A Study of Architectural Measures to Reduce Overheating

Literature Review and Analysis

Summary

Historic England commissioned this report to identify historic architectural measures that can demonstrate and support England's historic buildings in adapting to the changing climate. The purpose of this report is to investigate how passive architectural measures, such as awnings or shutters, have been used in the past to reduce solar gain and seasonal overheating.

The research is not limited to shading devices but also considers both historic and contemporary passive architectural measures. This research will enable Historic England to suggest possible options for passive architectural measures which may help reduce the risk of overheating to owners and managers of historic buildings in response to the changing climate.

Front cover:
Metal louvres designed by Thread at Grade II* listed Nymans Gardens.
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Glossary

For ease of reference, definitions of terms not defined within the text are provided below.

Active or mechanical services – systems installed in a building such as air conditioning, heating and ventilation, which require a source of power for their operation.
Albedo – the ability of a surface to reflect light, also known as solar reflectance.
Awning – a covering (traditionally of fabric) supported by a frame to protect a window or door opening from sun or rain.
Background ventilation – continuous provision of low levels of fresh air through small openings in a building, such as trickle vents or air bricks.
Brise-soleil – an external feature of a building used to provide shade through the use of angled horizontal, vertical or patterned fins or screens.
Cantilevered – a projecting structural element supported or fixed only at one end.
Clerestory window – a window situated in a wall at high-level, typically above an adjacent roof, to provide natural lighting and/or ventilation.
Climate impacts – consequences of the risks resulting from climate change hazards (such as extreme weather events). Examples of impacts may be water ingress due to heavy rainfall, or slipped slates due to strong winds.
Climate impact drivers – physical climate conditions
Cross ventilation – natural flow of fresh air typically achieved by providing opening windows on opposite sides of a building.
Cupola – a small, typically domed, structure built on top of a roof to provide natural ventilation by drawing out hot air from the interior.
Deciduous – refers to a plant or tree that loses its leaves annually, normally in autumn.
Embodied carbon – the greenhouse gas emissions associated with materials and construction processes used in the construction of a building.
Energy efficiency – the use of less energy with the same or better performance (such as reduced energy bills for heating or cooling).
Fabric (historic or building) – refers to the physical materials which make up a building such as walls, roofs and joinery.
Green wall – a vertical system for growing plants, also known as a living wall, often used to form an external façade covered in irrigated vegetation.
Greenhouse gases – gases in the Earth's atmosphere that trap heat and lead to increased temperatures.
Hygroscopic – the property that causes a material to absorb moisture from the environment.

Louvres – angled narrow slats spaced regularly to provide shading from direct sun while letting some light and fresh air through.
Low emissivity – a material's ability to emit low levels of absorbed heat radiation, resulting in lower levels of heat loss or gain.
Maladaptation – poor adaptations or changes to a building that may result in poor building performance or increased risks due to climate changes.
Natural ventilation – the provision of fresh air to the interior of a building using natural forces such as pressure differences between hot and cool air, without the use of powered mechanical systems.
Occupant – refers to any person living in, working in or using a building. For the purpose of this report, an occupant could be either a tenant or an owner.
Passive architectural measures – physical features designed or retrofitted to improve the internal comfort of a building by working with the local climate to reduce the demand for mechanical heating or cooling systems.
Passive cooling – reduction of heat gain in a building to reduce internal temperatures by using methods such as shading, natural ventilation and thermal mass to store and release heat.
Pergola – an un-roofed external framed structure, typically constructed to support climbing or trailing plants to create shade below.
Purge ventilation – a strategy for quickly removing stale, warm or moist internal air or fumes from a building as required, by opening windows or through mechanical extract ventilation.
Relative humidity – the percentage of water vapour in the air compared to the maximum amount of water vapour the air could hold at the same temperature.
Retrofit – alterations or upgrades to an existing building to provide it with features it did not previously have, which may include improvements to energy efficiency or passive architectural measures.
Reversibility – alterations or adaptations which can be removed to return a building to its previous condition without causing damage or loss to the building fabric.
Roof ventilator – an outlet installed on a roof to provide natural, or sometimes powered, ventilation to help cool the roof space and reduce condensation by drawing warm, moist air out.
Secondary glazing – an additional glazed window fitted to the inside of an existing window to help retain heat and provide sound insulation.
Shutter – a solid or louvred panel, often a hinged pair, that can be closed inside or outside a window to provide shade, privacy or security.
Significance – the heritage value of a building or place, which may include archaeological, architectural, artistic, historic interest or social value.
Solar angle – the position of the sun in the sky in relation to the horizon, based on location, time and date.
Solar gain – the temperature of an internal space increases due to solar radiation, which has been absorbed and trapped by glazed or transparent surfaces such as windows.
Solar reflective index (SRI) – the ability of a material to reflect solar radiation and not absorb heat.
Stack ventilation – a natural passive system of promoting air flow to draw hot, stale air up and out of a building through tall chimneys or shafts.

Stoep – the South African or Afrikaans term for a veranda, or roofed outdoor space
Thermal bridge – a cold spot in a building's envelope which allows heat to escape more easily.
Thermal comfort – a subjective state in which a person does not feel too hot or too cold in their environment, affected by the temperature, relative humidity, the presence of draughts and personal activity levels.
Thermal emittance – the ability of a material to radiate heat away.
Thermal mass – the ability of a material to absorb, store and release heat.
Thermal stress – heat-related conditions or illnesses which prevent a person from functioning normally when exposed to high temperatures.
Turret – a small tower forming part of a larger roof, as an ornamental feature or historically for surveillance, but also to provide stack ventilation or natural light.
Urban Heat Island Effect – the build-up of heat in urban environments compared to rural areas due to the absorption and storage of solar radiation by dark building materials, reduced evaporation of surface water with less vegetation, and reduced air flow.
Veranda – a roofed outdoor space used to provide shade and protection from rain, while providing an extension to the living space.

Introduction

Historic England commissioned this report to identify historic measures that can demonstrate and support England's historic buildings in adapting to the changing climate. Most of England's existing buildings have been adapted with a focus on retaining heat for a temperate maritime climate characterised by mild winters, cool summers, and relatively high rainfall. As climate impacts intensify, with increasing temperatures and more frequent high temperature events, there is a growing risk of overheating in buildings.[1] This could lead to thermal discomfort, health implications for building occupants due to thermal stress, and increased energy usage due to a rising demand for cooling to counter the overheating.

The purpose of this report is to investigate how passive architectural measures, such as awnings or shutters, have been used in the past to reduce solar gain and seasonal overheating. The research is not limited to shading devices but also considers both historic and contemporary passive architectural measures.

The work seeks to identify limitations, risks or opportunities presented by current regulations, standards, health, safety and future climate events, that might prevent the implementation of these methods for passive cooling in England's historic building stock. The work includes discussion of the increased risk of overheating that may result from poor or ill-conceived retrofit, by way of unintended consequences (causing harm to the significance of the building, its fabric or occupants) or maladaptation (undermining the building's performance and resilience to climate change).

It highlights the importance of addressing the interlinked impacts of reduced heat loss in winter and increased cooling needs in summer. This research will enable Historic England to suggest possible options for passive architectural measures which may help reduce the risk of overheating to owners and managers of historic buildings in response to the changing climate. While this report focuses on buildings and measures in England, many of these will be applicable across the UK.

This research follows the publication of Historic England Advice Note 18: Adapting Historic Buildings for Energy and Carbon Efficiency in July 2024.[2] It could help inform further development of Historic England's existing suite of guidance for the sector on Overheating and Historic Buildings, including guidance on how passive measures may be used in combination with active or mechanical services, to reduce the risk of overheating.[3]

Aims

This project relates to activities within Historic England's ***Corporate Plan and Climate Change Strategy***, and to commitments made in the Government's third ***National Adaptation Programme (NAP3: H1 Risks to health from heat, H6 Risks to energy demand, H11 risks to cultural heritage).***[4] This project directly supports the Climate Action Priorities outlined in Historic England's Corporate Plan and Climate Change Strategy.

This project will help Historic England to:

- Establish a range of architectural measures that can potentially be used to adapt existing historic buildings to reduce the risk of overheating;
- Identify relevant risks, limitations or opportunities relating to regulations, standards, health and safety, or predicted future climate events that might prevent the implementation of, or change the proposed method, for interventions to reduce overheating in England's historic building stock.

The research aligns with Historic England's Climate Change Strategy (Historic England 2022), including:

- Strand 1:1.4 Develop guidance and training on retrofitting historic buildings;
- Strand 1:1.5 Invest in research;
- Strand 3:3.4 Develop new adaptive approaches for heritage assets;
- Strand 3:3.8 Share solutions to common problems with climate change responses.

The work will inform Historic England's technical guidance and provide evidence-based opportunities for potential climate change adaptation and mitigation options within the heritage sector. It will also act as evidence to be provided to the Building Safety Regulator if the production of Approved Document O for existing buildings is introduced.

Climate Change and Overheating

Overheating occurs when internal temperatures increase to a point where occupants may experience discomfort. It may be caused by internal heat gains from mechanical and electrical equipment, people, or from external weather conditions.[5]

In order to robustly assess which architectural measures have potential to effectively reduce overheating risk, it is important to understand the exposure to overheating risk in the future as a result of projected impacts of climate change.

It is anticipated that, while the hours of sunlight will remain consistent, as these are related to the earth's rotation and tilt, increasing levels of greenhouse gases will further insulate the earth's atmosphere and trap the sun's heat.[6] An increase in greenhouse gases correlates to an increase in global temperature, which in turn will require solutions which improve thermal comfort.[7] Exposure to solar radiation may also increase due to reduced cloud cover, making the provision of solar shading a relevant solution to investigate.[8] Changes to wind patterns could also reduce the availability of natural ventilation, so designing buildings to maximise flexibility for openings to provide natural purge or background ventilation could help.[9]

However, weather predictions are variable due to the complexity of calculations and the butterfly effect, meaning small changes to input data cause large changes to predictions.[10] This is particularly true in relation to humidity and moisture. It is not clear if summers will be hot and wet or hot and dry, nor what wind-driven natural ventilation may be possible during heat events. Proposals for architectural measures should be robust and appropriate for both scenarios as it is currently unclear which will occur. For suitable solutions to be found, it is important to understand that thermal comfort is also impacted by relative humidity. We perceive humid air as being hotter than the air temperature value as the increased moisture content makes us less able to cool ourselves by perspiration.[11]

The surrounding context of the building for which proposed measures are being considered is also important. While understanding orientation helps limit solar radiation gain from the south side of the building (in the northern hemisphere), understanding the building's setting is also critical. In cities, for example, overheating can be compounded by the Urban Heat Island effect. This scenario is caused by various factors, including decreased areas of greenery and increased areas of dark and thermally massive surfaces, which act as heat stores that release heat energy back into the city overnight. It is also thought that the improved surface water drainage strategies of cities limit any cooling which was previously achieved by the evaporation of surface water.[12]

To summarise, it is predicted that the risk of overheating is likely to be caused by various and combined mechanisms, including:

- Increased air temperatures caused by greenhouse gases
- Increased exposure to solar radiation caused by changes to cloud cover
- Changes to natural ventilation caused by changes to wind patterns
- Changes to atmospheric humidity and moisture
- Increased Urban Heat Island effect, which compounds the issues above.

These factors are likely to be exacerbated by building-specific issues caused by poor adaptations such as reduced cross-ventilation caused by additional internal partitions or reduced natural ventilation caused by retrofits intended to reduce heat loss.

The architectural measures reviewed in this report target responses to these mechanisms.

Literature Review

Passive architectural measures used historically in England

In Victorian England, measures to promote natural ventilation were designed and promoted primarily in public buildings such as libraries and halls, which were prone to overheating due to high levels of occupancy and the heat emitted by gas lights. For example, Richardson illustrated the detailed construction of a ventilating turret in 1895, while companies such as John Gibbs and Son advertised patent roof ventilators, which were widely used in England and much further afield in an age known for its prefabricated metal and cast-iron fixtures.[13]

Figure 1: Louvred bellcote and ridge vent details to Grade II listed Captain Cook School, Middlesbrough. © Mr Alan Bradley. Source: Historic England Archive

Schoenefeldt has undertaken a significant body of research to understand the natural ventilative cooling strategies incorporated into the design of the Houses of Parliament.[14] His research describes the investigations and testing of ventilation and thermal comfort by Scottish physician David Boswell Reid between 1836 and 1851. This initially included the design and trialling of stack ventilation to the Temporary House of Commons, involving perforated floors and a large chimney to promote air flow.

