Historic England

Energy Efficiency and Historic Buildings

How to Improve Energy Efficiency

Summary

This guidance is for anyone who wishes to improve energy efficiency in an historic building. There are many reasons to do this. Improving energy efficiency will lower carbon emissions and fuel bills and often increase comfort. It also might be necessary to ensure that a building complies with legal requirements. More broadly, improving energy efficiency forms a part of the wider objective to achieve a sustainable environment.

It is a widely held view that older buildings are not energy-efficient, and must be radically upgraded in order to improve their performance. In reality, the situation is more complicated, and assumptions about poor performance are not always justified. Even so, the energy and carbon performance of most historic buildings can be improved, which will help them remain viable and useful, now and in the future. But striking the right balance between benefit and harm is not easy. The unintended consequences of getting energy efficiency measures wrong (or doing them badly) include: harm to heritage values and significance, harm to human health and building fabric, and failure to achieve the predicted savings or reductions in environmental impact.

Getting the balance right (and avoiding unintended consequences) is best done with a holistic approach that uses an understanding of a building, its context, its significance, and all the factors affecting energy use as the starting point for devising an energy-efficiency strategy. This 'whole building approach' ensures that energy-efficiency measures are suitable, robust, well integrated, properly coordinated and sustainable. In addition, this approach provides an effective framework for communication and understanding between the various parties involved in the process. These include assessors, designers, installers and the people who occupy and manage the building.

A logical and systematic process of energy planning underpins the 'whole building approach'. This guidance describes the key stages of the process, illuminating any problems that might occur and providing solutions. It also includes checklists of practical measures that might be considered, along with links to sources of more detailed information about how to install these measures.

This guidance note has been prepared by Iain McCaig, Robyn Pender and David Pickles, Historic England.
Published by Historic England June 2018.

HistoricEngland.org.uk/energyefficiency

Contents

Introduction 1

1 Improving Energy Efficiency 2

1.1 Factors affecting energy use 2
1.2 Fundamental principles 3

2 Planning Energy Efficiency Improvements 7

2.1 Why do older buildings need a special approach?...................................7
2.2 What is a 'whole building approach'? 9
2.3 Planning energy efficiency measures.........9
2.4 Whole building approach in practice 10

3 Guidance on Measures 25

Understanding what you've got 26
Low-risk options 29
Some-risk options.....................................31
High-risk options 35

4 Glossary 40

5 Where to Get Advice...................42

5.1 Historic England guidance and research...42
5.2 Other sources of advice............................44
5.3 Further reading 44
5.4 Contact Historic England 45

6 Acknowledgements 46

Introduction

What is the purpose of this guidance?

This guidance is for anyone interested in reducing energy use in older buildings. It describes a whole building energy-planning process for devising and implementing suitable, well-integrated solutions that:

- avoid harm to significance
- are effective, cost efficient, proportionate and sustainable
- ensure a healthy and comfortable environment for occupants
- minimise the risk of unintended consequences

Section 1 considers the factors that influence the levels of energy use in historic buildings. In Section 2, the whole building energy planning approach is set out in detail. Section 3 includes checklists of measures that might be suitable as part of this approach, and provides links to sources of more detailed technical information on upgrading building elements such as roofs, walls and floors. Finally, Section 5 gives guidance on other sources of advice, and provides links to the complete range of Historic England advice on energy efficiency.

Who is this guidance for?

- **Architects, surveyors, project managers and energy advisors** who are participating in projects to improve energy efficiency in historic buildings
- **Building contractors and materials and component suppliers** who need to understand the implications of decisions they make when carrying out work and the technical advice they give to customers
- **Local authority conservation and planning officers, building control surveyors, approved inspectors, environmental health officers, housing officers**, and other officials who specialise in one field, but need to know about other areas of concern in order to make better informed decisions
- **Building owners and occupants** who wish to reduce their energy use and carbon emissions, and meet or surpass a range of statutory requirements

1 Improving Energy Efficiency

Every building is different due to its location, orientation, design, construction, engineering services, and the way it is used, managed and maintained. All these factors influence energy use and the effectiveness of energy saving measures.

1.1 Factors affecting energy use

The four most important factors affecting a building's energy use in operation are:

- Building location and orientation
  The performance of a building envelope will be affected by regional variations in climate and its exposure to wind, rain and sun.

- Building fabric
  The form and design of the building envelope and the physical properties (and condition) of the construction materials and components also affect performance.

- Building services and equipment
  Heating, cooling, lighting and ventilating a building all use energy. Energy is also consumed by equipment and appliances employed for business, cooking and entertainment.

- People
  Occupants use their buildings in different ways. The amount of energy they use varies too. The number of people in a building, the levels of comfort they expect, and the technical services and equipment they require all have a significant effect on how much energy is consumed.

To understand the energy performance in a building – and identify opportunities for improvements – it is important to view it holistically as an interactive system.

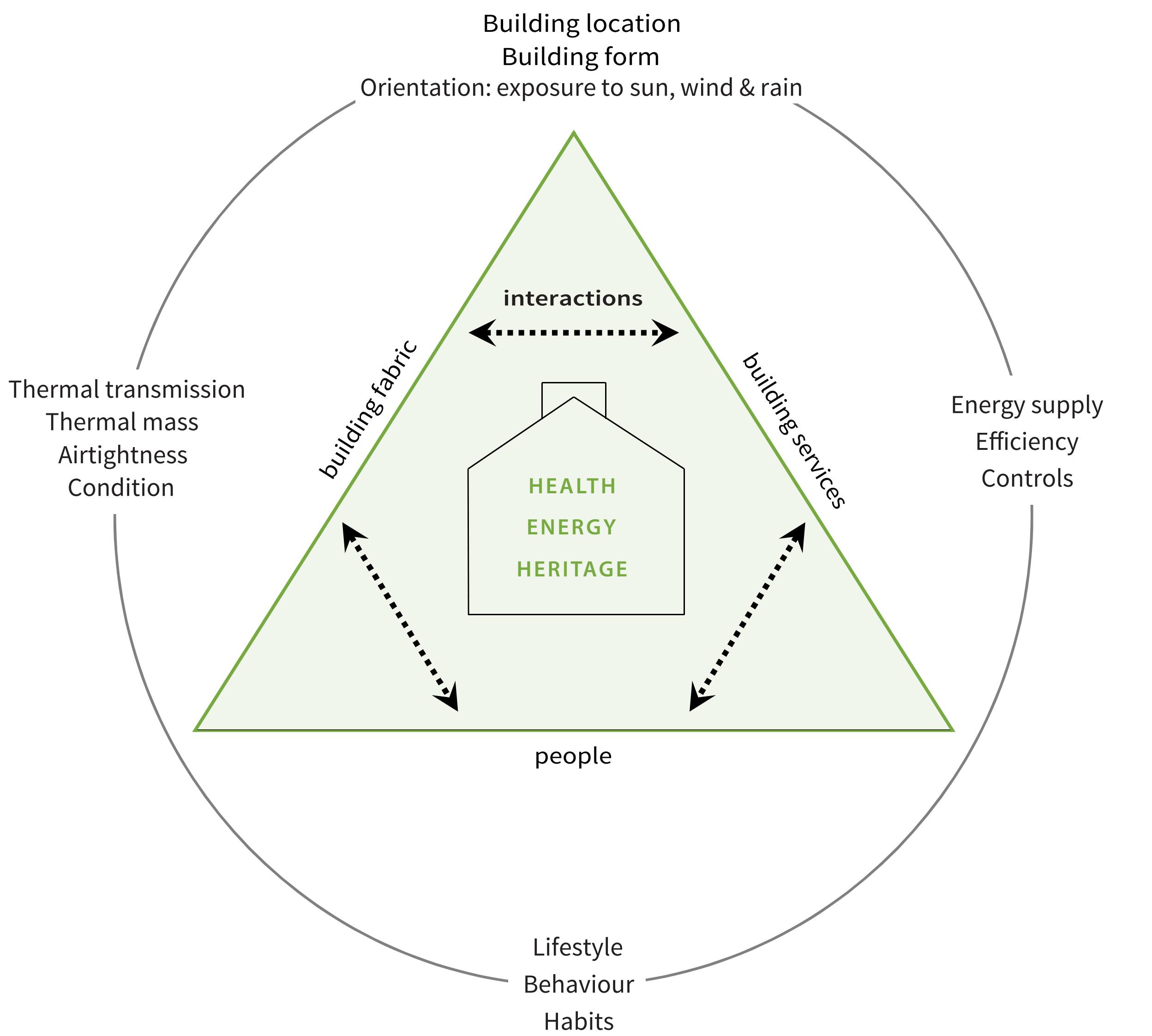


Figure 1
Building performance triangle.

1.2 Fundamental principles

Although there are no 'one-size-fits-all' solutions for making energy and carbon savings in older buildings, there are some general principles that apply across the board:

Understanding the building and its context

- The significance of the building and potential harm from possible changes
- Influence of local environmental factors such as exposure to sun, wind and rain
- Design, construction and condition of the building
- Performance and behaviour of the building fabric
- Design, condition and operation of engineering services
- Building use, occupancy and management
- Requirements, aspirations and aims
- Available resources: financial; skills; materials
- Opportunities and constraints

Engaging building users, owners and managers

Success cannot be achieved by technical means alone; the owners, managers and occupiers of the building should be fully involved in the plans for saving energy at every stage.

Reducing demand on energy-using systems

Current expectations, habits and standards should be reviewed and questioned to find out what is really necessary. Energy savings might be made through a more flexible approach to comfort standards in different parts of the building.

Avoiding waste

Much equipment in buildings operates wastefully, or is left on unnecessarily. It is important to commission and control energy-using systems properly, and to turn all energy-using equipment off or down when not needed.

Increasing efficiency

Building services such as heating, hot water supply and lighting and other energy-using equipment like computers and appliances should be designed, selected and run to use as little energy as possible.

The thermal efficiency of the building fabric can be enhanced both by carrying out repairs promptly and through regular maintenance.

Improving controls

Control systems should be as efficient as possible and easy to understand and use. Many systems are not as manageable and responsive as they could be. This can lead to increased energy use.

Using lower-carbon energy supplies

Switch to energy sources with lower emissions such as on- or off-site renewable energy (solar, wind or water power), or select lower-carbon supplies such as gas or wood instead of coal.

Avoiding complication

Unmanageable complication is the enemy of good performance. Solutions should be kept as simple as possible and done well.

Reviewing outcomes

Solutions of all kinds should be reviewed and assessed carefully at every stage of the energy-planning process. The aims should be to understand how measures perform as part of the overall system, and to minimise unintended consequences, such as overheating, moisture problems and poor indoor air quality. Measures used in combination can have a powerful multiplier effect. For instance, combining a 50% reduction in the demand for energy and the amount of carbon in the energy supply with a 100% increase in equipment-efficiency can cut carbon emissions by seven-eighths.

Thermal comfort

Building occupants will be satisfied with their environment if they don't feel discomfort. Many factors influence thermal comfort. These include air temperature, the humidity, quality and movement of air, solar gain, and the emissivity and temperature of walls, floors, and ceilings. The clothing and physical activities of building occupants also play a role.

Finally, the expectations and social and cultural attitudes of the occupants will affect the perception of thermal comfort. For instance, someone raised in a house where the temperature was kept low might have different expectations for thermal comfort than someone who was raised in a warmer home.

