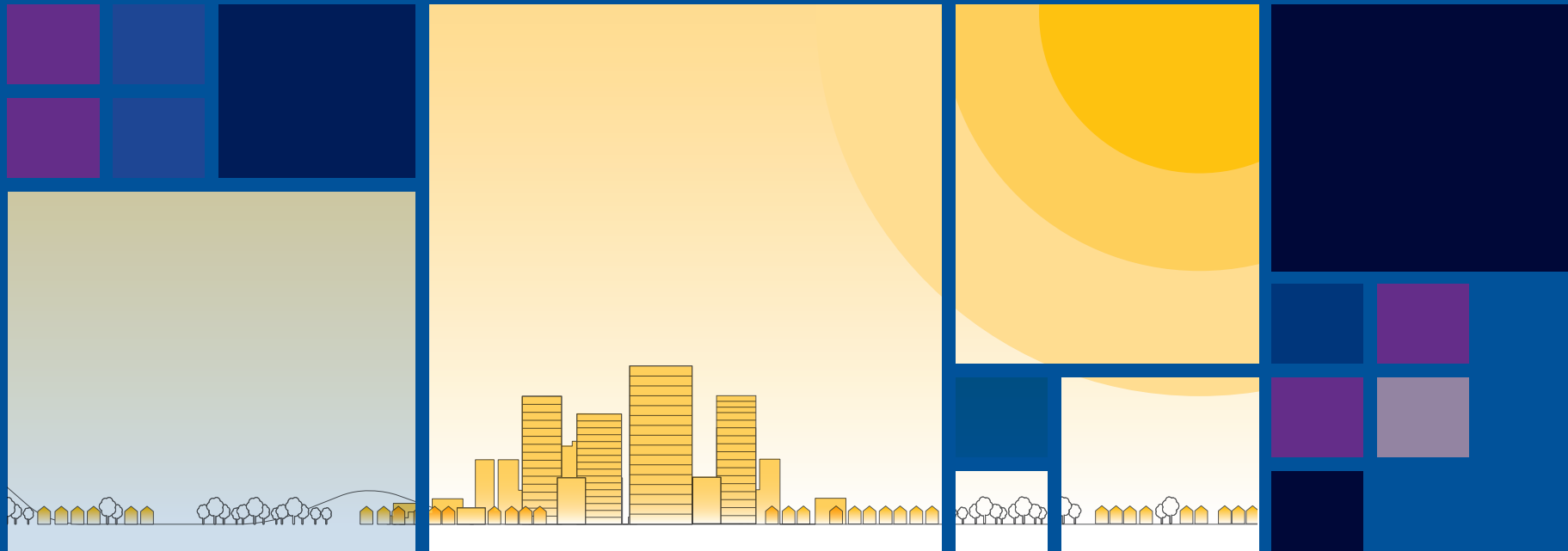


Understanding overheating – where to start:

An introduction for house builders and designers



Guide

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About the NHBC Foundation

The NHBC Foundation was established in 2006 by the NHBC in partnership with the BRE Trust. Its purpose is to deliver high-quality research and practical guidance to help the industry meet its considerable challenges.

Since its inception, the NHBC Foundation's work has focused primarily on the sustainability agenda and the challenges of the Government's 2016 zero carbon homes target.

The NHBC Foundation is also involved in a programme of positive engagement with Government, development agencies, academics and other key stakeholders, focusing on current and pressing issues relevant to the industry.

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Foreword

Homes in the UK have not historically been associated with overheating. This is probably due to a combination of the heavyweight materials from which they were constructed, a low level of thermal insulation and plenty of unplanned ventilation through minor gaps in the fabric. Added to that, sash windows provided high- and low-level ventilation that would rapidly purge excess heat on a hot day if the home had been closed up all day.

Contrast that with very highly insulated low and zero carbon homes, which have been built and tested to high standards of airtightness, with double-glazed windows that have coatings specifically designed to trap the sun's heat. Add in some communal heating pipework and additional services that permanently stay warm and it's hardly surprising that there is growing concern about overheating in new homes.

Although the number of incidences reported so far is thankfully low, it would seem fair to assume that the risk of overheating will increase as we make progress towards the zero carbon homes standard. Also, if as expected, climate change leads to a further increase in summer temperatures, then overheating will become even more of an issue and one that cannot be ignored. A heat wave in Northern France in 2003 that lasted three weeks and is estimated to have resulted in 15,000 excess deaths, the majority of which were older people, serves to remind us of how pressing an issue this is for us to deal with.

For those of us who have not until now given much attention to overheating, I hope this guide, which outlines some key aspects of design and specification, will serve as a useful introduction to the topic.



Neil Jefferson
Chief Executive
Zero Carbon Hub

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In the UK, the effects of climate change will lead to more extreme weather conditions with potentially hotter, drier summers and milder, wetter winters. Occupants in some modern highly insulated homes are already experiencing uncomfortably high internal temperatures, even in fairly moderate summers, and it is evident we need to adapt the way in which we design, construct and use homes to accommodate the anticipated changes.

What is meant by overheating?

Overheating is generally understood to be the accumulation of warmth within a building to an extent where it causes discomfort to the occupants. There is no clear definition of the term 'overheating' or the specific conditions under which this can be said to occur. Nor is there any statutory maximum internal temperature in UK Building Regulations or current health and safety guidance.

Work by CIBSE and Arup suggests that most people begin to feel 'warm' at 25°C and 'hot' at 28°C¹. Their report also defines 35°C as the internal temperature above which there is a significant danger of heat stress. However, overheating is not just a function of high temperature, other factors such as lack of air movement and sustained exposure to high temperatures will also affect the comfort level of occupants. Summer overheating is a 'dynamic' phenomenon and all the contributing factors and their interactions are difficult to simulate with steady state modelling tools. Furthermore, some factors may only manifest themselves in particular geographical areas or at a 'micro-scale', such as the 'heat island' effect, which is particular to dense urban areas.

The health impacts of overheating can include an increased risk of illness from respiratory and cardiovascular disease, and the consequences of exposure to extreme warm temperatures sustained over a period are significant: the summer heat wave of 2003 resulted in more than 2,000 extra deaths in the UK².

Where is the evidence?

The extent of any existing problem in new homes is hard to gauge but it is likely that many instances of overheating, caused by hot summer weather, are tolerated for short spells and the discomfort and health effects are soon forgotten when cooler weather returns. The BRE have investigated and will report on case studies that demonstrate how overheating can occur in modern homes as a result of a combination of factors³.

Evidence from surveys also suggests that occupants in well-insulated homes are experiencing uncomfortably high summer temperatures. As the focus has been on reducing heating bills during the winter in the last few years, it may be that occupants are disregarding a small amount of discomfort in the summer. In a warming climate will this continue to be an acceptable compromise? An alternative may be that people are driven to use fans and air conditioning units, which may considerably undermine the integrity of any energy efficiency design strategy of their homes.

Housing associations and house builders have procedures in place to record post-occupation complaints, but generally these will not identify overheating as a recordable defect. Commercial organisations may be reluctant to include overheating problems on their customer feedback forms. Many builders believe that the problem is restricted to one-off instances in exceptional circumstances, but evidence presented by the BRE suggests that this is a dangerous assumption. The last serious heat wave in Europe was in 2003, well before the improvements to the external envelope and airtightness brought about by changes to the Building Regulations in 2006 and 2010. It is not really known how houses built to these standards will perform, either in the next hot summer or over time with the effects of climate change.

¹ Hacker, JN, Belcher, SE & Connell, RK (2005). Beating the Heat: keeping UK buildings cool in a warming climate. UKCIP Briefing Report. UKCIP, Oxford. p.8. Contributions to this report were made by Arup and CISBE. Further information is also available from TSB: Technology Strategy Board (2010). Design for future climate.

² Brown, G, Fearn, V & Wells, C (2010). Office for National Statistics: Exploratory analysis of seasonal mortality in England and Wales, 1998 to 2007. Health Statistics Quarterly, 48, p.5.

³ NHBC Foundation (in preparation).

2 Principles of overheating

Overheating in homes may be attributed to either a single predominant factor or a number of compounded problems. Excessive heat gains from both internal and external sources along with inappropriate or ineffective ventilation strategies are among the fundamental concerns that must be understood and addressed by designers.

Light



Heat



Ventilation – warm air



Ventilation – cool air



Pollution



Noise



External gains

Internal gains

Appropriate ventilation strategy

External gains

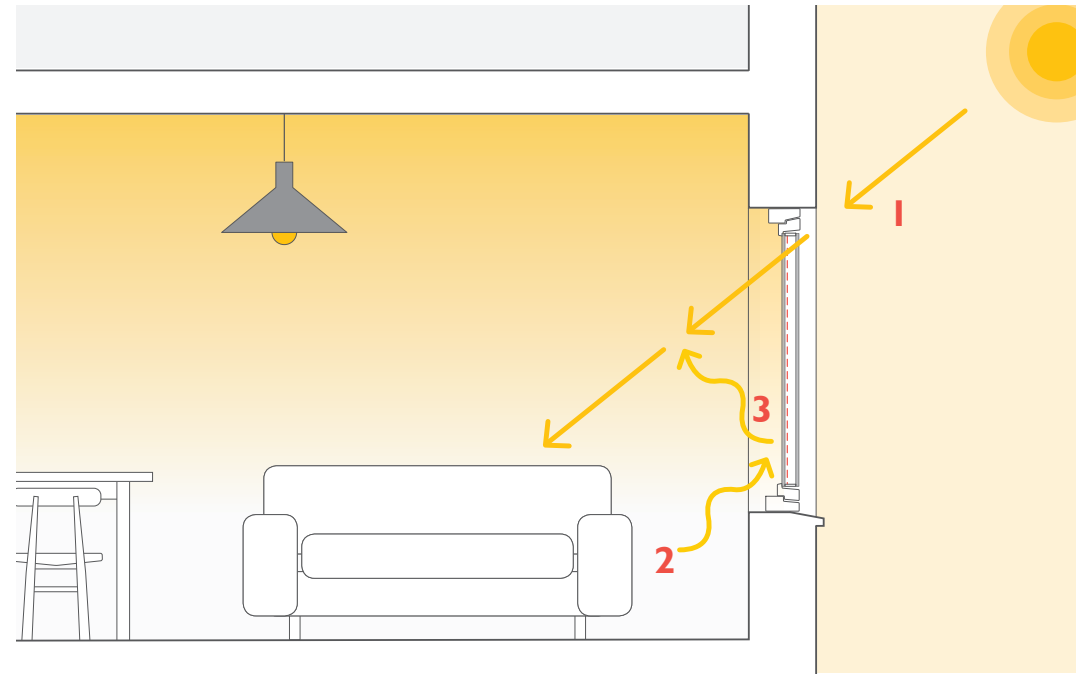
The external conditions that generally contribute to overheating are sunlight and high external temperatures. A well-insulated fabric will prevent heat gains and losses between the internal environment of homes and the outside. Retaining heat within homes will help keep them warm in the winter, but could potentially cause a problem in warm summer months.

Sunlight passes through windows in buildings and is absorbed as heat by surfaces and objects within a space. This heat remains trapped within the building: a phenomenon called the 'greenhouse effect' as it is most commonly utilised in greenhouses. These structures are traditionally built with single-glazed windows and panels through which the trapped heat can escape when there is no direct sun. New energy-efficient double-glazed windows are designed to retain heat in the winter. However, in the summer these may prevent unwanted built-up heat from escaping.

With an increase in the frequency of spells of warm weather, opening windows may not be the most appropriate way to prevent overheating, as the outside air may be too warm. Site-specific features like hard-paved surfaces and macadam can contribute to increasing external temperatures locally.