In the 1840s, Reid worked with architect Charles Barry to develop the ventilation and heating systems of the House of Parliament and House of Lords, drawing on the feedback received from the occupants of the Temporary House of Commons. Barry went on to seal the perforated floors to reduce the sensation of draughts or chill to the feet, but the altered system did not improve overheating issues during the summer. In 1854 Goldsworthy Gurney was appointed to address the building's thermal comfort issues. Gurney reinstated the use of perforated floors in the House of Lords, but in opposition to Reid and Barry, he introduced openable windows in the House of Lords to provide natural cross ventilation when needed and to allow for night purge cooling. External roller blinds to the west and east elevations were used to reduce glare and heat gain in the afternoon.[15]

Schoenefeldt's work highlights the many difficulties faced by these designers in their attempts to meet different expectations or perceptions of thermal comfort by the occupants of these spaces. It also shows the need to combine passive techniques to achieve the greatest comfort.

Schoenefeldt has also investigated techniques historically used to reduce overheating in glasshouse structures, which is useful when considering options for more extensively glazed buildings. Joseph Paxton designed an exhibition hall in the form of a glasshouse for the 1851 Crystal Palace in Hyde Park. This necessitated adapting the design to improve thermal comfort for occupants, and to reduce the condensation issues and leaks commonly found in glasshouses. Externally hung calico screens were used to provide shading to reduce overheating.

Louvres were incorporated into the design of the structure's vertical panels to provide top and bottom ventilators. These provided a breeze, but the regular temperature monitoring which was undertaken in the structure post-occupation showed they did not prevent overheating.[16]

Figure 2:
View of Crystal Palace from south east showing bands of louvres, curtains and screens.
© Historic England Archive. York and Son Collection.

Pender discusses the loss of historic awnings on British buildings, noting that many buildings still retain their awning hoods despite having lost their fabric awnings over time.[17] Awnings enabled ventilation while blocking direct sunlight and they were adjustable, giving occupants control over their own thermal comfort.

Mansfield discusses the traditional shop awning typically seen in images of Victorian and Edwardian high streets, noting how these awnings or canopy blinds increased in popularity with increased glazing to shopfronts following the repeal of the Glass Excise Tax in 1845.[18]

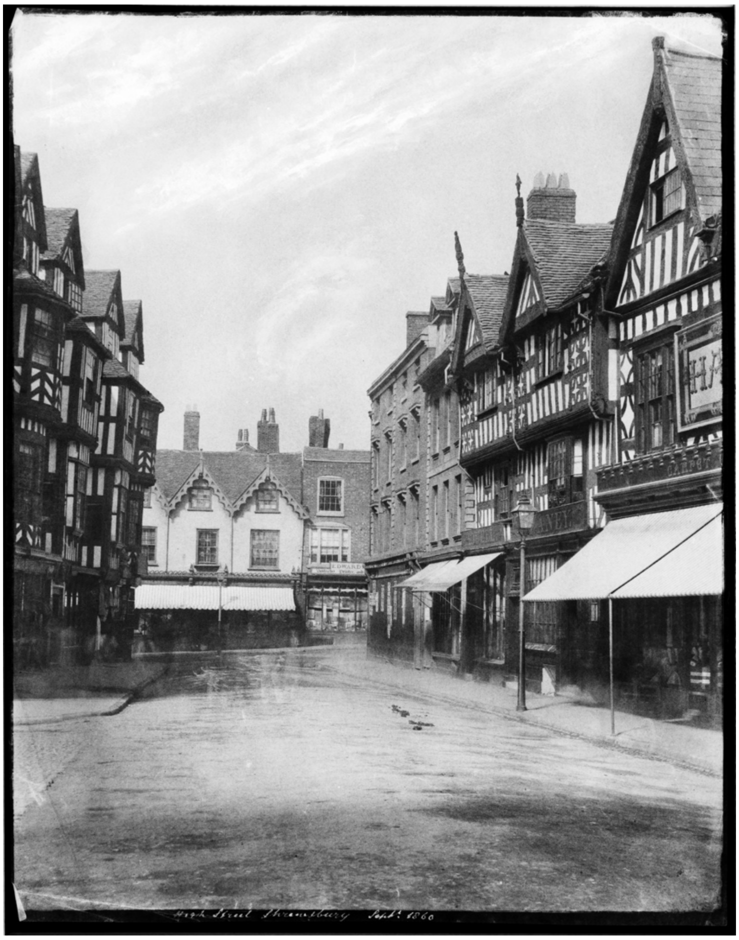

Figure 3:
View of shop awnings on Shrewsbury High Street in 1860.
© Historic England Archive. Henry Taylor Paper Negative Collection

Numerous papers and articles exist which outline a general range of possible architectural measures currently available to reduce overheating in England. Gupta lists passive solutions or strategies for retrofitting domestic buildings, including natural ventilation, several shading options, and the use of green and cool surfaces.[19]

While the article provides a helpful overview of possible strategies and accompanying considerations and consequences, it does not discuss the historical use of these methods. Similarly, the Department of Energy and Climate Change has issued guidance on low to high cost options for preventing overheating in the home.[20] Pelsmaker's ***The Environmental Design Pocketbook*** provides guidance for implementing many of these features.[21]

Porritt et al. modelled the effectiveness of roof and wall insulation, external window shutters and lighter external wall and roof colours on Victorian terraced houses in the UK.[22] They found closing external window shutters most effective at reducing temperatures in a heat wave. Another author, Cassar, suggests learning from the Mediterranean region, describing the hygroscopic qualities of traditional roofs which are able to absorb and release moisture for passive cooling, the use of loggias, deep eaves, shading and surface colour.[23]

Passive architectural measures used historically in the Mediterranean

Climate change experts predict that England's weather will become similar to conditions historically experienced in the Mediterranean region — namely warmer, wetter winters and hotter, drier summers as shown in the UKCP18 climate projections for the UK.[24] Therefore, this report reviews architectural measures adopted in the Mediterranean as well as in England.

Oikonomou and Bougiatioti assessed traditional domestic buildings from the 19th/early 20th century in Florina, Greece. The study examined their thermal behaviour as affected by typology, building materials and techniques, including the use of the hayat, a semi-open covered living space.[25] Similarly, Achenza et al researched the use of the loggia, the covered outer room typically found in the traditional houses of southern Sardinia, to understand how the design of this architectural feature impacts its effectiveness in improving comfort by protecting inner rooms from solar radiation.[26] Philokyprou and Michael also investigated different types of semi-open spaces in traditional houses in Cyprus, including timber post and beam structures, stone arches, and plant-, or vine-covered pergola structures, as well as the effect of their orientation, enclosure and materials on temperature fluctuation.[27]

A study on the use of colour in a Mediterranean town, Ostuni, Italy, showed that the typical white lime wash finish used there provided greater thermal comfort than darker surface finishes.[28] Pal et al. and others have noted that the use of white or lighter coloured finishes on the exterior of buildings in hot climates results in buildings that are cooler than buildings painted in darker colours such as black or grey, as less surface heat is absorbed and transferred to the interior.[29] The benefit of using cool or solar reflective coatings to surface finishes on shutters has also been studied.[30] Cool materials have high solar reflectance (albedo) and high thermal emittance values, and have also been found beneficial for roof surfaces.[31]

Desogus et al. used the vernacular architecture of Sardinia to understand the effectiveness of traditional passive or bioclimatic design features in the Mediterranean climate.[32]

Bioclimatic architecture is designed with an understanding of the local climate, with the aim of enhancing thermal comfort, as described in Olgyays' pioneering and widely cited work of 1963 and later editions.[33]

Desogus et al. also refer to earlier work by Egyptian architect Hassan Fathy, who studied how vernacular construction techniques could be applied to contemporary architecture in hot arid climates and the more recent work of Cañas et al., which focused on the vernacular design strategies of Spanish architecture and how these could be translated into contemporary constructions.[34]

Vernacular architecture is indigenous to a region, using local materials and construction methods which often respond to the local climate.

Further to the studies on historic building techniques in the Mediterranean, numerous studies have been undertaken to research the effectiveness of these methods alongside more recently developed strategies and technologies. The effectiveness of traditional timber window shutters is compared to the contemporary aluminium roller shutter in the Mediterranean climate of Istanbul, finding that thermal roller shutters provide better thermal performance to reduce heat loss.[35]

However, that study does not consider their adaptability for ventilation, natural lighting, views out, or their effectiveness in reducing solar gain. In addition to the traditional loggia noted above, other techniques investigated have included the use of overhangs for shading, balconies, thermal or insulative improvements to glazing, natural ventilation strategies such as cross-ventilation, one-sided ventilation and night purge ventilation in conjunction with thermal mass.[36]

The studies on ventilation showed that night-time purge ventilation was the most effective type of passive ventilation to achieve summertime cooling.

Figure 4:
Shutters on the Musee de la Vie Romantique, Paris. Note additional awnings to the top windows.
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Several studies have found that vines, climbing deciduous plants and trees used as shading devices help to reduce overheating, whilst responding to the changing seasons.[37] In the same way, vertically planted structures, or green walls, may be used to provide effective shading and cooling.[38]

Wittchen et al. have compared the impact of external window recess depth, finding that deeper external window recesses are an effective measure to help reduce solar gain on the glazing.[39]

Pajek et al. discuss the effectiveness of passive measures in five European countries, four of which are in the Mediterranean.[40] Here, modelling was undertaken for five locations including Moscow, Ljubljana, Milan, Athens, and Porto. The study showed that the most effective methods to achieve cooler temperatures are shading of glazed areas and minimising window-to-floor area ratio (the proportion of glazed window area in a room to its floor area). The research focused largely on contemporary building design but is relevant as it focused on which passive measures would become more relevant methods to reduce overheating as temperatures increase.

Pajek and Kosir tested the relationship between different passive measures and energy use in single-family detached residential buildings, finding that the most effective measure for long-term energy efficiency is the reduction of window sizes.[41]

Blavier et al. examined previous studies on the effect of climate change on historic building fabric, including accelerated decay of materials, with a view to enhance understanding of adaptive measures that can address these negative effects.[42]

While this study did not specifically address the prevention of overheating, it highlights the lack of existing literature on practical solutions for historical or heritage structures. The use of UV-absorbing films on windows is noted as being a possible solution which should be carefully considered due to the risk of deterioration of historic glazing from photophoresis (particle movement of the glass from uneven temperatures). Where the application of glazing films is found to be inappropriate, the use of shutters, blinds or vegetation is suggested as alternatives. A study on the use of low emissivity window films in historical buildings showed that it could reduce solar gains by about 35%.[43]

A study by Marino et al. showed how “cool paints” or coatings could be used to enhance the solar reflectivity of existing historic tiled roofs, as seen in many historic centres in Europe.[44] The clay roof tiles typically used in these regions have low solar reflectance values without any treatment.

Cool paints or cool coatings have a high Solar Reflective Index (SRI) which helps them reflect solar radiation more effectively from the surface they finish. This reduces the absorption of heat which in turn can help reduce the risk of overheating. Many of these products contain quartzene to improve their reflectivity.[45]

This study also addressed the need for solutions which respect the aesthetic characteristics of historic buildings, investigating the use of “cool colour” coatings which match the appearance of historic materials. However further work is needed to understand their impact on moisture and the hygroscopic qualities of these materials.

The use of reflective coatings is also mentioned by Blavier et al., with reference to the EFFESUS (Energy Efficiency for EU Historic Districts’ Sustainability) project in Europe, which reports to have developed a low-impact, reversible reflective coating for porous substrates.[46]

The 2012 to 2016 study asserted that adaptive solutions at the time had not been designed for the specific needs of historic buildings. The EFFESUS project took place in thirteen European countries and comprised seven case studies to test and model data illustrating the suitability of different materials such as aerogel insulation for wall cavities; an NHL5 lime based insulative mortar; radiant reflective coating; and various options for upgrading single glazing. These studies have generated concerns around the appropriateness of certain of the materials selected for investigation and focused on energy efficiency rather than seeking measures to target overheating.[47]

Vieites et al. also cite the EFFESUS project among several European initiatives to improve the energy efficiency of existing and historic buildings.[48] The other projects discussed in their paper include NEW4OLD, a project to retrofit an historic building in Brussels with multiple measures; 3ENCULT, comprising eight case studies using new technologies; RENERPATH, which monitored the energy demands of historic buildings; RESSEEPE; LIFE-INSU-SHELL; and PIME’s, which all researched innovative technologies to reduce overheating.[49]

As some of the studies noted the benefits of external and internal wall insulation to improve energy efficiency, the possibility of their use to reduce summertime heat gain was further reviewed. Research in this area is presently minimal, particularly on the potential benefits of mass solid wall construction in a warming UK climate. It was noted that while these techniques may be beneficial in preventing heat loss in colder months, there is growing concern and evidence that they may increase risk of overheating, particularly when a robust whole building approach is not undertaken to inform decision making at an early stage.[50] For example, without additional measures to counter overheating such as ventilation and shading, buildings retrofitted with internal wall insulation have the potential to exacerbate overheating risks.[51]

Passive architectural measures used historically in hot climates

This project also identified the opportunity to learn from the passive techniques used by British colonial architects and builders in overseas territories, where they implemented British building design but adapted it to suit the hotter climates. The late 19th and early 20th century saw the increased use of industrially produced materials as they were found to be ideal for withstanding hot weather, storm conditions and termite attack. For example, mass produced cast-iron detailing and corrugated iron sheeting were easily transported by ship to the Cape, South Africa, resulting in its prolific use in the region, which experiences winter rainfall (unlike the rest of Southern Africa) and Mediterranean weather conditions.