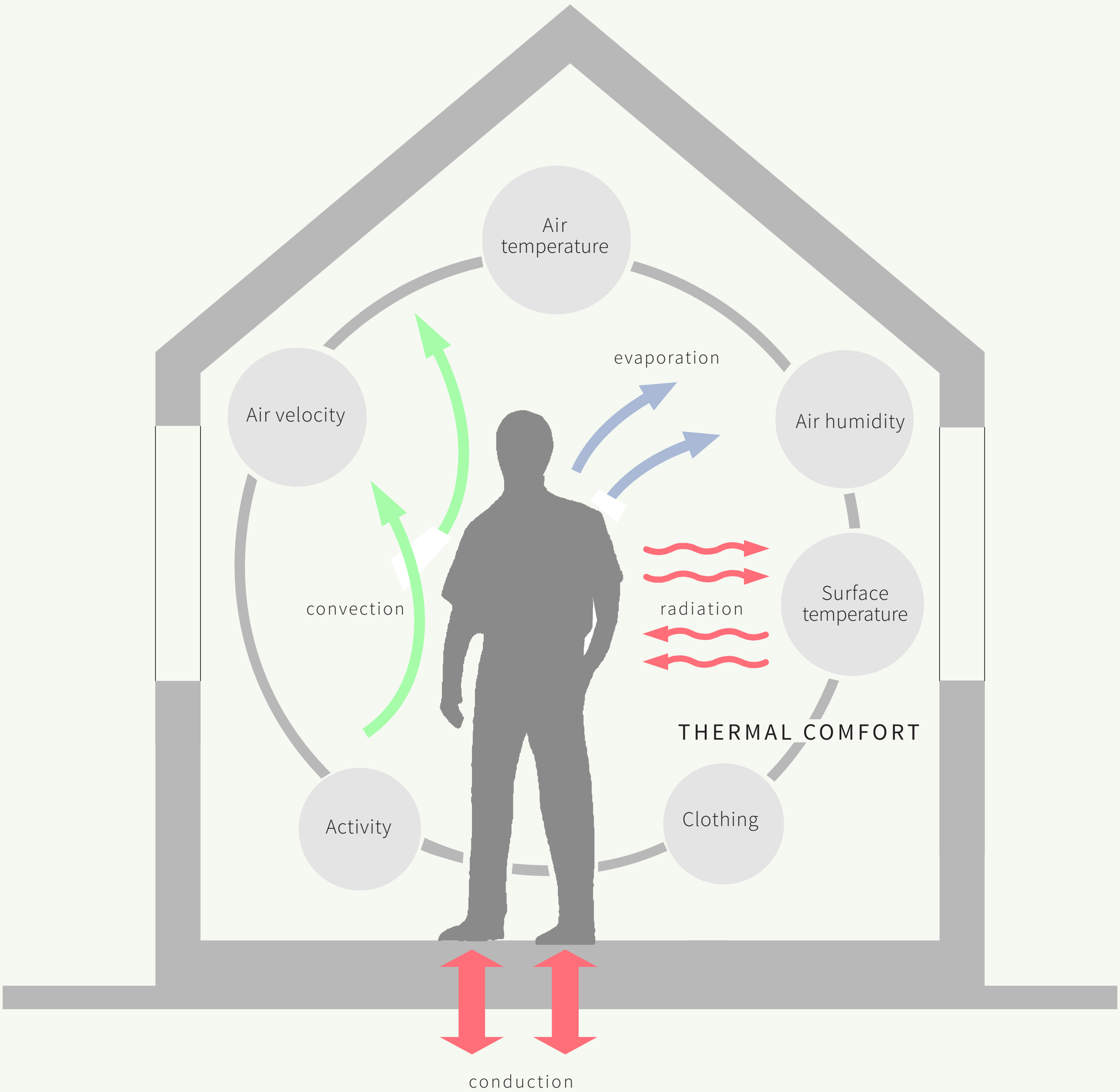


Figure 2

Factors affecting thermal comfort.

If they can, building occupants will adjust conditions until they feel comfortable. Traditional buildings and furnishings provide numerous ways for them to do this. In addition, the thermal inertia of thick walls can help buffer changes in external temperatures, and the subdivision of interiors allows the environment in individual rooms to be controlled separately. In contrast, occupants of many contemporary buildings often have little or no control over their internal environment. The building is often automatically conditioned at a near constant temperature throughout the year. In some situations, occupants cannot even open windows.

Surveys reveal that having some control over the thermal environment is necessary for a sense of comfort. In situations where occupants have some control over conditions, most do not mind small seasonal variations in building temperature. These small variations can have a big impact on energy use. Turning down the thermostat by just one degree C in a central-heated dwelling may reduce its annual heating energy consumption by 10% or more.

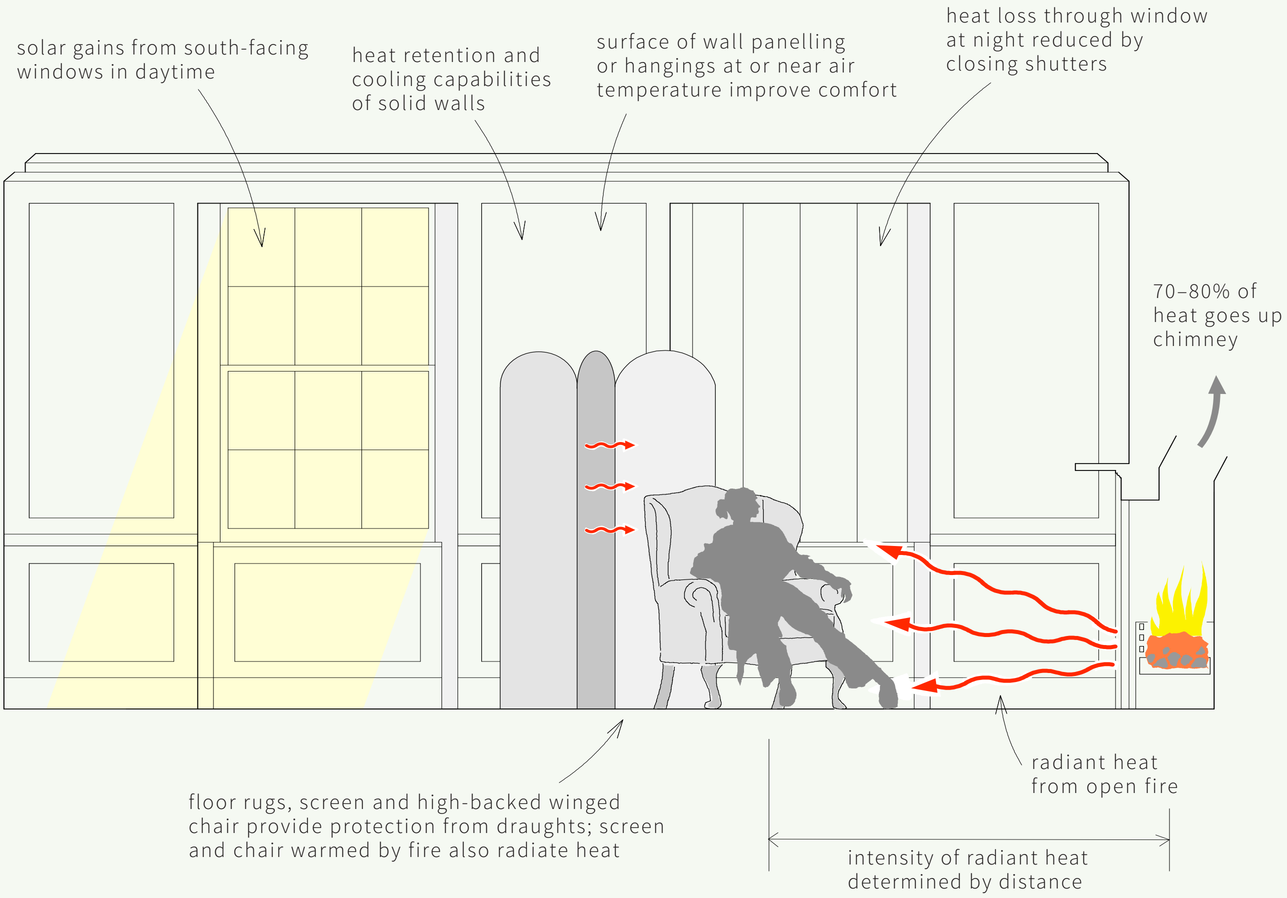


Figure 3

Traditional forms of heating and thermal comfort.

2 Planning Energy Efficiency Improvements

This section describes the 'whole building approach' and looks at the process of energy planning that underpins it.

2.1 Why do older buildings need a special approach?

Most modern buildings depend on impermeable barriers to control the movement of moisture and air through the building fabric. In contrast, traditional forms of building construction take up moisture from their surroundings and release it according to environmental conditions. Buildings of traditional construction also tend to have greater thermal inertia than their modern counterparts – they heat up and cool down more slowly. This ability to 'buffer' moisture and heat helps to even out fluctuations in humidity and temperature.

The interrelationship between heat and moisture in buildings is complex. In a well-maintained building that is adequately heated and ventilated, the daily and seasonal cycles of wetting and drying, heating and cooling, balance out. However, the equilibrium may be adversely affected when changes to building fabric, heating or ventilation are made to increase energy efficiency. This can lead to problems of moisture accumulation, overheating and fabric damage. Occupants may also experience ill health due to poor indoor air quality. Thus, when planning energy efficiency improvements, it is important to understand the way a building is performing as an integrated environmental system.

In addition, older buildings are part of our evolving cultural heritage, reflecting the nature and history both of the communities that created them and those who followed. They add distinctiveness, meaning, and quality to the places people inhabit, and provide a sense of continuity and identity. When attempting to make such buildings more energy efficient a special approach is needed to ensure these values are sustained for future generations.

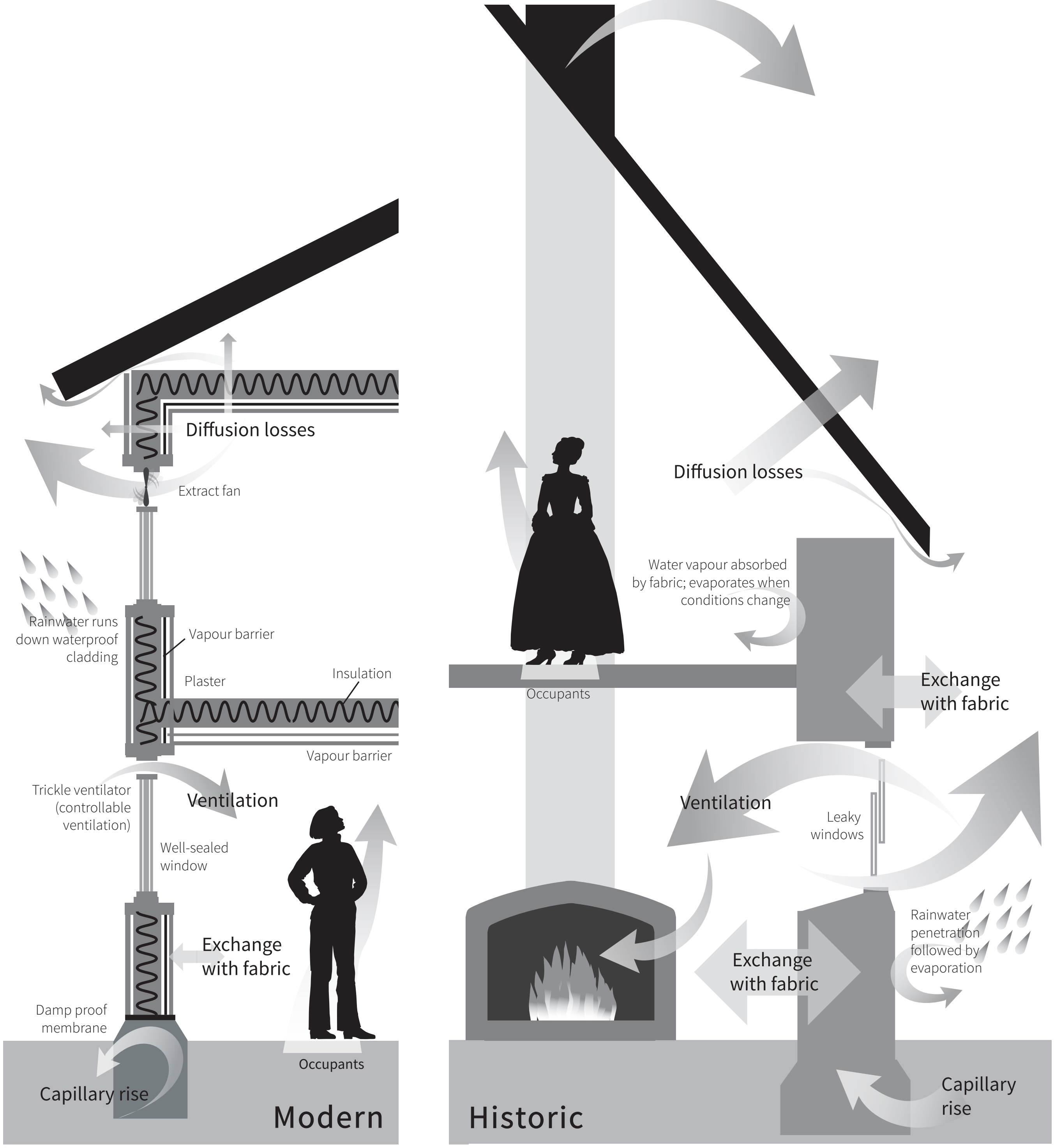


Figure 4
Typical differences in the movement of moisture and air in modern and traditional construction.

2.2 What is a 'whole building approach'?

A true 'whole building approach' is one that uses an understanding of a building in its context to find balanced solutions that save energy, sustain heritage significance, and maintain a comfortable and healthy indoor environment. A whole building approach also takes into account wider environmental, cultural, community and economic issues, including energy supply. It ensures improvements are suitable, proportionate, timely, well integrated, properly coordinated, effective and sustainable, and helps to highlight and resolve uncertainties, reconcile conflicting aims, and manage the risks of unintended consequences.

Most of all, it deals with specific situations as opposed to generalities. Opportunities and constraints can vary widely depending on context. The optimum solution in one case might be quite different in another, even if buildings appear similar. Therefore, a site-specific approach is needed: one that considers the interrelationship between building fabric, engineering services, and people.

