mesh.

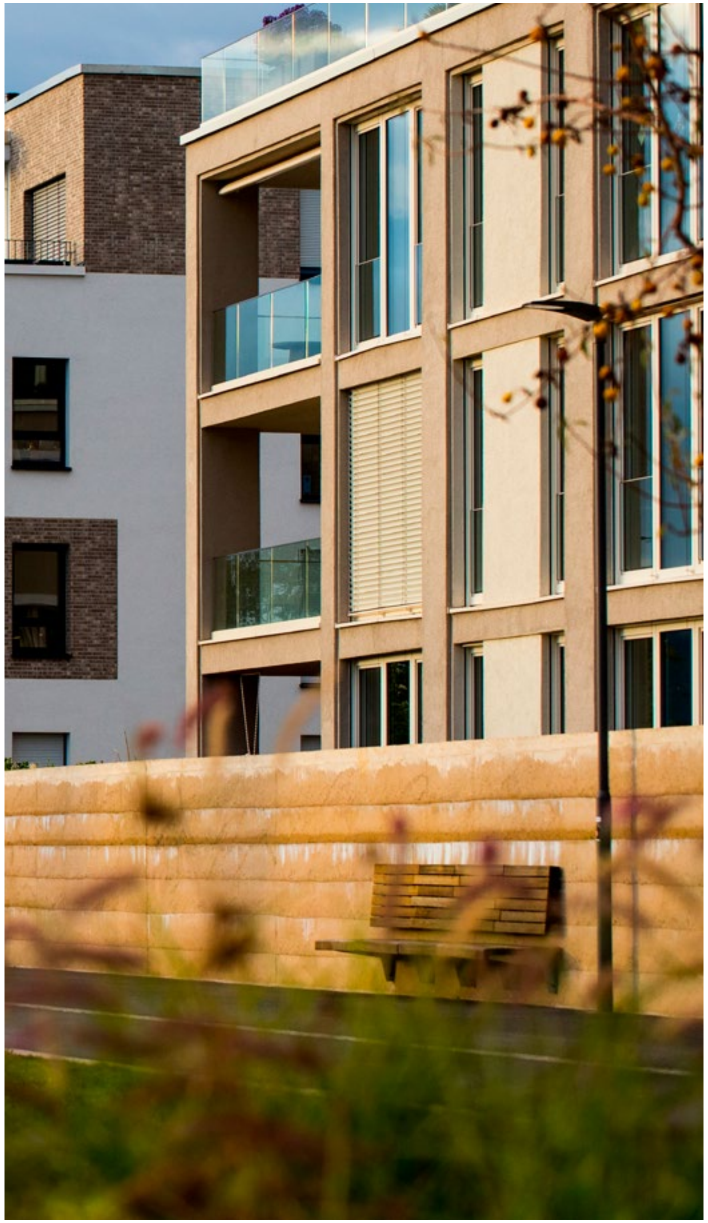
Overheating in building design: considerations and solutions

For more information on our overheating consultancy service, please visit our website or get in touch or visit: www.mesh-energy.com

Introduction

Part O Overheating regulations took effect in June 2022, requiring all new residential buildings to satisfy certain thermal regulation specifications in order to gain planning approval. We have published a comprehensive overview of the 2022 Part O Overheating Regulations, which you can find here.

In the second of our two guides on the subject, we concentrate on the elements of a building's design that affect its temperature and practical solutions that exist to ensure consistent, long-term thermal comfort.



But first, let's recap on why overheating has become more of a problem in recent years and why changes to modern building methods and our climate have made it such an important topic.

01 INCREASED USE OF GLAZING

Modern buildings often feature large expanses of glass to let in more natural light. But glass naturally absorbs and re-radiates heat from the sun, leading to overheating indoors.

02 IMPROVED INSULATION AND AIR-TIGHTNESS

While better insulation and air-tight buildings are good for energy efficiency, they also stop hot air from escaping during hot weather.

03 INTERNAL HEAT GAINS

Electrical devices and appliances, as well as modern water heating systems, all serve to generate heat inside a building. When combined with external heat factors, internal temperatures can rise significantly.

04 URBAN HEAT ISLAND EFFECT

Densely built and highly-populated urban areas can be several degrees hotter than their rural surroundings. Part O regulations categorise central London and areas of Manchester as being high risk locations for overheating.

05 CLIMATE CHANGE

Rising global temperatures due to climate change mean hotter summers are becoming more frequent in the UK. Heatwaves are putting increasing strain on buildings not designed for warmer conditions.

Building design hierarchy

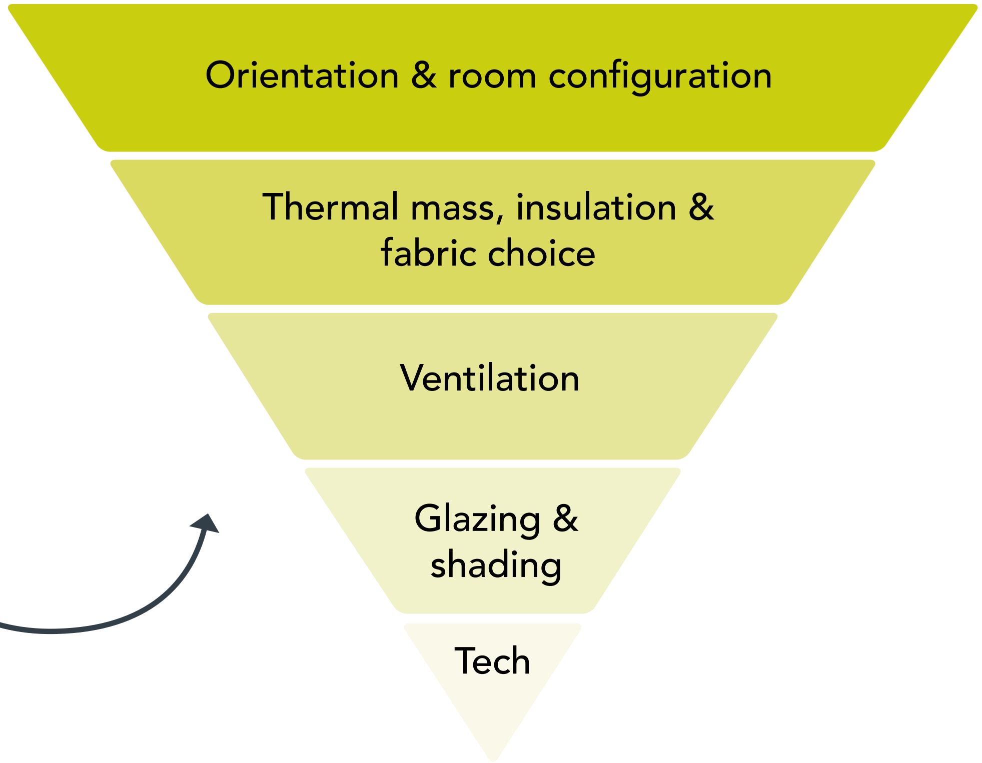
In order to meet overheating regulations, you will need to demonstrate the thermal consistency of your building through one of two methods (see PART O: All you need to know about overheating regulations for more information).

