National Trust

Climate Change Adaptation Guidance – Buildings

Historic Building Fabric

Climate change vulnerability: high

Historic building fabric – introduction

From mansions to monuments, farm buildings, mills, cottages and follies, our historic buildings represent a broad range of architectural styles, periods and functions.

The National Trust owns around 28,500 buildings across England, Northern Ireland and Wales. Many of these are listed, and some are on the schedule of historic monuments. Most are made of traditional materials and were constructed before 1919.

From lead to lime, brick to stone, and slate to thatch, building fabric includes specific materials working together to provide protection from the elements. The exact combination will be unique to each building.

If historic structures have material and structural integrity, and they are regularly maintained and repaired with appropriate materials, they can be sustainable and perform well over many years. The thick walls of traditionally constructed buildings have high thermal mass, which can keep them thermally stable in the context of higher temperatures. Good condition of building fabric contributes to a building's overall thermal performance, energy efficiency and resilience. Continuing to use historic buildings harnesses embodied energy and avoids construction emissions associated with demolition and/or new builds.

Nevertheless, climate change may increase the strain on building fabric through higher temperatures, drought, more frequent and intense storms, and higher rainfall and flooding. A building's capacity to withstand the impacts of a changing climate will depend on its construction materials, construction detailing and current condition. In time, building fabric that previously withstood the impacts of occasional extreme weather may now not be able to cope with the frequency and intensity of climate hazards such as heavy rainfall.

Maintenance remains the most cost-effective approach to sustaining the life of a building. We need to enhance repair and maintenance regimes to keep buildings in good condition. But we must also anticipate where like-for-like repairs will become ineffective as a result of climate change. Generally, adaptive measures should only be considered in such cases, and should respect the building's architectural and historical significance.