Many of the features described below were intentionally designed into colonial buildings to suit the hot climates, rather than being subsequent adaptations. They have been included in this review as they provide precedents for possible retrofits to existing buildings, using design styles and features which could be deemed sympathetic to a large proportion of the historic building stock in England, and potentially the wider UK.

An ICCROM report on the role of architecture in preventive conservation notes there are not many studies on the potential use of original passive building design features and materials to control the indoor climate.[52] While the ICCROM report explores this in relation to the internal conditions of museums and archives, it is useful in providing examples of colonial building strategies used in warm, humid regions. These include ventilated pitched roofs, long eaves, openings on all facades, above ground basements, deep Verandas, and stilts to maintain air flow, as seen in The Museum of Colonial History in Aba, Nigeria.[53] The report describes how although these adaptations were often prone to insect infestation and water ingress in heavy rains, they also helped the buildings maintain a constant internal environment.[54]

Nee et al. identified the use of the ventilating turret, tower and cupola as distinguishing features of British colonial buildings constructed in 19^{th} century George Town, Penang.[55] Whilst being highly ornamental to denote importance to the buildings they adorned, these features also fulfilled the role of providing additional passive ventilation, often situated above a staircase in order to pull hot air up and out of the building.

In Namibia, similar features can be seen in its German colonial architecture. Builder Otto Busch made use of chimneys, towers and different types of ventilators to define the roofscape of his buildings.[56] This was reminiscent of the decorative features, including turrets and cupolas, typical of the rich Wilhelminian architecture seen in Berlin at the time. Busch's villas were elevated on basements, and featured towers or turrets with ornamental umbrella roofs, which distinguished them from other houses in the area. With a staircase at the bottom, hot air could be pulled up through the turret and out of the building.

These buildings also featured verandas, colonnades and sail blinds to provide shade. Peters notes that the presence of the basement alone did not provide cooling, but when used with openings to bring cool air into the space at night it offered the ability to retain cooler temperatures during the day with the windows closed.[57]

Peters notes that German colonial architects in Namibia developed a unique building style that was tied to the availability of local materials, determined by climatic requirements and restrained by budget.[58] This led to the development of the "Verandenstil" (veranda style), used consistently in domestic and administrative buildings in the country.

Peters also notes that missionary Dr C.G. Büttner recommended the construction of a veranda all around a building, to prevent rain and direct sunlight falling on the clay walls which were typical of the region. Verandas not only took on the role of the hallway but also became a significant extension of a house's living space, unlike the smaller European porch, which is used as a threshold or transition to the exterior.

While the verandas or stoeps which developed in South Africa were built of timber or cast iron, materials widely accessible from Britain, German architecture – and subsequently German colonial architecture – did not make use of cast iron features to the same extent. German settlers found that timber was highly susceptible to attack by termites in the hotter, drier climate of Namibia and therefore made use of clay brick to construct their verandas, developing a style unique to its other African counterparts.

Figure 5:
19th-century shopfronts with covered stoeps and balconies in Simon's Town, Cape Town.
© Vanessa Ruhlig

Figure 6:
Veranda of the 1903 Central Hotel in Omaruru, Namibia.
© Vanessa Ruhlig

British colonial builders in India adapted to the local conditions by increasing shading and ventilation to make their buildings more comfortable. Cassar describes measures taken to enhance natural ventilation through the use of deep eaves, ridge ventilators, clerestory windows and raised floors.[59]

Another feature seen in buildings constructed for hot climates is the high ceiling, which allows the hot air to remain further away from the building occupants below. A study by Guimarães et al. showed an increase in room temperature of 1ºC for every 20cm reduction in ceiling height, illustrating the benefit of higher ceilings.[60]

Modern architecture was also adapted internationally to suit local climate conditions. The V&A discusses the design features of Tropical Modernism in West Africa, designed by architects Maxwell Fry and Jane Drew in the 1940s and 50s, who found the opportunity to develop their modern style in the context of the hot climate of British colonial West Africa.[61] They used brise-soleils, louvres and wide eaves to create modern buildings that were adapted to the local climate. Their work did not incorporate indigenous building techniques, choosing instead to adapt European design and building elements to the local conditions.

Baweja describes tropical architecture as “a trans-colonial set of architectural practices that originated in the colonial experiences of European modernist architects.”[62] He uses the work of exiled German architect Otto Koenigsberger in India to discuss how an understanding of limited local construction materials and the use of passive technologies informed Koenigsberger’s theorisation of Tropical Architecture.

Koenigsberger investigated vernacular, pre-colonial and colonial architecture in India in 1939, noting the use of semi-enclosed spaces for outdoor living, veranda corridors, chhajjas (sunshades or overhangs), jaali (lattice screens) and glazed high level ventilators to avoid the need for mechanical cooling.

Alongside studies of historically used and contemporary passive design measures, there is also a body of research on achieving thermal comfort in buildings without mechanical cooling, how this may differ across climatic regions, and how perception of this comfort may differ widely.[63] Kini et al. assessed the difference in thermal comfort achieved in a commercial building by testing several passive design variations and combinations of these, including roof insulation, window overhangs, vertical fins, night ventilation and blinds.[64]

Nematchoua et al. discuss the energy consumption for cooling in buildings using different passive design techniques in several climatic zones in former French colony, Madagascar.[65] This example highlights that the range of comfort varies according to geographical position or climatic zone, useful when considering the extent of potential architectural measures needed across the regions of England.

The effectiveness of the techniques mentioned above can be enhanced through combination and integration with other energy saving measures. For example, Mandalaki et al. found that shading devices with integrated south facing photovoltaic panels are ideally located to efficiently harness energy whilst providing shading.[66] The orientation of photovoltaics remains key to increasing their efficiency at energy generation. McClelland suggests incorporating photovoltaics into fixed shading devices or movable shading panels which can be adjusted to suit the solar angle.[67] Gindi et al. note the possibility of using external or internal venetian blinds with integrated PV, inclined canopies (awnings), and brise-soleils.[68]

Figure 7:
Combination of features including awnings, roof ventilation and a ventilating turret in Windhoek, Namibia.
© Vanessa Ruhlig

Figure 8:
A veranda, shutters, louvred roof ventilation and deep eaves of 1906 former office of the Chief Justice, Windhoek.
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Summary of passive architectural measures

Based on the discussion of the literature review, a summary of possible passive architectural measures is provided below. These fall under three main categories, namely shading, ventilation and surface/material applications.

Shading:

These measures respond to overheating caused by increased solar radiation.

- Awnings
- Overhangs/deeper eaves
- Balconies
- Verandas/stoeps/loggias
- Vertical fins/slats
- Brise-soleil/screens
- External louvres/shutters
- External roller shutters
- Internal blinds
- Trees/planting
- Green walls
- Reduction of window-to-floor ratio
- Deeper window recesses

Ventilation:

These measures respond to changes in natural ventilation and changes in atmospheric humidity and moisture.

- Alteration of fixed windows to openable windows
- Openable clerestory windows
- Ridge ventilators
- Towers/turrets/cupolas
- Increased ceiling height

Surface/Material Applications:

These measures respond to overheating caused by increased solar radiation and the Urban Heat Island effect.

- Surface colour
- Solar reflective paints/coatings
- UV-absorbing/solar reflective window film

These measures and their general considerations are discussed below. The potential risks and limitations of utilising these measures are discussed in Section 6 and detailed in an accompanying risk identification matrix with the aim of providing further guidance on considerations for their appropriate use in historic buildings.

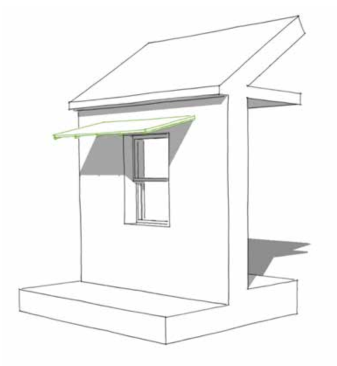
Please note that all diagrams below are provided as simplified sketches for illustrative purposes only.

Shading

External shading devices have been found to be the most effective method of reducing solar gain, by deflecting solar radiation before it has entered the building. For all the proposed shading methods, designs should reduce solar gain in summer whilst enabling solar gain in winter. This avoids additional heating costs in winter that may counter any energy reductions achieved in summer.[69]

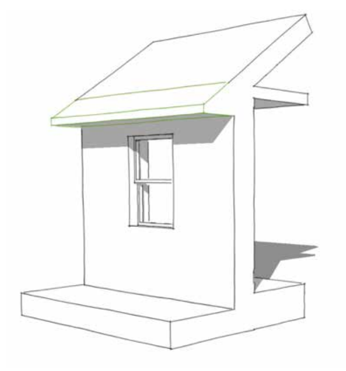
Solar shading should be used in combination with night-time cooling or night ventilation to achieve thermal comfort. Provision of secure methods, such as lockable shutters should be considered to allow for this.[70]

Awnings



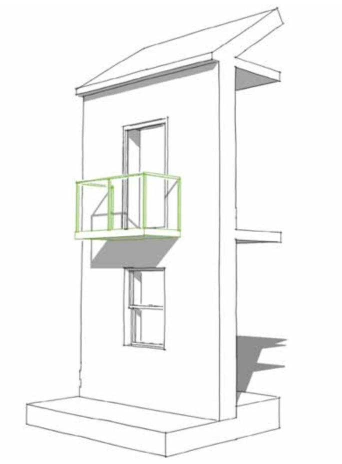
Awnings provide horizontal or inclined shading to building openings. They are most effective on the south elevation, with a total shading depth of around 50% of the window height, and maximum 1.5 metres deep to allow for solar gain in winter and maximise daylight.[71] The horizontal shading provided by awnings is least effective on the east or west elevations of a building due to low sun angles in this direction. The use of integrated photovoltaic panels is also possible as part of this solution. As this technique would require positioning of the panels to suit the solar angle to maximise their efficiency, it can be considered to have similar benefits and challenges as awnings.

Overhangs/deeper eaves



The use of overhangs or deeper/wider eaves has been noted as a consistent feature of buildings in hotter climates, to reduce solar gain on walls and openings below. They also reduce the building's exposure to heavy rainfall and storm conditions. This method is more difficult to retrofit in historic buildings, requiring work to extend the existing roof and rafter ends. It may have a significant visual impact on historic buildings, particularly in the context of terrace housing, for example, where roofs of adjoining properties are often continuous. However, its use should be carefully considered when reviewing possible upgrades, structural repairs or wholesale replacement of an existing roof.

The concept of overhangs and deeper eaves could be implemented in a more reversible way, through the installation of secondary or add-on roof structures or canopies which are sympathetic to the existing building style. For example, a porch roof could extend across the southern façade, offering shading to the ground floor. This approach would be similar to the use of verandahs/stoeps/loggias (see below).

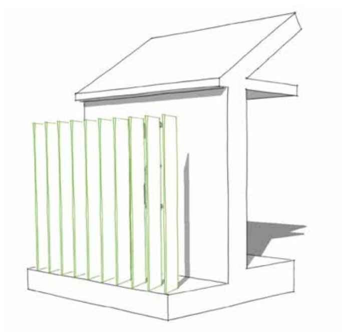


Balconies

The use of shaded balconies to provide shading and shelter to dwellings below, whilst providing outdoor space above, has been used frequently in Europe in response to its climate. The insertion of a balcony structure onto an existing building may offer mitigation against overheating by providing suitable overhangs and horizontal shading. As with the horizontal shading provided by awnings, this benefit is least effective on the east or west elevations. The work required to retrofit a balcony may require the insertion of an additional doorway to replace an existing window so that access to the balcony is possible. If this is the case, this will increase the impact of the intervention on the existing building fabric and could result in the loss of significant historic building fabric such as original walling and windows. In addition, the retrofitting of a cantilevered structure onto a traditional building is particularly challenging and may require significant material alteration and strengthening.