As you'll see in this document, there are various ways to ensure a comfortable internal temperature, but it's key to start thinking about it in the earliest stages of the design process. That's because the most effective changes are made through the choices you make over the fundamental design of your build – like which way your rooms face, what materials you use to build with, and where your windows are positioned.

Completing an overheating analysis once the design is set will either lead to an expensive redesign, or an over-reliance on mechanical solutions that in turn lead to higher running and maintenance costs. Mechanical solutions also undermine a core priority of new Building Regulations – to improve the sustainability credentials of our homes.

This diagram demonstrates the relative effectiveness of the various elements of building design are when it comes to tackling overheating.

Throughout the rest of this guide, we will look at each of these elements in turn and explain how they affect the thermal consistency of your building, giving hints and tips on how to use them to your advantage.



01 Orientation

WHAT IS IT AND WHY DOES IT MATTER?

Orientation is the position of a building in relation to the path of the sun and the prevailing wind, which for most of the UK comes from the south-west.

Solar gains from the sun and the cooling power of the wind are both vital considerations when designing a building resilient to overheating. The orientation of glazing, thermal mass and window openings are all important considerations, not only to take advantage of solar gains during the wintertime but also to avoid these solar gains in the summer.

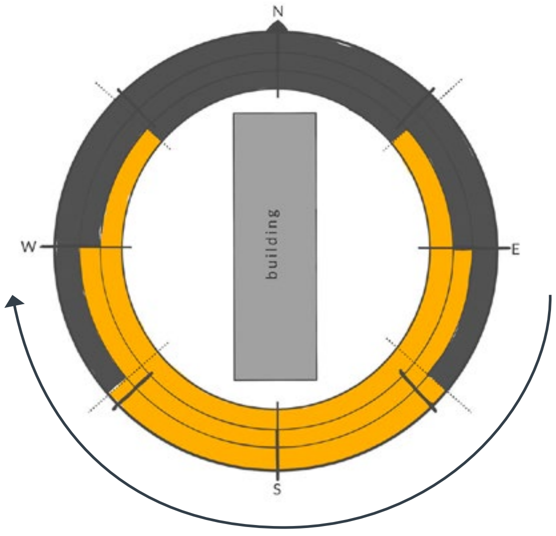
In one-off designs, these decisions may be straightforward, but in larger housing estates, the same house type is usually repeated, making it harder to regulate the orientation of each house. This can mean that identical house types can have drastically different internal temperatures. The main design challenge is to orientate rooms or buildings to take full advantage of sunlight but to minimise overheating and solar glare.

Orientation for passive cooling reduces solar access from the east and west and maximises access to cooling breezes. Orientation for warming in winter and cooling in summer aims to maximise southern exposure of walls and windows but block solar access with appropriate eaves and other shading in summer.

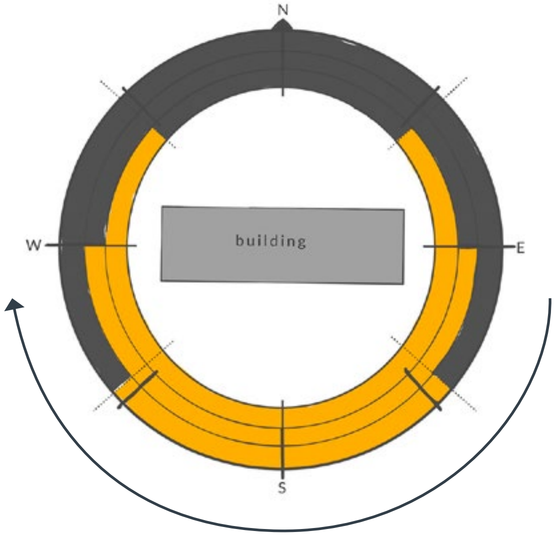
ORIENTATION AND SOLAR GLARE

Because the path of the sun in the UK is to the south, north and north-east facing rooms are at minimal risk of overheating; east, south-east, and north-west rooms are at medium risk of overheating and south, south-west and west rooms are at high risk of overheating.