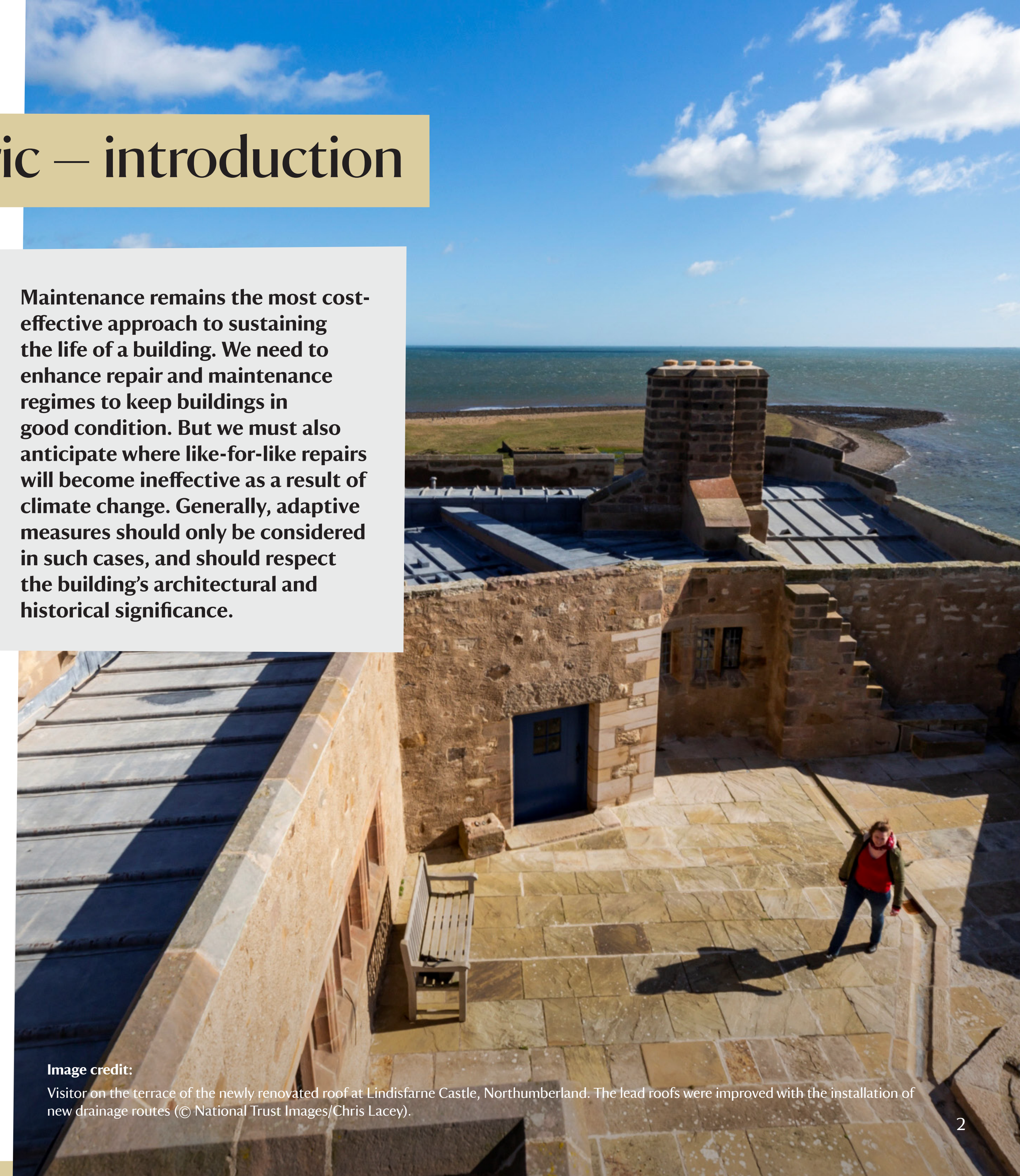


Image credit:
Visitor on the terrace of the newly renovated roof at Lindisfarne Castle, Northumberland. The lead roofs were improved with the installation of new drainage routes (© National Trust Images/Chris Lacey).

Historic building fabric – why does it matter?

When building fabric fails, it can cause discomfort and harm to users – and sometimes, serious damage to a building's interior and collections. Water ingress, and wetting and drying, can lead to decay and progressive damage to building fabric over time. In extreme cases, flooding, drought and shrink/swell may affect building foundations.

The fabric of historic buildings performs effectively when the principles of breathable construction are applied, using materials such as stone, lime and timber. Combined with appropriate levels of ventilation, the ability of traditional buildings to allow water vapour to move through the building envelope helps the structure to remain in a stable condition. The levels of moisture are balanced so that the internal environment is healthy for both the occupants and the contents. Climate change may challenge this equilibrium.

When trying to protect a building from the impact of a changing climate, it is important to consider the wider site context. A key principle is to direct excess water away from the building fabric wherever possible. Measures to protect the building from flooding and water ingress may involve improvements to surface water drainage, and management of surge flows around buildings. It is important to consider the location and direction of flow of local water courses, together with the functionality of existing rainwater goods and drainage systems. See our separate guidance on *Buildings: Rainwater Goods*.

In some cases, where increased maintenance is insufficient to help building fabric withstand the impacts of climate change, sensitive and appropriate adaptation of details or materials may be necessary to safeguard the building. Adaptation will usually involve simple measures such as improving weathering details with like-for-like materials, repointing of masonry walls, using higher codes of lead/cast lead on roofs, or additional fastenings of ridges and slates. Where there has been previous maladaptation of the building fabric, changing the material back to the original may be considered. For example, a change from cement to lime render may help walls to breathe and dry out. However, the aesthetic impact of such changes should be considered, and consents may be needed.

The next page outlines the key elements of building fabric and how these may be impacted by climate change. This is followed by a breakdown of the most likely climate change hazards, their impacts on built fabric, and possible adaptation options.

Image credit:

View of scaffolding surrounding the Victorian mansion at Dyffryn Gardens, Vale of Glamorgan, South Wales (© National Trust Images/James Dobson).

