compatible with traditional building fabric, its loose fill form offers a substandard level of insulation, and may pose a risk of fire.

Roof Insulation Materials

It is recommended that for roof insulation in historic buildings in the Lancaster district, options i. sheep's wool insulation, or ii. hemp fibre insulation are specified as easily accessible, sustainable and materially compatible solutions.

The location of roof insulation has some impact on its performance and on the building environment:

i. <u>Above the ceiling</u>

The easiest means of reducing heat loss through the roof of a historic building is to insulate above the top floor ceiling, creating a 'cold roof' (sometimes called 'loft insulation') (Historic England 2016).

This approach offers an appropriate solution in most cases, as long as the type of insulation is permeable; of a thickness which will continue to allow air and moisture penetration; and the ceiling below is not fragile, and can therefore bear the increased weight.

This approach will not be suitable in some cases, where the roof structure is of particularly significant historic timber, as the 'cold roof' approach increases the likelihood of condensation in the roof space which can accelerate decay of timber.

ii. <u>Between the rafters</u>

Insulating between the rafters in a historic building is often an appropriate method of reducing heat loss, but must be based on an understanding of the building fabric and ability to accommodate reduced ventilation. As there is an increased risk of thermal bridging where the insulation is not correctly installed, the work must be carried out by a competent person with relevant experience.

b) Floor Insulation

In some cases, historic suspended timber floors will be able to accommodate insulation in the floor space. This needs to be carefully handled so that air and vapour movement is not impeded, and that due consideration is given to the significance of the historic floor. As with roof insulation, vapour permeable materials are recommended for use under timber floors.

The thermal benefit of insulating a solid floor is usually minimal compared to the loss of significance which usually results from attempts to lift the floor material in order to install it. Where there is a non-original solid floor in place, such as a modern concrete floor, it may be possible to install insulation boards on top in order to reduce heat loss.

c) Insulation of timber panelled doors internally

Many of the Georgian and Victorian buildings in the district retain historic timber panelled doors. The thermal performance of these doors can be improved by installation of internal insulation to the thinner panels. The insulation material chosen for this purpose should be vapour permeable, and should only be installed where the internal appearance of the door is of little significance (Historic Environment Scotland 2013). For this reason, while the majority of buildings in Conservation Areas and many Listed Buildings will be able to accommodate this intervention, insulating the front door of a Listed Building with a well-preserved interior will not be appropriate in every case.

d) Installation of secondary glazing to windows

Secondary glazing installed to the interior side of historic windows can result in a substantial reduction in heat loss without the risk of harm to aesthetic value and potential damage to building fabric which can result from double glazing. Research carried out by Historic England and Historic Environment Scotland has demonstrated reduction over 60% in heat loss via installation of secondary glazing with a low-emissivity (low-E) coating (Historic England 2017).

There are several secondary glazing systems available which can be selected to suit the particular building and occupants. The glazing industry is continuing to develop new secondary glazing products which are increasingly discreet. Fixed type secondary glazing systems are not recommended for buildings in the Lancaster district as issues with maintenance and condensation make them unsuited to the local climate.

Options for buildings in the district include:

i. Sliding systems

Horizontal and vertical sliding systems are available. These styles are suitable where regular ventilation is required.

ii. Hinged systems

Hinged casements are frequently used where the whole window is to be covered to avoid any sightlines on the secondary unit. These work well for large panes, where high compression seals are required to optimise noise insulation or to minimise airflow, or where full access is required for cleaning/maintenance or to provide a means of escape. These styles are suitable where regular ventilation is required.

iii. Lift-outs

These are best used for windows that are fixed or seldom opened and where access is only occasionally necessary for cleaning. They are also useful for windows of unusual shapes.

iv. Magnetic

Magnetic secondary glazing systems are similar to lift-outs, but easier to remove. Magnetic strips on the edge of the window frame hold the panels in place. (Historic England 2016)

e) Installation of microrenewables on the ground or an outbuilding

It may be possible to install microrenewables such as photovoltaic panels or wind generators within a building's setting, or on an outbuilding, in order to reap some of the benefit without causing as much harm. The decision to do so must be informed by an assessment of the contribution the building's setting and outbuilding(s) make to its significance; outbuildings may also be curtilage listed or they may be non-designated heritage assets in their own right.

Microrenewables in the Setting or Curtilage of Heritage Assets

It is recommended that proposals for new microrenewable systems in the setting or curtilage of Heritage Assets should be based on an assessment of the contribution the setting and/or curtilage make to the significance of the asset.

The potential for below ground archaeology should also be assessed where proposals would require breaking ground or cause vibrations.

Where it is judged that harm to the significance of the heritage asset would be caused by the proposal, appropriate mitigation and screening measures should be considered.