A single-aspect building, facing one direction, is more prone to overheating than a double aspect house. That's because a double



North-south orientation
Source: First In Architecture



East-west orientation
Source: First In Architecture

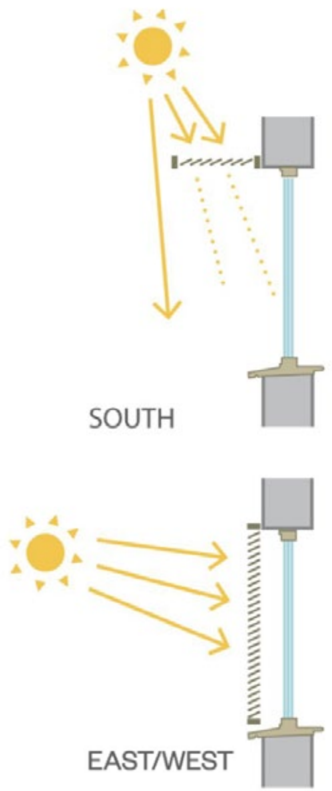
01 Orientation

aspect house can be designed with openable windows on two or more walls allowing for the use of cross ventilation (see page 10).

The ideal situation is for a double aspect building to have a north-south orientation, with daylight-optimised glazing on the north façade and somewhere between 15 and 25% glazing on the south façade.

While you may think the south façade would not be an ideal place for glazing, the height of the sun is important here. During the summer, the sun is at its highest in the sky when it's in the south, while its location is far lower when in the east or west. This affects the angle at which the sun hits the building and therefore the extent and type of shading that can be used.

By putting glazing on the south façade, you can easily protect it from the sun's rays with minimal use of shading due to its high angle as shown in the diagram below. In the winter months, when the sun is generally lower in the sky, this shading will not interfere with desired warming gains.



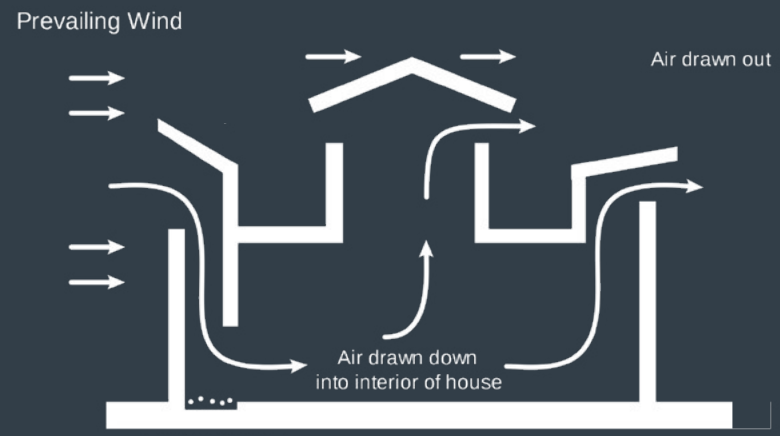
Changing sun angles
Source: Levitt Bernstein and Passivhaus Trust

However, it is not always possible to orient a building north-south. Where there is an east-west aspect, additional care should be taken when designing glazing areas and shading to deal with lower sun angles.

You can find out more about shading options on page 14.

A cooling breeze

Configuring rooms to capture and encourage the flow-through of prevailing breezes, and positioning door and window openings to improve cross-ventilation paths is a good passive ventilation option (see page 10.) However, it's worth noting that landforms, vegetation, or other buildings can affect the direction of breezes by up to a few hundred metres.



Cross ventilation
Source: Wikipedia

02 Thermal Mass

WHAT IS IT AND WHY DOES IT MATTER?

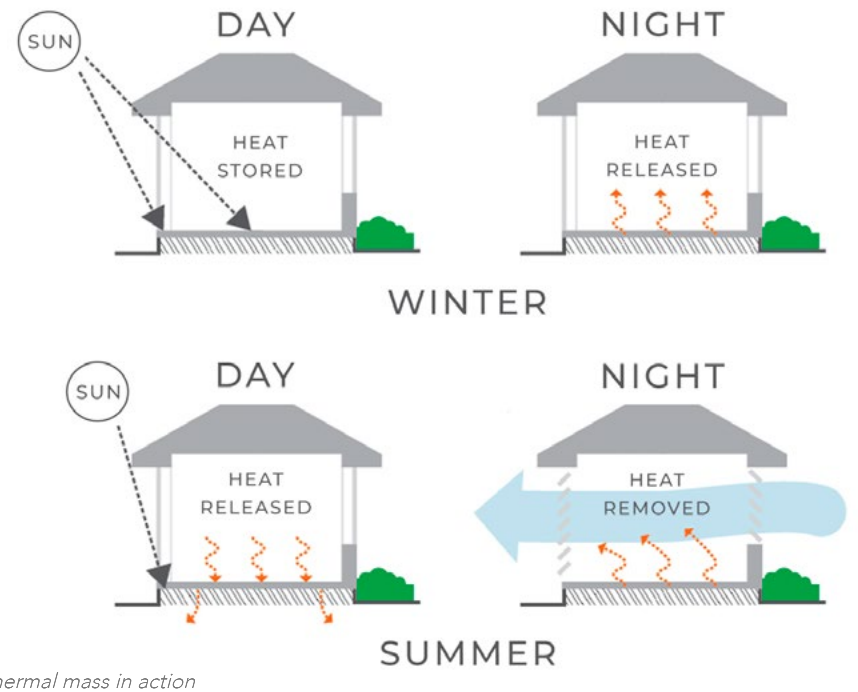
Thermal mass refers to a material's ability to absorb, store and release heat.

- Materials such as concrete, bricks and tiles absorb and store heat and are therefore said to have ***high thermal mass.***
- Materials such as timber and cloth do not absorb and store heat and are said to have ***low thermal mass.***

Thermal lag is the rate at which a material releases stored heat. For most common building materials, the higher the thermal mass, the longer the thermal lag.

TELL ME MORE...

When used correctly, materials with a high thermal mass can significantly increase comfort and reduce energy use in your home. Thermal mass acts like a battery, moderating internal temperatures by averaging out day–night extremes. This means it is particularly useful in climates where temperatures vary greatly across the day and night, as in the UK.