Historic building fabric – key elements

Roofs

Most roofs of historic buildings are covered with slate or clay tiles; a smaller number are thatched. The quality of the roofing material used, together with construction detailing, repair and maintenance, will contribute to the overall capacity of the roof to withstand weathering and the increased frequency of extreme rainfall and wind events.

Slates and tiles can suffer surface deterioration and delamination over time, which may be exacerbated by frost damage. The source quarry, extraction, cutting, quality of slate and fixings may determine the resilience of a roof.

Similarly, the resilience of clay tiles to climate change may be influenced by their source, manufacture and thickness. Some locations may see increased damage caused by wind lift and penetration of driving rain due to climate change. The ability of thatch to withstand weather and climate change may also be influenced by the type of thatching material, its source and detailing, including depth and standard of fixing (for example, spars or scallops).

Walls

Most walls of historic buildings are constructed of stone, brick, timber, or mud. Rates of surface delamination and recession of stone, brick or external renders may be affected by higher temperatures, higher levels of rainfall, and freeze/thaw action. This may be exacerbated when material is already damaged, and therefore vulnerable.

The maintenance of the primary material(s) in main walls, together with the integrity of component joints in timber, render and lime mortar, will contribute to the capacity of external walls to withstand continued exposure to increased rain and storm events. Timber and mud walls are likely to be particularly vulnerable to more extreme wet weather.

Increased rainfall may result in more prolonged saturation of masonry. Cracking in walls may be associated with the movement of foundations where there has been flooding or waterlogging, followed by periods of dry weather or drought, which result in shrink/swell.

Foundations

It is important that water is directed away from a building's ground and basement levels, to avoid water ingress or flooding that can damage building fabric and collections. Ground shrinkage or expansion may result in movement. Flooding, a rising water table and poor drainage may also have an impact on footings and foundations.

Some older buildings may not have been designed with sufficient drainage capacity to cope with increased rainfall, a rising water table or the effects of weather extremes. Where historic drainage exists and has been blocked or decommissioned, the option to bring it back into use may be explored. Beware of hardscaping areas adjacent to buildings and the loss of gardens or adjacent natural land, which may increase surface water run-off.

Image credits:

Top to bottom: Wall of the original Great Hall at Godolphin, Cornwall; visitor on the roof at Dinefwr, Carmarthenshire, Wales; the Servants' Rooms in the basement at Seaton Delaval Hall, Northumberland (all © National Trust Images/James Dobson).

Historic building fabric – hazards, impacts and options

Hazard	Impacts	Options
Heavier rainfall	Flooding of buildings resulting in damage to fabric, interiors and collections.	Flood resilience work to include more regular maintenance of roofs, rainwater goods and drainage. Drains may block more frequently, especially if silt is washed into drains and culverts. Investigate historic drainage infrastructure and clear/renovate or reuse where beneficial; where existing drainage is not efficient, add drainage including soakaways; develop a flood management plan, ideally looking at the flow of water across the whole catchment (not just within the boundaries of the property).
	Shrink/swell caused by heavier rainfall in combination with periods of drought, especially in areas with clay-based soils.	See *flooding*, above. Monitor any cracking or movement of foundations and walls during and after periods of flooding, particularly when combined with periods of drought.
	Water ingress as existing rainwater goods cease to be effective, causing damp and structural issues. Damp in walls.	More regular maintenance, monitoring, clearing and repair of rainwater goods and drainage. Where maintenance is not sufficient, increase capacity of rainwater goods and drainage (see separate guidance: Buildings: Rainwater Goods).
	Increased masonry decay and delamination; failure of mortar joints; increased risk of water ingress at interfaces between building elements.	More regular maintenance of mortar joints and external coatings on masonry. Improve weathering detailing where appropriate, e.g. drip detailing or consider adding lead capping to masonry. Reinstate historic render, or introduce render or limewash where appropriate.
	Movement/warping/decay of timber windows, doors, sills and lintels caused by water ingress/increased damp.	More regular maintenance and monitoring; increase repair and improve drip details and seals on windows and doors.
	Increased deterioration of thatched roofs and earthen walls.	More regular maintenance and monitoring of roofs and render protecting mud walls. The practice of covering failing thatch with tin, while common in older vernacular buildings, is not recommended as it can cause the thatch to 'sweat'. More regular maintenance may be needed.
Overheating	Lead buckling in windows and on roofs.	Repair of lead, replacement with higher-coded lead where appropriate. On roofs, increased movement could be accommodated through changes to detailing, e.g. size of bays.
	Cracking of render, open joints, missing or crumbling joints.	Appropriate material and finish of masonry repointing; improved weathering detailing in architectural elements; external coatings on masonry, e.g. harling or lime render.
Drought	Shrink/swell causing movement of foundations and masonry structures (visible as cracking in joints).	Take measures to improve drainage of water away from the building, to avoid saturation of foundations during wetter weather, which will help minimise extent of shrink during drier periods.
	Elevated risk of wildfire during prolonged hot and dry periods.	Maximise water storage capacity; develop and implement a drought management plan. See separate guidance Water: Water Sourcing and Efficiency. Develop a wildfire management plan in collaboration with local partners. See separate guidance Places: Wildfires.