FIGURE 3. ST MARY'S CHAPEL, CROSSKIRK (SCHEDULED MONUMENT)

Stage 4. Options: Moderately Disruptive Interventions

The following measures should be considered where stage 1-3 measures have been ineffective or unsuitable. These measures have the potential to be more disruptive to the fabric of the building, and carry a higher risk of harm to significance. Nevertheless, they are all measures which can be appropriate in the right circumstances. It is essential that a judgement is made by a conservation professional on the appropriateness of these measures in each case, and that any work is specified by a conservation accredited architect.

a) Roof Insulation Above or Below the Rafters

Insulating above the rafters (a 'warm roof' approach) reduces the risk of condensation in the roof space, and may therefore be an appropriate approach where historic roof timbers need to be protected. This approach will however result in the roof line being slightly raised. For this reason it will not be suitable in buildings which derive part of their value from their contribution to a group, which would be eroded through a change to uniform rooflines. This approach would be unsuccessful in terraces of uniform design, for example.

b) Introduction of slim profile double glazing or thermally upgraded single glazing

The functionality of Insulated Glass Units (IGUs) depends on the seals that prevent air and moisture from entering the cavity; when these fail, the units will become much less thermally effective and are also likely to fog because of internal condensation. The lifespan of current IGUs is estimated to be between 15 and 25 years. In energy terms, IGUs have pay-back periods that can greatly exceed their design life, especially for units filled with inert gases. For this reason, it is recommended that repair and refurbishment of existing timber windows is recommended as the preferred course of action.

Many of the historic buildings in the Lancaster district are not well suited for double glazing. This is a result of several factors, including their appearance and materials of construction. Many historic buildings in the district have multi-paned sash windows. It is often impossible to replace existing glass in multi-paned windows with double glazing without having to alter the frames and glazing bars to accommodate the increased thickness and weight of the glazing, resulting in harm to the significance of the building through loss of historic fabric and altered appearance. If used in multi-paned windows, IGUs will also generally be less efficient than secondary glazing due to thermal bridging through the frame and glazing bars.

The capacity of historic window structures to support the increased weight of double-glazed units must be considered. Bay windows in particular, such as those common in the Morecambe and West End Conservation Areas and in parts of Lancaster, are not always able to withstand replacement windows and may collapse under the additional weight (English Heritage 2011). Timber windows that are more than 150 years old will often have been weakened through general wear and tear, and distorted from both the weight of glazing and any movement of the building. Experience has shown that where slim-profile IGUs are inserted, window sashes often have to be replaced. For this reason, and because of the potential loss of any surviving historic glass, the installation of IGUs in historic windows is likely to seriously harm their significance.

However, there are certain circumstances in which IGUs might be considered.

Double Glazing

Double glazing could be considered in these circumstances:

i. Where a historic window retains no glass of heritage value, has sufficiently deep glazing rebates and is robust enough to accommodate the increased thickness and weight (e.g. 1/1 Victorian sashes).
ii. Where the existing window is a replacement of low significance

Where a window in a historic building meets the above criteria, the following types are options for their replacement:

i. Low-emissivity glass

The transmission of radiant energy through window glass can be decreased by applying coatings that reflect infra-red wavelengths while letting visible light pass. In winter, heating is reflected back indoors; in summer, heat from the sun is reflected away, keeping the room cooler. This can be in the form of either single or slim-profile double glazing.

ii. Slim Profile double glazing

Slim-profile double-glazing has a narrower gap between the panes of glass and ranges in total thickness from l0mm to l6mm. It is anticipated that even slimmer types will be developed in years to come.

iii. Acrylic double glazing

To overcome the weight problems of double glazing and to avoid the need to remove existing glazing, acrylic systems are available. Potential problems include cleaning, scratching and discolouration. While the use of high grade acrylics can minimise the risk of scratches and discolouration, these are not recommended except in occasional circumstances (Historic England 2017).

c) Installation of a suspended ceiling or floor

There may in some cases be scope for a new suspended ceiling or floor to be installed. This will depend on the interior or the building, and the extent to which these interventions would impact on its significance. Where there is no historic ceiling or floor present, no significant internal wall finishes which could be adversely impacted, and the significance of the building would not be harmed by alterations to the proportions of the room, this approach can be considered. Adequate ventilation will need to be maintained within the newly formed cavity or cavities.

d) Installation of panelling to interior walls

Insulating walls internally may be an option in some historic buildings. This will depend primarily on the significance of the interior, the reversibility of the proposed panelling, and the effect of reduced permeability on the building fabric. This is not an option which is likely to be successful when combined with other measures which reduce permeability.

e) Reinstatement of permeable render where formerly removed

Some of the vernacular buildings in the district have had their render removed for aesthetic reasons. Cottages in Heysham and Poulton, for example, were historically finished with permeable wet-dash render which helped the buildings withstand the effects of weather. There may be occasional circumstances where it is considered appropriate to reinstate the render in order to improve the thermal efficiency of the solid walls. This decision will be based on the history and pathology of the individual building, and the impact that reinstating render will have on its aesthetic value.