Thermal mass in action
Source: Tim Pullen, Alan Corfield Architects

- **IN WINTER** thermal mass will absorb heat from solar and internal gains during the day and release this warmth back into the home throughout the night as the internal temperature drops.
- **IN SUMMER** thermal mass can be used to reduce overheating. If the sun is blocked from reaching the mass externally (through the use of shading), the mass will instead absorb warmth from inside the home. By encouraging cool breezes and convection currents to pass over the thermal mass overnight, it's possible to draw out stored energy.

02 Thermal Mass

USING THERMAL MASS TO CONTROL HEAT

Poor use of thermal mass can reduce comfort and increase energy use. Inappropriate thermal mass can absorb all the heat you produce on a winter night or radiate heat to you all night as you try to sleep during a summer heatwave.

To determine the best location for thermal mass, identify whether your house requires passive heating, passive cooling, or both.

- ✓ ***For passive heating,*** locate thermal mass in areas that receive direct sunlight or radiant heat from heaters.
- ✓ ***For passive cooling***, protect thermal mass from summer sun with shading and insulation. Ensure cool night breezes and air currents can pass over the thermal mass to draw out stored energy.
- ✓ Locate thermal mass inside the building on the ground floor for ideal summer and winter efficiency.
- ✓ Locate thermal mass in south-facing rooms with good solar access, exposure to cooling night breezes in summer, and additional sources of heating or cooling. Include appropriate shading to protect the mass from summer sun.
- ✓ Locate additional thermal mass near the centre of the building. Feature brick walls, slabs, water features and large earth or water-filled pots or even water tanks can be used.

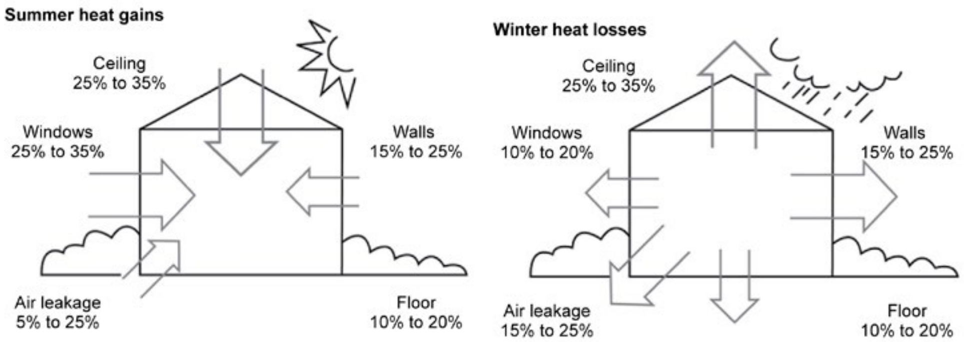
> Thermal mass only works well in combination with insulation (see page 8). In order to work most efficiently, thermal mass should be left exposed on the inside, but insulated against external temperature fluctuations. For example, concrete flooring or brick walls can be plastered or polished, but not covered for example by a carpet. In turn, flooring should be insulated underneath and walls insulated on external surfaces using cladding or similar.

03 Insulation

WHAT IS IT AND WHY DOES IT MATTER?

Insulation is a material that slows or prevents the flow of heat. Insulation is a key part of any passive home, helping to keep heat inside the building in winter and outside in summer.

Heat loss and gains can occur through all areas of a building, including the roof, ceilings, walls, and floor. The diagrams below show the typical proportionate heat loss and gains of the various areas of a building.



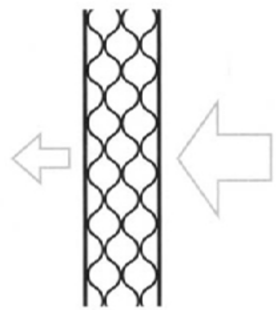
Source: SEAV (2002), updated in Energy Smart Housing Manual (2018)

TYPES OF INSULATION

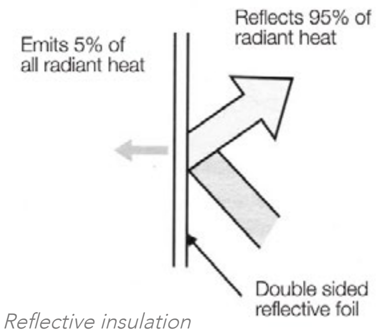
The performance of any insulation product – how well it resists heat flow – is known as its R value. The higher the R value, the higher the level of insulation. The 'total R value' refers to the total sum of R value from the various components of a roof, ceiling, wall or floor, including the insulation.

There are a wide range of insulation types available:

- ***Bulk insulation*** like glass wool, cellulose fibre, PUR or PIR boards, or natural fibres, all uses air pockets within a thick material to slow the flow of heat.
- ***Reflective insulation*** bounces heat back to where it came from. When double sided it does not re-radiate heat on the opposite side, which makes it effective for reducing overheating. Reflective insulation is usually shiny aluminium foil laminated onto paper or plastic.
- ***Composite insulation*** combines bulk insulation with a reflective surface.



Bulk insulation
Source: SEAV 2002



Reflective insulation
Source: SEAV 2002

03 Insulation

THERMAL BRIDGES

Thermal bridges are pathways for heat and cold to cross from the inside to the outside (or vice versa). Thermal bridges reduce the effectiveness of insulation and can also lead to condensation and damp. Things like building frames, windows, and doors all act like thermal bridges, particularly when made of metal.

Thermal bridging can be minimised by:

- ✓ installing thermal breaks (materials that prevent conductive thermal energy loss) between metal frames and cladding, or within door or window frames
- ✓ fixing bulk insulation over frames
- ✓ using less conductive framing materials like timber or uPVC.

HEALTH AND SAFETY

Insulation must be installed with care, to minimise the risk of condensation or fire. It is important to allow insulation clearance around hot flues, exhaust fans, appliances and fittings that penetrate the ceiling , floors or walls to ensure heat does not build up and cause a fire.

04 Ventilation and airtightness

WHAT ARE THEY AND WHY DO THEY MATTER?

Having a healthy home that also has good thermal performance requires a balance of reliable ventilation and good airtightness.