Verandas/stoeps/loggias

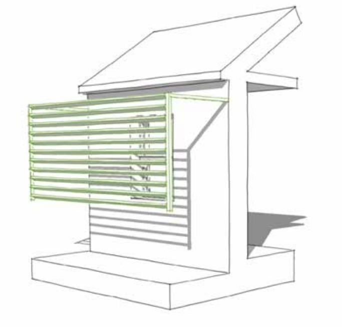
Providing a veranda, stoep or loggia offers similar benefits to an awning or overhang but has the potential to also enhance the building's connection to the outdoors by creating an extension to the occupants' living space if space allows for it to be constructed deep enough. Unlike a porch, the veranda can be used as an external room, rather than a threshold space. Its use may not always be appropriate due to space limitations, structural implications, or because of the visual impact in the context of the historic building and its environment.



Vertical fins/slats

The provision of vertical fins or slats is recommended for south-east or south-west facing facades to account for low sun angles, in combination with horizontal shading.[72]

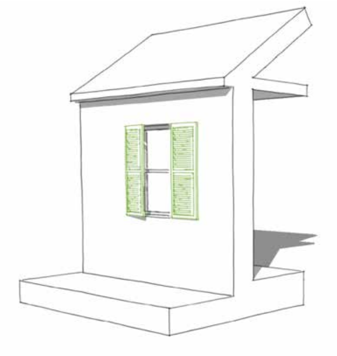
The positioning of vertical fins or slats may negatively impact the view out of windows.[73] Permanently fixed, or closely spaced fins or slats may also reduce a building's means of escape in the event of fire.



Brise-soleil/screens

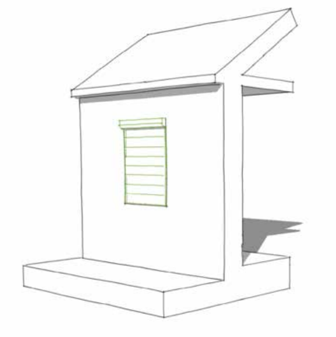
In this report, the term brise-soleil refers to a vertical fixture placed in front of windows or glazed openings to provide shading. This may include the use of horizontal louvres as seen in commercially available options, or more bespoke perforated screens which may take inspiration from historically used jaali (lattice screens). Contemporary perforated screens may be constructed of mesh or perforated metal, while designs inspired by the modernist brise-soleil of Le Corbusier's Unité d'Habitation or the Tropical Modernist movement may be constructed of masonry arranged to form decorative shading patterns. They are typically installed on commercial buildings or apartment blocks – large structures with extensive fenestration to shade.

These installations are often fixed and may impact on the views out of windows and reduce natural daylight.[74] Without careful design and positioning, fixed screens may also limit solar gain in winter, resulting in increased heating costs. This might however be countered by the reduction in cooling costs in the summer. The use of brise-soleil or screens may also reduce a building's means of escape in the event of fire. However, if found appropriate, the use of brise-soleil and lattice screens may provide beneficial shading and privacy to building occupants.



External louvres/shutters

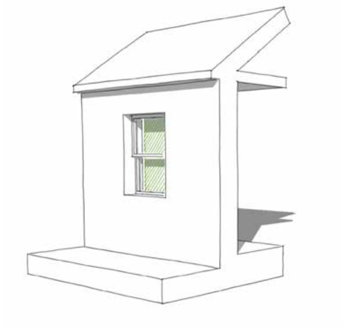
The use of vertically fixed, but movable or openable external louvres or shutters is typically recommended for east or west elevations, in response to low solar angles in these directions, but they are also effective in providing shading on south elevations.[75] Lockable shutters have an additional advantage of providing secure night-time cooling with the windows left open, or additional reduction of heat loss in winter with the windows closed, if designed with adequate thickness and insulation.[76] The presence of existing outward-opening windows may prevent the use of external louvres or shutters, unless these can also be retrofitted to be sliding or inward-opening.



External roller shutters

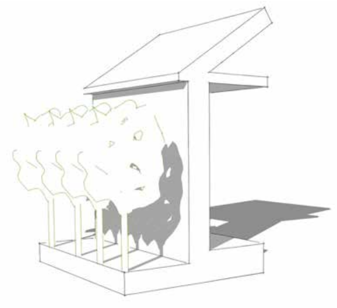
For the purpose of this report, the term external roller shutter refers to the commercially available shutters which have become widely used in European countries such as Germany and France. Some retailers market them as Continental Roller Shutters, referencing their extensive use in Europe. They are generally electrically operated and can be used to provide security, shading, and insulation. External roller shutters provide comparable shading to external louvres or shutters and have similar limitations. When closed, they may have a negative impact on views out of the building. Some varieties are available with perforated shutters, which allow views out, although, as with the solid models, these shutters will still have an impact on natural daylight. In winter, the use of insulated external roller shutters may be beneficial in reducing heat loss.

Careful integration with the building's fire detection and alarm system will be required to ensure that shutters to any openings which function as a means of escape can automatically open or release in the event of a fire. The use of external roller shutters should be carefully considered to avoid damage to historic building fabric, and that their use is visually appropriate.



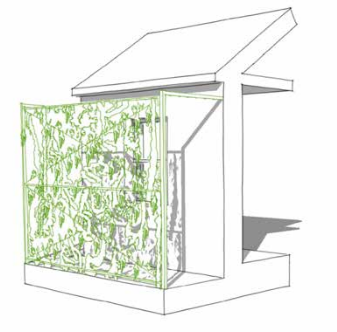
Internal blinds/shutters/curtains

Shading devices fixed internally have been found to be significantly less effective than external shading fixtures as they allow solar radiation to pass to the internal environment through unobstructed glazing. They do however provide some reduction in solar gains, whilst being easily operable by occupants inside the building. This method may also be more acceptable in listed historic buildings where the use external shading fixtures cannot be adequately justified or detrimental to the historic or aesthetic character of the building.



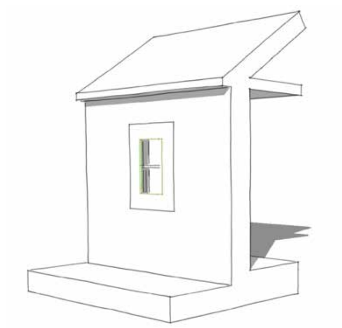
Trees/planting

Planting deciduous trees outside a building can provide solar shading in summer, whilst allowing solar gain in winter when the trees' leaves have fallen.[77] This technique is most useful for the east and west elevations of a building's lower or ground floors. Up to 80% solar gain can be reduced by a planting scheme that includes trees as shading.[78] Careful consideration of planting distance, spacing and tree species is required to make this application successful. Understanding of the trees' root systems or potential growth is required to avoid serious damage to the foundations and below ground services of the building. The use of root barriers when planting can reduce this risk. In addition, it should be noted that the effectiveness of planting will be variable, from initial establishment of plants and through different seasons.



Green walls

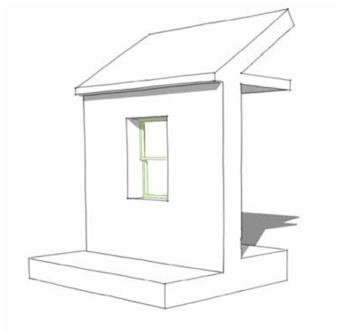
The use of green walls provides a similar benefit to the planting of deciduous trees, combined with the intentional design characteristics of a brise-soleil or screen. This method reduces the risk of tree-root damage to the building as smaller climbing plant species can be selected rather than larger trees (see above). Regular maintenance of the plants will be needed to prevent them growing beyond the constraints of the screen they are planted on, as well as regular watering to prevent the loss of the vegetation which would reduce the efficiency of the system. The process of watering may also provide beneficial evaporative cooling. Careful consideration of how the green wall is affixed to the building will be needed to avoid damage to historic building fabric.



Reduction of window-to-floor ratio

The reduction of a building's window-to-floor ratio is one of the most effective measures to reduce the risk of overheating.[79] This could be achieved by replacing existing windows with smaller windows. The new window reveal and infilled wall panel would need to be appropriately designed to achieve the same hygrothermal performance as the existing adjacent wall to mitigate risks of thermal bridging and moisture related issues. However, without adequate consideration of the impact on ventilation provision, the reduction of window size may result in condensation issues. In the context of historic and listed buildings, this solution may not be acceptable, unless it can be robustly justified. For example, the insertion of smaller windows may reflect an earlier or historic iteration of the building's fenestration.

Deeper external window recesses

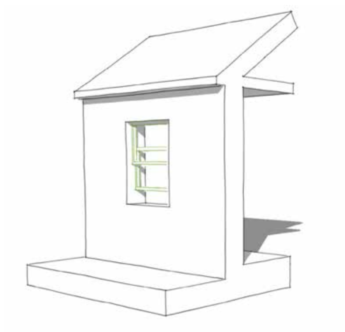


Deeper external window recesses help to reduce solar gain without reducing natural daylight in a building. This may be achieved by setting windows further back into the window opening, to reduce the absorption of solar radiation on the glazing. Additional benefits of deeper window recesses include better protection of the glazing and window edges from wind driven rain and reducing potential thermal bridges by limiting the gap between the glazing and any internal wall insulation. The visual impact of moving windows back will need to be carefully considered, as well as any potential loss of historic fabric such as internal joinery.

Ventilation

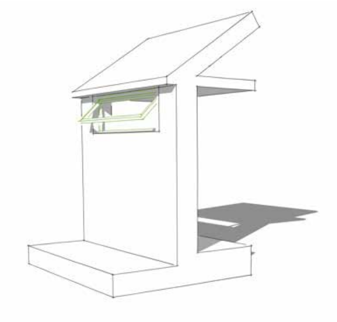
Although this report does not aim to investigate different mechanical ventilation principles as measures to reduce overheating, this research has identified several design and retrofit options which will contribute to the passive ventilation of buildings, which in turn may aid in the reduction of temperatures and the risk of overheating.

Alteration of fixed windows to openable windows

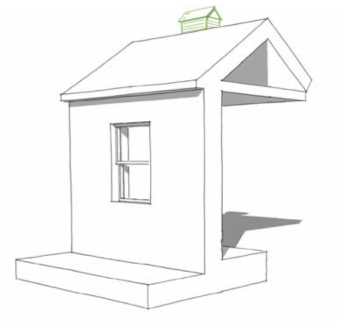


A simple measure available to retrofit existing buildings is the replacement or alteration of existing fixed windows to make them openable. This will help to create cross-ventilation in the building and increase ventilation rates. Providing occupants with the ability to open and close windows also assists in enhancing thermal comfort by giving occupants choice and increasing occupant engagement with the building. The suitability of this measure will need to be considered in terms of impact on original window features and may need to be combined with other measures such as shading to be effective and reducing internal temperatures.

Openable clerestory windows



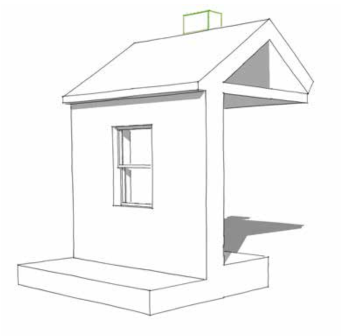
The provision of openable clerestory windows is a design strategy used in many new build projects in hotter climates as it creates natural stack ventilation to draw hot air up and out of the building and allows for secure night-time purge ventilation. Although this technique is more difficult to incorporate in an existing building, it could be explored when alterations or repairs to an existing roof are considered. It may be more appropriate in mid-century or recently constructed existing buildings, but with robust justification may also be possible in older buildings depending on their roof and ceiling arrangement. The insertion of openable clerestory windows is likely to require structural alterations to open up the ceiling void. Consideration of how occupants can operate and maintain these windows, as well as careful weatherproofing will also be needed.



Ridge ventilators

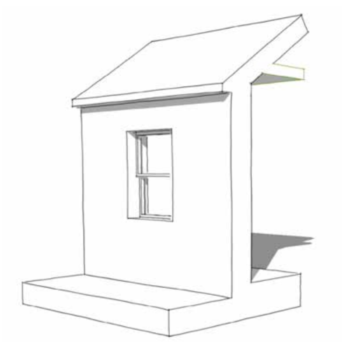
As described in the literature review, ridge ventilators were used in England's Victorian public halls, libraries and railway sheds. Additionally, in British territories, colonial buildings frequently included them to deal with high temperatures by creating a natural stack ventilation effect to draw the hot air out of the building, increase natural ventilation and provide night ventilation. The work to retrospectively install ridge ventilators onto existing roofs will have an impact on the existing fabric, requiring the opening up of the existing covering, structural enhancements to support the weight of the ventilator, and weatherproofing such as lead flashing. If not correctly installed this option could have a detrimental impact on the building, such as allowing water ingress due to poor flashing details or exposure to wind-driven rain.

The visual impact of a new ridge ventilator would need to be carefully considered in terms of sizing, design and finishes which are sympathetic to the existing building and its roof.