2.3 Planning energy efficiency measures

The whole building approach depends on a logical and systematic process in which an informed understanding develops by continually questioning what is required and why, and whether the goals are achievable. It also questions whether proposals are justifiable and in accordance with established conservation principles and philosophy, and if there are any valid reasons to deviate from them.

The key stages in this process are:

- assessment – understanding the context
- setting objectives and planning improvements
- detailed design and specification
- installation
- use and evaluation
- maintenance

It is important to remember that success is unlikely to be achieved by technical means alone. Building owners, managers and occupants play a crucial role in reducing energy use and should be fully engaged throughout the energy planning process. Decisions and actions taken at every stage of the process have a bearing on the quality and success of the outcome. Good communication and understanding is essential between all parties involved, including project managers, energy assessors, building professionals, installers, and people who use and manage the building.

A 'mean, lean, green' philosophy has evolved for the design, construction and use of new buildings. This is based on a hierarchy that begins by considering the siting, orientation, design, detailing and construction of a building to minimise the demand for energy, materials, water and other resources ('mean'). Next comes the design, management and control of its services and systems to ensure they operate as efficiently as possible ('lean'). The final consideration is supplying energy and other resources from renewable or sustainable sources ('green').

Although this philosophy can be applied in principle to existing buildings, a more nuanced approach is needed, and the priorities will differ. While the 'fabric first' approach makes perfect sense for a new building, in a historic building this may be neither practicable nor desirable.

Instead, effective, cost-efficient, and less risky measures that have minimal impact on significance might be identified. Such measures include improving building services and controls, changing the way a building is occupied, used and managed, and questioning current expectations and standards to find out what is really necessary.

2.4 Whole building approach in practice

This section looks in more detail at the issues that need to be considered at each stage of the process.

In principle, managing a programme of energy efficiency improvements is no different to managing any other kind of building project. Success depends on several key factors:

- the availability of adequate financial and human resources (knowledge, skills and experience)
- a realistic timescale for carrying out the project
- the commitment, enthusiasm and open-mindedness of the client and project team

A whole building approach should always be proportionate in scope to the significance and sensitivity of the building in question, and the complexity of the envisaged proposals. Often, the range of knowledge and skills required will not be available from a single source. Individual specialists might be needed to perform the tasks of assessment, design and installation. This is especially true with larger, more complicated projects. It may be necessary to obtain professional advice on heritage conservation issues if a building is listed or in a conservation area. For obvious reasons, assessments or inspections carried out free of charge by companies with a product or treatment to sell should be treated with caution.

Good communication between all members of the project team (assessor; designer; supplier/installers) and the client is important throughout the process and will help ensure that the project is adequately coordinated. Decisions and actions taken at every stage of the process have a bearing on the quality of the works eventually carried out.

Stage 1: Assessment - understanding the building and its context

A good assessment will consider the context and current situation of the building, identify constraints, and potential opportunities for improvements. This is done by gathering information about the building and the behaviours and needs of its occupants, as well as current modes and levels of energy consumption, and factors affecting the feasibility of improvements.

Assessments can range from a simple 'walk-through' to a highly detailed analysis that might include computer simulations. The scope and depth of investigation and documentation should be proportionate to the size and sensitivity of the building and the scale and complexity of the envisaged improvements. Although householders can carry out useful do-it-yourself appraisals, suitably qualified, experienced and independent practitioners will provide more thorough assessments.

A comprehensive assessment allows informed decisions to be made about energy-saving strategies that protect the historic importance of the building and occupant health. It also provides baseline data against which the impact, effectiveness and cost-efficiency of improvements can be measured. Furthermore, it lowers risk of unintended consequences from measures that might, for example, cause the building envelope to deteriorate by trapping moisture, or harm the health of the occupants by lowering indoor air quality.

Character and significance of the building

Proposals for energy-saving measures are more likely to be acceptable if they are designed with the knowledge and understanding of the building's significance. Therefore, it is important at the outset to assess the nature and level of significance (including the contribution made by its setting). The potential impact on significance of the energy-saving measures on significance should also be assessed. Assessments of character and significance can vary considerably in scope and detail. According to the National Planning Policy Framework (NPFF), an assessment of significance should be proportionate to a heritage asset's importance and the potential impact of any changes.

Local climate, orientation and exposure

Many aspects of a building's setting can affect energy use and the opportunities for improvements. These include exposure to wind, rain and sun. If a building is frequently subjected to driving rain, and walls remain wet for long periods, then options for wall insulation may be limited. Similarly, where a building has a high degree of exposure to sun, the risks of summer overheating or 'reverse condensation' will have a bearing on decisions about wall insulation. Assessments should take into account nearby features that provide shelter or shade or otherwise affect a building's microclimate.

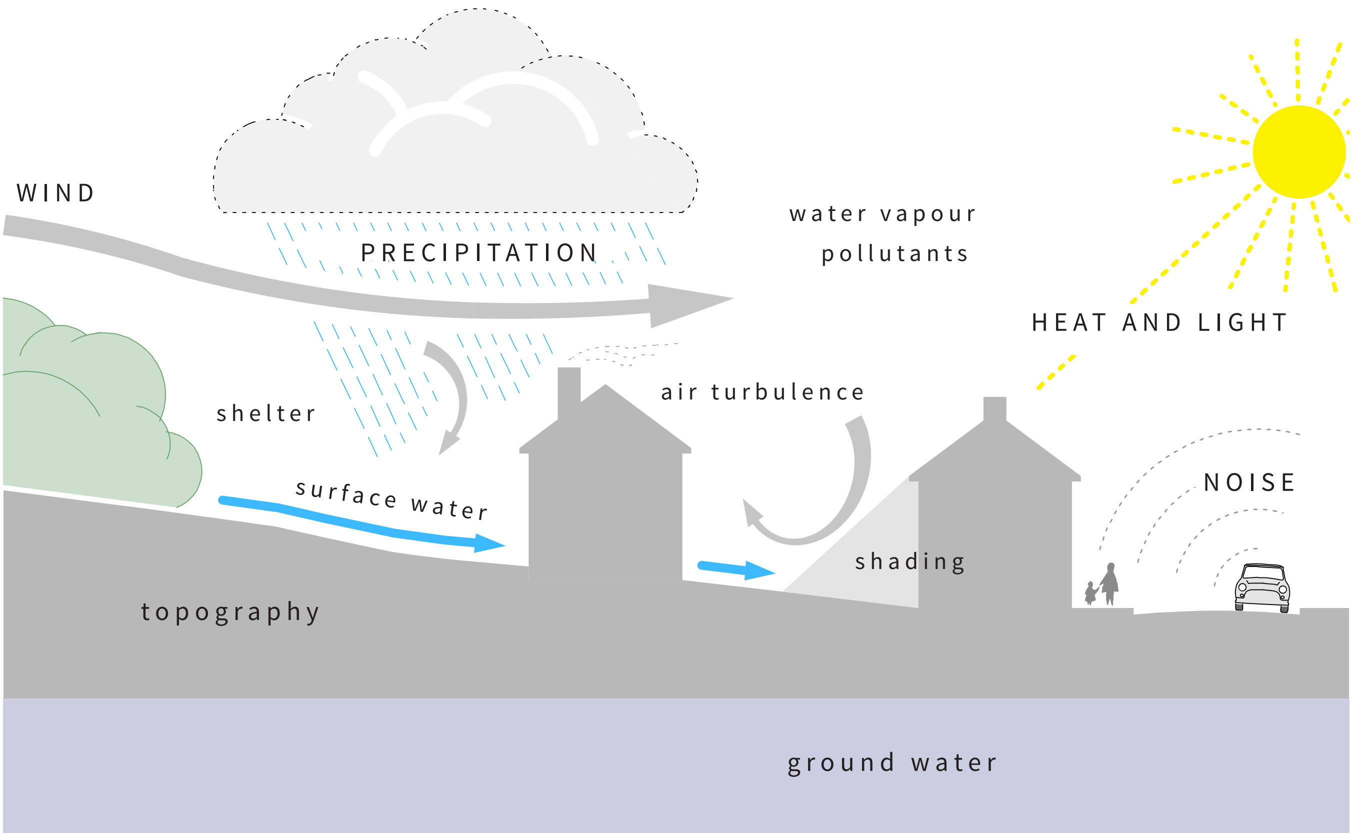


Figure 5
Many aspects of a building's setting can affect energy use and the opportunities for improvements.

Using significance in decisions about energy efficiency measures

In essence, energy efficiency measures are no different to any other works affecting the significance of a heritage asset, and the same conservation planning principles apply in decision-making.

Given the right approach, the twin objectives of protecting significance and improving energy performance are compatible and achievable. However, there may sometimes be a temptation to achieve one objective at the expense of another. In such cases, there is often a compromise to be reached. For instance, an energy performance improvement measure can be modified to lessen its impact on a particular aspect of significance. The key approach here is to understand the risks, see how they can be minimised or eliminated, and gauge whether this can be done to a degree that makes the proposal acceptable while retaining sufficient benefit.

Historic England's *Good Practice Advice in Planning 2: Managing Significance in Decision-Taking in the Historic Environment* sets out the following the assessment process:

- Understand the significance of the affected assets
- Understand the impact of the proposal on that significance
- Avoid, minimise and mitigate impact in ways that meets the objectives of the National Planning Policy Framework
- Look for opportunities to better reveal or enhance significance
- Justify any harmful impacts in terms of the sustainable development objective of conserving significance and the need for change
- Offset negative impacts on aspects of significance by enhancing others through recording, disseminating and archiving archaeological and historical interest of the important elements of the heritage assets affected

Many historic buildings have undergone alterations over the years that may have diminished their significance or put it at risk. Harmful past alterations may, however, present opportunities for more sensitive refurbishment as part of wider energy saving improvements. For example, where a rubble wall has been stripped of its original finish, re-rendering in a compatible material as part of a solid wall insulation project might be considered an enhancement. In fact, energy-saving measures may be used as an opportunity to enhance a building's significance through associated works that might otherwise not have been undertaken.

Historic buildings often incorporate elements that may be assigned differing levels of significance. For example, many have frontages where the majority of architectural detailing is focused, while other elevations of lower status may be less ornate and more functional. Where these are less conspicuous and of lower significance, they may provide opportunities for enhancements that would be considered too harmful on higher status elevations.

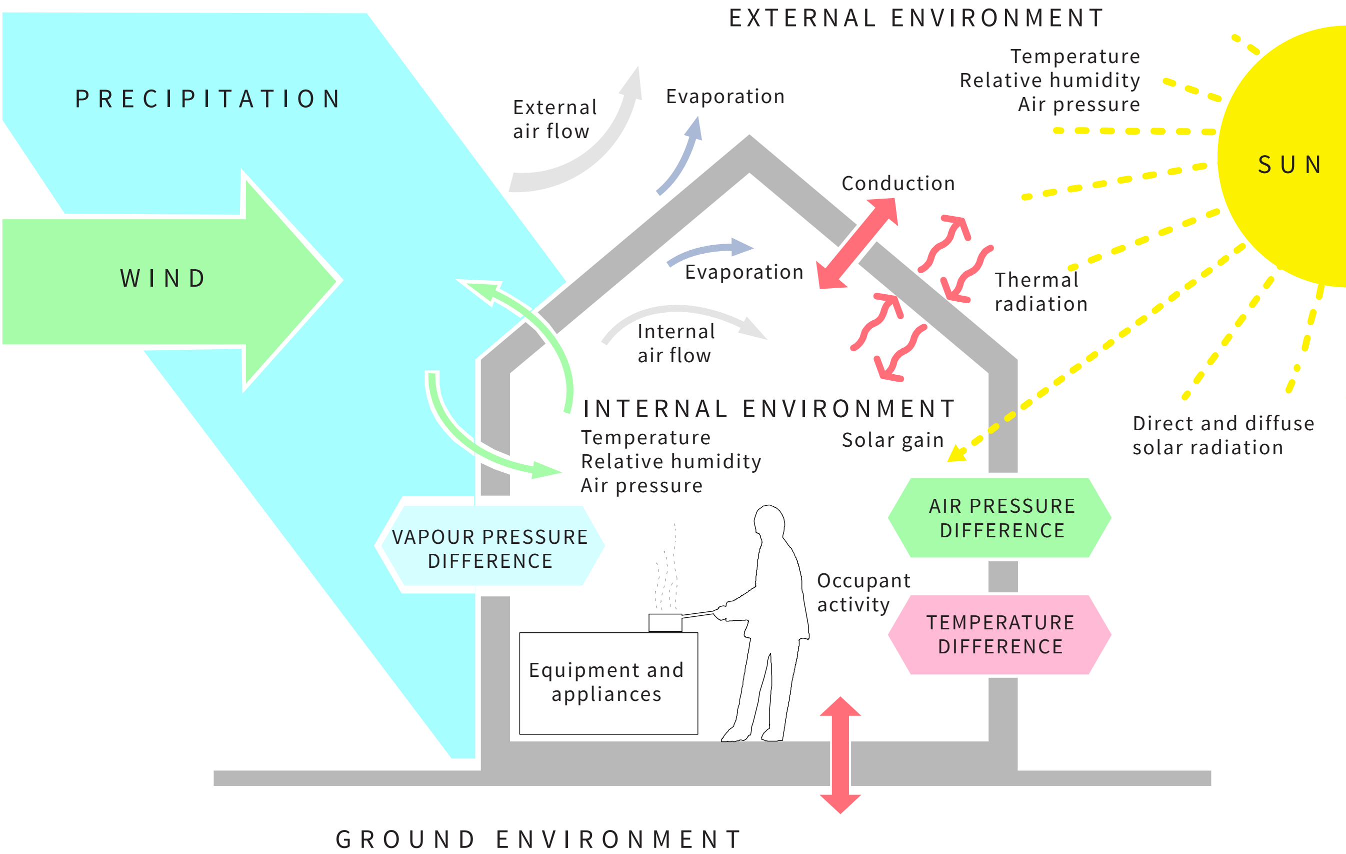
Energy performance of the building envelope

The amount of energy used in heating, cooling and lighting a building is influenced greatly by the size, form and thermal performance of its envelope. Factors affecting thermal performance include the movement of air and the transfer of heat and moisture through the building fabric. The building's size, design, construction, and the physical properties of its materials also play a part, as do the subdivision of the interior by partition walls, and the existence of features such as fireplaces and flues.