Historic building fabric – hazards, impacts and options

Hazard	Impacts	Options
High winds	Damage to roofs and windows from high winds, resulting in water ingress; damage caused by wind-driven rain.	Increase checks and monitoring of building elements after storms or high winds, looking especially for loose tiles, damage to rainwater goods and signs of water ingress internally caused by either storm damage or wind-driven rain.
	Damage to building fabric from nearby falling trees.	Regular monitoring of surrounding trees – check for signs of pest and disease or weakness; where compromised, careful removal or replanting of trees to retain as key features of the designed or evolved landscape.
Sea level rise	Increased likelihood of flooding and coastal erosion. Increased salt-related damage to building fabric.	Flood prevention should be combined with measures to minimise flood damage, such as flood stop boards and moving electrical supply and outlets to a higher level. In cases of extreme repeated flooding and/or coastal erosion, explore options for adaptive reuse/release with a conservation professional.



Image credits:

Left to right: A lead window at Little Moreton Hall, Cheshire (© National Trust Images/John Millar); the roof at Hanbury Hall, Worcestershire, with lead flashing and new tiles (© National Trust Images/Dennis Gilbert); water rushing into the house during flooding in July 2007 at The Vyne, Hampshire (© National Trust Images/John Hammond).

Historic building fabric – options and thresholds

Climate change may affect the ability of building fabric to cope with the elements and exacerbate issues already caused by deterioration, especially when maintenance regimes are poor or lacking.

Specific options for adapting our approach to the conservation of building fabric in context of climate change include:

Maintenance – a maintenance plan is required for any historic building. This should include regular seasonal checks of the roof, walls, windows, doors and internal fabric: a minimum of four visual assessments per year, and reactive checks after any extreme weather events such as storms or high winds. Where defects are identified, repairs should be carried out as soon as possible. This may include drainage renewal and/or refurbishment.

Monitoring – where a climate change impact is identified, additional regular checks should be scheduled to monitor and record changes. Electronic monitoring may be necessary, for example, to record wall moisture levels. Movements/cracks in foundations, walls and ceilings can be recorded to millimetre accuracy using using tagged gauges, or 'tell-tales'.

Management – consider adopting or reviewing flood and drought management plans. Consider change of operations/use, including relocation of contents/collections either in the short term, while impacts are addressed, or in the longer term if the impacts are more difficult to resolve. The latter may represent a pathway towards adaptive release.

Adapt detailing/materials – when maintenance and repair are insufficient. Minor adaptation can be explored with a conservation professional: for example, using thicker codes of lead, redesigning junctions, or adding fastenings to ridges and slates are all simple measures which increase the resilience of the building but have minimal impact on its significance and character. In some cases, major changes to materials or construction design could be explored with a conservation professional: for example. glass fibre- or terne-coated stainless steel could replace lead.