Towers/turrets/cupolas

Towers, turrets and cupolas perform a similar role to ridge ventilators, creating a natural stack ventilation effect to help reduce overheating. These features could potentially be retrospectively installed on existing buildings. The same considerations and risks apply as noted for ridge ventilators, with towers potentially having a greater structural and visual impact depending on their size and function. Redundant chimney flues may also be repurposed to serve this function. The use of additional mechanical ventilation to the bottom of the chimney and oscillating cowls to the top may be required to assist in the stack ventilation effect. Historic England has published guidance on reusing disused chimney flues.[80]



Increased ceiling height

Historically, buildings in hot climates made use of high ceilings, in conjunction with ventilation such as openable windows, ridge ventilators or turrets, to allow hot air to rise above the height of the building's occupants. This helped to improve thermal comfort.

This measure may already be present in much of England's existing building stock, such as Georgian and Victorian homes, but where low ceilings exist (such as those in post-war buildings), it may be possible to retrospectively increase the ceiling height, depending on the roof structure and loading from above. This option may not be appropriate in listed buildings or buildings with particularly sensitive interiors due to the risk of loss or damage to historic fabric and potential for extensive structural alterations to support a new ceiling.

Consideration of the impact of increased internal volumes will be needed to ensure that possible increases in heating requirements in winter do not counter the benefits of a higher ceiling in summer. Consideration of how changes in the ratio of internal volumes and window openings will also be needed to ensure natural ventilation remains effective. Any increase in ceiling height may also provide the height required for the potential installation of ceiling fans, which can provide a low-energy mechanical means of creating air movement to enhance thermal comfort.

Surface/Material Applications

Surface colour

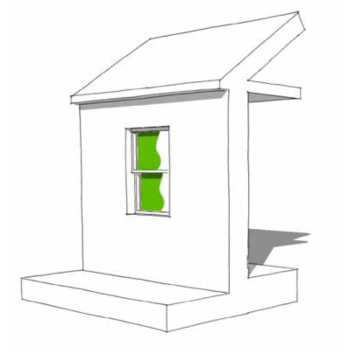
The use of white or lighter coloured finishes is a relatively low-cost action which can be applied to most rendered buildings or those which are already painted. It may also be applied to flat roofing or roof coverings where these are ordinarily coated or painted, such as metal roof sheeting, to lower the surface temperature of the roof. Where existing buildings do not have a painted finish, for example, consisting of unrendered clay brick, or timber cladding, this measure is less appropriate and should be carefully considered.

Lack of maintenance or inadequate re-coating of surface paints may render them less efficient over time.

Solar reflective paints/coatings

Solar reflective paints or coatings, or "cool" paints, have a high solar reflectance index (SRI) or albedo effect. They may be applied to existing external finishes, such as roof tiles and rendered walls, to reduce the amount of surface heat which is absorbed and transferred to the interior. They have similar benefits to the application of light surface colours, but are also available as clear coatings, thus minimising the visual impact on historic building fabric. Understanding of the full impact of solar reflective coatings on historic materials is required before their application, such as impacts on moisture transport mechanisms and true 'reversibility', to avoid detrimental long-term damage to the existing building. Lack of maintenance or inadequate re-coating of these surface paints may render them less efficient over time.

UV-absorbing/solar reflective window film



Where the replacement or alteration of existing windows is not appropriate for an existing or historic building, the application of UV-absorbing or solar reflective window film may be a viable alternative for upgrading existing windows. Replacement of existing glazing with UV or infrared reflective glass may be an alternative solution where the loss of existing glazing can be justified.

When considering use of these films, the impact on visibility and the visual impact they may have when viewed externally should be carefully assessed, as they often have a darker or tinted effect which may have an anti-social connotation or have a detrimental impact on the character of an historic building.

Pelsmakers cautions against the use of solar or tinted glazing as its solar reflectance capability continues through all seasons, including winter when solar gain would be beneficial.[81] However, the beneficial reduction of heat gain in hotter months may outweigh this small risk.

Historic England has previously produced guidance on the benefits, risks, materials and methods for upgrading the thermal performance of windows through the use of secondary glazing.[82] Overheating may be reduced when secondary glazing is used in conjunction with ventilation, internal shading and solar reflective coatings or glazing. There is a risk of overheating, moisture and condensation issues if secondary glazing is used in isolation of these other measures.

Figures 9 to 29: Schematic diagrams of possible architectural measures. © Thread

Evaluation of Architectural Measures, Risks and Limitations

Discussion of Measures, Risks and Limitations

Risks and Regulations

The suggested passive architectural measures to prevent overheating have been reviewed against relevant risks, limitations and opportunities for historic buildings. The suitability of these architectural measures has been reviewed against England's Approved Documents of the Building Regulations.[83] This study has also considered the impact these proposed measures might have on Health and Safety with reference to CDM 2015, Health, Safety and Welfare Regulations 1992 and HSE guidance.[84] Alongside these, other aspects have been considered, including fire safety, CIBSE thermal comfort standards, passive house principles for occupant comfort and anticipated changes to England's weather due to climate change.[85]

The matrix of identified risks at the end of this document quantifies the risks against architectural measures. This can be used as a first step to review the suitability of various architectural measures to reduce overheating in different project scenarios. Risks have been categorised, but as several risks fall under more than one category, their overlap is explained below to assist with locating each item in the matrix.

The identified categories of risk are:

Climate Impact Drivers and Associated Hazards

Predicted changes to our weather systems anticipate not only a hotter climate, but other extreme weather events - such as storms with increased wind speeds and rain fall. Risks associated with these hazards include structural failure due to increased loads, damage to building fabric caused by water ingress due to flooding or frequent, heavy, wind-driven rain and material failure due to increased temperature or UV exposure.[86]

Cost, Sustainability, Programme and Maintenance

For proposed architectural measures to be successful, they must be effective, feasible and proportionate. Risks in this category relate to cost, embodied carbon, ease of installation and maintenance. Intended project life span must be understood to work out if the investment in proposals is appropriate.

Occupant Experience

For proposals to be successful, they must create or maintain thermal comfort in ways that offer simplicity, understanding and ease of use to help building occupants engage confidently with the measures.[87]

Health and Safety

As with all construction projects, there are risks relating to health and safety which must be considered against the proposed architectural measures. Risks in this category include those covered by Building Regulations, e.g. Structure and Fire. These relate to the project during construction, as well as during use.[88]

Quality of Intervention

There is a risk that low quality interventions do not perform as intended. Risks in this category include causing deterioration of building fabric, compromising aesthetic and performance relying on quality materials or installation.

Legislation

Proposals for architectural measures must comply with relevant legislation, as listed in the matrix.

Risks identified and the categories they fall under are tabled below. Where risks fall into more than one category, the first category they fall into is the category they are tabled under in the matrix.

	Climate Impact Drivers and Associated Hazards	Cost, Sustainability, Programme and Maintenance	Occupant Experience	Health and Safety	Quality of Intervention	Legislation
Wind	X			X	X	X
Snow and Ice	X			X	X	X
Increased Rainfall	X			X	X	X
Heat and Cold	X		X	X	X	X
Wet and Dry - Flooding	X		X	X	X	X
Wet and Dry – Fire Weather	X			X	X	X
Level of Intervention		X		X	X	X
Carbon Emissions		X		X	X	X
Ease of Installation		X	X	X	X	X
Ease of Ongoing Maintenance		X	X	X	X	X
Reversibility of Proposal		X	X			X
Increased Winter Heating Load			X	X	X	X
Increased Draughts			X	X	X	X
Ventilation			X	X	X	X
Internal Relative Humidity			X	X	X	X
Acoustics			X	X	X	X
Natural Light			X	X	X	X
User Operability Requirements			X	X		X
Access and Inclusivity			X	X		X
Structure				X	X	X
Fire Escape				X	X	X
Fire				X	X	X
Contaminants				X	X	X
Protection from Falling, Collision and Impact				X	X	X
Thermal Bridging				X	X	X
Security				X	X	X
Deterioration of Building Fabric				X	X	X
Compromising the Building's Aesthetic					X	X
Compromising Material Performance				X	X	X
Quality of Installation					X	X
Building Regulations						X
Planning Consent						X
Conservation Area						
Listed Building Consent						X
Party Wall Legislation						X
Right to Light Legislation						X
Archaeology						X
Ecology						X

Table 1: Identified categories of risk, to be read alongside matrix of risks at the end of this document.

Quantification of Risk

The matrix ranks risks from 3 to 0, with + denoted to measures which are considered beneficial. This section explains the meaning of these values and explains that risk is a factor of likelihood and severity:

3. High Risk

Risks relating to architectural measures have a high likelihood of occurring and will cause problems of high severity if they do occur. For example, brise-soleil will almost certainly be exposed to solar gain, UV and increased temperatures. The outcome will be deterioration of the intervention and failure, which could cause damage to people, property or animals, if mitigation measures are not implemented. Another example: fabric awnings may be less robust in strong winds than photovoltaic arrays and are denoted higher risk under wind loads.

2. Medium Risk

Risks relating to architectural measures may have:

a) a low likelihood of occurring and will cause problems of high severity,
b) a high likelihood of occurring and will cause problems of low severity if they do occur, or
c) a medium likelihood of occurring and will cause problems of medium severity if they do occur.

For example, due to the location of photovoltaic arrays above flood risk height, it is unlikely that they will be affected by flooding. However, in the event they are affected by rainwater, the electrics are highly likely to fail and potentially cause damage to people, property or animals. When comparing the risk of wind on roller shutters (fixed within window reveal) and timber shutters (fixed on outer wall), the risk of wind damage is higher on the more exposed timber shutters.

1. Low Risk

Risks relating to architectural measures have a low likelihood of occurring and will cause problems of low severity if they do occur. For example, vertical fins are unlikely to be affected by increased snow loads, and if they are it is unlikely that these would cause failure of the intervention.

0. No Risk - Not Applicable

Architectural measures have no interaction with this risk. For example, UV-absorbing window film will not be affected by wind loads.

+ No Risk - Beneficial Proposal

Architectural measures could be beneficial and low in risk. For example, roller shutters would lower risks in relation to security as they can be used to protect windows against break ins.

Limitations of the Matrix

The matrix provided intends to give building owners and managers a helpful overview of potential risks and mitigation methods in relation to architectural measures which might be retrofitted to reduce building overheating. However, due to the bespoke nature of each potential project, there are limitations on the information provided within this matrix.

The scores in the matrix are subjective based on a collective of individual professionals' experience and knowledge of each risk.

The matrix assesses potential risks relating to retrofit architectural measures. Given the unique nature of existing buildings, these risks must be reviewed and considered on a case-by-case basis. The matrix presents the highest possible risk level and individual projects are likely to begin with lower actual risk levels. Additionally, implementing mitigation strategies can reduce these risks during the project. As such, the architectural measures should not be discounted for appearing to have many high risks identified, but instead projects should be managed and designed with careful consideration of these constraints.

The suitability of architectural measures will depend on features of the existing building, including, but not limited to:

Location

The location of a building changes factors that affect overheating risk. The predicted number of days of overheating varies by location, as does the solar angle during summer and winter. Even within the same location, the orientation of a building will change which interventions are suitable.[89]

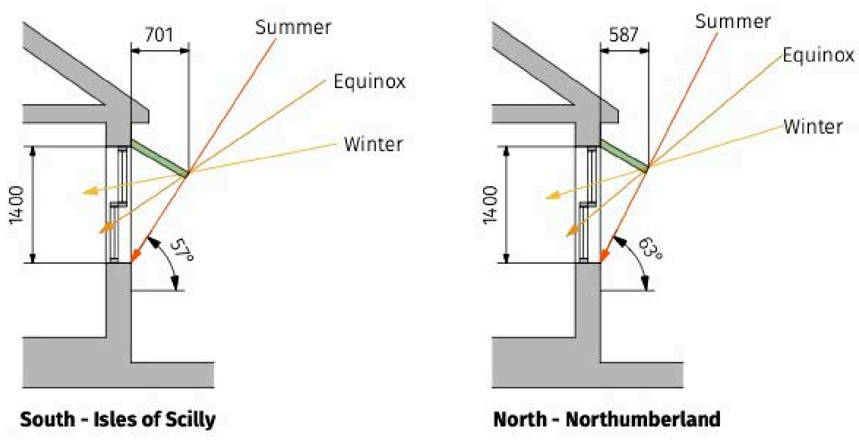


Figure 30:
Ideal shading depth depends on latitude.
© Thread

Existing Construction

An understanding of the existing building's construction, materials and detailing is critical to ensure that proposed measures can be adequately supported by the building structure and to avoid damage to the existing building fabric. Structural appraisal by a competent professional is needed when altering existing structures or load paths.[90] For example, identifying suitable materials or structure to fix proposals to will help to avoid failure of the proposed measure.