Historic buildings vary widely in form and construction. Few of them survive as originally built. Therefore, their thermal characteristics can differ significantly. There has been a tendency to underestimate the energy performance of buildings of traditional construction. In fact, in-situ measurements of thermal transmittance (U-values) in solid brick walls have been found to be up to a third lower than figures stated in published guidance. (See Section 5)

Therefore, it is important to study a building carefully before making assumptions about its thermal performance. The assessment should record dimensions, construction methods, and materials of the relevant building elements and components. Existing energy-saving features-including insulation, draught sealing, shutters, double or secondary glazing should be noted. Aspects of the building fabric that might adversely affect comfort or energy performance should be highlighted. Some characteristics of a building might present obvious potential for improvements. Others might make improvement difficult and demand more imaginative solutions. In both cases, these characteristics should be highlighted too.

Figure 6
Interactions between the building envelope and the environment.



Hygrothermal behaviour of building fabric

Traditional building materials, such as timber, lime mortars and plasters, porous stones, brick, and earth are moisture permeable. They continuously take up or release moisture in response to changes in the humidity of their surroundings. In a well-maintained, adequately heated and ventilated building these daily and seasonal fluctuations tend to balance out over time without causing problems. In fact, the moisture buffering effect of many traditional materials helps to control the risk of condensation and maintain a healthy, comfortable internal environment.

Some energy efficiency improvements can affect the moisture balance. For example, in a heated building, internally insulated walls will tend to be colder, therefore wetter, during winter months than uninsulated walls. If the airtightness of a building is increased without providing adequate ventilation to remove excess moisture, the risks of condensation are increased. Furthermore, the introduction of new materials can cause problems if they reduce the capacity of the host fabric to release moisture freely.

Understanding the way a building interacts with heat and moisture is important. It will enable the likely consequences of energy efficiency improvements to be anticipated. However, the physical processes involved are dynamic and complex. Although computer simulations can be used to assess risks of moisture accumulation in building fabric, site-specific meteorological and material properties data are needed for predictions to be reliable, although in many instances this may not be readily available. But using standard 'library' or default values provided with the software can produce misleading results (see Historic England Conservation Research).

The condition of the building

Building condition has a major influence on energy use. Defects such as damp walls and poorly fitting doors and windows can substantially reduce thermal performance. Thus pinpointing building defects is an essential objective of assessment. Close attention should always be paid to the adequacy and condition of rainwater disposal arrangements and drainage, and areas of dampness should be identified and diagnosed.

Repairs are an important energy-saving measure in their own right. They are also an essential prerequisite for some thermal improvements, such as the addition of wall insulation. Failure to deal with leaking gutters and rainwater pipes, defective drainage and dampness before installation can lead to serious damage. In some extreme instances, buildings have become uninhabitable.

Figure 7

Defects such as damp walls can reduce the thermal performance of the building envelope.

Assessing the thermal performance of the building envelope

Non-destructive tests can be carried out to assess the thermal performance of the building envelope. The information obtained from these tests can be very useful when developing proposals for upgrading. The following might be considered:

- **Air pressurisation testing**
  This test is used to determine the airtightness of a building. A fan is set temporarily into a doorway to create a pressure differential that allows the amount of air leakage through the building envelope to be quantified. When used in conjunction with infrared thermography (see below), cracks, open joints and other defects allowing air leakage can be readily located. Air pressurisation testing can also be used to test the effectiveness of draught-proofing measures.

- **Infrared thermography**
  Infrared video and still cameras can be used to produce images of the building envelope that show variations in surface temperature. In this way, thermal defects, such as cold bridges, can be detected. Used internally in conjunction with air pressurisation tests, air leakage can be located. When used externally, best results are obtained on winter nights when the building is heated and there is a large temperature gradient across the building envelope.

Figure 8 (top)
When used in conjunction with air pressurisation testing, thermal imaging can also show clearly where air is leaking through the building envelope.
Figure 9 (bottom)
Air pressurisation tests are used to determine the airtightness of the building and the amount of air leaking out of the building envelope.

- **U-value measurement**
  The thermal performance of building elements can be assessed *in situ* using sensors to measure the rate that heat flows through them. Measurements are usually carried out over a period of at least two weeks during the winter when the temperature gradient across the element is at least 20°C. The resulting U-values may differ from those obtained by conventional calculation methods, but will usually be more accurate.

- **Co-heating test**
  This test measures the amount of heat lost through the building envelope and is used to determine the heat loss coefficient in W/K. It is normally carried out on an unoccupied building over a period of 1–3 weeks during the winter months. During this period the building is heated to a constant temperature (usually 25°C) with electric heaters. Fans are used to ensure an even temperature is maintained throughout the building. Plotting the daily energy input against the daily temperature difference between inside and outside enables the heat loss coefficient to be calculated.

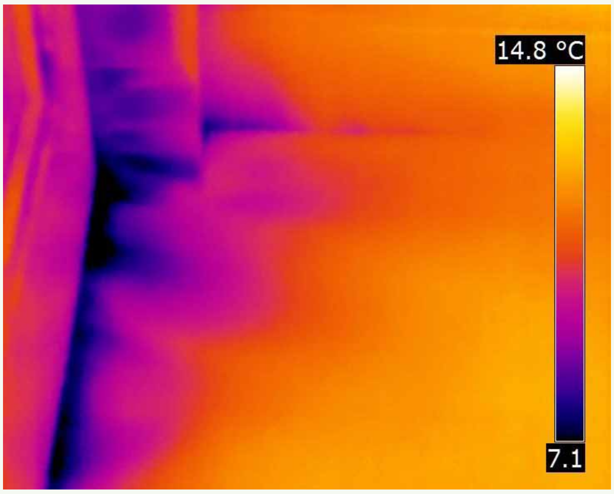


Figure 10
Thermal imaging cameras show variations in surface temperature and can highlight thermal defects such as cold bridges.

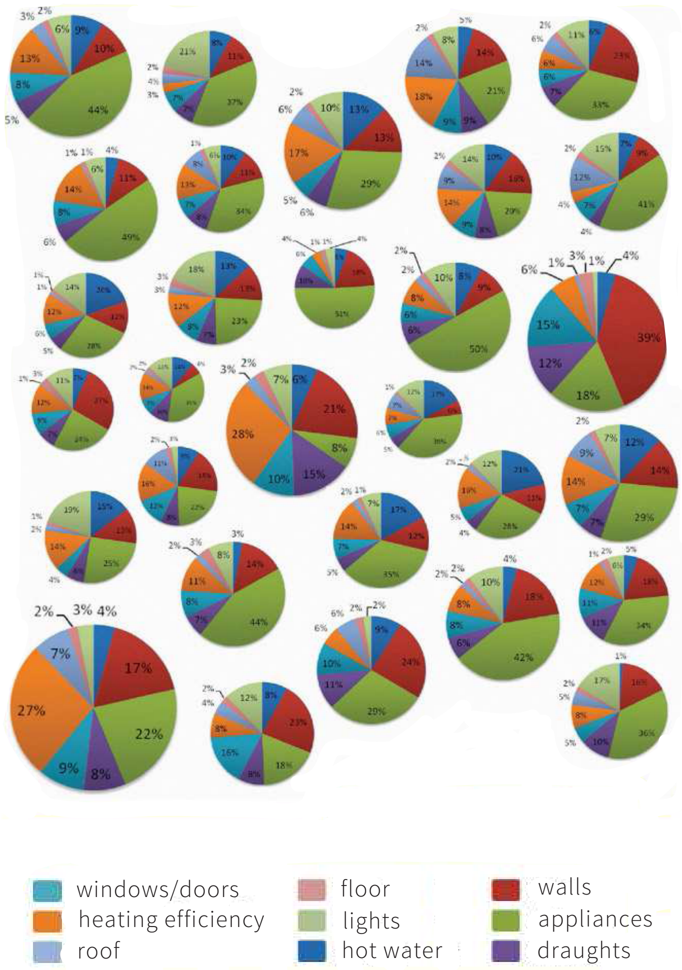


Figure 11

Levels of energy use in similar dwellings can vary greatly. These diagrams show the differences in energy use between households in similar homes in a single neighbourhood. The size of each 'pie' represents the total amount of energy used in each household.

Energy performance of building services

The efficiency, control and management of building engineering services – heating and cooling, hot water supply and lighting, and equipment and appliances – are key factors affecting energy use. Assessments should identify fuel sources and the type, size, age and condition of all the energy-consuming services and equipment. The way the engineering services are controlled and operated should also be reviewed. Any defects that need to be rectified and opportunities for improvement should be highlighted.

Levels of energy use related to occupancy and human behaviour

Occupant behaviour is a major factor affecting levels of energy use. However, there can be considerable variations from one building to another. In fact, the annual energy use of two apparently similar households in similar houses in the same neighbourhood can vary by a factor of three or more. Furthermore, energy is used differently in different types of building. In an office, for example, the energy used to power appliances and equipment will be greater than in a home, but less energy will be used in heating water. Since occupant behaviour can have such a strong effect on the efficiency of energy saving measures, assessment should include both the analysis of fuel bills and interviews with building occupants to obtain information about the way they use (or plan to use) the building. Occupants should also be asked about their attitudes to energy saving, and what they would like energy-saving measures to achieve.

Stage 2: Setting objectives

After all necessary information has been gathered in the assessment stage, the next stage is to devise a preliminary energy plan. This will set out both short and long term objectives for the project and identify the measures likely to be appropriate and practicable in the specific context. It will also help to ensure that measures are properly integrated and technically compatible.

User requirements, aspirations and aims

People may have different reasons for wanting an energy efficiency upgrade for their building. For some, the aim will be to save money on fuel bills. Others might want to reduce greenhouse gas emissions or make a building more comfortable. Energy-saving measures that require significant capital investment might be cost-effective for a high-energy user, but not for a low-energy one. Furthermore, the people and organisations involved in the different stages of a project may have varied, sometimes conflicting, priorities and objectives. For some, the top priority might be the improvement of occupant health; for others, it might be sustaining the significance of the building. Understanding the requirements, aspirations and aims of the various stakeholders is key to devising a suitable energy-efficiency strategy.

Saving energy is as much a social and cultural enterprise as it is a technical one. Occupants and building managers are often not aware of how much energy they waste or the impact of their behaviour. In order to choose the appropriate measures, their attitudes and behaviours need to be understood. This will help identify measures that will be the most effective and the least risky. Eventually, it is hoped, occupants will become aware of wasteful behaviours and habits and be willing to change them.

Opportunities, constraints, and resources

Opportunities and constraints vary widely depending on context. When a building is being repaired, altered or extended, the installation of fabric improvements, such as internal wall insulation, will be relatively easy and economical. But in an occupied building, the level of disruption and relative costs may be unacceptably high. If a building is listed or in a conservation area, the range of acceptable improvements may be more restricted than would otherwise be the case. Building use and occupancy levels will also influence decisions about improvements, such as the choice between natural or mechanical ventilation. Identifying opportunities and constraints is, therefore, an important part of the assessment process.

The funding of energy-saving improvements is a key factor to consider during the whole building assessment stage. Options for improvements should be prioritised and planned to suit the available resources. Some measures may have to be delayed or carried out in phases. Where grants or other financial incentives are offered for single measures, such as solid wall insulation, it is important to see how they fit into the energy strategy overall. A whole building approach allows all the energy-saving options to be properly integrated and coordinated at every stage.

Identifying areas for improvement

A whole building energy plan should cover building use, engineering services and equipment, building fabric, and energy supply. These four areas offer opportunities for saving energy and reducing greenhouse gas emissions:

- **Building use and occupation**
  Changing behaviour; adjusting the way the building, engineering services and equipment are used and managed to minimise energy demands and avoid waste.