During recent years, the focus for the housing industry has been to reduce the amount of energy needed for heating by utilising highly insulated fabric and passive solar design. While these measures have been effective in reducing the space heating demand in the winter, they can potentially lead to undesirable overheating in the summer.

For further information refer to: Case study 7.



External gains

1. Solar gains pass through the glass and heat the internal spaces.
2. These gains are absorbed by internal surfaces and emitted as heat.
3. In modern homes with double-glazed windows, this heat is retained well, especially if there is a low-e coating, and cannot easily dissipate through the highly insulated building fabric.

Internal gains

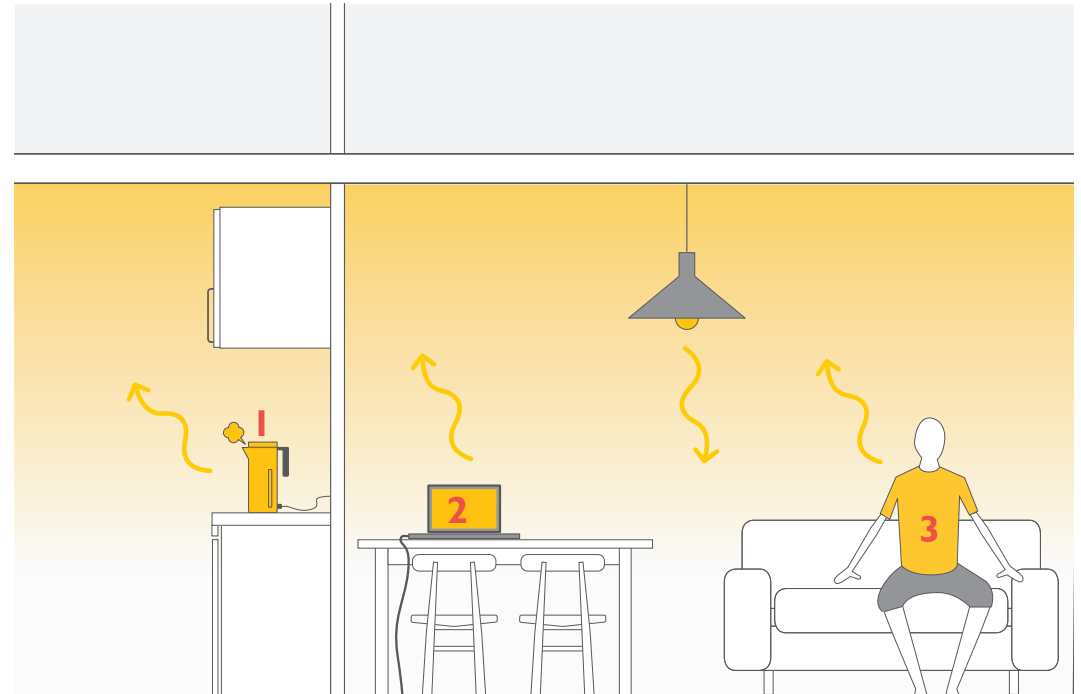
The same amount of heat gains in a well-insulated, airtight home will have a more noticeable impact than in a poorly insulated draughty one. Sources of internal gains may include:

- Lighting – even low energy light fittings can contribute to internal gains if the number of fittings is high. Plug-in lamps often do not have an energy rating and can be a significant source of heat.
- Appliances – fridges, dishwashers, washing machines, televisions, laptops and chargers emit heat, often even in stand-by mode.
- Occupants – people within homes give off heat in the form of 'metabolic' gains.
- Building services – mechanical ventilation systems and hot water distribution and storage systems can be a source of unwanted heat in the summer.

During winter these gains can be beneficial as they supplement the space heating system but in the summer these may contribute towards overheating within homes.

While some of the sources listed above are unavoidable, the impact of others can be limited. Electronic appliances can be switched off from the mains when not in use. Hot water storage and distribution systems should be insulated according to guidance provided in the Domestic Building Services Compliance Guide 2010⁴. Areas which will have high heat gains like boiler cupboards should be isolated from living spaces if possible and gains into living areas from spaces like kitchens in open plan homes should be considered.

For further information refer to: Case study 2.



Internal gains

1. Occupants' activities: Cooking, bathing, showering all release heat into the dwelling.
2. Electrical appliances: Most electrical appliances give off heat when in use.
3. Occupants: People occupying a home all give off heat; the amount of heat is dependent on the level of their activity.

⁴ DCLG (2010). The Domestic Building Services Compliance Guide. This document provides guidance for the installation of fixed building services in new and existing homes. It is available from: <http://www.planningportal.gov.uk>

Is the ventilation strategy appropriate?

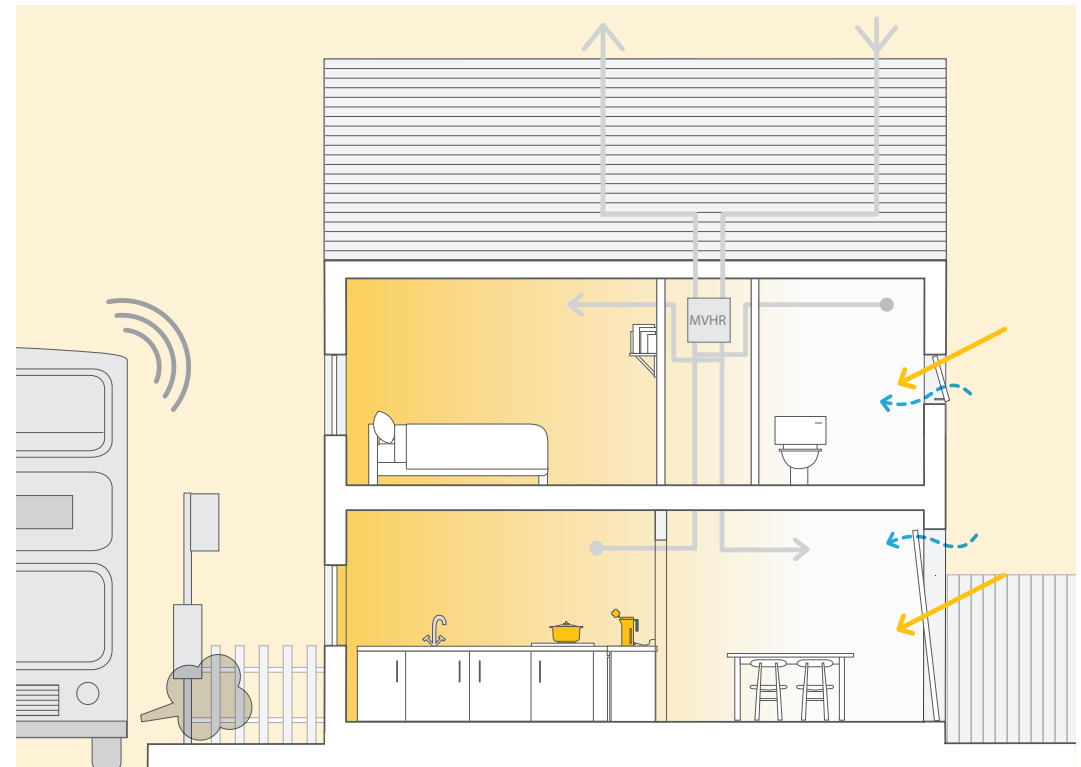
While it may be possible to limit the effects of excessive internal and external heat gains, these cannot be completely eliminated. The most effective way to remove built-up heat is by 'purging' the dwelling, that is, by introducing high levels of ventilation over a short period of time, to replace existing warm air with fresh air from outside.

Purge ventilation is discussed in both Approved Documents F and L. Approved Document F is concerned with fresh air for health and well-being and relies on purge ventilation to quickly remove pollutants and odours from a dwelling. Purge ventilation may also help to improve thermal comfort. Approved Document L seeks to minimise energy demand for cooling due to excessive solar gains and acknowledges cross-ventilation as one of the passive measures to offset this demand.

For the removal of heat, the total volume of air within a home will need to be replaced rapidly. To achieve this in practice there must be adequate opening area in the external walls and/or roofs provided by windows, rooflights, doors and ventilators. However, in urban settings, it may not be possible to open windows as intended due to their proximity to sources of noise, pollution and/or reflected heat. The potential for ventilation through windows may be limited if restrictors are fitted to address security and safety concerns.

Although simple in theory, providing adequate ventilation to remove heat from a home is much harder to achieve in practice. With the use of case studies, this guide aims to identify situations where the primary objective of providing appropriate ventilation to remove heat has been undermined.

For further information refer to: Case study 6.



Ventilation strategies

Background ventilation.

Ventilation is supplied at a continuously low rate to dilute pollutants and provide fresh air. It may be provided by vents or grilles in windows and doors or ventilators in the wall.

Summer background ventilation.

Provisions should be made so that higher levels of ventilation can be provided in a secure manner during the warmer months. Typically, this type of ventilation is provided by opening windows and doors.

Purge ventilation.

Purge ventilation should be provided, not only to remove pollutants, but also as a means of quickly expelling hot air.

3 Factors that increase the risk of overheating

It is highly likely that a large proportion of new homes will have a greater risk of overheating when seemingly insignificant factors occur at the same time. The greatest challenge to designers is that overheating in homes can be triggered by cumulative effects.

Site context

Urban heat island effect

Orientation

Building design

Thermal mass

Service design

Restricted ventilation

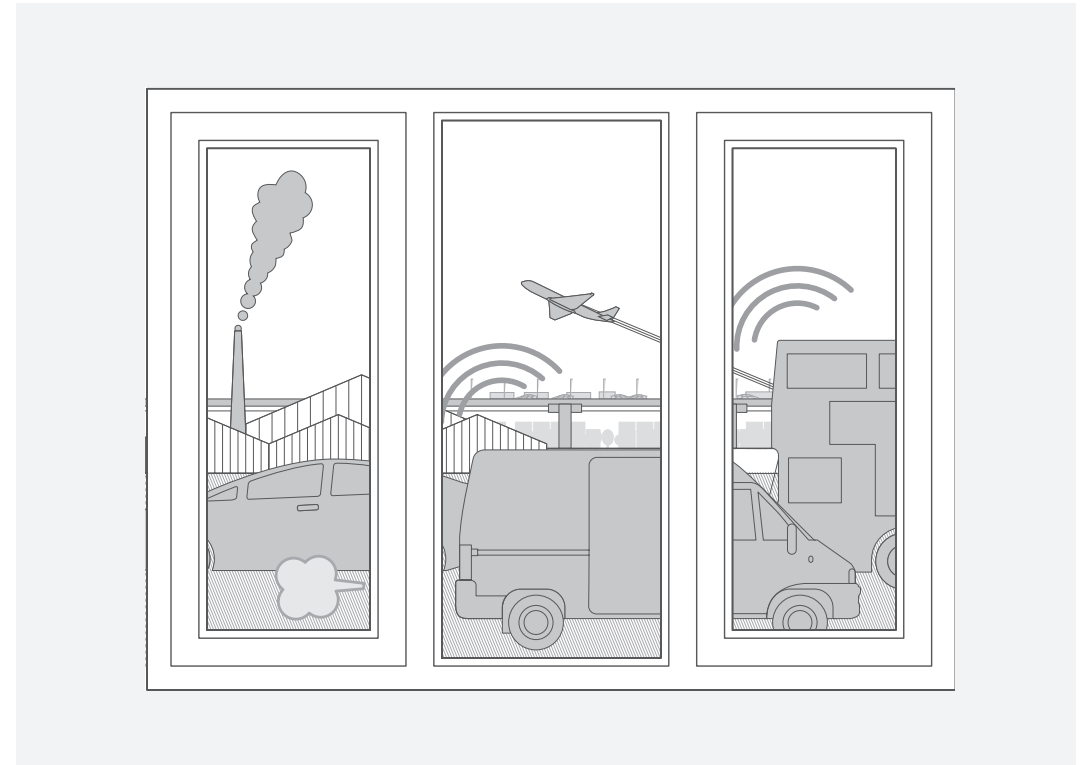
Cumulative effects

Site context

The location of the building in its context will have an influence on the likelihood of it overheating. A number of factors, such as the location of mechanical services close to windows and the proximity of the dwelling to noisy roads, railways lines or polluting industrial plants, may compromise the occupant's ability to use the means of ventilation as intended. In urban situations these factors may be coupled with anxieties about air quality, pollution or odour.