Character

The potential impact on the existing building's character should be carefully considered, particularly when working with listed buildings and buildings in conservation areas. Each project will need to assess the potential impact any measure may pose to the building's aesthetic, architectural or historic values, as well as any permissions required. This research report has not focused on impacts on heritage significance, due to this being a broad study of technical options within the historic built environment. Historic England publishes and regularly updates an extensive range of guidance on conservation and planning considerations for building owners and professionals.

Use

Suitability of proposals will depend on building typology and occupancy.

For example, in a domestic property where the homeowner is the occupant, they may be motivated and feel empowered to engage with the building and adapt architectural measures to meet their requirements. However, in a public or let building, occupants or tenants may not feel they have the authority to do this, meaning interventions may be left in their default position and not provide the benefits they are designed to provide. A mitigation for this risk could be using AI smart home technology, although consideration should also be made as to the operational carbon impact of these technologies and whether building occupants have the option to override the systems if the technology fails.

The physical and cognitive abilities of building occupants are also important considerations as they will impact on their ability to engage effectively with the proposed measures. Lack of accessibility could increase potential health risks due to overheating, a risk prevalent in housing.[91]

Matrix

The matrix of identified risks is included at the end of this document.

Case Studies

As part of this research, a selection of case studies has been sought to illustrate projects where these architectural measures have been successfully and effectively introduced or retrofitted to historic buildings. The search was limited to retrofit projects involving commercial or residential buildings that are listed or within a conservation area, which could be supported with accurate measuring and monitoring data collected before and after installation.

One of the case studies involves a new construction extension, selected for its careful placement between historic facades on the edge of a conservation area, offering an example of how passive architectural measures can be implemented creatively within a sensitive heritage context. The availability of publishable projects was also restricted to those which could make this information publicly available.

Case Studies:

- Queens' College Erasmus Building
- Jerez de la Frontera
- Backstage at The Old Vic.

Queens' College Erasmus Building

Architectural Measures:

External louvred shutters, reduction of window-to-floor ratio.

Figure 31: Queens' College Erasmus Building with new shutters and windows installed. © JG Consulting

About the building:

The Erasmus Building is located within the Grade II registered park and garden of Queens' College within the Historic Core Conservation Area of Cambridge. Although it is not yet listed, it is considered a Local Heritage Asset in the Cambridge Local Plan 2018, as the first modernist building on the Backs at the university, designed by Sir Basil Spence and built from 1959 to 1961.[92]

The design was inspired by the work of Le Corbusier, comprising three floors of student accommodation, constructed of unrendered brickwork raised on piloti. All elevations feature large sliding panels of single glazing which punctuate the brickwork. The original concrete shelf ledges and joinery remain in the rooms.[93]

About the adaptation:

The building is occupied throughout the summer months and experiences overheating due to several factors. These include heat gain through the existing uninsulated cavity masonry, the uninsulated flat roof and through the sliding single-glazed aluminium windows, most of which were original to the building. The unshaded windows on the south and west facades were particularly prone to solar gain.

Haysom Ward Miller Chartered Architects worked with Joel Gustafsson Consultants to propose thermal improvements to the walls and roof, alongside works to adapt the windows to reduce heat gain. A new triple-glazed high-performance aluminium window system was proposed to retain the narrow appearance of the window profiles whilst improving the windows' thermal performance to reduce heat gain in the summer months and heat loss in the winter months.

In addition to the new windows, new external sliding shutters were designed to reduce solar radiation to help lower internal heat gain. Their design prevents low-angle sunshine coming into the rooms in the afternoons. They can be operated electrically from inside to give occupants control.[94]

Design process:

During site opening up works the design team found that there was no scope for concealed external roller blind shading due to the positioning of the existing concrete lintels. Fixed projecting sunshades were considered but would detract from the building's aesthetics and be less effective for low-angle sun.[95]

Discussions on the design of the external shutters between the design team and conservation officer resulted in the use of different colours to reflect Sir Basil Spence's early design inspiration.

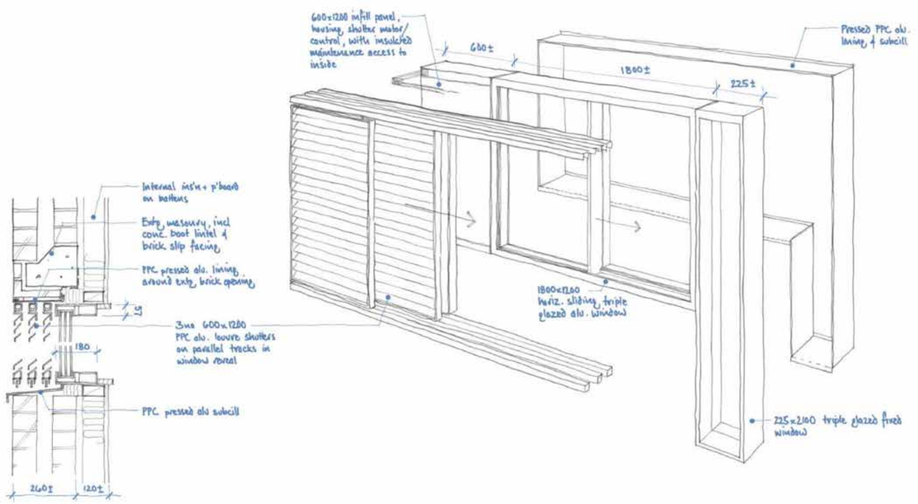


Figure 32:
Sketch of proposed shutters.
© Haysom Ward Miller Chartered Architects

Installation process:

The design of the shutters required the window openings to be reduced slightly to accommodate the shutter sliding mechanisms within the reveal while keeping the external profiles slim and tight to the building. This will have resulted in a slight reduction of the window-to-floor ratio.

Impact and lessons learned:

During a heat wave in May 2025, temperatures were recorded as being three degrees cooler in the rooms with closed shutters, compared to the rooms with open shutters. These temperatures were measured while the building's newly installed light cooling hybrid radiator system was disabled, to test the effectiveness of the shutters on their own.

England experienced its warmest June on record in 2025.[96] Temperatures were monitored by the building management system during a heatwave on 21 June 2025, with the mechanical cooling turned off and windows closed. The graph below shows that the two rooms with closed shutters (K39 and K23) remained consistently two to four degrees cooler than the control room (K38) which had the shutters left open. The internal temperatures of the shuttered rooms remained up to 11 degrees cooler than the peak external temperature of 37 degrees.

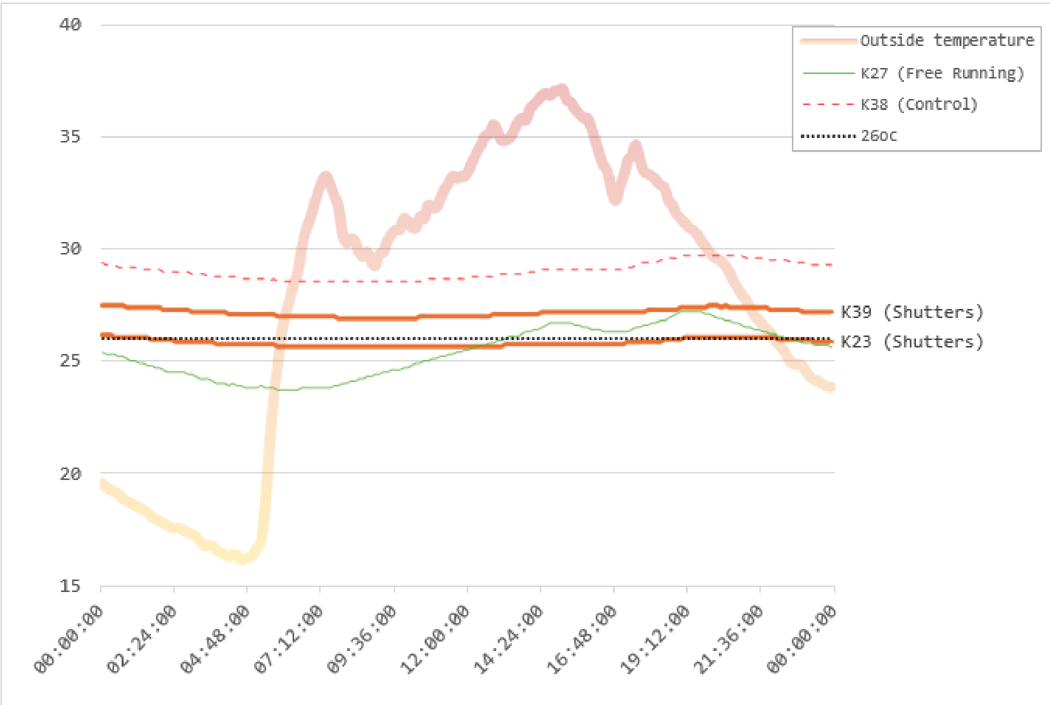


Figure 33: Temperature monitoring during a heatwave shows consistently lower temperatures in the shuttered rooms. © JG Consulting

While the reduction in temperatures cannot be attributed to the new shutters alone, it is clear the combination of thermal improvements and careful consideration of window shading have provided significantly improved thermal comfort to the building's occupants in extreme temperatures.

Jerez de la Frontera

Architectural Measures:

Trees/planting in the form of vine arbours or ***emparrados***

About the buildings:

Jerez de la Frontera is a city in Andalusia, Spain, which has been recognised by UNESCO for its intangible cultural heritage as the birthplace of flamenco art, for its Cartujana horses and for its continued tradition of sherry wine-making. The historic medieval centre of Jerez consists of a tightly woven network of historic buildings and narrow streets. Many of the buildings dotted throughout the centre include traditional wine cellars or ***bodegas***, constructed with thick, white-washed walls and high ceilings to ensure constant temperatures for the storage of wine barrels. Traditionally, many ***bodegas*** have been kept cool through the use of vine arbours, known locally as ***emparrados****,* which help to shade the interiors with their deciduous leaves. The González Byass winery pioneered the expansion of the ***emparrados*** in the 1960s, by planting more vines throughout the streets of their winery on Calle Ciegos in Jerez.[97]

Figure 34: Established vine canopy on Calle Ciegos, part of the González Byass winery in Jerez. © S. Rodríguez - Nomad Garden

About the adaptation:

Building on this tradition, a pilot project entitled SONE (Songs of Nearby Earth) was developed under the Horizon Europe 2020 and New European Bauhaus funded framework of PALIMPSEST. The aim of the project is to regenerate lost sustainability wisdom through nature-based solutions for climate adaptation and local cultural expression through the collaborative co-creation of partners including PALIMPSEST, Estelle Jullian, landscape designers Nomad Garden, local residents group Los Emparrados, the Amigos de los Árboles, Ayuntamiento de Jerez (Jerez City Council), students of the Escuela de Arte y Superior de Diseño de Jerez de la Frontera (EASDJ) and FabLab Jerez.[98]

Since 2024, four streets have been planted with vines to provide shading and cooling to more buildings across the city. The City of Jerez hopes to extend planting to twenty streets.[99] The selected vine variety, ***Vitis riparia***, does not produce many grapes, minimising the presence of fruit flies or insects and sticky fallen grapes on the paving. A single vine can be trained up the side of a building and across a trellis of cables to provide a horizontal canopy of up to 60m^2.[100] The roots do not cause damage to adjacent buildings as they penetrate the ground vertically

Design process:

The project partners held several workshops to plan the implementation of the planting, including discussions on the design of new ceramic guards to help protect the young vines at ground level.[101] The ceramic pieces are inspired by the ***zambomba*** (a traditional ceramic friction drum made in the region) and made using the ashes of the pruned vines, drawing from the agricultural cycle of the region. The ceramics have also been designed as part of a wider cultural heritage collaboration of local students, ceramic artists, composers and ***zambomba*** luthiers. This cultural expression of local ritual and repurposing of traditional objects forms part of the co-creation process of the project to root it within its context.

Installation process:

The extensive consultation and collaboration of local volunteers and creative teams with Jerez City Council led to the Council agreeing to dig holes in the city's pedestrianised streets to accommodate the proposed new vines. These were planted by volunteers of the local Los Emparrados and Amigo de los Árboles groups. FabLab Jerez fabricated an environmental monitoring system to collect temperature and microclimatic data within the urban context.

Figure 35: Vines extended over the narrow Calle Cadenas to form a canopy above. © S. Mendoza – Nomad Garden

Impact and lessons learned:

After three months of monitoring the planted streets, using the system designed by FabLab Jerez, it was found that temperatures were reduced by up to 10 degrees in places in August 2025.[102] Nomad Garden have noted that this technique has worked well in Jerez because of the low humidity levels of the area and the vines' effect of evaporative cooling.

The success of this measure may be more limited in areas of high humidity as the presence of the vines increases the humidity of the space below them. Additionally, as the vines grow in density, their summer foliage may reduce the natural ventilation of the narrow streets below, which could reduce thermal comfort. Whether this would outweigh the benefits of provided by shading and evaporative cooling is yet to be understood. More monitoring is needed as the vines develop over time to understand their optimal use in differing street contexts and scenarios.