f) Reinstatement of ceiling where formerly removed

Some buildings have similarly had their ceiling removed for aesthetic reasons, especially where a historic roof structure survives which past occupants wished to expose. Where the interior finish of the walls will not be harmed by doing so, there may likewise be scope to install new ceilings to such buildings, which - in addition to providing their own thermal benefits – would in turn allow loft insulation to be installed. This decision will be similarly based on the history and pathology of the individual building, and would only be considered where there would be no adverse effect on a significant interior.

g) Install microrenewables in or on the building

Key Principles for installing Microrenewable Systems

It is recommended that the following general principles are used to guide the decision-making process concerning installation of microrenewables on historic buildings:

i. Reversibility
The principle of reversibility is especially important when it comes to microrenewables. It is anticipated that as technologies continue to develop, current renewable systems will become obsolete. When this happens, it should be possible to remove systems from historic settings without causing additional harm to the building or site.

ii. Visual Impact
Consideration should be given to the design and siting of renewable systems to minimise their visual impact. The setting of a site and its significance should be carefully assessed: the visual impact beyond that of a single building or site; entire streetscapes or landscapes may be affected. Consideration of a communal system may avoid unnecessary cumulative effects of multiple single installations.

iii. Physical Impact
Physical impacts include those affecting structural, archaeological, fabric and environmental aspects of the site. Any intervention to historic fabric should be minimised and undertaken only after careful analysis and design of the system. The installation and use of a microrenewable system may affect airtightness, breathability, ventilation and condensation. This should be taken into account when identifying the most appropriate energy solutions.

iv. Archaeology
Installation of renewable systems can damage or destroy archaeological deposits. Ground-breaking works should be carefully planned to avoid disturbing known archaeological deposits and monitored to ensure unknown archaeology is not damaged.

i. Solar Thermal or Photovoltaic Panels

The benefits of installing solar panels (PV panels) on historic buildings will need to be weighed against the potential impact they might have on the historic, evidential and aesthetic values of the building, as well as the integrity of the building fabric. The first and most important consideration must be the capacity of the historic roof structure to withstand the additional weight and wind resistance of a photovoltaic array, and the likely damage that will be caused by future replacement, repair and renewal.

There are cases where panels can be installed without harm to a building's heritage values; the design of the panels, their roof location and positioning are key factors in mitigating any harm that does result. The CPRE have produced a useful design guidance document for installing PV panels, the principles of which are considered to equate to current best practice, and are recommended here (BRE and CPRE 2016).

Solar Panels

It is recommended that the following principles are used to guide the installation of new solar photovoltaic panels on historic buildings in the district:

i. The colour and finish of panels should be chosen to complement the building.
ii. The framing and mounting system should be chosen to be as inconspicuous as possible.
iii. The size of panels should be chosen to match the scale and proportions of the building and/or its existing roof covering.
iv. Panels should be laid out in a balanced formation which does not disrupt the symmetry or architectural composition of the building.
v. Panels should be positioned on the least visible roof slope wherever possible.
vi. Buildings in Conservation Areas and streetscapes of uniform character should seek to match other like buildings.

ii. Heat Pumps

Heat pump systems provide more sustainable alternatives to traditional heating systems. They are often best used with underfloor heating.

The most common types are:

i. Ground-source heat pumps (GSHPs)

GSHPs tend to achieve higher efficiency but require long lengths or coils of pipe in either a trench or vertical borehole. This means careful attention has to be given to any potentially irreversible harm to archaeology or designed settings.

ii. Water-source heat pumps (WSHPs)

WSHPs are less common but can be as efficient as ground-source heat pumps, provided the water source does not freeze.

iii. Air-source heat pumps (ASHPs)

ASHPs can operate as long as the air temperature is above -15^{o}C. These require internal and external units and therefore need to be located as unobtrusively as possible.

All heat pump systems require careful design to minimise impacts to the significance of the building. Pipework and pump equipment will need to be carefully located to avoid both physical and visual impacts. Pumps may require trenches or boreholes to be dug, and underfloor heating often requires setting heating coils in a concrete floor slab, which can damage historic floors or archaeology. Where archaeological sites are known to be present or likely, a different form of renewable energy system may be more appropriate, or an archaeological watching brief may be necessary to monitor the works. (Historic Environment Scotland 2016).

iii. Rainwater harvesting

Rainwater harvesting systems can be used to provide water for all non-potable household functions, such as washing machines, gardening and toilet flushing. Where water storage tanks are to be installed above ground, the effect on the setting of the heritage asset will need to be assessed. Excavations for siting of a below ground tank will only be possible where there will be no impact on known or potential archaeology, and the building foundations will not be undermined by the work.

iv. Biomass Systems

Biomass systems require adequate infrastructure for the delivery of fuel, fuel storage and boiler storage. The space requirements mean that they may be suitable for properties with large estates. Where a new boiler house is required, the siting and design of the structure will need to be considered.

Conclusion and Next Steps

The findings of this paper indicate that Responsible Retrofit, designed on a case-by-case basis, is the most appropriate approach for climate change adaptation and mitigation in the context of historic buildings. This will be considered in the Climate Emergency Review of the Local Plan, and may require introduction of one or more new policies which specifically relate to retrofit measures.

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