The assessment for a risk of overheating is carried out using Appendix P of the Standard Assessment Procedure, which only takes into account the site surroundings in a very limited amount of detail. Often homes may be designed as prototype units with a passive solar design strategy to maximise solar heat gains during the winter. When an overheating check is being made, the additional impact of the site context may easily be overlooked due to the limitations of the calculation methodology.

The conditions experienced on upper floors of homes may also be different to those on lower floors. The extent to which windows on lower floors can be used is affected by factors such as concerns for security, proximity to busy parking areas or pavements. In blocks of flats especially, it is important to consider each part of the building and not generalise the approach.



Site context

Close proximity to airborne noise, pollution or odour from busy roads, railways and industrial uses may prevent an occupant from opening and using the windows as they were intended.

For further information refer to: Case study 3.

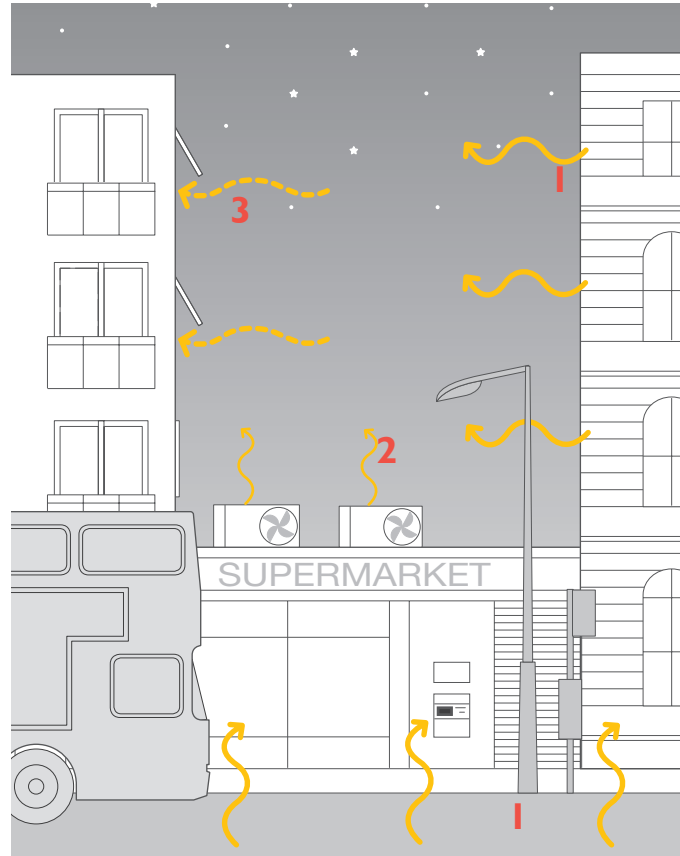
Urban heat island effect

In urban areas, surface materials that are often used for landscaping and paving, and even the external finishes of surrounding buildings can affect the temperature of the surrounding air. Hard and dark coloured materials like concrete, brick and macadam have the tendency to absorb the sun's energy and heat generated during the day and re-radiate this at night. As a result of this, the night-time air temperature remains high.

Mixed-use schemes common to urban locations often include supermarkets or small food stores on lower floors which have plant and equipment for cooling and refrigeration. The vents for this plant are often located on the roof and are constantly running, contributing to localised heat gains, both during the day and night.

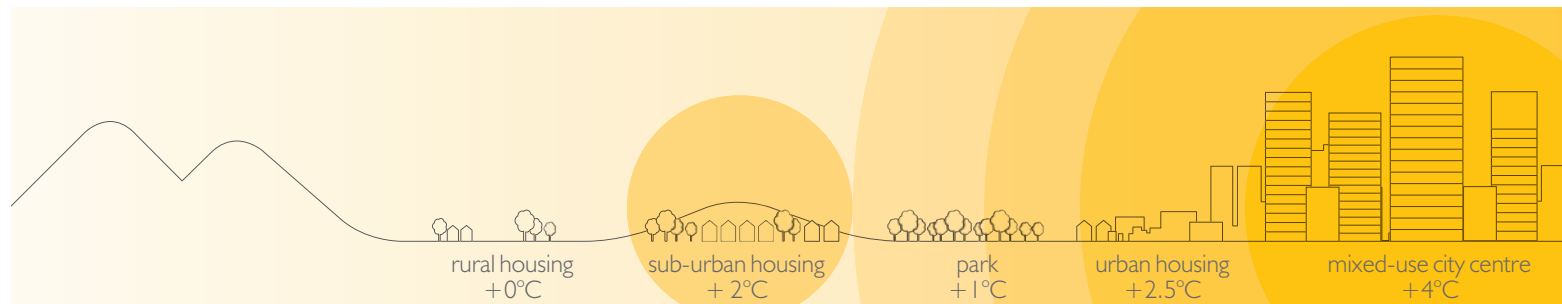
A night-time ventilation strategy depends on cooler night-time air temperatures and will become less effective if the surrounding air is warmed by these surfaces.

For further information refer to: Case study 7.



Urban heat island

1. During the day, surrounding buildings and other hard materials absorb heat which is re-radiated into the air when the external temperature drops at night.
2. In mixed-use schemes unwanted heat is given off by air conditioning and chiller plant.
3. As a result of heat being radiated, the night-time air temperature remains high. This means it will not be possible to ventilate the apartments with cool air at night and internal temperatures will continue to rise.



Typical urban heat island profile

This diagram shows a typical urban heat temperature profile. At night, temperatures in dense urban city centres may be up to 4°C higher than those measured in rural areas. The effects can be reduced by the integration of parks, lakes and green spaces into urban areas.

Orientation

The orientation of a home is an important consideration, not only to take advantage of solar gains during the winter to reduce heating loads, but also to protect against unwanted solar gains that could contribute to overheating in the summer.

In one-off designs it is relatively straightforward to consider the orientation with regard to its effects on potential overheating. On larger schemes however, it is possible that one flat or house type must be repeated in different orientations. This could cause identical homes to have drastically different internal environments.

A home, when orientated with its main windows facing west will behave differently than if it were facing due south. A west-facing elevation may experience more unwanted solar gains from low-level sun in the evenings. A south-west facing elevation will also receive direct sunlight in the late afternoon when the ambient external temperature is at its highest, making the rooms on this elevation more prone to overheating.

An appropriate approach would be to optimise the amount of glazing and position for each orientation but the potential for this may be limited in instances where standard home types are used.



Orientation

One house type rotated through different orientations will behave differently. Houses with large amounts of west-facing glass will suffer from high levels of solar gain late in the day, coinciding with the time at which external temperatures are highest.

For further information refer to: Case study 7.

Building design

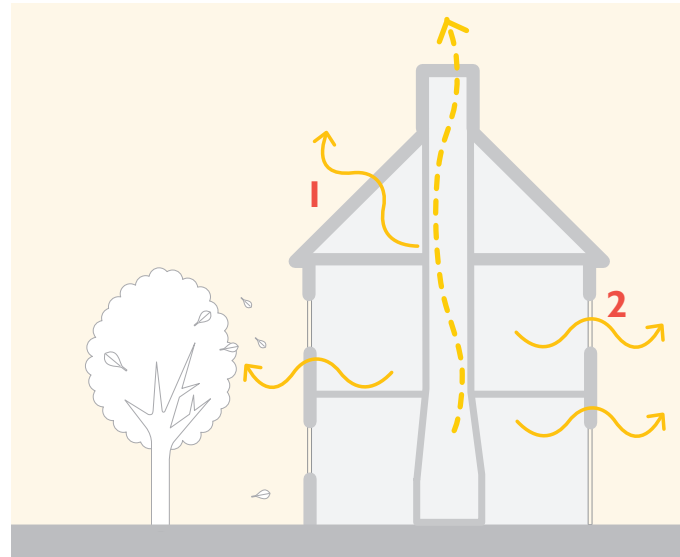
As a result of the need to conserve energy in winter and to reduce carbon dioxide emissions, the Building Regulations have changed with the aim of improving the energy efficiency of new homes by encouraging higher standards of thermal mass, insulation and airtightness. Passive solar design strategies such as optimised orientation and south-facing windows are often incorporated to reduce the space heating load during the winter.

The warming climate and these improved thermal standards are likely to lead to overheating in homes unless appropriate measures are incorporated into the design or have the potential to be easily and effectively retrofitted. Features like recesses, overhangs and balconies may also be integrated into the building elevation as a means of providing solar shading.

With urban environments growing at a fast pace, the amount of available space is limited and smaller homes built in dense city centres are common. These homes are often single-aspect apartments that have limited potential for natural ventilation. In addition to this, window restrictors may be used on upper storeys to prevent the risk of occupants falling and on lower floors to prevent intruders from forcing entry.

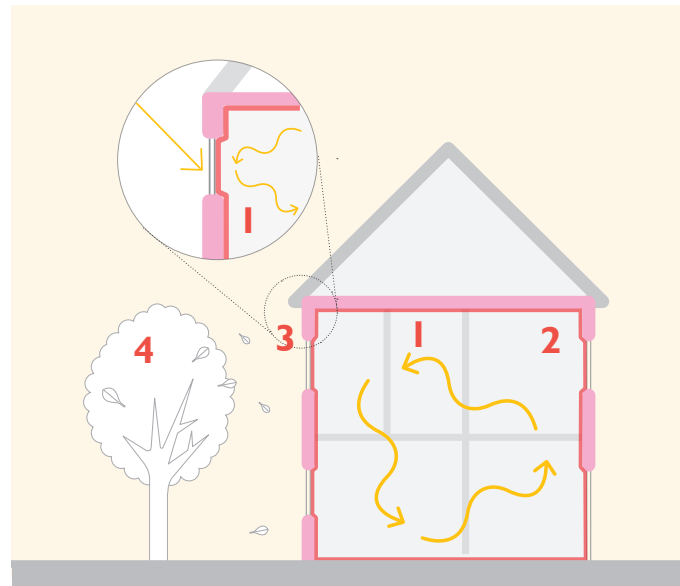
Designers should consider building orientation, glazing areas and types of construction to avoid overheating. Design features and strategies, such as purge ventilation and solar shading, must also be explained to occupants to ensure that these are effective.

For further information refer to: Case study 2.



Conventional house

1. Heat loss through building fabric due to lower levels of insulation.
2. Heat loss through leaky building fabric such as minor gaps between windows and openings in walls.



Highly insulated house

1. Increased insulation in new homes limits heat losses and gains through the building fabric.
2. Improved airtightness can reduce ventilation heat losses and may also lead to the retention of unwanted heat gains inside the home.
3. Smaller windows in bedrooms help reduce solar gains in spaces occupied at night.
4. Use of obstructions such as optimally located trees can provide solar shading from strong and unwanted sun from the west.