The project provides a positive example of how learning from traditional practices of a place can offer culturally rich opportunities for climate adaptation.

Backstage at The Old Vic

Architectural Measures:

Balcony, brise-soleil, passive ventilation.

Figure 36:
South elevation/
Waterloo Road view
of The Old Vic
Backstage, showing
bespoke brise-soleil.
© Philip Vile

About the building:

The Old Vic theatre is a Grade II* listed building situated in Lambeth, London. It is not located within a conservation area, but adjacent to Mitre Road and Ufford Street Conservation Area. It is one of London's oldest theatres, opened in 1818, then known as the Royal Coburg Theatre.[103] Its heritage significance lies not only in its architectural quality, but also due to its role as a leading centre of opera, ballet and serious theatre in the twentieth century. It is one of only four theatres in London comprising pre-Victorian fabric, including its flank walls, part of the rear stage wall and three original timber roof trusses.

The theatre's Waterloo Road elevation comprises the highly significant pre-Victorian flank walls and a smaller post-war façade which forms the front of a separate unlisted structure, 131 Waterloo Road, a former public house that suffered extensive bomb damage during the Second World War and was replaced.

Figure 37: Waterloo Road elevation, showing post-war structure on 131 Waterloo Road prior to demolition. © Lucy Picardo

About the adaptation:

The Backstage building will creates a new hospitality offering for the theatre before and after shows, to provide an additional stream of revenue for the theatre, whilst enhancing the street presence on Waterloo Road. The Backstage building also forms an important connection to the newly refurbished back of house areas, significantly improving accessibility across the expanded dressing rooms, providing step-free access to the stage door and a large lift to ensure all areas are inclusive and easily reachable by all users. An accessible Clore Learning Centre, Free Script Library and Studio Theatre enhance the theatre's community offering.[104]

The Backstage building comprises six levels to provide a building of a similar scale to The Old Vic and surrounding structures. The building's new timber-frame structure has low embodied carbon, and the design makes use of several passive architectural measures to minimise energy use and reduce the risk of overheating.

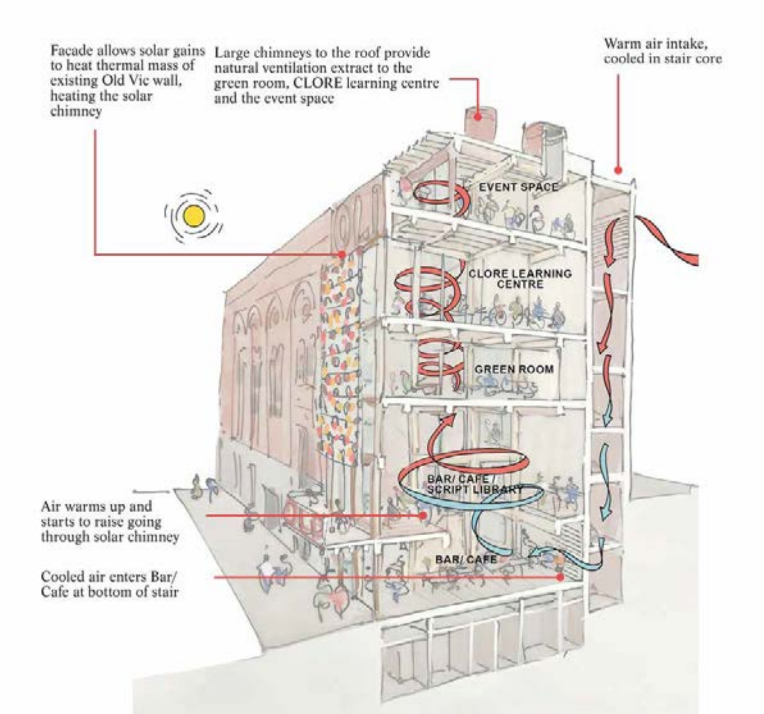
A bespoke brise-soleil made of repurposed theatre barn door lights provides solar shading to the glazed south-west facing façade, whilst creating a decorative feature to bring colour and playfulness to the street-face of the building.

Figure 38:
View of the Brise-soleil and balcony on Waterloo Road.
© Philip Vile

A projecting balcony provides shading and weather protection to the ground floor and entrance. It is placed in line with the existing base plinth of the existing theatre façade.

Fresh air is directed down through the stairway core, bringing cooled air into the ground floor which then rises up out of the building via a central solar chimney through the internal spaces to roof level.

Figure 39:
Proposed passive ventilation strategy.
© Haworth Tompkins



Design process:

Architects Haworth Tompkins worked closely with services engineers, Skelly and Couch, from the early design stages to assess the most appropriate options for low or zero carbon technologies and to manage the heat risk of the proposed building. Natural ventilation was not possible from the front street façade to the south due to high air pollution levels. The brief specifically excluded mechanical cooling, requiring the engineers to devise a fully passive ventilation strategy. By providing a solar chimney they were able to provide passive ventilation and natural light to all levels.

The strategy to reduce the risk of overheating included the use of solar shading, high performance glazing, increased ventilation rates, and nighttime purge ventilation through automated damper controls. The strategy was assessed by modelling the proposal for thermal comfort against CIBSE TM52 criteria (number of hours temperature exceeds threshold comfort temperature, severity of overheating on any one day, and maximum temperature for a room).

Installation process:

The assessment by Skelly and Couch showed that the large areas of unopenable glazing to the south façade would require a minimum of 33% to 45% shading provided by the brise-soleil to avoid overheating.[105] The Old Vic put out a call for disused barn door lights from theatres across the country, which were catalogued so that Haworth Tompkins could explore, model and test possible shading arrangements to repurpose the barn doors as a suitable brise-soleil.
The resulting feature is both functional and unique, providing a connection to cultural venues throughout the country.

Impact and lessons learned:

The new Backstage building opened in October 2025. The building management system and The Old Vic management team are monitoring temperatures and post-occupancy data to understand its success. Additional manual controls may be introduced to help occupants comfortably manage temperatures in extreme conditions. The design team noted that a naturally ventilated building requires a shift in mindset, away from conventional air-conditioned settings. They are hopeful that with time, this adjustment will come with greater understanding of how the building adapts with the seasons.

This case study describes work that included partial demolition of an existing structure (with an existing basement retained) and the construction of a new low embodied carbon building above ground floor. The new building demonstrates the creative solutions that can be found to combine and implement passive architectural measures in a way that enhances the street presence of a historic building and its connection to its cultural context, whilst practically reducing the risk of overheating.

Conclusion

The suggested measures may all successfully contribute to reducing the risk of overheating in historic buildings. A combination of external shading and other measures identified in this report will in many cases provide the most effective reduction of overheating risk. Consideration of how these measures might impact on passive solar gain in winter is also required, to balance any reduction in summertime overheating against potential heat loss (and resulting increased space heating requirements) in colder months. Simple interventions which reduce overheating, without complicated requirements for occupant engagement, should be prioritised. A holistic approach, considering context and seasonal responsiveness is therefore recommended to gain the benefits of these measures.

Recommendations

While the literature review showed there is a wealth of published internationally based work including theoretical data modelling which proves the effectiveness of many of the passive architectural measures described, there is a distinct lack of relevant and well-evidenced case studies which demonstrate the successful use of these measures in practice in England. This highlights the need for more publicly accessible documentation of real-world projects by heritage and built environment professionals and organisations. Greater emphasis is needed on collecting supporting data, such as internal temperature recording, from an early stage of the project through to occupation. In this way, the improved availability of data-backed case studies will help promote the use of passive architectural measures by clearly demonstrating their practical benefits and help building owners make more informed decisions to improve the resilience of their buildings.

This research has not specifically addressed the potential impact any measure may pose to the architectural or historic character, appearance and heritage significance of an historic building, although these considerations have been mentioned in some of the descriptions of the measures. This has highlighted the need for further work to seek examples of adaptations which remain sympathetic to the character of the buildings they were designed for. There is further scope to compile more guidance on the suitability of these architectural measures for different building types or architectural periods, as well as guidance tailored to different user groups (such as building owners, conservation officers) to help them apply the different measures.

Matrix

Architectural Measures to Reduce Overheating against Risks

Risk Identification Key

3	High Risk
2	Medium Risk
1	Low Risk
0	No Risk - Not Applicable
+	No Risk - Beneficial Proposal

	Risks Identified	Considerations for Mitigation
	Climactic Impact Driver and Associated Hazards	
1	Wind Predicted increased mean wind speeds, severe wind speeds, frequency and changes of direction could cause extreme forces and low temperatures. Adaptations may fail and detach from the existing building, causing damage to people, property or animals.	Involve a Structural Engineer to design the adaptation for the structure with increased wind loads in mind. Ensure that fixings are appropriately sized and proportionate to prevent damage to the historic building fabric.
2	Snow and Ice Predicted increases in extreme weather events including heavy snowfall and associated loads could cause adaptations to detach from the existing building, causing damage to people, property or animals.	Involve a Structural Engineer to design the adaption for the structure with increased snow loads in mind. Ensure that fixings are appropriately sized and proportionate to prevent damage to the historic building fabric.
3	Increased Rainfall Predicted increased episodes of heavy precipitation and wind-driven rain could cause water penetration at site of proposals and compromise building fabric. Increased frequency of rain will increase saturation of materials due to reduced drying periods.	Ensure proposals are designed to consider the existing building envelope. Include flashings to shed water and avoid penetrating existing membranes. Proposed fixings should designed to avoid creating the opportunities for water to track internally. Review any changes to the drainage strategy and ensure surface water is not increased, and that water is discharged in suitable a location.
4	Heat and Cold Predicted increases in solar and UV exposure alongside extremes of temperature could cause materials to degrade or deteriorate and interventions to fail.	Consider UV & temperature durability of material choices and ensure materials are suitable for proposed use (e.g. external or in direct sunlight). When specifying materials review reaction to UV particularly if positioned in direct sunlight. Consider impact of extreme temperatures. Ensure materials are suitable for proposed use and location.
5	Wet and Dry - Flooding Predicted increased episodes of flooding, including in coastal areas, could caused interventions to fail.	Consider flood risk of site and hazards if flooding were to occur (for example increased structural loads, water penetration, compromised building fabric). If flood risk is present, ensure interventions below flood risk height are designed to be resilient or recoverable in the event of flooding.
6	Wet and Dry - Fire Weather Predicted increased episodes of wildfires could mean interventions are responsible for aggravating spread of fire and cause damage to people, property or animals.	Only use non-combustible materials - refer to Building Regulations Approved Document B and ensure proposals are compliant. See also 'Fire' risk.
	Cost, Sustainability, Programme & Maintenance	
7	Level of Intervention Proposals may not be effective or durable and costs may not be proportionate.	Consider anticipated number of days per year it is predicted the building will overheat based on predictions, local site conditions (e.g. shading by adjacent objects) and anticipated level of heat reduction by intervention. Review this against cost of proposals to check if proposals are effective and proportionate.
8	Carbon Emissions Proposals may not be sustainable as the carbon cost of the intervention may be greater than anticipated benefits.	Consider embodied carbon of proposals against changes to operational carbon (also consider alternative methods to reduce overheating in Summer and review impact on heating demand in Winter). Review this against life expectancy of interventions to check if proposals are effective and proportionate.
9	Ease of Installation Proposals may cause accidental damage to existing building fabric, be difficult to access or complicated to install. Installation may require access to hazardous areas or locations.	Consider method of installation (following CDM 2015 regulations) to ensure safe access during installation. This will include reviewing: Requirements for temporary works during installation and ensuring these are designed by a qualified person; Complexity of proposal and weight of prefabricated components, decreasing these where possible; Installation details which may cause accidental damage to existing membranes or insulation to avoid compromising existing building fabric; Dimension tolerances for proposal and site arrangements, and ensuring these can be met.
10	Ease of Ongoing Maintenance Proposals may be difficult to access or be complicated to maintain.	Consider method of maintenance (following CDM 2015 regulations) to ensure safe access during maintenance. Review ongoing maintenance interval and complexity. Decrease complexity of proposals (e.g. number of moving parts) where possible.
11	Reversibility of Proposal Proposals may be difficult to remove and cause damage to existing building if changes are required in the future. Original building fabric may be removed and lost during proposals installation.	Consider end of proposal life (following CDM 2015 regulations) to ensure safe access and easy alteration, refurbishment, removal or demolition. Any loss of historic building fabric should be minimised, documented and justified.
	Occupant Experience	
12	Increased Winter Heating Load Proposals may cause reductions to internal temperatures (preference is 18 degrees air temperature), making the building uncomfortable to occupy and increasing winter space heating requirements.	Consider impact of proposals on solar gains during summer and winter months based on building orientation and geographical location. Review options for flexibility so that arrangements can be changed seasonally. Refer to Building Regulations Approved Document L and ensure proposals are compliant.
13	Increased Draughts Causing User Discomfort Proposals may reduce airtightness and cause uncomfortable draughts, differential or stratified temperatures or cold surfaces.	Ensure proposals are designed to consider the existing building envelope and avoid penetrating existing membranes, gaps in construction and thermal bridges. Refer to Building Regulations Approved Document L and ensure proposals are compliant.
14	Ventilation Proposals may change opening sizes or reduce levels of outdoor air so that there is insufficient purge or background ventilation. Indoor air pollutants (e.g. water vapour, CO2, volatile organic compounds, radon, dust, pollen) may be increased to levels which compromise occupant health.	Refer to Building Regulations Approved Document F and ensure proposals are compliant.
15	Internal Relative Humidity Proposals may cause changes to internal humidity (preference is between 35-60%, ideally 50%), making the building uncomfortable or unsafe to occupy.	Refer to Building Regulations Approved Document F and Approved Document L and ensure proposals are compliant.