Supplementary shelter – in cases of significant water ingress and/or degradation of building fabric, one option may be to install a temporary shelter over a building or monument to protect it while adaptive options are considered, or to dry it out before repairs. Structures erected to protect a building or monument are rarely permanent. They are likely to affect the building and its visual setting; therefore, designated assets will require consent.

Adaptive release and managed decline – some buildings can be maintained in perpetuity, but others were not built to last, are in a vulnerable location, or have suffered an event that has left them in a ruinous state. Some buildings that are more vulnerable to future loss, for example those in coastal locations, may also be preserved by record, as a pathway towards adaptive release.

Thresholds & tipping points

Maintenance is crucial and is the first line of defence against climate change. At what point, based on monitoring the building, might you change management strategy or diverge from your management plan? What thresholds or tipping points might trigger a change of approach (action/philosophy)?

- The frequency of required maintenance and repair interventions increases.
- Repair is proven to fail more regularly.
- Despite regular maintenance, monitoring and repair, water ingress, flooding or damp conditions persist which are adversely impacting on the condition of building fabric, interiors and standards of collections care.
- Natural ventilation and/or dehumidification is ineffective at stabilising relative humidity and moisture levels over an extended period of time, despite more regular maintenance and repairs.
- There is evidence that previous maladaptation has caused, or is causing damage to the building fabric, and that this damage is being exacerbated by the force of climate change impacts.
- Adaptive opportunities may arise from building projects/condition surveys, for example where there is a window to integrate adaptive response for future climate resilience into capital building projects/plans.

Historic building fabric – worked pathway example

This page applies the options and thresholds to a real site example, showing how and when you might wish to make changes to your adaptive response to climate hazards.

It is important to work with a multi-disciplinary group to think about options and thresholds for adaptation. Decisions cannot be made in isolation as there are significant implications for everything from operations, to aesthetics to collections care. It is always most effective to bring together the right people to agree a mutually acceptable solution that benefits the building fabric and, where possible, ensures comfortable and continued use.

Maintaining or enhancing the durability of existing materials and details, and their ability to withstand future changes such as increased rainfall, storms and drought, is key. Adaptive pathways will vary from building to building and will need to take account of historic and architectural significance. The designation and/or relative significance of a building should be paramount in defining the acceptable parameters for change.

The worked example on the right[1] is based on a National Trust residential let estate building at Dyffryn Mymbyr, Conwy, Wales. The internal finishes of the stone gable wall were suffering from penetrating wind-driven rain. With more frequent and intense rainfall, the problem persisted despite maintenance, monitoring and several attempts at re-pointing. Learning from the vernacular architecture style in Snowdonia, we decided to redesign the materials and details and install 'slate hanging' on the exposed end of the building. This was sympathetic to the character of the building and typical of the locality, so listed building consent was granted. The pathway below considers hypothetical options for the longer term ranging from more extensive adaptations to adaptive reuse and release. Note that at each stage, the pathway is likely to circle back to monitoring and maintenance.

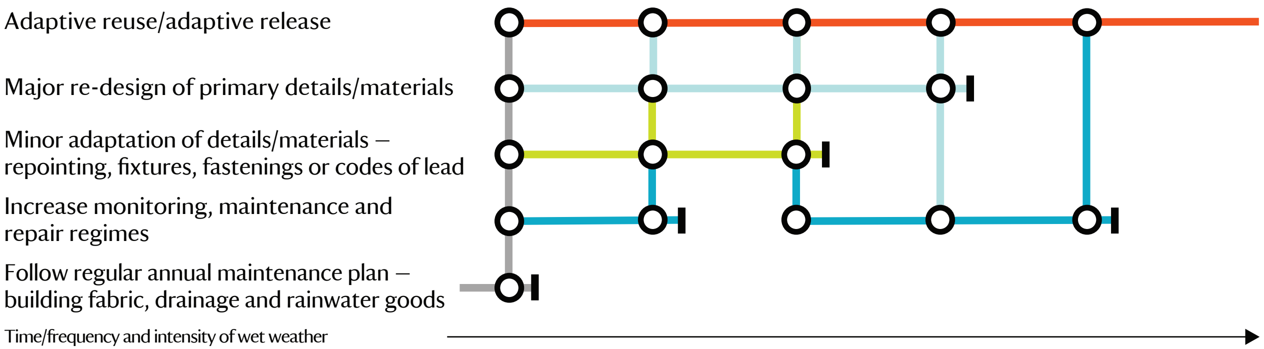
Image credit:
The exterior of Dyffyn Mymbyr cottage, Conwy, with slate hanging on the gable wall (© National Trust Images/Annapurna Mellor).