Thermal mass

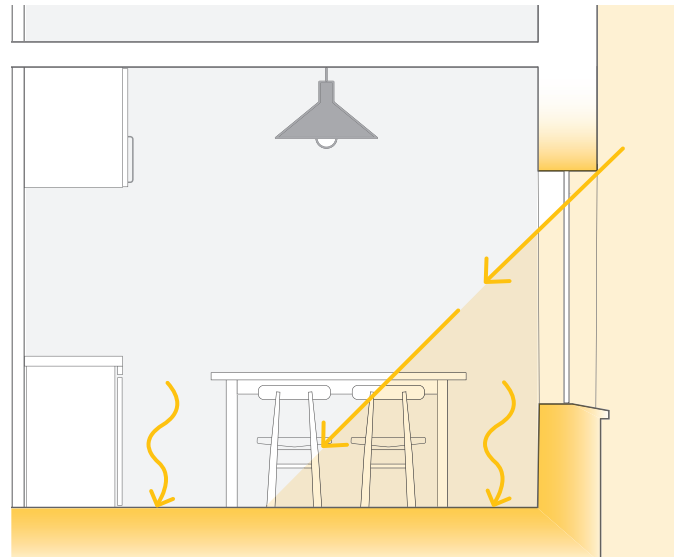
Thermal mass refers to the ability of building materials to store and emit heat. If the design does not properly integrate thermal mass with adequate ventilation it may contribute to overheating within homes.

When the air within a space is warmed due to direct sunlight or heat gains from people and appliances, some building materials absorb heat. As the space begins to cool down at night, this heat is then re-emitted into the space. Generally, heavier masonry-based materials have a higher thermal mass and absorb more heat than lighter timber-based materials.

Dense building materials must be exposed to the internal environment to be able to absorb and release warmth due to their thermal mass and the presence of plasterboard, service voids and internal insulation will reduce the effectiveness of the high thermal mass materials.

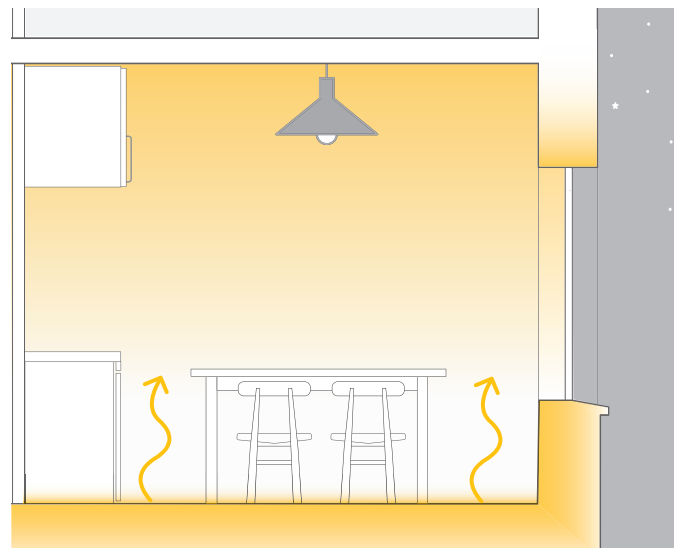
Homes constructed to recent standards of energy efficiency are well insulated and airtight to limit heat losses in the winter. In the summer months, when the heat absorbed by building materials is re-emitted into the living space, it can contribute to uncomfortably high internal temperatures. Therefore, high thermal mass in homes can contribute to overheating unless specific measures are undertaken to limit solar gains by shading and remove heat by adequate ventilation.

For further information refer to: Case study 2.



Thermal mass during the day

During the day, the heavy thermal mass of the exposed external walls and floors will absorb the solar gains that enter the home.



Thermal mass at night

Heat absorbed during the day is released back into the home. In a highly insulated and airtight home where there is no provision for secure night-time ventilation, the built-up heat cannot be removed and can increase the risk of overheating.

Service design in houses

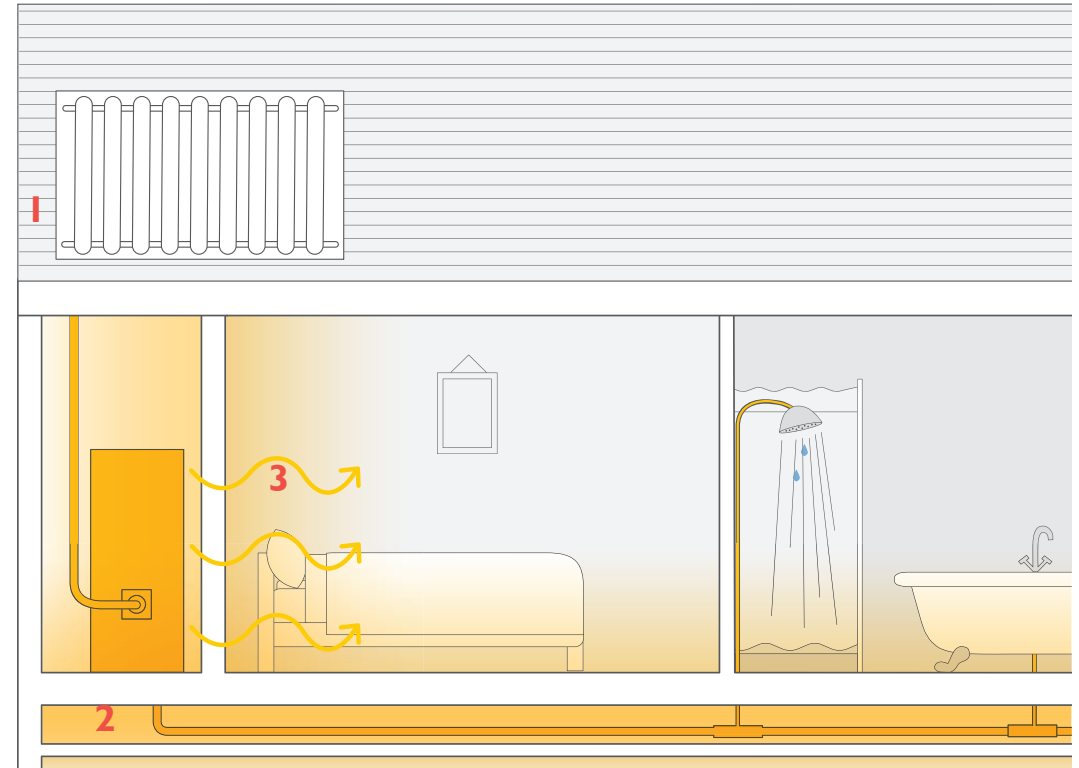
Recently, many overheating problems have been attributed to heat gain from consumer interface units (CIUs), hot water storage and distribution. Unless these components are very well insulated, they can become a source of unwanted heat gains in the summer as the demand for domestic hot water needs to be met throughout the year.

In older houses, the building fabric is generally leaky and not well insulated, which could prevent heat from building up. In modern highly insulated and airtight homes built-up heat cannot readily escape. The effects of building services may be localised, for instance in a bedroom next to the water storage cylinder, or adjacent to a CIU where there is community heating.

In homes where ventilation is provided by a mechanical ventilation system with heat recovery (MVHR), this heat will be distributed internally, especially if a summer bypass has not been provided. There is also the possibility that the ventilation system itself can become an unwanted source of heat. An MVHR system should be located within the insulated part of the home but its proximity to bedrooms should be limited where possible.

The distribution and storage systems for solar thermal panels need to also be well insulated as these will be circulating hot water throughout the summer months.

For further information refer to: Case study 1.



Service design in houses

1. Solar hot water system delivering hot water to storage tank. Even if the tank and pipework are insulated this may lead to an internal heat gain.
2. Hot water pipework runs through the house and is continuously charged, causing an unwanted heating source.
3. While the heat gains from both the hot water cylinder and pipework may be small, when introduced into a well-insulated, airtight home they can contribute to overheating.

Service design in apartments

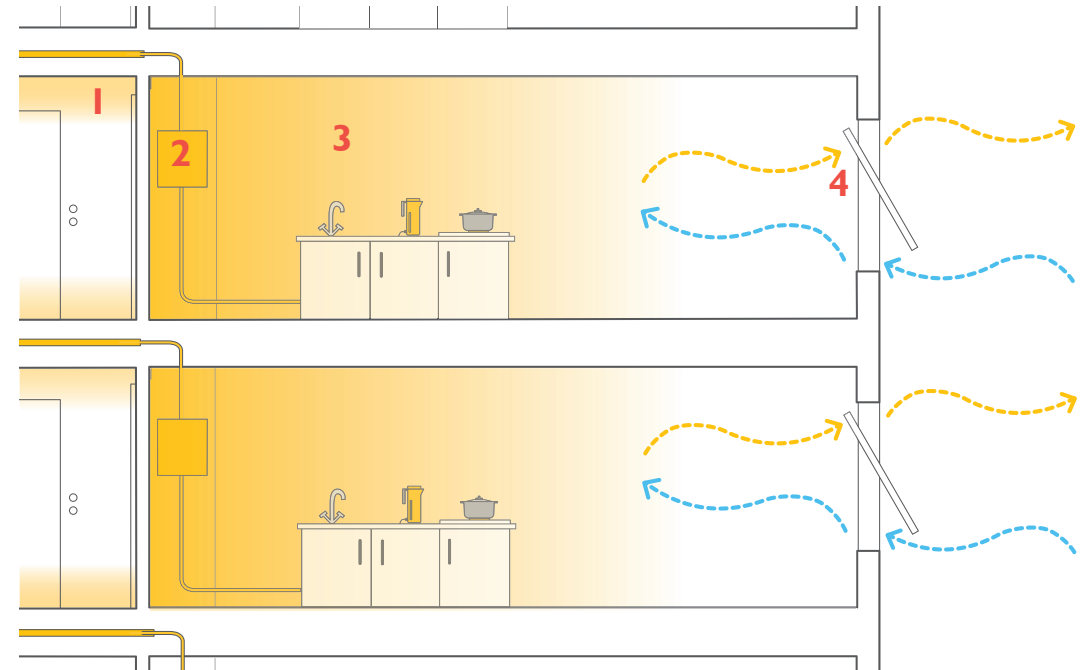
Overheating in apartments has become a greater risk as a result of single-aspect apartment designs and also where community heating pipework is routed through corridors and common spaces. In these situations, high internal temperatures are often caused by a combination of inadequate ventilation and excessive heat discharged by heating pipework.

Mechanical services installed in apartments cause heat gains in the same way as in houses but with limited scope for ventilation their impact becomes more significant. Consequently, a different strategy is required to ensure that unwanted heat is removed.

In blocks where space and water heating is provided by a community heating system, the CIU is permanently charged with hot water all year round to meet the hot water demand. This unit, particularly if not well insulated, may effectively emit heat like a radiator in the dwelling. It is often positioned in an unventilated cupboard or kitchen so heat transfers directly to the living spaces.

In addition, the distribution pipework for the community heating system often runs through the corridors and common spaces. Since this pipework is constantly emitting heat, it can cause high temperatures in these spaces, especially when there is insufficient ventilation. Even well-insulated heating systems will emit heat, albeit at a slower rate. Unless there is a strategy to remove this heat it will be transferred from common areas into the adjacent apartments.

For further information refer to: Case studies 1, 2 and 5.



Service design in apartments

1. Community heating pipework running in common areas causing internal gain within corridor.
2. The CIU is permanently charged with hot water.
3. If sufficient purge ventilation is not provided the internal gains from the communal areas and permanently charged CIU will lead to overheating of the apartments on warm days.
4. It is very difficult to provide natural purge ventilation to single-aspect apartments. Sources of internal gains from services installations are likely to be located deep in the plan of the apartment and therefore furthest from the ventilation.