Shading

Architectural Measure:	A Awnings	B Overhangs / Deeper Eaves	C Balconies	D Veranda / Stoeps / Loggias	E Vertical Fins / Slats	F Brise-Soleil / Screens	G External Louvres / Shutters	H External Roller Shutters	I Internal Blinds / Shutters / Curtains	J PV Arrays as Awnings	K Trees / Planting	L Green Walls	M Reduction of Window-to-floor Ratio	N Deeper Window Recesses
1	3	3	3	3	2	0	2	1	0	2	1	2	0	0
2	2	3	3	3	1	0	1	1	0	2	1	1	0	0
3	3	2	3	3	3	3	3	1	0	1	2	2	0	0
4	3	3	3	3	3	3	3	3	2	3	2	3	1	0
5	1	1	1	3	2	2	2	+	0	2	1	1	1	0
6	2	2	3	3	2	2	2	2	0	3	1	2	1	0
7	3	3	3	3	3	3	3	3	1	3	1	3	3	3
8	3	3	3	3	3	3	3	3	2	3	+	1	3	3
9	3	3	3	3	3	3	3	3	2	3	1	3	3	3
10	3	1	3	3	3	3	3	3	1	3	1	3	2	2
11	3	3	3	3	3	3	3	3	1	2	1	3	3	2
12	2	3	3	2	2	2	2	2	0	2	2	1	3	3
13	1	2	2	1	1	1	1	1	+	1	0	1	+	0
14	1	2	3	1	1	0	+	1	0	1	0	0	3	1
15	1	2	2	1	1	1	1	1	0	1	1	1	2	1

Ventilation & Surface Treatments

Architectural Measure:	O Alteration of Fixed Windows to Openable Windows	P Openable Clerestory Windows	Q Ridge Ventilators	R Turrets or Cupolas	S Increased Ceiling Height	T Surface Colour	U Clear Solar Reflective Paints / Coatings	V UV-absorbing Window Film
1	1	1	1	1	0	1	1	0
2	0	0	0	0	0	0	0	0
3	1	1	1	1	0	1	1	0
4	1	1	1	1	0	1	1	3
5	1	1	1	1	1	1	1	1
6	1	1	2	2	1	1	1	2
7	3	3	3	3	3	1	3	1
8	3	3	3	3	3	2	3	2
9	3	3	3	3	3	3	3	1
10	2	3	3	3	3	2	2	1
11	3	2	2	2	3	2	2	1
12	0	0	0	0	2	1	1	1
13	2	2	2	2	2	0	0	0
14	+	+	+	+	+	0	0	0
15	1	1	1	1	1	1	1	1

16	**Acoustics** Proposals may increase sound levels (e.g. external sounds entering through open windows) and negatively affect occupant experience.	Refer to Building Regulations Approved Document E and Approved Document F and ensure proposals are compliant.	0	1	1	0	0	0	+	+	+	0	+	+	+	0	3	3	3	3	1	0	0	0
17	**Natural Light** Proposals may permanently decrease levels of natural light and negatively affect occupant's experience, particularly during winter.	Consider impact of proposals on natural light during summer and winter months based on building orientation and geographical location. Review options for flexibility so that arrangements can be changed seasonally.	2	3	3	3	3	2	2	3	1	2	2	1	3	2	1	1	0	0	0	0	0	1
18	**User Operability Requirements** Proposals may require high levels of occupant engagement to achieve comfortable environments (e.g. needing to open and close shutters on a daily basis) and may be complicated to interact with (e.g. having to go outside to move shutters).	Consider simplicity of ongoing user engagement and reduce complexity where possible (particularly in public buildings where responsibility for changing proposal settings may be unclear). Test user interface before installation to check useability.	2	0	0	0	0	0	2	2	1	2	1	3	0	0	2	2	0	0	0	0	0	0
19	**Access and Inclusivity** Proposals may change access arrangements (e.g. localised obstructions or door and circulation widths) or not be designed with inclusivity in mind (e.g. handles may be hard to grasp) and make the building difficult for some people to occupy and use.	Refer to Building Regulations Approved Document M and ensure proposals are compliant. Consider how occupants engage with proposals and any barriers to inclusivity - review how these can be removed by considerate design.	2	1	3	2	2	2	2	1	1	2	2	2	1	1	2	2	0	0	0	1	0	1
	Health & Safety																							
20	**Structure** Proposals may compromise ground stability or existing structural integrity. Additional loading and alterations to existing structure may cause excessive deflection or structural failure, causing damage to people, property or animals.	Refer to Building Regulations Approved Document A and ensure proposals are compliant. Involve a Structural Engineer to calculate loadings, confirm fixing requirements and existing structural capacity for medium and high risk items. Oversized fixings could cause damage to historic building fabric and therefore fixings should be appropriately sized.	2	3	3	3	2	2	1	1	0	2	3	2	1	1	1	1	1	2	3	0	0	0
21	**Fire Escape** Proposals may change the building's means of escape and make this non-compliant which could cause loss of life.	Refer to Building Regulations Approved Document B and ensure proposals are compliant. Review and update Fire Risk Assessment and Fire Strategy if required.	1	1	3	3	3	1	3	3	1	1	2	2	3	1	+	0	0	0	0	0	0	0
22	**Fire** Proposals may change the building's fire strategy (e.g. materials surface spread of flame, partition fire resistance, separation distance between building and boundary) and make this non-compliant which could cause damage to property or loss of life.	Refer to Building Regulations Approved Document B and the Building Safety Act to ensure proposals are compliant. Review and update Fire Risk Assessment and Fire Strategy if required.	2	3	3	3	2	2	2	2	1	3	1	3	2	1	1	1	1	1	1	1	1	3
23	**Contaminants** Proposals may disturb existing contaminants (e.g. asbestos, lead paint, contaminated ground) and make the building unsafe to work on or occupy.	Refer to existing building's O&M manual (if available). Refer to Building Regulations Approved Document C and Health & Safety Act. Involve specialists to undertake surveys of contaminants when required.	2	3	3	3	2	2	2	2	1	2	1	2	1	1	1	1	2	2	2	1	1	1
24	**Protection From Falling, Collision & Impact** Proposals may change windows, doors, steps or edge guarding and make these non-compliant (e.g. not meeting standards for collision protection, manifestation, trapping risk, safety glazing, protection from falling) and make the building unsafe to occupy.	Refer to Building Regulations Approved Document K and ensure proposals are compliant.	2	3	3	3	2	2	2	3	1	2	1	1	3	3	3	3	0	0	0	0	0	0
25	**Thermal Bridging** Creation of a thermal bridge from introducing the proposed architectural measure may cause mould growth to some interior surfaces of the building	Ensure proposals are designed to consider the existing building envelope and avoid penetrating existing insulation or membranes where possible. Consider undertaking a thermal bridge analysis, Refer to Building Regulations Approved Document C and Approved Document L and ensure proposals are compliant.	2	3	3	3	2	2	2	2	0	2	0	3	3	3	1	1	1	1	1	0	0	0
26	**Security** Proposals may make changes to doors and windows and compromise building security.	Ensure any openings for ventilation are designed so they can be made secure. Refer to Building Regulations Approved Document Q and ensure proposals are compliant.	0	2	3	0	0	0	+	+	0	0	1	2	1	0	3	1	1	1	0	0	0	0
	Quality of Intervention																							
27	**Deterioration of Building Fabric** Proposed design interventions may negatively affect building fabric (e.g. causing interstitial condensation and deterioration of insulation or corrosion of metal elements). In regards to historic buildings, this could cause the loss or decay of particularly significant material.	Refer to existing building's O&M manual (if available). Ensure interventions are designed to consider the existing building envelope. Refer to Building Regulations Approved Document C and Approved Document L and ensure proposals are compliant.	3	3	3	3	3	3	3	3	1	3	3	3	3	2	1	1	1	1	2	2	2	1
28	**Compromising the Building's Aesthetic** Proposed design interventions may negatively affect the building's aesthetic. This is a particular concern when proposed alterations would compromise the special characteristics of a listed or historic building.	Consider impact of interventions on the existing building's aesthetic. Involve a designer to draw or model and test proposals before choosing a preferred option. Refer to Historic England guidance in relation to special characteristics if existing building is historic or listed.	3	3	3	3	3	3	3	3	1	3	1	3	3	2	1	3	2	2	2	2	0	1
29	**Compromising Material Performance** Proposed design interventions may create unintended consequences (causing harm to the significance of the building, its fabric or occupants) or maladaptation (undermining the building's performance and resilience to climate change).	Consider consequences of interventions on existing building materials. Involve designers and materials specialists to ensure existing material performance is understood before choosing a preferred option.	1	2	2	2	1	1	1	1	0	1	0	3	2	2	2	2	2	2	2	3	3	1
30	**Quality of Installation** Proposed design interventions may rely on the quality of materials, products or installation methods to be effective (including reliance on electricity to operate).	Consider how the quality of materials, product or installation will affect durability or effectiveness of proposals. Take steps to review quality of proposals prior to installation (e.g. review samples, compare quotations).	3	3	3	3	3	3	3	3	2	3	1	3	2	2	1	1	1	1	1	2	2	2
	Legislation																							
31	**Building Regulations** Proposals may result in non-compliance with building regulations.	Refer to Building Regulations Approved Documents, other relevant standards and best practice guidance to ensure proposals are compliant. If appropriate, where proposals are complex involve specialists to ensure compliance.	3	3	3	3	3	3	3	3	1	3	1	3	3	3	3	3	3	3	3	1	1	1
32	**Planning Consent** Proposals may cause changes which require planning consent.	Refer to Local Planning Authority information to ensure planning approval is obtained prior to installation, if required.	2	2	3	3	2	2	2	2	0	2	0	2	2	1	1	2	1	1	1	1	1	1
33	**Conservation Area** Proposals may be located within in a Conservation Area which means there are extra planning controls and considerations.	Refer to Historic England "Advice Note 1: Conservation Area Appraisal, Designation and Management" for advice on living in a Conservation Area and Local Planning Authority information to ensure planning approval is obtained prior to installation, if required.	3	3	3	3	3	3	3	3	0	3	1	3	3	3	3	3	3	3	2	3	2	2
34	**Listed Building Consent** Proposals may cause changes which require listed building consent.	Refer to Historic England "Advice Note 16: Listed Building Consent" and Local Planning Authority information to ensure listed building consent is obtained prior to installation, if required.	3	3	3	3	3	3	3	3	1	3	1	3	3	3	3	3	3	3	3	3	3	3
35	**Party Wall Legislation** Proposals may cause changes to shared boundaries which require party wall consent.	If proposals relate to elements of a building near or on a shared boundary, refer to Party Wall information to ensure neighbours are in agreement before progressing work.	1	2	2	2	2	1	1	2	0	2	1	2	2	1	2	2	0	0	0	0	0	0
36	**Right to Light Legislation** Proposals may cause changes to neighbour's light which is protected by right to light legislation.	If proposals relate to elements of a building near or on a shared boundary, refer to Right to Light information to ensure neighbours are in agreement before progressing work.	2	2	3	2	1	1	1	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0
37	**Archaeology** Proposals may cause disturbance to archaeology (buried below ground or part of the building) and damage heritage assets.	Refer to Historic England "Advice Note 17: Planning and Archaeology" and Local Planning Authority information to confirm if involvement of an Archaeologist is required.	1	1	2	2	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1
38	**Ecology** Proposals may cause changes which negatively affect ecology (organisms or habitat), for example by increasing artificial light levels and disrupting animal's natural behaviour.	Refer to Local Planning Authority information to confirm if involvement of an Ecologist is required.	1	2	3	3	1	1	1	2	0	2	+	+	1	1	0	0	0	0	0	0	0	0

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