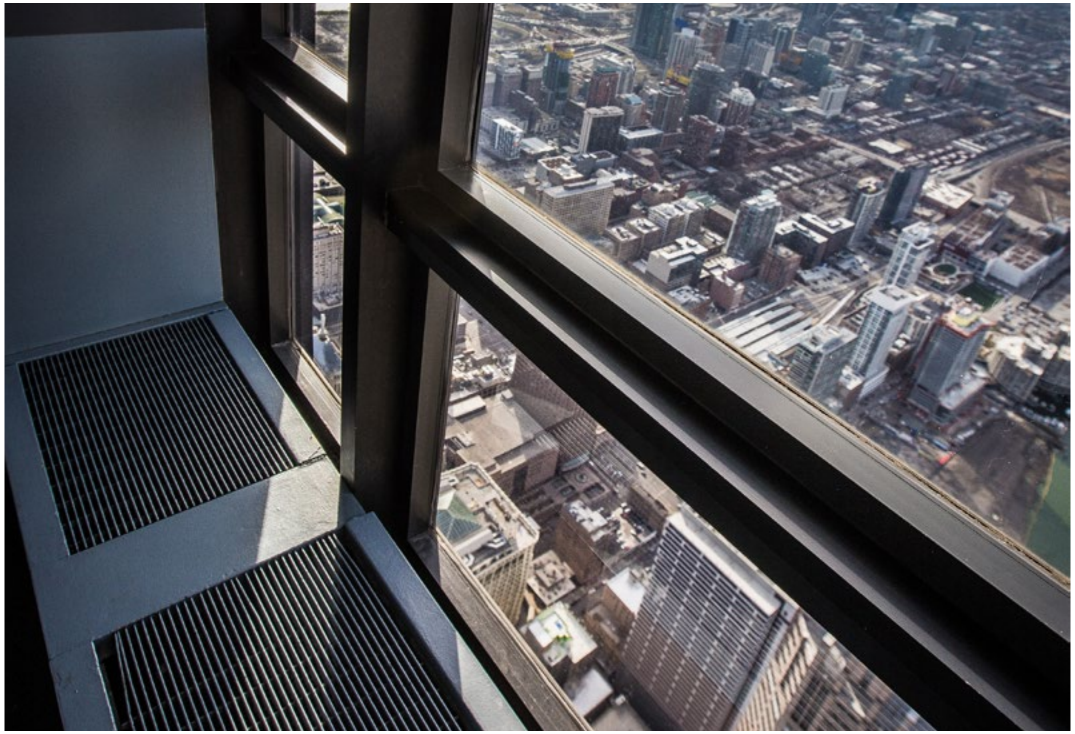
VENTILATION is the intentional introduction of outdoor air into a building to maintain good air quality and cool internal temperatures, and reduce humidity. External air increases oxygen levels and dilutes and displaces carbon dioxide and airborne pollutants.

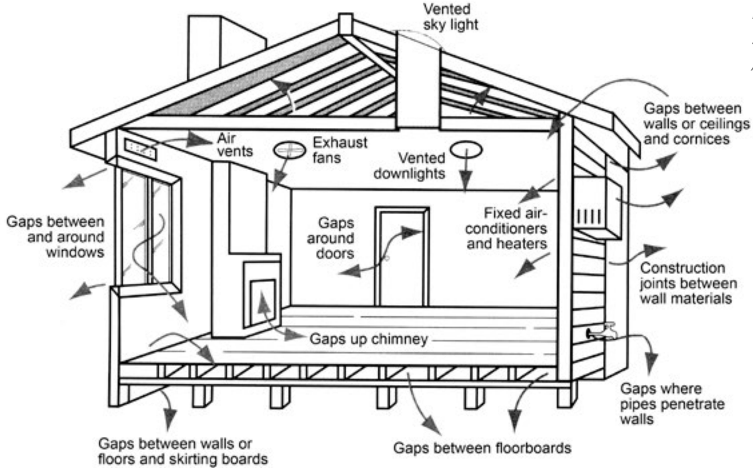
AIRTIGHTNESS avoids the unintended introduction of outdoor air into a building or loss of air to the outside. Improving airtightness can improve the thermal performance of your home by reducing the influx of cold air in winter and hot air in summer. Air typically leaks through:

- unsealed or poorly sealed doors and windows
- unsealed vents, skylights, and exhaust fans
- gaps in or around insulation or penetrations like downlights, pipes, and cables
- gaps between building envelope junctions i.e. floor–wall or wall–ceiling
- poorly fitted floorboards.

In general, modern building construction methods have seen extensive improvements in airtightness, which means good ventilation has become even more important.

An airtight house with inadequate ventilation can lead to condensation, mould, and high internal levels of carbon dioxide, and of course, increased chances of overheating. The rule of thumb: build airtight for thermal comfort and energy efficiency, but not so tight that it compromises indoor air quality.





How air moves
Source: Sustainable Energy Authority Victoria

04 Ventilation and airtightness

NATURAL VS MECHANICAL

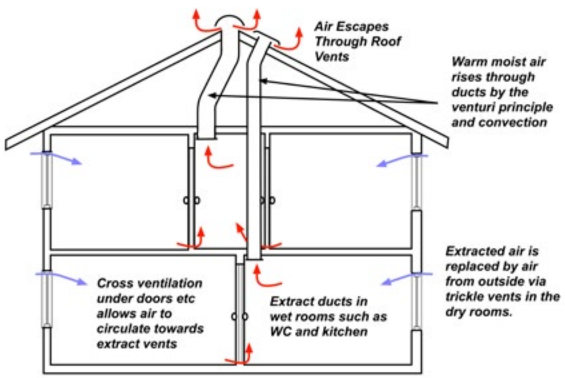
Introducing external air can be done through either natural or mechanical means.