- **Building fabric**
  Improving the thermal performance of the building envelope.

- **Engineering services and equipment**
  Increasing efficiency of building services and equipment and improving controls to reduce the amount of energy used.

- **Energy supply**
  Changing fuels or using renewable systems to reduce carbon emissions.

Figure 12
Draughtproofing is a quick low cost measure that will significantly improve energy efficiency.

Quick wins

Opportunities for simple cost-effective improvements should be identified at the outset. Changes in occupant behaviour and remedying poorly adjusted, faulty or inappropriate controls and badly maintained or malfunctioning systems and equipment will have a positive effect. So can straightforward low-cost fabric-related measures, such as using curtains, repairing or reinstating window shutters and awnings, draught-proofing and installing loft insulation.

Appraising the options

Measures should be appraised to evaluate their efficiency, cost-effectiveness and suitability. Their impact on the character and significance of the building should also be assessed, along with technical risks and the likelihood of unintended consequences. The measures finally selected need to form a coherent and well-integrated package. For example, fabric improvements that reduce air infiltration should be accompanied by a ventilation strategy to remove excess moisture and maintain indoor air quality.

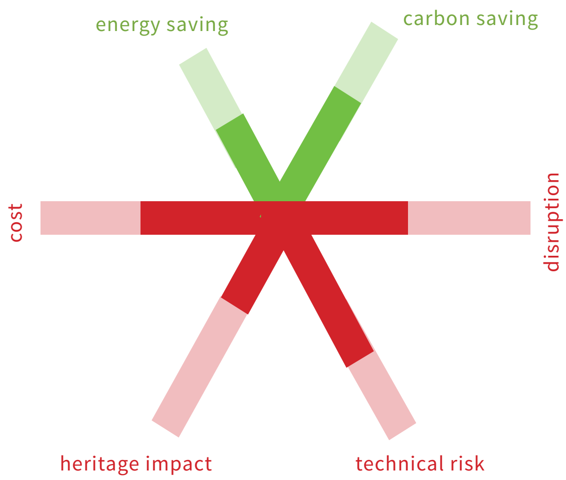
In practice it is not always easy to weigh up the costs and benefits of various measures. Different households, occupant behaviours, and variations in building location, form, construction and services can make it difficult to fully understand the energy performance of an individual property. Also, many homes have been adapted or added to over time, altering their energy characteristics and complicating the picture still more. As a result, there are often discrepancies in the predicted energy savings and those achieved in practice.

For a scheme to be successful, adequate funding and access to appropriate professional expertise and practical skills will be needed. The project should be realistic to allow sufficient time to prepare the detailed design and specifications, obtain any necessary statutory consents, and carry out the work.

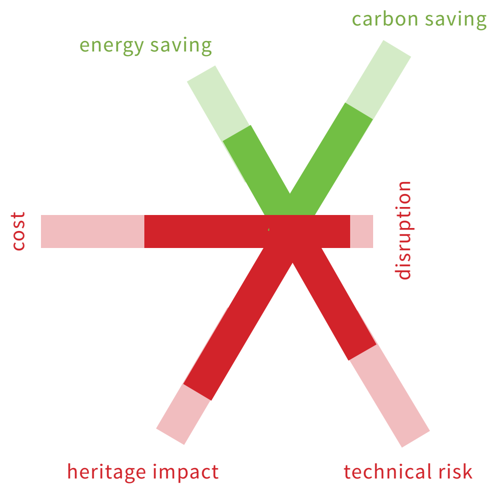
Figure 13

Weighing up the cost and benefits of various measures can be challenging.

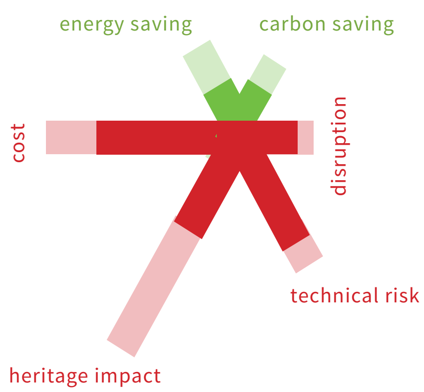
INTERNAL WALL INSULATION



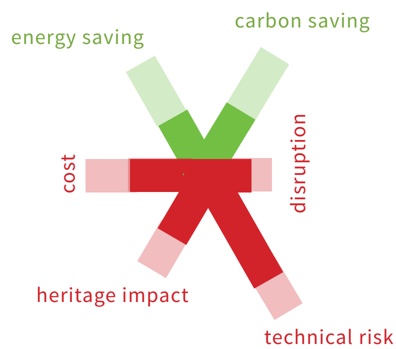
EXTERNAL WALL INSULATION



REPLACE GLAZING WITH DOUBLE GLAZING



DRAUGHT SEALING



Determining priorities

Work may be carried out in stages to enable specific measures to be incorporated in future planned maintenance or improvements or to spread costs. It is important to consider the interactions between the measures at every stage to ensure they are properly integrated (for example, providing for adequate ventilation when draught seals are installed). In general, priority should be given to simple cost-effective improvements that deal with wasteful operational practices, and to correct poorly adjusted, faulty or inappropriate controls. Badly maintained or malfunctioning systems and equipment should also be remedied at the earliest opportunity. Straightforward, low-cost fabric-related measures (such as draught-proofing) should usually be carried out before more complex and expensive ones.

Defects and dampness can significantly lower the energy performance of building elements, reducing the effectiveness (and increasing the risks) of energy efficiency measures. Carrying out any outstanding repairs and maintenance should be a priority. However, even in cases where all the measures can be completed in a single phase, an incremental approach may still be preferable, as it allows for continuing assessment and review. This enables the energy plan to be adjusted in response to any gains made, and allows time to uncover and deal with unanticipated problems.

It is important to note that repairing (or reinstating) historic features, such as window shutters or wall panelling, not only helps reduce energy use, but enhances a building's character and significance.

See Section 3 for more detailed information on what measures may be appropriate.

The importance of building maintenance

Buildings of traditional construction are inherently sustainable. In general they are robust, durable and adaptable, and built with materials that can be easily repaired and maintained. Their service life can be extended indefinitely provided they are well looked after.

Building condition strongly influences energy performance. Poorly maintained building services do not operate efficiently. The thermal resistance of porous building materials reduces when they are damp, and building defects, such as leaking gutters and defective drains that allow moisture to accumulate, will reduce thermal performance. Uncontrolled air infiltration through cracks and poorly maintained doors and windows contributes further to heat loss.

Investing in regular and timely maintenance optimises building performance and increases the benefits (and reduces the technical risks) of any additional energy-efficiency improvements. By dealing with faults before they develop into major defects, the need for larger, more costly and invasive programmes of repair and conservation treatment will frequently be averted.

Stage 3: Detailed design and specification

In this stage the preliminary energy plan is developed in detail. Depending on the size and complexity of the project, detailed design drawings and specifications will be required to enable necessary consents to be obtained and the works procured. Documentation should be detailed, clear and unambiguous. For example, where insulation is to be added to roofs, walls or floors, details showing how the junctions between each of the elements are to be formed will be needed to avoid improvising solutions on site. Specifications should be explicit about products and material to ensure that lower quality alternatives are not substituted.

If designers find that an important issue has been overlooked at the assessment stage, they should report this to the client and assessor so the assessment can be revised if necessary.

Consents for energy improvements

Applications to the local planning authority for planning permission and/or listed building consent may be required for certain energy efficiency measures. General advice can be obtained on the Historic England website. More detailed site-specific advice will be available from the local planning authority.

In some circumstances, proposed energy efficiency measures will require approval under the Building Regulations (from either the local authority's Building Control team or an approved inspector). Whichever route for approval is taken, early consultation can help to ensure that works are appropriate. *Approved Document Part L1B* and *L2B* give practical guidance on meeting requirements for the conservation of fuel and power in both existing dwellings and non-residential buildings. Approval is needed where substantial alterations to thermal elements or controlled fittings or services are to be made, or extensions or changes of use are proposed.

Conservation principles, measures and techniques

The following high-level principles apply to the repair of historic buildings. They should also be considered when designing energy efficiency improvements:

- Only techniques and materials that have been demonstrated to be appropriate to the building fabric should be used. These will normally be the same as the original or host material. When this material is no longer available or appropriate, the intervention should employ a material that has compatible properties, both technically and aesthetically.
- Interventions should maximise the life expectancy of significant building fabric, consistent with sustaining its significance.
- Interventions should be technically feasible, practicable and reversible – or at least retreatable – and should not prejudice future interventions when they become necessary.
- All works should be adequately recorded, and the records made available for others who may take on the building in the future.
- Interventions should contribute to, or at least not compromise, the sustainability of future management and maintenance.

With regard to Building Regulations (Part L), listed buildings and buildings in conservation areas are exempted from the need to comply with energy efficiency requirements where compliance would unacceptably alter their character or appearance. 'Special considerations' also apply to buildings that are locally listed, in national parks or other designated historic areas and to buildings of traditional construction. Historic England has published detailed 'second tier' guidance on the Building Regulations (Part L) which the Approved Documents state should be taken into account in determining appropriate energy performance standards: *Energy Efficiency and Historic Buildings; Application of Part L of the Building Regulations to historic and traditionally constructed buildings*.

Stage 4: Installation

Installers should have sufficient training, expertise and interest in the whole building approach. An experienced installer will be able to contribute valuable specialist practical knowledge to a project. Maintaining good communications between installer, and the designer, assessor and client is key in ensuring a successful outcome. The costings should be based on the whole building approach and allows for adequate levels of supervision, checks, testing and feedback as the work proceeds.

Before starting installation works, make sure that all necessary permissions have been obtained and any conditions complied with. If something unexpected is found as the work proceeds or a design detail does not work, this should be reported back to the assessor and designer so that suitable modifications can be made. Good levels of site supervision will help to ensure that works are carried out to the required standards. On larger or more complex projects, a clerk of works could be appointed to monitor the quality and progress of the works on the client's behalf. Where fabric improvements have been carried out, the quality of completed work should be checked using thermal imaging and air pressurisation tests.

Stage 5: Use, review and maintenance

Handover should be managed in a way that ensures that building engineering services are properly commissioned, and building users/managers understand what has been done, how it is intended to work, and how they can maintain it. Advice should also be given on the importance of ventilation in reducing the risks of condensation and maintaining good indoor air quality. Projects where user manuals, maintenance schedules, verbal briefings and follow up visits have been provided prove to be significantly more successful than those where little or no information was offered.

After handover, energy efficiency improvements should be checked and reviewed to make sure everything is working as planned. Energy bills can be used to compare levels of energy use before and after improvements. And where fabric improvements have been carried out, (for example, added insulation to roof, walls and floors), inspections should be made annually to check for signs of condensation, mould or decay. In larger, more complicated projects a full Post Occupancy Evaluation (POE) may be carried out. Normally, a proportionate step-wise approach is preferable, with more advanced investigations being done only if needed. If necessary, findings should be used to adjust the energy plan.

Both information gathered in reviews, and the steps taken to remedy any problems, should be documented and made available to the building users and managers. They should also be passed on when a building changes hands. The energy strategy should be reviewed and adjusted whenever a building is altered, or if its use or occupancy changes.

The Performance Gap

Measures installed to reduce energy use in new and existing buildings sometimes fail to achieve the savings predicted. The reasons for this 'performance gap' include:

- incorrect assumptions about the thermal performance of existing buildings
- inaccuracies in the data and models used to predict energy performance
- inadequate design and specification of improvements
- poor installation, integration and commissioning of improvements
- ineffective or confusing control systems
- building occupancy and patterns of use
- occupant behaviour – 'comfort taking'

A 'rebound effect' may occur when energy efficiency improvements lead to behaviours that increase energy consumption. For example, when a heating system becomes less expensive to run, it may be used more frequently or at higher temperatures than before. Savings may also be less than expected if the energy consumption in a building prior to improvement is overestimated. This is sometimes called the 'prebound effect'. In many cases, this happens when the thermal performance of a building is under-estimated, or where incorrect assumptions are made about the levels of energy use in individual households.

Therefore, when planning improvements it is important to assess as accurately as possible existing levels of energy use. The energy performance of the building and services, and the attitudes and behaviour of the building occupants, are all contributory factors that need to be taken into account.

3 Guidance on Measures

This section summarises practical energy efficiency improvements and considers their respective benefits, costs and technical risks. It should be read in conjunction with the full range of Historic England guidance which can be found at: HistoricEngland.org.uk/energyefficiency

The information is presented in checklist form as an overview. Measures are arranged in order of priority and represent a step-by-step approach to energy efficiency improvements. However, in reality, priorities will depend on the circumstances of each particular case, as determined by the 'whole building approach'. References are given to Historic England's detailed guidance on the principles, risks, materials and methods for improving the thermal performance of roofs, walls, floors and windows.

The checklist is divided into the following sections:

Understanding what you've got
Determining the original arrangements and assessing how the building is currently being used

GREEN actions to improve thermal performance
Low-cost and low-risk options that could be considered for every building.