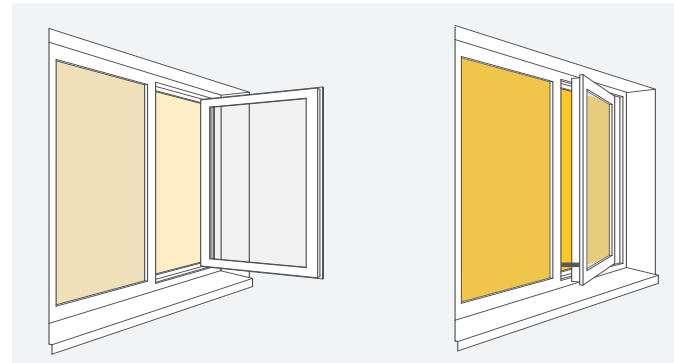
Restricted ventilation

Adequate ventilation is necessary to remove heat from homes. While this may seem simple in theory, it is much harder to achieve in practice. For instance in houses, it is common to find large patio doors opening onto a garden on the ground floor. However, it is unlikely that these will be left open to provide purge ventilation, especially at night even in the safest of neighbourhoods.

If purge ventilation is to be provided only by first-floor windows, it is likely that more than half of the window area would need to be fully open. Windows are often a combination of fixed and opening panels and may be fitted with restrictors for safety and security reasons, further limiting the amount of ventilation that can be practically achieved.

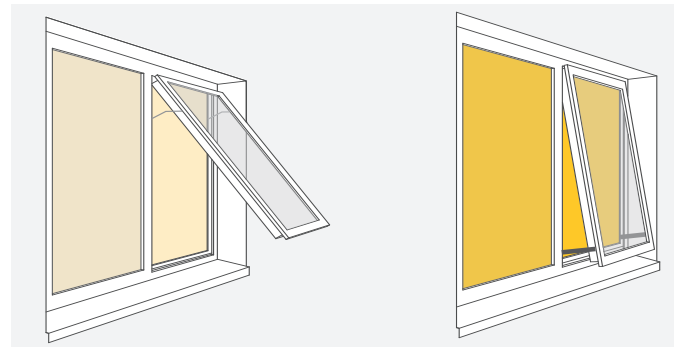
Night-time ventilation becomes more important in hot weather, but will only be achieved if secure ventilation is possible. In urban areas where the difference between daytime and night-time external temperatures may be small, the effectiveness of night ventilation will be reduced.

For further information refer to: Case studies 3, 5 and 6.



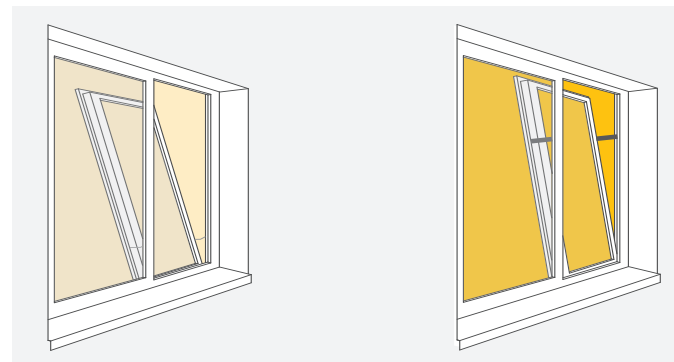
Side-hung windows

When fully open, side-hung windows have the capacity to allow a high level of ventilation. However, they are particularly vulnerable to driving rain and difficult to clean.



Top-hung windows

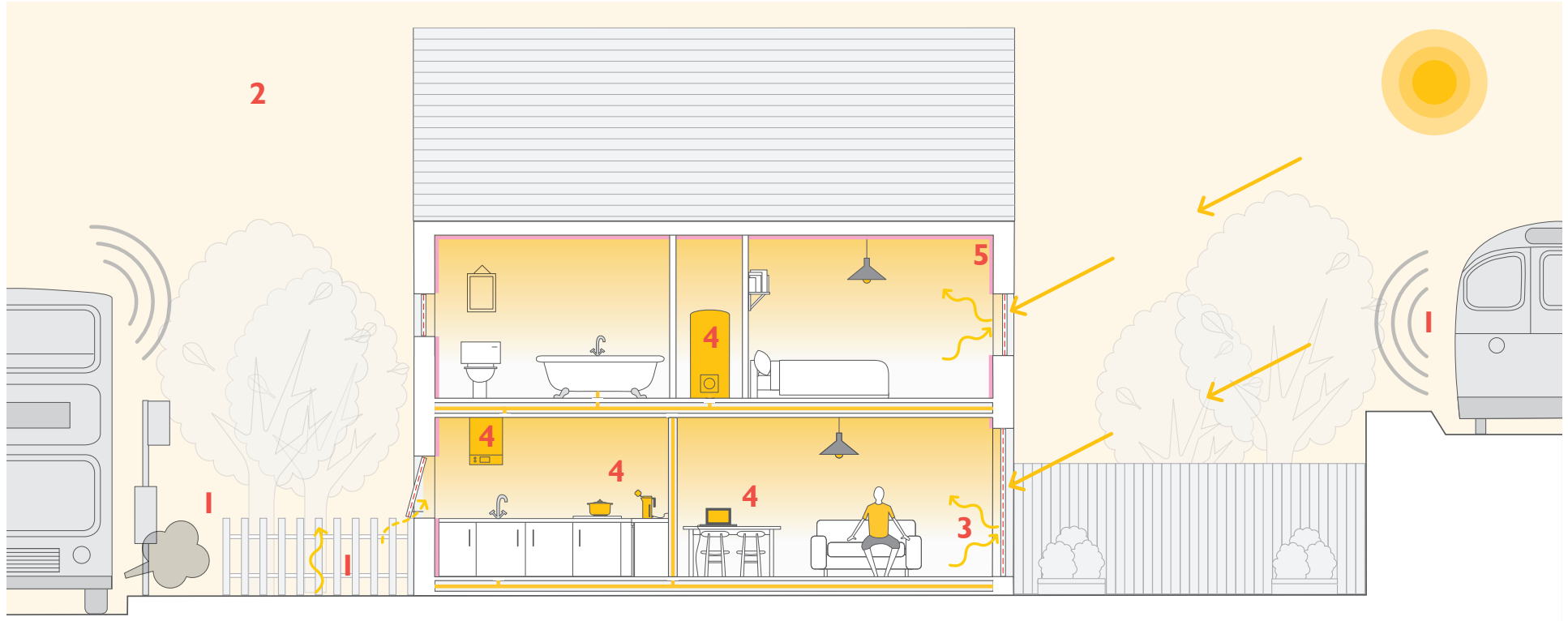
Top-hung windows have the potential to allow high rates of air flow. However, due to security and safety concerns, the length of the throw of the stays is often restricted.



Tilt and turn windows

If well designed, this type of window can offer versatility with regard to the types of air flow that can be provided.

Cumulative effects



Cumulative effects

1. Site context

External pollution, noise and excessive noise may prevent occupants from opening their windows.

Surrounding hard surfaces will absorb heat and release this during the night.

2. External temperature

On a warm, still day when external temperatures are high, fresh air may not provide enough of a cooling effect to address overheating.

3. Solar gains

Double-glazed windows with a low-e coating prevent heat from escaping. Houses with unshaded west-facing glass will suffer from higher levels of solar gain in the warmer part of the day.

4. Internal gains

Electrical appliances, occupant activities such as cooking, and building services, e.g. boiler and hot water storage, all have the potential to radiate heat that may contribute significantly to the increasing internal temperatures.

5. Building design

Modern homes have increased levels of insulation and airtightness, resulting in more heat being retained within the homes. This means any built-up heat in the homes will have to be actively removed.

4 Factors that reduce the risk of overheating

We need to design our homes so that people can live in comfort as the temperatures rise. Careful attention to building design is essential to meet the challenges of warmer summers and winters, while reducing the amount of energy that we use.

Occupant behaviour

Purge ventilation

Thermal mass

Window design

Secure ventilation

Solar shading

Shading devices

Occupant behaviour

According to predictions, in the coming decades, we will experience temperatures in the south-east comparable to those experienced in the south of France today, but our built environment will not have developed an appropriate arrangement or built form to deal with this effect⁵. Many of the common behavioural responses to hot weather seen in Mediterranean countries, up to now, have not been necessary in our milder climate and so are not instinctive to us. The building form typical to Mediterranean regions has evolved to deal with the heat – external shutters are often used during the hottest parts of the day to keep out the sun while windows are kept open to allow the circulation of air. At night the home is opened up and the heavy masonry structure is cooled down.

Although predictions are showing that future temperatures may be comparable to those in the Mediterranean, our sun angles will remain comparatively low in the late summer months. This will mean that awnings and external balconies will be relatively less effective in preventing direct sunlight from entering our homes. Therefore the problem of adapting our building designs to deal with a warming climate will require different strategies to those used in the Mediterranean.

Historically in the UK, residents have responded to winter conditions by having heavy curtains that retain heat. Relatively mild external conditions and thermally heavy construction meant that small adjustments like opening windows for short periods of time were adequate in the summer months to deal with any increases in internal temperature. New homes also have to consider the cumulative effects of having the capability to retain more heat as a result of a more efficient building fabric, the impact of increasing internal gains and new mechanical systems, such as MVHR units, which may also contribute to internal heat gains.

Strategies for reducing the risk of overheating in homes generally tend to require the participation and understanding of the occupants. The dissemination of information to occupants and their understanding of these measures has lagged behind their increasing awareness of the benefits of insulation and heat retention in winter.

Evidence from other countries suggests that the most convenient response to a problem of overheating is to invest in a local active cooling system such as a fixed or portable air conditioning unit⁶. But for many, this is not an affordable solution, both in capital outlay and energy costs, and the installation of active cooling systems will undo many of the reductions in carbon dioxide emissions achieved by the improvements made to building standards. Furthermore, it is certainly not a sustainable solution considering the relatively mild climate in the UK where the risk of overheating can be addressed effectively by passive design measures. All active cooling systems dump heat somewhere, and so in urban environments, while dwellings might stay cool, there is the possibility that the heat island will intensify.

⁵UK climate projections show that in London the average summer night-time temperatures will rise between 0.5°C – 3°C by 2020's, 1°C – 6°C by 2050's and 1°C – 9°C by 2080's.