NATURAL VENTILATION

Natural ventilation relies on the movement of air through a building, either due to wind applying a pressure differential from one side of the building to the other, or through an internal to external temperature difference, which generates a pressure differential from inside to outside, and creates a draught.

Adequate ventilation using only windows and doors requires the occupants to open sufficiently sized windows at all times of year, which may be less likely during winter.

An alternative is passive stack ventilation (PSV). This is where openings are placed on the roof – a simple version is a skylight – while more sophisticated versions use ceiling vents and a kind of chimney. PSV combines cross-ventilation, buoyancy (warm air rising) and the venturi effect (wind passing over the terminals causing suction). Use of PSV can ventilate twice the depth into a building compared to single sided ventilation strategies and provides effective night cooling when internal and external temperatures have a higher variance increasing convection.



Passive stack ventilation
Source: Eco-home essentials

MECHANICAL VENTILATION

Where natural ventilation is not possible, Part O does allow for mechanical ventilation to be used. Mechanical ventilation involves using fans to introduce air from the outside and distribute it through a building. Examples of mechanical ventilation systems include exhaust air ventilation, positive pressure air replacement and mechanical ventilation heat recovery systems.

When using mechanical ventilation, the Dynamic Thermal Modelling option must be used to meet the Part O requirements. It triggers a change in criteria within TM59 from adaptive thermal comfort, instead, requiring a fixed threshold, meaning rooms cannot exceed 26°C for more than 3% of occupied hours.

WHY CHOOSE PASSIVE METHODS?

- Passive techniques involve low or zero energy consumption, while mechanical heating, cooling, and ventilation involve ongoing energy use and carbon emissions, even if efficient systems are specified.
- Part O's primary energy targets favour designs that reduce overall energy demand through smart passive techniques so you're more likely to get planning permission if you prioritise with passive techniques.
- Passive systems require minimal maintenance versus periodic servicing and replacements needed for mechanical equipment.
- Passive strategies are inherently robust even during power outages. Mechanical systems may fail if electricity is disrupted.
- Natural ventilation enhances indoor air quality and occupant health when applied appropriately.
- Passive systems are simpler for occupants to understand and interact with compared to complex mechanical controls.

05 Glazing

WHAT IS IT AND WHY DOES IT MATTER?

Glazing – the glass and frames in windows, external doors and skylights – has a significant effect on thermal performance.

> Up to **40%** of a home's heating energy can be lost and up to **87%** of its heat gained through windows.

In fact it's so important, the Simplified Method for Part O approval focuses almost entirely on restricting the size and orientation of glazing and openings.

Naturally, many of us want our homes filled with natural daylight and to make the most of any views we may be lucky enough to have. The key to clever glazing design is therefore maximising daylight and views, while minimising the consequent effect on thermal efficiency.

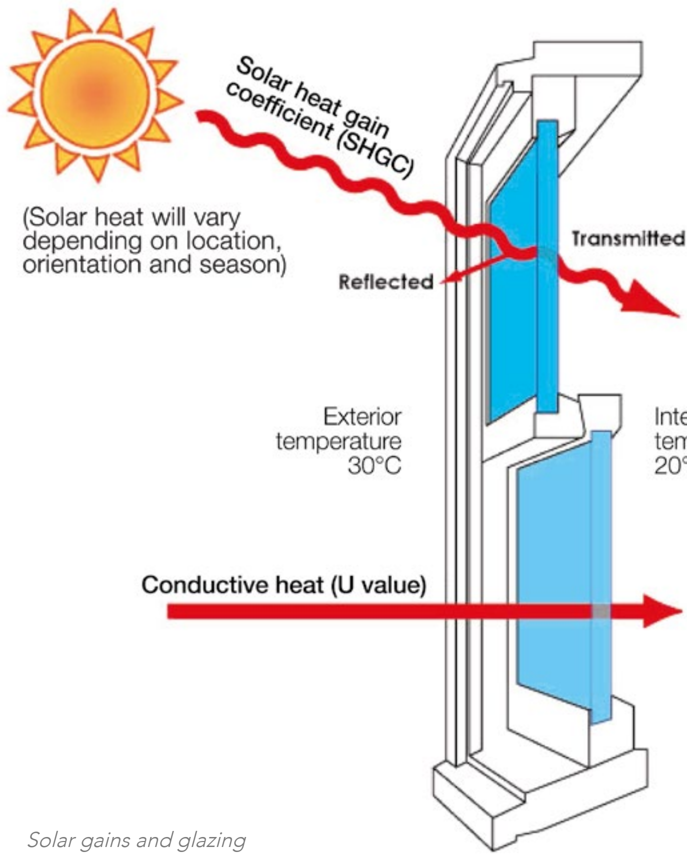
As we discussed on page 4, the same window can have different solar gain depending on its position and the season, which is why orientation is a vital consideration. But once we've decided where to put our windows, we need to think about size and type.

TELL ME MORE...

The thermal performance of a window, door, or skylight depends on how well the glass and frame conduct heat (conduction or U value) and how well the glass and frame transmit heat from direct sunlight (the solar heat gain coefficient or SHGC).

- The lower the U value, the greater a window's resistance to heat flow and the better its insulating value.
- The lower a window's SHGC, the less solar heat it transmits to the house interior.

The amount of light that passes through the glazing is known as visible light transmittance (VLT). A low VLT can reduce heat gain from the sun but if the VLT of your glass is too low, it will be too dark inside the room.



Solar gains and glazing
Source: Australian Government

05 Glazing

GLAZING CHOICES

There are a lot of choices to make when considering what type of glazing to use, from the type of glass to the fabric of the frame.

01 THE GLASS

Here are some of the options available:

- Single glazed glass is not hugely efficient when it comes to heat loss or gain so should be avoided.
- Double or triple glazed panes combine 2 or more layers of glass sealed into a frame with a gap between the layers. They generally offer better energy performance than single glazing because they transmit less thermal energy, however this depends on the properties of the glass, the contents and size of the cavity, and the nature of the sealant.
- Low emissivity glass, which uses a transparent, microscopic coating to reduce the amount of solar heat gain.
- Toned glass which reduces the window's SHGC without effecting its U value, but also changes the colour of the glass.
- Additional films with absorbent colouring or reflective properties – these are a particularly low-cost option for existing windows.