AMBER actions to improve thermal performance
Options that involve some risk and/or some cost: suitability will depend on the particular building.

RED actions to improve thermal performance
High-risk and/or high-cost options: careful consideration needed.

Understanding what you've got	
Current arrangements	**Comments**
Building and context	
Where is the building located? Is it in a sheltered or exposed position? Which way does the building face? Which parts are sunny and which parts are shaded? What was the original form of construction? What alterations have been made subsequently? Are there existing energy-saving features? Is the building in good condition? Are there defects that make the building less energy efficient? Are there signs of problems such as dampness or mould? Is the building terraced, semi-detached or detached? Is the interior open-plan or subdivided? How many people occupy the building? What are the usual daily patterns of occupation? What heritage values and significance does the building embody? How might energy efficiency improvements affect these?	Location, exposure and orientation Problems with dampness and draughts due to inadequate maintenance adversely affect the energy performance of buildings and health of occupants Building and lifestyle affect the energy efficiency and healthiness of homes
Heating systems	
Determine the **original** arrangements for heating, including: ▪ plant (boilers, warm air furnaces) ▪ delivery (fireplaces, radiators and warm air outlets) ▪ outlets (chimneys and flues) ▪ what is still present, and in what condition is it? Determine the **current** arrangements: ▪ What systems are used (both built-in and free standing)? ▪ How are they used? ▪ How effective are they in the eyes of the building users?	Are any of the heating arrangements of historic interest, and requiring of protection? Could any parts of the existing older systems be reused in any new system? Are the existing heating controls easy for occupants to understand and use?

Understanding what you've got

Current arrangements	Comments
Cooling systems	
Determine the **original** arrangements (if any) for cooling the building, including: ▪ solar protection (awnings, blinds etc) ▪ windows and other ventilation (is cross-flow possible?) ▪ built-in systems such as fans and heating, ventilation and air conditioning (HVAC) ▪ free-standing systems such as table fans ▪ what is still present, and what condition it is in Determine the **current** arrangements: ▪ What systems are used (both built-in and free standing)? ▪ How are they used? ▪ How effective are they for the building users?	Are any of the cooling arrangements of historic interest, and should be retained? Could any parts of the existing older systems be reused in any new system? Are the existing cooling controls easy for occupants to understand and use?
Ventilation systems	
What is the natural ventilation? Is it controllable (for example by opening or closing windows)? Are there any artificial ventilation systems? If so, how and when do they operate? In each space, is the ventilation inadequate or excessive?	Even well-ventilated spaces can have stagnant corners What are the control systems for natural and artificial ventilation? Are they easy for occupants to understand and use? Artificial ventilation systems may not be used correctly because of noise concerns
Lighting	
Are lighting levels satisfactory, poor, or excessive? Assess the natural daylighting of the space: ▪ How was this originally controlled (blinds, shutters, awnings)? ▪ What is present, and what condition is it in? ▪ Are issues such as glare and solar gain restricting use? ▪ Are furnishings arranged to make the best use of the natural lighting? Assess the artificial lighting: ▪ What are the types and numbers of fittings, and the energy ratings of the lamps? ▪ How and when is artificial lighting used? Is it used when daylight would be an effective alternative? ▪ How is it controlled: at point of use, or centrally? If the latter, what are the allowable settings?	Could occupants make better use of natural lighting? It can sometimes be optimised by redirecting with mirrors or white-painted surfaces Task lighting is usually more efficient than lighting whole spaces, particularly where occupancy is light or patchy Lamp replacement can be a good low-cost measure, but replacing fittings may not be cost-effective (demands an energy cost-benefit analysis, taking into account warm-up times, illuminance, light distribution, colour temperature, glare and service life) Mock up any proposed new lighting such as over-lighting Simple and well-considered controls are critical if lighting is to be effective and efficient Presence detection can be useful where people would not normally be able or expected to switch the lights on and off; but a good general rule is to have a manual ON switch, and both an automatic and manual OFF switch

Understanding what you’ve got

Current arrangements	Comments
Hot water systems	
Determine the **original** arrangements for supplying hot and cold water Assess the **current** arrangements: ■ Pipework: ▪ What is the layout? If pipes are too long or too wide that may increase warm-up times and heat losses ▪ Is it well insulated? ▪ In what condition are the taps and other hot-water outlets? Are the flow rates too low or too high? ▪ How long does it take to get the water to a satisfactory temperature? ▪ Are all the hot-water outlets needed? Could some be cold water only? ■ Water-heating systems: ▪ Are there any point-of-use water heaters? ▪ Is there a central hot water system? If so, what is its age, condition and capacity and efficiency? How well is it insulated? ▪ Is it efficient in summer? Older systems can be very wasteful	Are any of the hot water systems of historic interest, and requiring of protection? Could any parts of the existing older systems be reused in any new system? Are the controls easy for occupants to understand and use? Is the system well suited to the needs of the occupants? Possibilities for improvements include local point-of-use heaters (particularly for remote outlets with only occasional use), and solar heating of water
Appliances and other energy-using equipment	
Record and assess the energy use of all: ■ kitchen appliances ■ security, IT and communication systems ■ entertainment and other systems (including televisions) What is the equipment? How efficient is it? Can inefficient systems be upgraded? How is it being used? Can operating times be reduced? Is all the equipment really needed, or can numbers be reduced?	Visualising energy use via small energy meters that show the difference when equipment is turned off can help identify unexpected sources of significant energy use Commercial catering equipment is often inefficient and operated too liberally, with everything being turned on first thing; catering specialists often over-specify requirements For advice on the efficient specification and operation of the technology, it is best not to rely on suppliers, building professionals, or even technology consultants: specialist expertise is required which understands both the technology and its energy performance
Occupant comfort	
How comfortable do the occupants feel? This will depend on who they are, and what they are doing in the space What sources of discomfort can be identified (draughts, radiant heat loss, solar gain)?	At this stage, consideration needs to be given to how the building is being used, and how discomfort might be affecting that use

'GREEN' actions to improve thermal performance Low-cost and low-risk options that could be considered for every building			
	Action	**General comments**	**Other considerations**
Reducing demand	Dealing with sources of discomfort	As far as possible remove or modify the sources of discomfort in reversible ways that do not require significant energy input. Examples include: ▪ dealing with draughts (incuding draughts from poorly chosen heating) ▪ using rugs, wall hangings, screens to reduce radiant heat loss into large heat-absorbent surfaces	By reducing the demand for heating or cooling, any artificial conditioning systems can be made smaller and more effective
Reducing demand	Optimising use of natural and artificial lighting	If possible, adjust building use so that any artificial lighting can be concentrated to best effect	By reducing the demand for lighting, any artificial lighting systems can be made smaller and more effective
Reducing demand	Reducing the quantity of energy-using equipment	Energy-using equipment tends to accrete with time, and a proper audit may identify equipment that could be removed with little loss to building operation but significant energy savings	Any energy-using equipment should have to 'pay its way': its use of resources should have to be justified by its utility
Roofs	Insulating pitched roofs at ceiling level (loft insulation)	Will usually be the simplest, cheapest and most straightforward approach Creates a 'cold roof': roof space must be ventilated by outside air to remove water vapour generated by the activities in the building Traditionally, air infiltration between slates and tiles usually provided enough ventilation; when sarking felts and membranes are included, specific arrangements need to be made Over-ventilation will reduce the effectiveness of the insulation	Existing insulation should be removed Avoid gaps in the insulation and variations in thickness that create cold spots, for example where there is a section of sloping ceiling near to the eaves Avoid creating thermal bridges at junctions with walls Insulate and seal loft hatches; seal cracks and gaps around services to prevent infiltration of moist air from below Separate insulation from damp chimneys and walls Insulate plumbing and water tanks Route electric cable above insulation Maintain eaves ventilation
Roofs		See the Historic England guidance on insulating pitched roofs	

'GREEN' actions to improve thermal performance Low-cost and low-risk options that could be considered for every building			
	Action	General comments	Other considerations
Roofs	Insulating flat or low-pitched roofs at ceiling level (for roofs with accessible voids)	Relatively straightforward and economic Creates a 'cold roof': roof space must be ventilated by outside air to remove water vapour generated by the activities in the building Can be difficult to provide adequate ventilation	Must take into account the same issues and considerations as pitched roofs Not regarded as robust, particularly above spaces producing moist air (such as kitchens, bathrooms, densely occupied spaces) If chosen, the roof void will need to be inspected regularly
		See the Historic England guidance on insulating flat roofs	
Walls	Repairing (Including repointing and repairs to permeable renders)	Appropriate repairs will improve airtightness and water penetration (a dry wall will transfer much less heat)	The correct intervention depends on the materials and construction of the wall; but permeable materials such as lime mortars and renders should always be used Consider replacement of impermeable renders and mortars where practicable
Windows and doors	Draughtproofing	Draughtproofing is an unobtrusive and cost-effective way of improving comfort and reducing energy use	Any necessary repairs should be carried out before draughtproofing
	Adding curtains and blinds	Curtains (including door curtains) can provide excellent draughtproofing On large areas of glass, can reduce both heating loads in winter, and cooling loads in summer	Traditionally, windows often had different curtains for summer and winter
	Refurbishing or replacing lost shutters	External shutters protect against both solar gain and heat loss, and provide security and weather protection Internal shutters are good at reducing heat loss, but are less effective against heat gain	Shutters can be of many types, designs and sizes Some traditional windows had both internal and external shutters Consider incorporating draughtproofing in new and refurbished shutters, to enhance performance
Floors	Adding rugs or carpets to solid ground floors	Reduces radiant heat loss	Floor coverings and underlays must be permeable to avoid trapping moisture
	Adding rugs or carpets to suspended timber floors	Reduces radiant heat loss and draughts through floorboards Close (fitted) carpeting will reduce air leakage through gaps in floorboards	Floor coverings and underlays must be permeable to avoid trapping moisture or preventing air flow

'AMBER' actions to improve thermal performance Involve some risk and/or some cost: suitability will depend on particular building			
	Action	General comments	Other considerations
Reducing demand	Installing measures to reduce discomfort	Consider measures that may require an energy input or incur a slight technical risk (such as installing panelling, secondary glazing, carpets)	The benefit of any measure will depend on how much of the energy being used in the building would be saved; for example, in a church with thick walls and small windows, secondary glazing is unlikely to save enough energy to justify its cost
Reducing demand	Replacing energy-using equipment	Need to consider whole-life costs if replacing: it may be better to wait until the equipment comes to the end of its natural lifespan	An assessment should be carried out to decide whether or not it is beneficial to replace energy-hungry equipment that has not yet come to the end of its life
Roofs	Reinstating a missing ceiling	If ceiling has been removed for aesthetic reasons, reinstatement can provide significant benefits	Check for signs that a ceiling once existed, such as lath marks on the beams Ceilings can also alleviate bat problems
Roofs	Insulating pitched roofs	BETWEEN THE RAFTERS Does not increase the visible height of the roof or reduce the usable floor area of the accommodation Effective ventilation should be provided above to remove excess moisture and water vapour Thickness of insulation will be limited by the depth of the rafters which, in addition, may form a potential thermal bridge	A high level of workmanship is required to minimise gaps between the rafters and the insulation; for this reason soft pliable insulation materials are preferable to rigid boards Insulation should never be fastened to or sprayed on the underside of slates or tiles, as this makes it impossible to maintain or reuse the roof coverings Infiltration of moist air from within interior must be minimised: cracks in ceilings and around service penetrations should be sealed, and recessed lighting fittings should not be used
Roofs	Insulating pitched roofs	ABOVE THE RAFTERS Becomes an option when the roof is being re-covered Raises the level of the roof coverings, which may often be unacceptable or impractical Roof structure is on the warm side of the insulation, reducing the risk of moisture accumulation Decreases solar gain through the roof	Insulation can sometimes be fitted as an unbroken layer, avoiding thermal bridging Undulations in roof slopes, which often make an important contribution to the visual character of old roofs, can make installation difficult; high standards of workmanship are required The additional weight of insulation can sometimes make it necessary to strengthen the roof Spray foams on the underside of roof finishes should not be used, as they may trap moisture; the roof covering also becomes difficult to re-use
Roofs	Insulating pitched roofs	See the Historic England guidance on insulating pitched roofs	