Defra, UKCP09. Available at: www.ukclimateprojections.defra.gov.uk

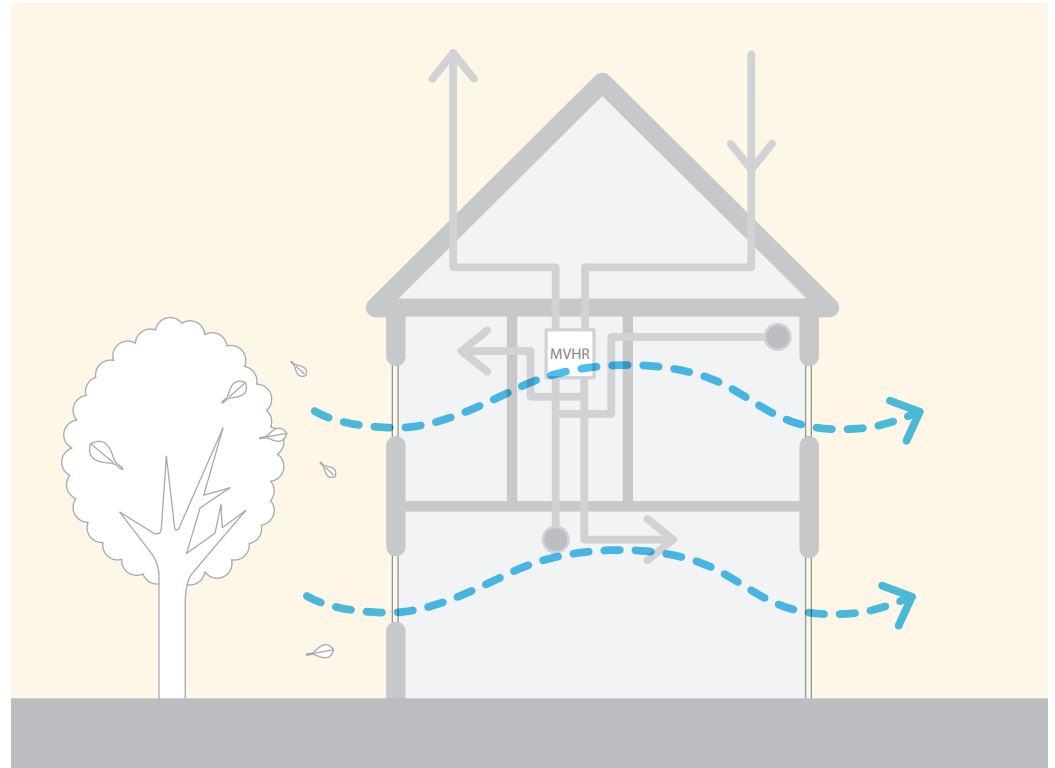
⁶In the USA, results from a 2009 residential energy consumption survey found that 87% of households now have air conditioning. http://205.254.135.7/consumption/residential/reports/air_conditioning09.cfm

Purge ventilation

One of the most effective ways of addressing the potential risk of overheating in homes is to have a well thought out strategy for purge ventilation. This can be achieved by providing means for cross-ventilation, that is, circulating large amounts of air throughout the home. Where mechanical ventilation is used, occupants should be able to open windows adequately and in a secure manner, even if for short periods of time.

If the purge strategy is intended to be implemented manually, occupants will need to understand how to use the features effectively. When purge ventilation is described in the context of overheating it refers to rate of air change required to remove heat. This is not the same as the purge ventilation that is required in Approved Document F, which is primarily concerned with the removal of humidity and odour at source.

Generally higher temperatures can be tolerated when there is a perception of air movement even if the air is not noticeably cooler. Even when the temperature difference is relatively small, occupants will benefit from the sensation of air on the skin. When occupants are able to control the features that would help address overheating they are likely to be more tolerant of higher temperatures.



Purge ventilation

Even homes with MVHR systems should allow for opening windows for the removal of heat. In these homes, background ventilation, in both summer and winter, is provided by the mechanical ventilation system.

Thermal mass

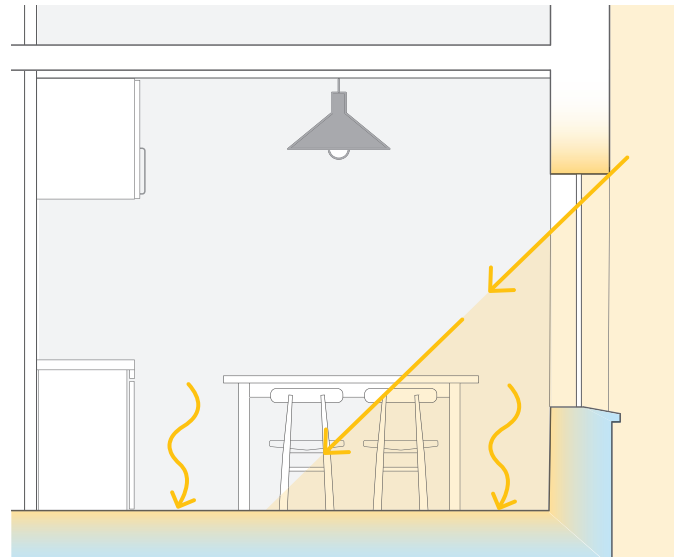
The thermal mass of building materials, or their ability to store heat, can be used to control overheating when used in conjunction with adequate ventilation.

Materials with high thermal mass will absorb sunlight and internal gains and store it during the day. This heat is released into the home at night, effectively 'shifting' the period of high internal temperature to when the outside air is cooler; this effect is called 'thermal lag'.

In order to achieve this effect, materials with high mass must be used where they are exposed to the internal environment but ideally not to direct sunlight. Internal finishes such as carpets and plasterboard can reduce the effectiveness of thermal mass and their impact must be considered in the early stages of design.

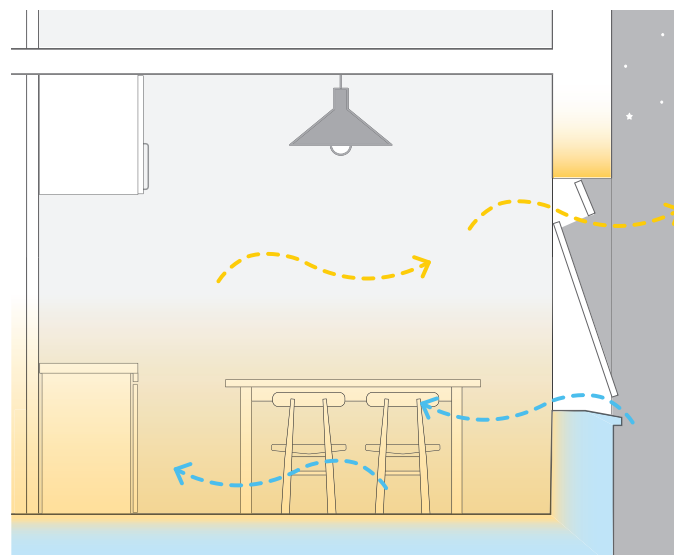
The materials that will store heat will need to be sufficiently cooled to be effective during prolonged periods of hot weather. One way of achieving this is by providing secure night-time ventilation, also called 'night purge' ventilation, to allow the thermally heavy materials to cool down so that they may absorb heat as temperatures rise the following day.

The heat being absorbed by these surfaces will also be perceived by occupants because of the radiant cooling effect of these exposed surfaces.



Thermal mass during the day

During the day, the heavy thermal mass of the exposed external walls and floors will absorb the solar gains that enter the dwelling through windows. Since the thermally heavy materials are absorbing this heat, they will be perceived as offering a cooling effect.



Thermal mass at night

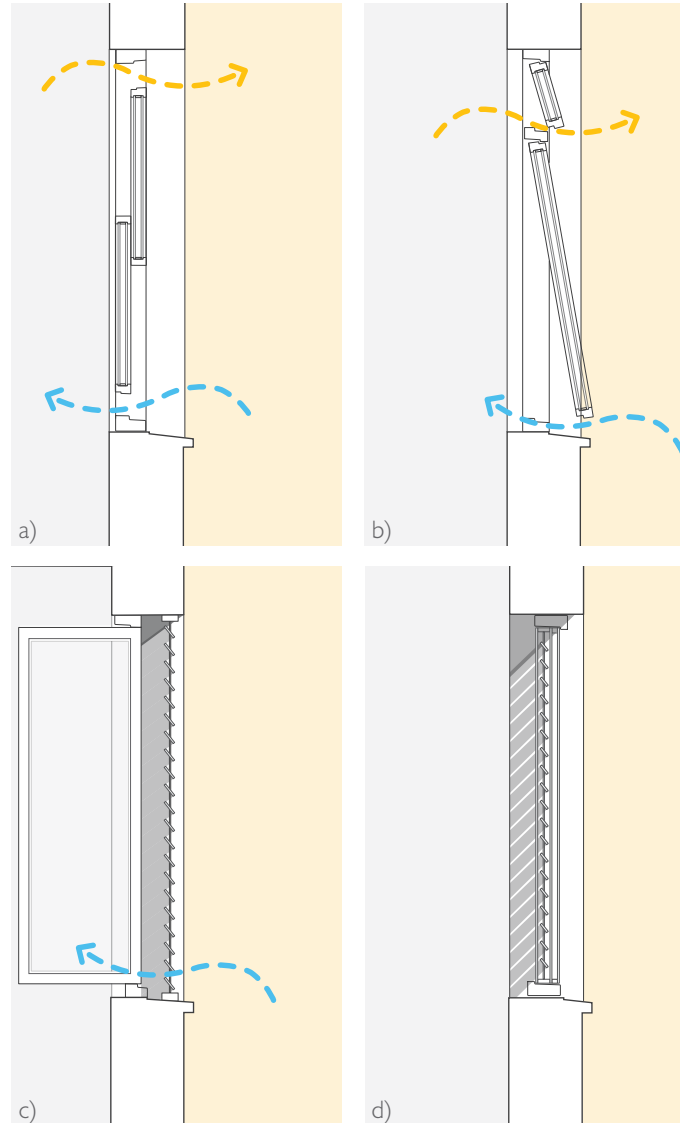
For thermal mass to be effective there must be some way of cooling down the structure at night in a secure manner.

Window design

Windows commonly incorporate trickle ventilators within their frames to provide background ventilation to maintain indoor air quality. In the summer, in well-insulated and airtight homes, a higher rate of ventilation is desirable for air circulation and regulating internal temperatures preferably at all times. Security needs to be taken into account and may be implemented by fitting restrictors in the window frames, ventilation panels or high-level windows, which can be left open when the occupants are not present or at night. Traditional sash windows, which can be left open at the top securely, are a good example of how secure ventilation has been achieved in the past.

In addition to this, it should be possible to open windows to their full capacity for short durations of time in order to get maximum air flow through homes.

The design of windows should also take into account regulating the amount of solar gains within homes. The glass in windows is generally specified to maximise daylight into spaces while reducing heat loss in the winter by the use of low-e coatings. However, window design should also consider the incorporation of solar shading. Inward and outward opening windows will also have implications for the choice of shading devices.



Secure ventilation

Both of these windows can be used in single-aspect homes when high- and low-level openings will help generate a stack effect.

- a) Traditional sash windows where the upper and lower panes can be moved to an opened position.
- b) Windows with a separate top vent that can be left open along with or independent of the main window.

Ventilation & solar shading

Solar shading devices like blinds may be :

- c) fixed to the outside of windows which would limit the extent to which sunlight will come into the room; or
- d) integral to the glazed unit and restrict sunlight before it enters the home.

Secure ventilation

For homes on a busy road or close to a railway, under a flight path or next to noisy neighbours there will be other reasons for not throwing the windows wide open. The occupants might be young children or frail and vulnerable adults and the windows could have been restricted for good reasons. The number of children between 1 and 15 years old that are injured from falls from windows each year is as high as 4,000 and the safety advice offered by the Royal Society for the Prevention of Accidents (RoSPA) is that all upper floor windows should have opening restrictors⁷.

There are solutions for instances where windows cannot be fully opened, such as that shown in the images opposite, but they are expensive to retrofit and must be considered early on in the design and specification process.

Provision of secure ventilation is also essential for thermal mass to be effective in limiting overheating in homes.

SAP Appendix P gives values for the effectiveness of various window strategies, recognising that in practice the assumption that all windows can open fully all the time is unrealistic.



Secure ventilation

Secure ventilation may be achieved by a louvered panel alongside a window.

⁷ Further information is available from: <http://www.rospa.com/homesafety/policy/childsafety.aspx>

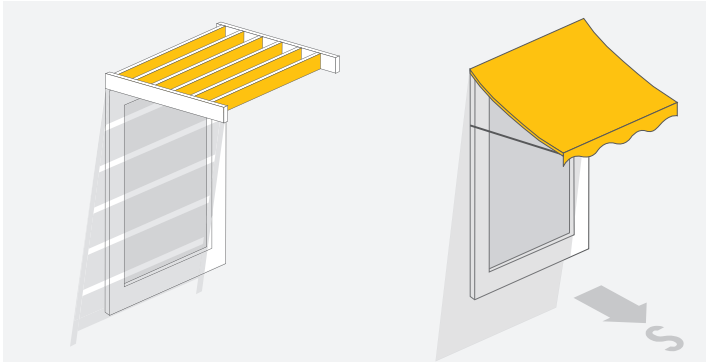
Solar shading

In the UK, windows in homes generally open outwards so that curtains can be used to retain heat in the winter. Curtains can also provide some protection from solar gains in the summer, but to prevent overheating, it is more efficient to provide shading that cuts sunlight before it enters the building.