02 WINDOW CONFIGURATION

This is an important choice when balancing the size of your glazing with cross-ventilation needs. The diagram here shows how the window configuration affects the opening capacity.

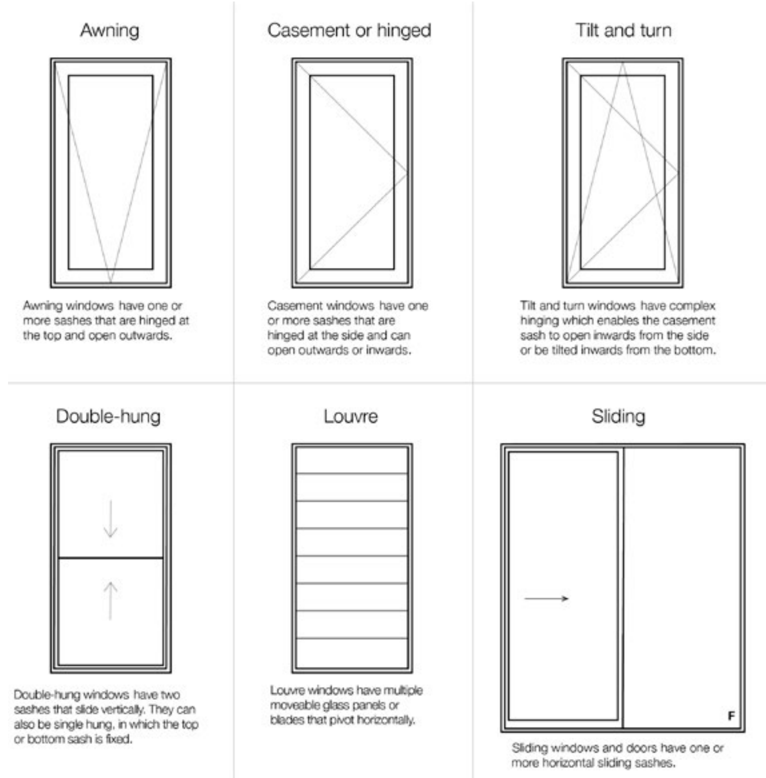
03 THE FRAME

The frame will have a significant impact on thermal performance:

- Aluminium frames are particularly good at conducting heat, and are therefore poor insulators
- Timber frames are better insulators but are liable to rot and swell/shrink with atmospheric humidity which can encourage gaps
- uPVC or composite frames provide excellent thermal performance and long-lasting solutions that require very little maintenance

04 WINDOW FURNISHINGS

External or internal furnishing like louvres, blinds, curtains can be used to improve the thermal performance of your windows, and are especially useful to add to existing windows.



Window configurations
Source: Your Home, Australian Government

06 Shading

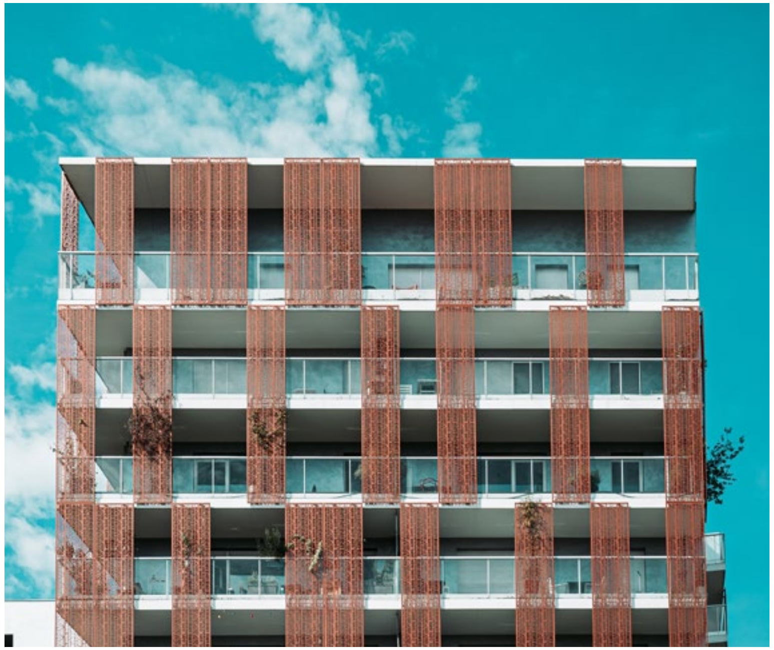
WHAT IS IT AND WHY DOES IT MATTER?

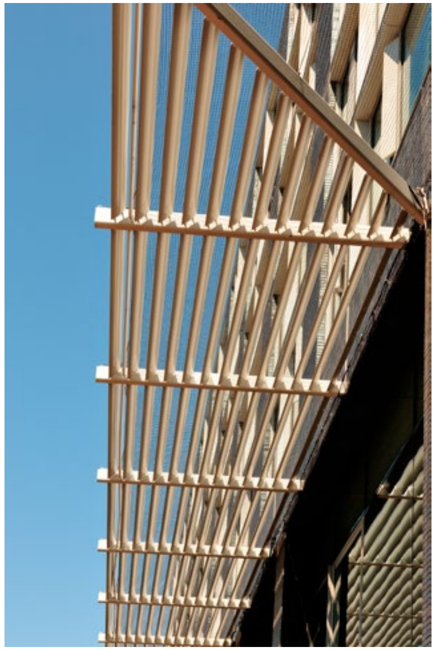
Shading your home, particularly windows and other forms of glazing, can have a significant impact on thermal comfort and energy costs.