<table>
<tr><th colspan="4">‘AMBER’ actions to improve thermal performance
Involve some risk and/or some cost: suitability will depend on particular building</th></tr>
<tr><th></th><th>Action</th><th>General comments</th><th>Other considerations</th></tr>
<tr><td rowspan="5">Roofs</td><td rowspan="4">Insulating pitched roofs</td><td>BELOW THE CEILING
Sometimes insulation and a new ceiling can be installed beneath the original ceiling; more rarely the original ceiling is not significant, and can be replaced
The installation should be airtight and vapour-resistant, otherwise too much moist air may enter the void space</td><td>Care should be taken with detailing at junctions and around openings: even small gaps, holes or cracks can lead to infiltration of moist air and condensation
One instance in which vapour-control layers may be necessary to stop rising moist air; but this is not a preferred option, since water can enter from other sources and other directions (including roof leaks)</td></tr>
<tr><td>AT RAFTER LEVEL
Ventilation may need to be introduced between the insulation and the roof covering to reduce the risk of condensation</td><td></td></tr>
<tr><td>BENEATH THE RAFTERS
Can be installed without stripping the roof covering or changing the height of the roof
Leaves the maximum room for natural air circulation under the roof covering
May reduce the amount of usable floor space</td><td>Installation must be airtight: even small gaps can lead to cold bridging and condensation, especially if the roof has an impermeable underlay
Care will need to be taken with detailing at junctions and around openings</td></tr>
<tr><td colspan="2">See the Historic England guidance on insulating pitched roofs</td></tr>
<tr><td>Insulating flat or low-pitched roofs</td><td>BELOW THE CEILING
Sometimes insulation and a new ceiling can be installed beneath the original ceiling; more rarely the original ceiling is not significant, and can be replaced
The installation should be airtight and vapour-resistant, otherwise too much moist air may enter the void space</td><td>Care should be taken with detailing at junctions and around openings: even small gaps, holes or cracks can lead to condensation
One instance in which vapour-control layers may be necessary to stop rising moist air; but this is not a preferred option, since water can enter from other sources and other directions (including roof leaks)</td></tr>
</table>

'AMBER' actions to improve thermal performance
Involve some risk and/or some cost: suitability will depend on particular building

	Action	General comments	Other considerations
Walls	Rendering	Walls were often rendered in the past, but the renders were lost through lack of repair or deliberately removed Applying a permeable render can benefit walls of every kind, cutting water penetration and air infiltration (dry walls have a much higher thermal resistance)	Rendering has a dramatic effect on the building appearance, but there may be a precedent in historic records Critical to use ONLY permeable materials such as lime-based mortars Additives such as hemp hurds or cork can increase insulating capacity
Walls	Plastering	Applying a permeable plaster can increase thermal resistance, but use in historic buildings may be restricted by presence of important decoration (for example, wall paintings)	Critical to use ONLY permeable materials such as lime-based mortars Additives such as hemp hurds or cork can increase insulating capacity
Walls	Lining interior walls with hangings or panelling	Lining the interior with thinnish sheets of permeable material, battened off the wall, will improve thermal response and reduce radiant heat loss Use in historic buildings may be restricted by presence of important decoration (for example, wall paintings)	There will be an impact on appearance, and some reduction in the usable area of the room; panelling may be difficult to detail around original features such as decorative cornices It is wise to design panelling to be easily openable to check the condition of the wall behind
Windows	Adding secondary glazing	Cuts draughts and reduces heat losses through the existing window frames, not just the glass Traditionally, widely used in cold climates, and for noise control (often with open-in casements) Traditional designs used wood-framed secondary sliding sash windows and casements Many commercial models use sliding, fixed or hinged panels in metal frames, but the frames are a thermal bridge Wooden-framed systems can be designed to fold or slide away like shutters	Primary and secondary windows must open and shut with ease where natural ventilation is required Poor heat conductors make better frame materials (for example, wood rather than metal) Do not draughtproof the primary glazing, so the interspace has some ventilation by external air, reducing the condensation risk For best thermal performance, secondary glazing can use hard-coated low-emissivity glass, or an IGU, which will last longer than normal since it is protected from the weather
Windows	Adding secondary glazing	See the Historic England guidance on secondary glazing	

'AMBER' actions to improve thermal performance Involve some risk and/or some cost: suitability will depend on particular building			
	Action	General comments	Other considerations
Windows	Adding shutters	Shutters were originally made to suit almost every type of window	Consider designing bespoke shutters
	Adding awnings or other shading and weather protection	Can protect windows from solar gain, or let them stay open for ventilation when raining Some Victorian models were specifically designed to assist ventilation through the window	Solar films and varnishes can be used to reduce solar gain, but they have short lifespans and are difficult to remove; they would not be suitable for use on handmade or early machine-made glass
Floors	Insulating existing solid ground floors	Thin, high-performance insulation board can be installed with minimal disturbance to the original floor Moisture problems must be tackled before work begins, and a good monitoring and maintenance regime set into place	Floor level will be raised, so skirting boards may need to be removed and reinstated, doors will have to be shortened, and junctions with staircases resolved
	Insulating suspended timber floors (draught-sealing)	Reduces air leakage between skirting boards and floor, and through gaps between floorboards Moisture problems must be eliminated before work begins, and a good monitoring and maintenance regime set into place	Reducing air movement in the floor void may affect the moisture equilibrium

‘RED’ actions to improve thermal performance
High-risk and/or high-cost options: careful consideration needed

	Action	General comments	Other considerations
Flat or low-pitched roofs	Insulating in the joist zone (where voids are not accessible)	Not recommended, owing to various risks, but may sometimes be possible to combine with insulation under the joists	Where this approach is chosen, a good ventilation space (ideally 150 mm or more) should be retained between the upper side of the insulation and the underside of the roof deck
	Insulating above the deck Weatherproofing directly above insulation	Creates a ‘warm roof’ Commonly used in modern construction, especially in the form of proprietary systems, but heavily reliant on the integrity of the weatherproofing layer above the insulation, the vapour barrier beneath and any ventilation of the interspace	The height of the roof will need to be raised Not normally recommended: if chosen, consider obtaining a package from a reputable supplier, with appropriate warranties
	Insulating above the deck Ventilated layer between insulation and weatherproofing	Creates a ‘ventilated warm roof’ Recommended for metal roofs, particularly lead and zinc Allows a very good air, water and vapour seal to be applied between the insulation and the roof structure; sometimes the original roofing membrane may be used for this purpose The ventilated airspace should be: ▪ 150–200 mm deep for a pitch up to 3° ▪ 100 mm for a pitch from 3° to 20° ▪ 50 mm for a pitch greater than 20°	The height of the roof will need to be raised, and the structure may need reinforcing Flat-roof inlets and outlets should be equivalent to a 25-mm continuous slot (as the pitch increases, the size can be reduced); insect screens may be needed, but ensure they do not block with debris (slots are better than meshes) Ventilation needs to be provided around (or above and below) obstructions such as rooflights, and complex geometries such as hips will need arrangements for ventilation towards the apex
	Insulating above weatherproofing	Creates an ‘inverted roof’ Waterproof insulation (such as extruded polystyrene) is placed above the weatherproofing layer, and weighted down with ballast or paving slab On small roof areas not subject to heavy foot traffic, lighter-weight pre-screeded interlocking insulation slabs can be used Weatherproofing layer must be of good quality and properly tested (for example, by adding water with rainwater outlets blocked)	The height of the roof will need to be raised, and the structure will often need reinforcing Can be very durable, because the roofing membrane is protected from temperature fluctuations and ultraviolet light damage Requires special drainage outlets that admit water from both the surface and the waterproof membrane levels Flowing water during rainstorms will degrade performance

'RED' actions to improve thermal performance
High-risk and/or high-cost options: careful consideration needed

Walls

- Demands careful design, correct choice of materials, good detailing and extremely high standards of workmanship
- Methods and materials will vary according to type of wall, and whether it is being insulated externally, internally or by filling a cavity
- Great care must be taken to eliminate all possible moisture sources from the wall before works begin
- Internal and external wall insulation will hide the condition of the wall beneath, so it is wise to consider installing time-of-wetness sensors or other moisture monitoring to reveal problems should they occur

Action	General comments	Other considerations
Insulating walls Internally	Permeable, hygroscopic insulation would normally be preferable Thickness may need to be limited to reduce moisture accumulation risk Significantly reduces interior floor space, which can be problematic in small rooms Installation requires the occupants to vacate the building Tends to cause problems of thermal bridging	To limit thermal bridging, partial insulation may be necessary to upper floors, partitions and party walls where these meet the insulated wall Walls will tend to become colder (therefore wetter) as the amount of heat transferred from inside the building is reduced Internal services, including electrical wiring and heating pipework, may need to be rerouted
Insulating walls externally	Where space is available, exterior wall insulation can safely be made much thicker than interior wall insulation Advantage can be taken of the thermal mass of the wall to help buffer temperature fluctuations and reduce risks of summer overheating if night ventilation is adequate Can be installed while the building remains in occupation Presents fewer problems with thermal bridges than internal wall insulation Insulation must be protected from the weather by a render, or some other protection such as cladding, or hanging tiles or slates	Carries a significant risk of inducing or exacerbating liquid-moisture problems External rainwater pipes and gutters and other services will usually need to be removed and altered before being replaced after the installation of the insulation Detailing (especially around openings, and at cornices and eaves) must be meticulous, since any water entering from leaks or condensation will be trapped behind the insulation; problems may go unnoticed until they become very serious Roof coverings at eaves and gable ends should be extended to protect insulation; cappings and sealants are unreliable in the long term and should be avoided
	See the Historic England guidance on insulating solid walls	

'RED' actions to improve thermal performance
High-risk and/or high-cost options: careful consideration needed

Walls

- Demands careful design, correct choice of materials, good detailing and extremely high standards of workmanship
- Methods and materials will vary according to type of wall, and whether it is being insulated externally, internally or by filling a cavity
- Great care must be taken to eliminate all possible moisture sources from the wall before works begin
- Internal and external wall insulation will hide the condition of the wall beneath, so it is wise to consider installing time-of-wetness sensors or other moisture monitoring to reveal problems should they occur

Action	General comments	Other considerations
Insulating cavity walls	Increases the thermal resistance of the wall, but does not affect its appearance Least risky in dry, sheltered areas; caution is needed in sites prone to driving rain Loose fill materials should be used rather than foam to give some potential for extraction (which is still extremely difficult) Cavity walls can also be insulated internally or externally	Carries a significant risk of inducing liquid-moisture problems If the cavities open into the roof space, they must be closed Borescope investigations should be made to locate moisture sources, and thermal and moisture bridges; these must be dealt with before insulation Not suitable for cavity walls bonded with bricks Always use reputable contractors, and obtain appropriate insurance-backed warranties
	See the Historic England guidance on insulating cavity walls	
Insulating a framed construction	Sometimes possible when cladding or interior finishes are removed for maintenance Options are similar to those for insulating roofs at rafter level	If insulation is entirely within the framing, the frames will act as thermal bridges; it is therefore best to combine insulation between the framing with a complete skin of render or insulation (preferably on the exterior)
	See the Historic England guidance on insulating timber-framed walls	

‘RED’ actions to improve thermal performance High-risk and/or high-cost options: careful consideration needed			
	Action	General comments	Other considerations
Windows	Replacing glass	Single glazing can be replaced with double glazing (insulated glass units/IGUs), but unlike secondary glazing, this will not directly reduce draughts or heat transfer through the frames; it can, however, be combined with draughtproofing Vacuum IGUs are relatively expensive, and where safety glass is required, a protective film will need to be applied	Hand-made and early machine-made glass are important assets, and should be retained IGUs are energy-intensive to manufacture, and have a short lifespan; the thin IGUs often fitted into older window frames may be even more energy-intensive, owing to both the low thermal-transfer gases they contain and their shorter lifespan Metal frames are cold bridges and are especially likely to attract condensation if reglazed with IGUs
Windows	Replacing windows	Historic windows, whether original or later insertions, whose design follows historic patterns, usually make an important contribution to the significance of historic buildings. When they do, they should be retained and repaired where possible; If beyond repair they should be replaced with accurate copies Where historic windows or replacement windows of historic pattern survive without historic glass it may be possible to introduce slim-profile double-glazing without harming the significance of the building. There are compatibility issues to consider as the introduction of double-glazing can require the renewal of the window frame to accommodate thicker glazing. Replacement windows whose design does not follow historic patterns are unlikely to contribute to significance, unless they relate to an important later phase Replacing such windows with new windows of a sympathetic historic pattern, whether single-glazed or incorporating slim-profile double-glazing, may cause no additional harm	Early materials (such as forest-grown hardwoods and softwoods, and hand-wrought iron) were of a quality and durability that it would now be difficult or impossible to match, and should always be retained Rarely windows will be in such a poor state that complete replacement is less expensive than repair and upgrading, but usually even very neglected windows can be brought back into condition relatively easily, and upgraded with systems such as secondary glazing
Windows	Replacing windows	See the Historic England guidance on traditional windows	

<table>
<tr><th colspan="4">‘RED’ actions to improve thermal performance
High-risk and/or high-cost options: careful consideration needed</th></tr>
<tr><th rowspan="7">Floors</th><th>Action</th><th>General comments</th><th>Other considerations</th></tr>
<tr><td rowspan="4">Insulating solid ground floors</td><td>REPLACING AN EXISTING FLOOR WITH A NEW INSULATED FLOOR
Insulation used will be impermeable, so work can affect moisture distribution in walls and other adjacent fabric
Moisture problems must be tackled before work begins, and a good monitoring and maintenance regime set into place</td><td rowspan="3">Often carried out in conjunction with underfloor heating
It may be possible to lift and reinstate some historic floor finishes, but the pattern of settlement and wear will be lost
Excavation risks undermining wall foundations</td></tr>
<tr><td>CONCRETE SLAB
Usual approach; insulation may be laid above or below the slab</td></tr>
<tr><td>LIME-CONCRETE SLAB
Insulation material is either mixed within the lime concrete, or laid as a layer beneath the slab
For same strength, will need to be thicker than concrete slab, and so may require deeper excavation</td></tr>
<tr><td colspan="2">See the Historic England guidance on insulating solid ground floors</td></tr>
<tr><td rowspan="2">Insulating suspended timber floors</td><td>ADDING INSULATION FROM ABOVE OR BELOW
Method of installation depends on whether floorboards can be lifted without undue damage (or are being lifted for other work to be carried out), or whether access can be gained from below
Moisture problems must be eliminated before work begins, and a good monitoring and maintenance regime set into place</td><td>Reducing air movement in the floor void may affect the moisture equilibrium
Any electrical services will need to be repositioned above the insulation, or preferably in the ventilated void space beneath the insulation to avoid overheating</td></tr>
<tr><td colspan="2">See the Historic England guidance on insulating suspended timber floors</td></tr>
</table>

4 Glossary

Air infiltration
The flow of air from one place to another generally through the building envelope. This might be due to building use, natural or forced ventilation.