Statutory consents

Check whether the building is designated and subject to statutory consents.

When planning adaptations to a historic building, you should always consult:

- An appropriate building professional such as a conservation-accredited building surveyor or architect.
- The relevant local authority (if the building is designated).



(Response thresholds are most likely to be based on the failure of maintenance and repair regimes. Specific trigger points would need to be agreed by the operations decision-maker and relevant consultants and consultees such as building surveyors, historic environment experts and planners. Design and significance of the asset are likely to impact your thresholds and options within the Dynamic Adaptive Policy Pathway.)

[1] Dynamic Adaptive Pathways Approach (Haasnoot, Kwakkel, Walker & Ter Maat, 2013).

Case studies, signposting and references

As the impacts of climate change are increasingly felt, the National Trust and other heritage organisations are constantly working to maintain historic buildings, while reviewing adaptation options. The following case studies outline some of the options already in place or being considered.

At the **Blickling Estate in Norfolk**, the Jacobean house is affected by a number of climate hazards, including extreme heat, which is causing leaded windows to distort, and extreme rainfall events, which have resulted in flooding to the house and movement due to shrink/swell. The latter has been addressed in part by landscape-level adaptations that help to absorb water from a stream into a meadow before it reaches the house. The Blickling team are also considering renovation of the historic drainage system. They are monitoring cracks in the building by photographic survey and electronic tell-tales to establish whether further adaptive interventions will be needed in the longer term.

At **Fountains Abbey and Studley Royal**, Yorkshire, the Skell Valley project has worked with local partners to slow the flow of the river, which runs through the abbey as part of the former monastic latrine, to prevent flooding and damage to the foundations of the abbey, part of a UNESCO World Heritage Site. The site team has also identified a historic tunnel likely to have been used to carry water away from the site and are considering the possibility of reinstating this to help manage flash flooding.

By the late 1990s, **Rosslyn Chapel, Midlothian** was suffering due to ineffective rainwater disposal and a lack of heating in the building, which resulted in the stone becoming porous and saturated, and problems with damp and algae growth. A protective canopy was built to protect the structure; this remained in place for 10 years and facilitated high-level visitor access. Adaptations to the building fabric itself included covering the exposed stone roof with lead, adding a rainwater system and biomass heating to manage relative humidity. The protective canopy was removed in 2010.

Signposting & additional guidance

Historic England's online guidance and webinars include information about safeguarding historic buildings from the impacts of climate change.

Historic Environment Scotland has published a short guide, *Climate Change Adaptation for Traditional Buildings* (2016).

Adaptation Scotland, *Guide to Building Maintenance in a Changing Climate* (2015).

Ulster Architectural Heritage and the Department for Communities, Northern Ireland, *Impacts of Climate Change on the Historic Built Environment* (2021).

The United Nations Environment Programme have published a *Practical Guide to Climate-Resilient Buildings and Communities* (2021), aimed at a non-specialist, global audience.

Please note: this guidance is a contribution to an ongoing debate and comments are encouraged. The advice given herein is generic and our historic buildings are unique. Any adaptation should usually be bespoke, if we are to respect the individual significance of each building.

Image credits:

Top to bottom: aerial view of Blickling Hall, Norfolk (© National Trust Images/Annapurna Mellor); Fountains Abbey, Yorkshire, with the river Skell in the foreground (© National Trust Images/ Chris Lacey); Rosslyn Chapel, Midlothian, with canopy (© Rosslyn Chapel Trust/Antonia Reeve).