In an ideal situation the choice of the shading device that is used is determined by the orientation of the opening where it is installed. South-facing windows need to be protected from high-level sun and this can be done by horizontal 'brise-soleil' and awnings or by the form of the building itself. Windows facing east or west experience the sun much lower in the sky and any shading will have implications for the view and daylight through them. It is especially important to shade from late-afternoon sun from the west as this is the warmer period of the day when more significant heat gains will take place.

Devices such as external louvres provide shading without completely blocking views. External shutters provide maximum protection from the sun and are appropriate in spaces that may not be occupied during the day or that have windows facing other orientations.

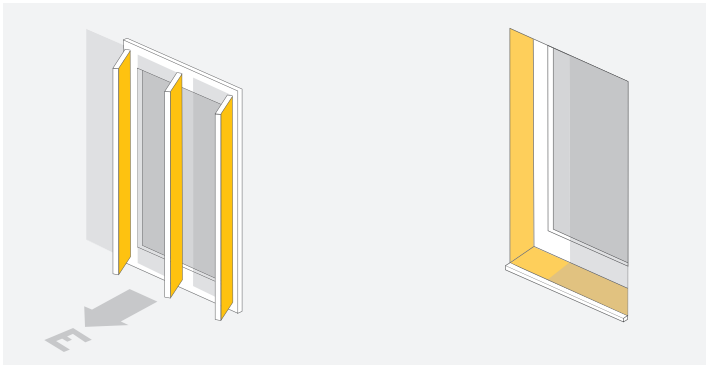
While externally installed shading devices are most effective to address the risk of overheating, these have an impact on the appearance of buildings which needs to be taken into account. Internal shading devices, such as curtains and blinds, though less effective, can be more easily retrofitted and prevent the sun from reaching deep in the rooms.



High-level sun

South-facing windows need to be protected from high-level sun. This may be done either by projections of the building form itself or balconies or overhanging eaves. Generally these devices block the sun, with a limited impact on views out.

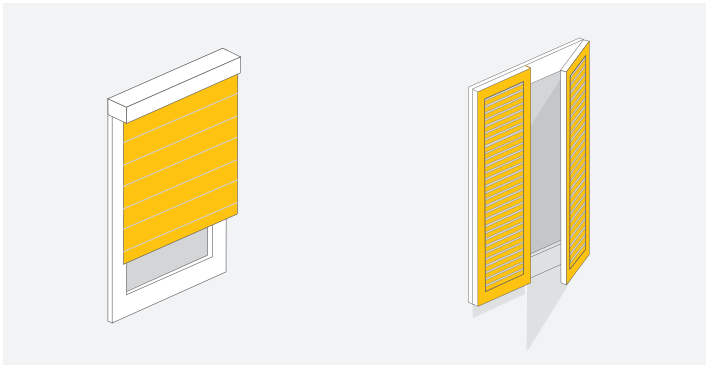
Far left: brise-soleil
Left: awning



Low-level sun

Vertical shading devices are most effective for windows facing the east or west, which are vulnerable to low-level sun. These often reduce the external views and, to a lesser extent, daylighting.

Far left: vertical louvres
Left: deep window reveals



General shading

Shading features which cover the windows are the most effective for both high- and low-level sun, but they may completely restrict views to the outside and daylighting.

Far left: external blinds
Left: external shutters

Shading devices

A balance between useful and unwanted solar gains can often be achieved with shading with carefully-thought-out shading. While internal blinds can offer relief from glare due to direct sunlight, they have a limited impact in protecting against solar gains. The homes should be shaded externally as far as possible. This may not always be an architectural statement consisting of external louvres, overhangs or screens, though these treatments are appropriate and highly effective.

In Mediterranean climates, porches or patio doors are frequently shaded by a pergola with deciduous planting. Vines can provide dense flat-leaved shading in the summer but during the winter, the minimal branch structure allows winter sun to penetrate the living space. Manual external shutters are also extremely effective devices and offer shade along with secure ventilation, provided that the window is designed to open inwards. Again the Mediterranean tradition of having inward opening windows and relying on the shutter to provide weather protection provides a ready-made solution that could easily be adopted within our traditional building apertures.



Shading devices in practice

There are a variety of approaches that may be taken when providing solar shading to a home. These include creating an overhang by the building form along with retractable awnings and external louvres.

Many of the case studies presented here reveal that modern homes can overheat, even if there are no obvious causes. High internal temperatures may be associated with location and orientation, fundamental oversights in design, or the way in which the home is being used.

Case study I

A programme of post-occupancy testing was undertaken in this recently built energy efficient house. In addition to a highly insulated and airtight building fabric, the energy strategy included an efficient mechanical ventilation system with heat recovery (MVHR).

The summer ventilation strategy used a passive solar stack located in the middle of the house through which warm air would rise and be expelled via an automatically operated vent. All the windows were designed to be openable and controlled by the occupants to allow them to cross-ventilate the house and facilitate stack ventilation to purge the house in warm weather.

The passive stack ventilation was found to be effective; however one bedroom on the first floor was reported to be uncomfortably warm all of the time. This bedroom was immediately adjacent to a room housing the hot water cylinder and the MVHR system, which was identified as a source of heat – a 'hot spot'. This problem was reduced by improving the insulation to the pipework of the hot water distribution system.

Monitoring of the use of windows revealed that only 4 of the 25 openable windows were regularly used. The summary report concluded that more thought was needed for the positioning of windows within the layout for effective cross-ventilation.



Creation of a 'hot spot'

A 'hot spot' was created in the airing cupboard by the MVHR unit and the pipework around the hot water cylinder. Additional insulation was later added to the pipework, which helped address the problem.

Photography: Fionn Stevenson

Case study 2

An environmental health survey was carried out in this new development located in a dense urban area. The flats were built to a high standard of fabric insulation and airtightness. A large proportion of these were single aspect and located near to a busy railway line. The ventilation was provided by a mechanical ventilation system that incorporated heat recovery for winter operation. Space and water heating was provided by a community heating system. Inadvertently, these features led to an overheating problem.

According to Inside Housing magazine, surveys carried out in the 267 flats in 2010 found an 'excess heat hazard', with temperatures peaking at 37°C, nearly 10°C higher than the recommended safe temperature for homes. At night, the rooms remained so hot that tenants claimed their children suffered nose bleeds as a result.

As a result of unshaded facades, a high level of occupancy and gains from the hot water distribution pipework, heat was building up during the day which could not be removed. It emerged from the survey that residents were not given proper advice about the operation of the mechanical ventilation system in their homes with most assuming this would provide cooling.

In order to address the problem, the developer improved insulation to the hot water distribution pipework and installed fans in the common areas to remove heat emitted from the community heating system. Although these measures will help to alleviate uncomfortable temperatures, the additional fans will increase the energy consumption of the development.



Varying degrees of shading

One part of the housing scheme, shown above, has no solar shading and some apartments overlook the busy railway. In contrast, the west-facing facade, shown below, has deep set balconies protecting the glazing from solar gains.

Photography: Richards Partington Architects

Case study 3

Overheating was observed in a predominantly north- and east-facing flat within an eleven-storey development, located in an urban area close to a busy elevated road. The building fabric is well insulated with low thermal mass due to light-weight internal walls and suspended ceilings.

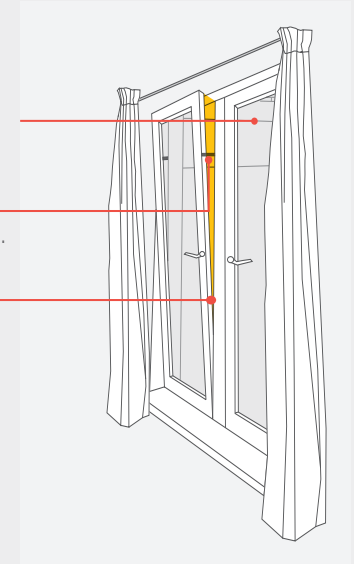
This corner apartment with large unshaded windows was intended to be naturally ventilated. Due to its proximity to the road, air supply was supplemented by means of ducted vents in the ceiling along with intermittent extract fans in the kitchen and bathroom. The bottom-hung windows were designed to be openable to allow for purge ventilation, but were fitted with restrictors.

The floor-to-ceiling glazing admits large amounts of sunlight during the day, with the only means of heat expulsion being through the windows. The restrictors however, limited their opening to 100 mm, due to which the panels could not extend beyond the window reveal, making the effective opening area very small. The proximity to the busy road makes it difficult for the windows to be left open overnight for effective night-time ventilation. In addition to this, the background ventilation grilles do not provide adequate air supply to remove the built-up heat.

Cross-ventilation is most effective when windows are located on opposite facades, which is not possible in this case. In addition to this, the night purge strategy could not be effectively used due to the location of the flat and design of windows.



Flyover close to building
Restrictors limit the opening lights.
Useful ventilation opening



Restricted ventilation

While the window openings are large, they have been restricted for safety, thereby providing a very limited open area for ventilation. The development is located close to a busy road, which limits the occupants' opportunity to open the windows as intended.

Photography: BRE

Case study 4

Four test houses were built by the BRE in the early 1990s. Two were built to comply with the current standards and the other two to meet the more stringent Swedish building fabric standards. Soon after completion, the houses built to meet the Swedish standards were experiencing high internal temperatures.

A study was then undertaken to assess the potential for passive cooling measures to limit the extent of overheating. The following measures were considered:

- Various window opening strategies, including single-sided ventilation and cross-ventilation,
- Thermostatically controlled mechanical ventilation and 24-hour ventilation, and
- The use of solar blinds on unshaded elevations.

The investigation concluded that to achieve effective cooling of the whole house cross-ventilation was required on both floors. One suggestion from the project was that houses might need different ventilation systems for the ground and first floors, recognising the security limitation for natural ventilation at night time on the ground floor. The study also concluded that external solar blinds were very effective at limiting solar gains within the homes, helping reduce daytime and night-time temperatures.



20°C 35°C 50°C



Test homes

Images of the houses built to the Swedish building fabric standards. After completion, high temperatures were observed during the day as a result of simulated internal gains and solar gains.

Photography: BRE

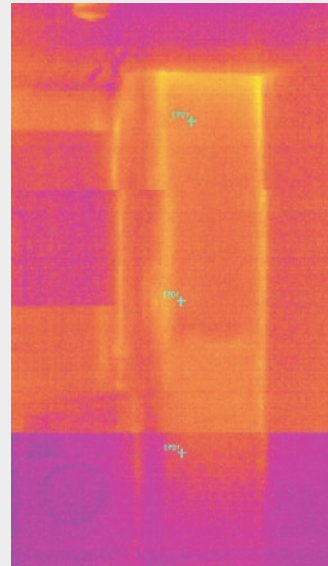
Case study 5

Overheating was reported in a number of apartments in an eleven-storey mixed-use urban development that overlooks a busy railway line. An MVHR system provides background ventilation and large side-hung windows are located on the unshaded east-facing facade for purge ventilation. A community heating system meets the space heating and domestic hot water demand, the distribution pipework for which runs through common circulation areas. Although solar gains to the apartment are high, these take place in the morning when the sun is not at its warmest and were not thought to be the main cause of overheating.