Direct sun can generate the same heat as a single bar radiator over each square metre of a surface, but effective shading can block up to 90% of this heat. Appropriate shading design allows us to reduce summer temperatures, without interrupting winter solar gains, thereby improving comfort and saving energy.

Shading can be fixed (overhangs, brise-soleil or external structures like other buildings or natural shading) or adjustable (external louvres, pergolas with adjustable shade cloth). The type of shading you use, their position, and dimension all depend upon the orientation of the façade upon which the glazing sits (see page 12).

Below you will see some examples of how shading is creatively integrated into the design of the building.





06 Shading

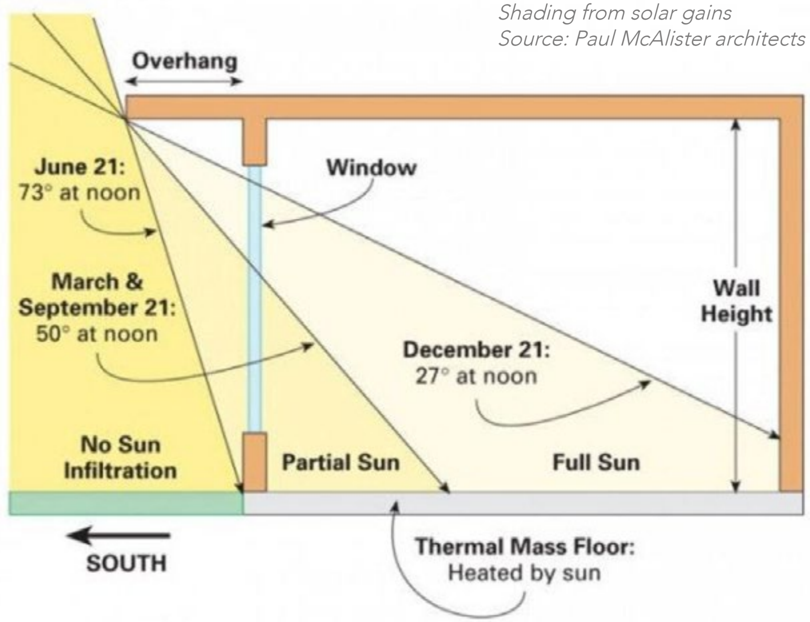
TELL ME MORE...

In designing appropriate shading for your home, it is helpful to know the angle at which the sun will hit your home – especially on any south-facing windows – in different seasons.

As we said on page 5, for most of the UK, north is the ideal orientation for glazing, where you are less likely to need shading. On south-facing façades, the easiest shading solution are horizontal overhangs that are wide enough to block high-angled sun in summer but admit low-angled sun in winter (as illustrated in the graphic below), or louvres angled to suit your needs.

On east-and west-facing façades, vertical shade structures or deep pergolas work well, particularly if they are adjustable, allowing you to let in winter sun when needed.

When implementing any mid-pane or external shading, maintenance and access for window cleaning should be considered.



Shading from solar gains
Source: Paul McAlister architects

OTHER SOURCES OF SHADING

External planting of evergreen or deciduous trees can provide good shading and can also improve cooling, air quality and the visual appeal of your home, as well as being generally positive for the environment. However, natural shade cannot be used to meet Part O specifications as it is not considered as a permanent solution.

Similarly, while internal blinds and curtains can do much to regulate thermal temperatures, they cannot be used within thermal modelling for Part O compliance. This kind of internal shading is far less effective than external options. External shading can reduce solar gain by between 80-100%. In contrast, even the most effective internal shading will only reduce solar gain by around 40% and in most cases considerably less. Internal shading can also reduce the effectiveness of cross-ventilation and are almost entirely reliant on occupant behaviour.

07 Other considerations

Overheating regulations interact with existing Building Regulations, therefore strategies need to take into account the following considerations.

NOISE

External noise will impact the ability to model windows as a means of ventilation, especially at night. Where external noise levels average over 40dB or exceeds 55dB more than 10 times between 10pm-7am, openable windows cannot be used as part of ventilation calculations. These will have to be modelled as closed which can result in a fail.

SECURITY

Where a window is accessible – like in a ground floor apartment bedroom – this must be modelled as closed at night. The only acceptable alternative which would allow accessible windows to open, are those with fixed bars or louvres.

PROTECTION FROM FALLING

Any windows used for ventilation must also include appropriate guarding to minimise risks of falling from height. In the simplified method this may result in failure as it involves restricting the opening size with fixed or lockable guards.

POLLUTION

Local sources of pollution may require limited use of windows as ventilation solutions. This will need to be analysed on a site-by-site basis but could also result in windows requiring to be closed. Any mechanical ventilation systems must take this into consideration within their design, meaning filtration and in-take locations carefully designed.

ENTRAPMENT

Where louvered shutters, window railings and ventilation grilles are used, care should be taken to ensure body parts cannot become trapped.

- They should not allow the passage of a 100mm diameter sphere.
- Any hole allowing the passage of an 8mm diameter rod should also allow the passage of a 25mm diameter rod and should not taper, this is to avoid finger entrapment.
- Any looped cords must be fitted with child safety devices.

How can Mesh help with you meet overheating regulations?

At Mesh, we work in collaboration with architects to develop practical and cost-effective solutions to guard against overheating. We cover both Part O Simplified Method and TM59 criteria and can advise on the best course of action for your project.

- ✓ You will work with a single contact from our Building Performance Team who will guide you through the process, from understanding your goals and priorities to advising you on the planning process.
- ✓ We work in collaboration with building designers to reduce overheating with a minimal impact on aesthetic ambitions.
- ✓ You will receive a comprehensive report, featuring high-level recommendations for improvement and detailed models demonstrating our conclusions.
- ✓ If mechanical ventilation is required, our in-house M&E team can provide technical feasibility solutions to bring theory to life with the most sustainable solution possible.

For more information on our overheating consultancy service, visit our website or get in touch.

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