Building envelope
The weathertight skin separating the interior of a building from its external environment. It is made up of the roof, walls, windows, doors, floors and foundations; and systems for controlling and disposing of water, including rainwater goods, roof coverings, damp-proof courses and drains).

Client
A person or organisation using the services of a professional person or company.

Cold bridges (Thermal bridges)
Heat loss or transfer through a building envelope from warm to cold areas by way of building fabric with low thermal inertia (for example metal or glass), or through uninsulated or less well-insulated areas.

Designer
A person who plans the work prior to installation by providing drawings/plans. They may also supervise the work on site.

Emissivity
The ability of the surface to emit radiation at a given temperature, governed by the type of material and especially by its surface texture and reflectivity.

Energy Assessor
Energy assessors should be part of an accredited scheme. They generally issue Energy Performance Certificates but some more specialist assessors can carry out a more detailed energy assessment.

Heritage asset
A building, monument, site, place area or landscape identified as having a degree of significance meriting consideration in planning decisions because of its heritage interest.

Hygrothermal behaviour
Relates to the movement of heat and moisture through buildings. Permeable materials tend to be hygroscopic because of the reduction in vapour pressure in the pores that occurs as a result of condensation, capillarity and salt action.

HVAC (Heating, ventilation and air-conditioning)
Branch of building services engineering that deals with interior environmental comfort in large buildings, and the plant and systems that regulate it.

IGU (Insulated glass unit)
Factory-made double- or triple-glazed panel, with two glass panes enclosing a hermetically sealed space; in the UK often known as ‘double-glazing’ or a ‘double-glazed unit’, especially when used in windows. Most IGUs are built from float glass and the cavity is either evacuated of air, or filled with an inert gas such as argon, krypton or xenon.

Installer
A person or company who fixes equipment of materials in position ready for use.

Moisture buffering
The use of permeable materials and mass construction in traditional buildings which can reduce the effect of fluctuations due to temperature, relative humidity, air pressure or radiation originating either outside the building (due to the external micro-climate) or inside the building (due to heating, lighting air conditioning and use or occupancy).

Permeability
The ability of a material to transmit fluids (especially water or gases) notably through its pores.

Post-occupancy evaluation
A building performance evaluation that establishes how an occupied building is working (in terms of thermal performance) over the first few years after construction or alteration.

Prebound effect
A situation where upgraded buildings are found to use much less energy than predicted by calculation prior to upgrading.

Precipitation
Any product of atmospheric condensation, including rain, snow and fog.

Radiant heat loss
Transfer of thermal energy from a source of heat by means of electromagnetic radiation.

Rebound effect
A situation where energy demand increases after implementing efficiency measures, due to the perception that overall energy costs have diminished and energy-saving actions can therefore be relaxed.

Relative humidity
The ratio of vapour pressure of water in the air to the vapour pressure of water in saturated air at the same temperature; in other words, the percentage of saturation at a given temperature. Air at 50% RH is holding half of the number of water molecules it potentially could hold at that temperature. As the temperature increases, the air can support more water vapour, so with an RH of 50% at 25°C will be holding great deal more moisture than air of 50% RH at 15°C (that is, it will have a much higher absolute humidity).

Retreatable
Works that can relatively easily be changed, reviewed or adapted.

Significance
The value of a heritage asset to this and future generations because of its heritage interest. That interest may be archaeological, architectural, artistic or historic. Significance derives not only from a heritage asset's physical presence but also from its setting.

Thermal elements/controlled fittings
These are parts of the building such as walls, floors, roofs and windows which must comply with Building Regulations when being installed or replaced.

Thermal inertia
The ability to absorb, store and release heat energy. Thick-walled traditional buildings can absorb and store heat effectively and transmit it slowly because of the mass, density, specific heat capacity and conductivity of stone, brick, lime, mortar and earth.

Thermal transmittance (U-values)
A measure of rate of heat loss or heat transfer through a given area of material or structure under the impetus of temperature difference between two faces of the material or structure. Expressed as a number and commonly used as an absolute measure of heat transfer through building envelopes.

Unintended consequences
Outcomes – often undesirable – that are not the ones foreseen. For thermal upgrading works, this might include creating conditions for condensation to occur where previously this was not the case.

5 Where to Get Advice

5.1 Historic England guidance and research

Energy Efficiency and Historic Buildings series

A range of guidance on energy efficiency providing good practice advice on adaptation to reduce energy use and the application and likely impact of carbon legislation on older buildings is available from the Historic England website: HistoricEngland.org.uk/energyefficiency

Application of Part L of the Building Regulations to historic and traditionally constructed buildings
This guidance has been produced to help prevent conflicts between the energy efficiency requirements in Part L of the Building Regulations and the conservation of historic buildings of traditional construction. The advice acts as second tier supporting guidance in the interpretation of the Approved Documents.

This is supported by a series of thirteen guidance documents providing advice on the principles, risks, materials and methods for improving the energy efficiency of building elements:

- Roofs
  Insulating roofs at rafter level
  Insulating at ceiling level
  Insulating flat roofs
  Insulating thatched roofs
  Open fires chimneys and flues

- Windows and doors
  Insulating dormer windows
  Draught-proofing windows and doors
  Secondary glazing for windows

- Walls
  Insulating timber-framed walls
  Insulating solid walls
  Insulating early cavity walls

- Floors
  Insulating suspended timber floors
  Insulating solid ground floors

Advice is also provided for homeowners and those managing or renting historic or older domestic buildings about Energy Performance Certificates (EPCs).
Energy Performance Certificates

In addition, advice on microgeneration energy supplies can be found at:
www.historicengland.org.uk/advice/your-home/saving-energy/generating-energy/

Other Historic England guidance

Conservation Principles, Policies and Guidance for the Sustainable Management of the Historic Environment. (2008)

Practical Building Conservation series
This series of fully illustrated books published by Routledge provide detailed guidance on understanding, deterioration, assessment and care and repair. More information is available on HistoricEngland.org.uk/pbc.

Basics (2013)
Building Environment (2014)
Concrete (2013)
Earth, Brick & Terracotta (2015)
Glass & Glazing (2012)
Metals (2012)
Mortars, Renders & Plasters (2012)
Roofing (2013)
Stone (2012)
Timber (2012)

Historic Environment Good Practice Advice in Planning: 2 Managing Significance in Decision-Taking in the Historic Environment (2015)

Managing Changes to Heritage Assets, Historic England Advice Note 2 (2016)

Traditional windows, their care, repair and upgrading (2017)

Historic England conservation research

Historic England carries out and commissions technical research on energy efficiency and related topics. Information on this can be obtained at:
www.HistoricEngland.org.uk/research/current/conservation-research/

Research into the Thermal Performance of Traditional Windows: Timber Sash Windows (2009)

Research into the Thermal Performance of Traditional Brick Walls (2013)

Retrofit of a Victorian Terrace House in New Bolsover: A Whole House Thermal Performance Assessment (2015)

Improving the Thermal Performance of Traditional windows: Metal Framed Windows (2017)

The Engine House, Swindon, Wiltshire: Thermal Performance of Energy Efficiency Improvements to Timber Windows (2017)

5.2 Other sources of advice

Sustainable Traditional Buildings Alliance (STBA)

This STBA is a collaboration of organisations that act as a forum for sustaining and improving traditional buildings.
stbauk.org

Guidance publications are available from the STBA's website including:

Responsible Retrofit of Traditional Buildings (2012)

Planning Responsible Retrofit of Traditional Buildings (2015)

A Bristolian's Guide to Solid Wall Insulation (2015)

What is Whole House Retrofit? (2016)

Also available is the STBA Guidance Wheel. This is an interactive retrofit guidance tool that helps users to see how different energy efficiency measures might interact in a particular building and what risks they could pose to character and significance, building fabric and occupant health.
responsible-retrofit.org/wheel

Society for the Protection of Ancient Buildings (SPAB)

The SPAB is a building conservation charity. Information about the SPAB's research into the thermal performance of walls of traditional construction and the effects of added insulation is available from:
www.spab.org.uk/advice/research/findings

Hughes, P 1986 'The Need for Old Buildings to "Breathe"'. *Information Sheet 4*

Historic Environment Scotland

This is the lead public body established to investigate, care for and promote Scotland's historic environment. Information about Historic Environment Scotland's work into thermal performance of traditional construction is available from:
www.historicenvironment.scot/advice-and-support

Fabric Improvements for Energy Efficiency in Traditional Buildings (2012)

5.3 Further reading

CIBSE 2002 *Guide to Building Services in Historic Buildings*. London: Chartered Institution of Building Services Engineers
www.cibse.org/publications)

HM Government, Building Regulations 2000 (2010 editions with later amendments 2011/2012/2013/2016) Published 2016
Approved Document L1B: Conservation of Fuel and Power in Existing Dwellings
Approved Document L2B: Conservation of Fuel and Power in Existing Buildings other than Dwellings
www.gov.uk/government/publications

Stirling, C 2002 *Thermal Insulation: Avoiding Risks* (3rd edition). London: Building Research Establishment
www.bre.co.uk/bookshop)

Suhr, M, Hunt, R 2013 *Old House Eco Handbook: A Practical Guide to Retrofitting for Energy-efficiency and Sustainability*. London: Frances Lincoln

5.4 Contact Historic England

East Midlands
2nd Floor, Windsor House
Cliftonville
Northampton NN1 5BE
Tel: 01604 735460
Email: eastmidlands@HistoricEngland.org.uk

East of England
Brooklands
24 Brooklands Avenue
Cambridge CB2 8BU
Tel: 01223 582749
Email: eastofengland@HistoricEngland.org.uk

Fort Cumberland
Fort Cumberland Road
Eastney
Portsmouth PO4 9LD
Tel: 023 9285 6704
Email: fort.cumberland@HistoricEngland.org.uk

London
4th Floor, Cannon Bridge House
25 Dowgate Hill
London EC4R 2YA
Tel: 020 7973 3700
Email: london@HistoricEngland.org.uk

North East
Bessie Surtees House
41-44 Sandhill
Newcastle Upon Tyne NE1 3JF
Tel: 0191 269 1255
Email: northeast@HistoricEngland.org.uk

North West
3rd Floor, Canada House
3 Chepstow Street
Manchester M1 5FW
Tel: 0161 242 1416
Email: northwest@HistoricEngland.org.uk

South East
Eastgate Court
195-205 High Street
Guildford GU1 3EH
Tel: 01483 252020
Email: southeast@HistoricEngland.org.uk

South West
29 Queen Square
Bristol BS1 4ND
Tel: 0117 975 1308
Email: southwest@HistoricEngland.org.uk

Swindon
The Engine House
Fire Fly Avenue
Swindon SN2 2EH
Tel: 01793 445050
Email: swindon@HistoricEngland.org.uk

West Midlands
The Axis
10 Holliday Street
Birmingham B1 1TF
Tel: 0121 625 6870
Email: westmidlands@HistoricEngland.org.uk

Yorkshire
37 Tanner Row
York YO1 6WP
Tel: 01904 601948
Email: yorkshire@HistoricEngland.org.uk

6 Acknowledgements

Contributors

Historic England would like to thank
Elisabeth Gold for copy editing this document.

Images

Historic England

We are the public body that looks after England's spectacular historic environment.

Please contact
guidance@HistoricEngland.org.uk
with any questions about this document.

HistoricEngland.org.uk

If you would like this document in a different format, please contact our customer services department on:

0370 333 0607
customers@HistoricEngland.org.uk

All information and weblinks accurate at the time of publication.

Please consider the environment before printing this document

HEAG094

Design: Historic England

< < Contents