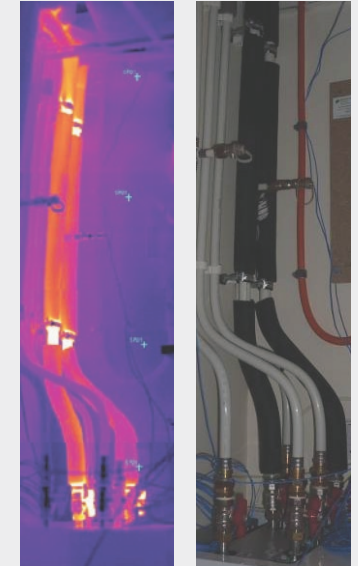
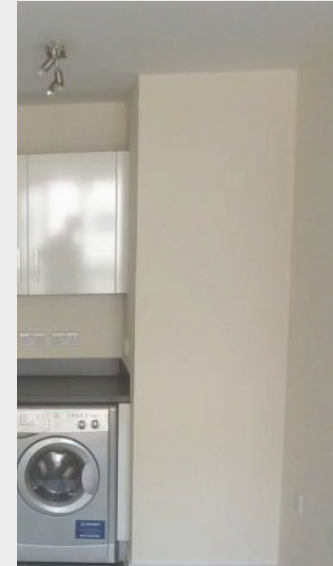
During the night, internal temperatures were high in the bedroom and living room, even with moderate external temperatures. A significant length of pipework to the CIU for the community heating system was poorly insulated, effectively making these a permanent heat source. Pipework located directly alongside the MVHR unit was pre-heating the fresh air supplied to the apartments.

The MVHR unit did not incorporate a summer bypass setting, due to which the supply air was always being pre-heated. Even in 'boost mode' the rate of mechanical ventilation was not high enough to help reduce internal temperatures. The windows could not be opened at night due to noise and security concerns, further limiting the potential for ventilation.

The ventilation strategy was inadequate for the apartments and even the relatively small heat gains from the CIU made a significant contribution towards high internal temperatures and occupant discomfort.



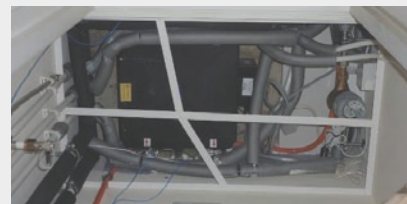
25°C 27°C 30°C



30°C 38°C 46°C



25°C 34°C 43°C



Excessive heat gain from the CIU

Infrared images of the airing cupboard in the kitchen show the extent of the heat that is constantly being emitted as a result of the poorly insulated pipework from the heating system that was running alongside the MVHR ductwork.

Photography: BRE

Case study 6

A Victorian school building was converted to accommodate one-bedroom flats in 2008. As part of the refurbishment, the original brick external facade and internal walls were retained, and secondary glazing was installed behind existing windows to reduce heat losses. The apartments were naturally ventilated via openable windows with extract fans installed in the kitchens and bathrooms. A community heating system provided space and water heating and a CIU was located in each apartment.

The community heating distribution system was running through the communal areas, which were found to be overheating. Although the distribution system was insulated, minimal heat gains from the pipework and fixed lighting were identified as a predominant source of heat due to the lack of ventilation in the spaces. The high temperatures in the corridors also contributed to heat gains in the flats.

A mid-floor west-facing flat was monitored and found to be overheating. The secondary glazing installed to the existing windows reduced the area of the casement window that could be opened, thereby reducing the potential for ventilation. The south-west and north-west facing windows were small and solar gains were minimal but the high thermal mass of the building fabric helped retain the heat within the homes. The CIU and distribution pipework within the flats were also a source of heat gains.

As the openable area of windows was significantly reduced due to the installation of the secondary glazing, it was not possible to purge the homes of built-up heat effectively.



Apartment with excessive internal heat gains

Photographs showing the west elevation of the converted building. Due to the secondary glazing units that were added behind the original windows, the openable area is quite small, making it difficult to expel excess heat.

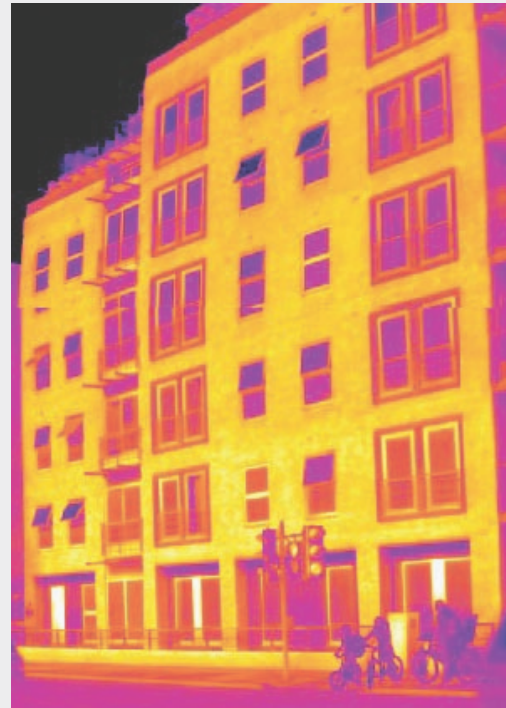
Photography: BRE

Case study 7

A number of factors contribute towards overheating of this one-bedroom flat located on the ground floor of an eight-storey development facing a major road. The single-aspect flat has a south-west facing facade incorporating large areas of unshaded glazing. It is ventilated via trickle vents in window frames and extract fans in the bathroom and kitchen. The outward-opening side-hung windows have been fitted with restrictors.

The flat experiences significant solar gains during the day due to its south-west orientation. Concerns regarding security, pollution and noise make it difficult for windows to be left open for extended periods during the day or night. Effective night-time purge ventilation is therefore not possible and only the trickle vents are used. In addition to this, the surfaces adjacent to the apartment, the hard paved areas and brickwork, absorb heat from the sun during the day and radiate it back at night, further limiting the effectiveness of night-time ventilation.

The combination of high solar gains and the urban heat island effect will cause this flat to be continuously exposed to high temperatures. The lack of effective day or night-time ventilation will make it difficult for the high internal temperatures to be reduced easily and these will be compounded over time.



25°C 40°C 60°C



Effect of the urban heat island

Thermographic images show the high temperatures of the external surfaces of the apartment building and its immediate surroundings because of their direct exposure to the sun. Air introduced into the flat by opening windows will therefore be significantly warm.

Photography: BRE

6 Assessment of overheating

SAP is the Government's approved tool that is used to demonstrate compliance with the Building Regulations with regard to the conservation of fuel and power for space and water heating, fixed lighting and ventilation in a home. It also checks for excessive solar gains during the summer to minimise demand for mechanical cooling.

SAP makes monthly average energy demand assessments and has limited ability to account for the complex interactions that occur in the home.

As an alternative to using SAP, 'dynamic' modelling can be carried out to assess various design strategies. Dynamic modelling evaluates the performance of a dwelling throughout the year and allows the designer to undertake a more detailed assessment of the risk of overheating.

The overheating check in SAP

The overheating check in SAP is used to assess the risk of overheating and demonstrate compliance with Criterion Three (limiting the effects of solar gains in summer) of Approved Document L1A. The SAP tool considers the effects of solar gains, external temperature, geographic location and the thermal properties of the construction itself (for instance thermal mass). However, the tool has limited ability to deal with the complex interactions between the contributing factors that are described in this guide and, being a compliance tool, it does not offer the designer any diagnostic information to remedy a 'high risk' of overheating.

The strategies available to a designer for limiting solar gains – reducing the amount of glazing and its distribution, the use of solar control glazing, and possible shading strategies will all have an impact on the appearance of the home. It is essential, therefore, that designers undertake some kind of overheating analysis at an appropriate stage in the design process. If the risk of overheating is identified too late in the process, for instance after planning consent has been granted, the available means for reducing overheating are severely limited and rely on achieving high rates of ventilation and improving the thermal mass of the construction. The examples in this guide show assumptions about ventilation and the area of window openings are often far too optimistic. Understanding the effects of thermal mass is also complex and to be effective it must be combined with an appropriate ventilation strategy. The designer should therefore take all reasonable measures to anticipate an overheating risk and reduce the likelihood of occupiers needing to retrofit solutions such as fans and air-conditioning units.

In a changing climate the risk of overheating in new homes is likely to increase.

An overheating problem may be caused by a single design or installation fault but it is just as likely to be caused by a combination of seemingly harmless factors.

Good design for 'purge' ventilation will go a long way to help reduce overheating.

Design measures to reduce overheating need to be able to be put into practice successfully, especially for window opening and cross-ventilation.

Designers need to consider external factors – the site and its surroundings – as well as the home itself.

Services, especially those that are fully charged with hot water all year round, need to be designed and installed with consideration for the potential to cause overheating.

Home users need to be made aware of the ways in which they can regulate their internal environment to address any possible overheating, while designers need to ensure that all features that would aid this are easy to understand and operate.

Glossary

Air changes per hour:

The rate of ventilation expressed in terms of the number of times the entire volume of air in a home is replaced within the duration of an hour.

Airtightness:

The descriptive term for the resistance of the building envelope to the leakage of air. The greater the airtightness, the lower the air infiltration.

Community heating:

A central heating system providing space and/or water heating to multiple residential units via a common distribution network.

Consumer interface unit (CIU):

A control interface within a home that comprises a heat exchanger, which transfers heat from the community heating network to the individual home's internal heating and/or hot water distribution system.

Cross-ventilation:

Natural ventilation that would generate air flow across a space and is achieved by opening windows on more than one facade of a building.

Mechanical ventilation with heat recovery (MVHR):

A balanced mechanical whole-house ventilation system where stale air is removed from wet rooms and fresh air is supplied to habitable rooms. In the ventilation unit, heat is removed from warm extracted air via a heat exchanger and is used to pre-heat the incoming supply air.

Standard Assessment Procedure (SAP):

The Government's approved method for calculating the energy efficiency and carbon emissions from homes to demonstrate compliance with the Building Regulations.

Stack effect:

The movement of air due to natural buoyancy caused by warm air rising up the height of a space. This would require a low-level inlet for air to enter the space and a high-level opening for the air to escape through.

Project credits



61 Warwall
Architects: Penoyre & Prasad
Photography: David von Sternberg



Lynn Road
Architects: Mole Architects
Photography: Mole Architects



Butts Orchard
Architects: Buchanan Partnership
Photography: Buchanan Partnership



Greenwich Millennium Village -
Phase 2a
Architects: Proctor and Matthews
Photography: Tim Crocker



The Black House
Architects: Mole Architects
Photography: Mole Architects



Extension in Kilmacolm
Architects: 3D Reid
Photography: 3D Reid

Understanding overheating – where to start: An introduction for house builders and designers

If the expected warming climate leads to hotter summers, the increasing threat of overheating in homes will become an issue that cannot be ignored. This NHBC Foundation guide is intended to give house builders and designers a broad understanding of overheating in new homes.

The guide identifies key factors that can lead to uncomfortably high internal temperatures and introduces measures that should be considered at the early stages of design to safeguard new homes against overheating. It also provides case studies of homes built recently where overheating was reported – highlighting common pitfalls in design that should be avoided.



The NHBC Foundation has been established by NHBC in partnership with the BRE Trust. It facilitates research and development, technology and knowledge sharing, and the capture of industry best practice. The NHBC Foundation promotes best practice to help builders, developers and the industry as it responds to the country's wider housing needs. The NHBC Foundation carries out practical, high quality research where it is needed most, particularly in areas such as building standards and processes. It also supports house builders in developing strong relationships with their customers.