Building Envelope Performance

Increasing occupancy comfort, health and well-being while reducing energy demand and increasing your building's value and construction standard

What's included in this fact sheet:

This fact sheet will provide you with an understanding of what is known as a 'Building Envelope'. The building envelope is essentially the main building components (walls, floor and roof) that make up a building. It is essential to understand the attributes of these components, as they all influence the building's architectural appearance, how comfortable the building is for occupants, as well as its energy efficiency and occupant amenity.

It will explain why it is so important to understand these attributes and how they influence a building's architectural appearance, environmental performance and occupancy amenity.

The term 'building envelope' or 'building fabric' refers to a building's walls, windows and doors, roof, slab, sub-floor (in the case of stump, bearer and joist construction) and floors. These are typically made up out of structural elements, external finishes, insulation, and interior finishes.

In combination, their aim is to provide a thermally efficient, durable and healthy separation between the internal and external environment.

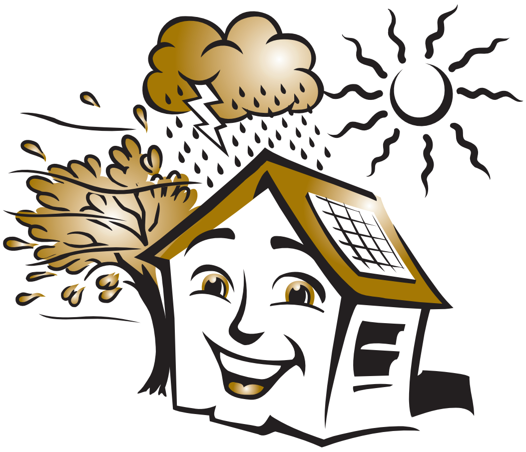
Why is the early consideration of building envelope performance so important?

The different building elements can be relatively complex, multi-layered systems, due to the multiple functions of the overall building envelope. Therefore, building envelopes are not simply barriers between interior and exterior environments. They are total building systems that create comfortable spaces by actively responding to the building's environment. The properties of a building envelope will largely determine heating and cooling loads, energy demand and greenhouse gas emissions of a building.

High-performance building envelopes go one step further, with the aim of ensuring that the least amount of energy is needed to maintain a comfortable, healthy and productive interior environment.

This fact sheet will help with further guidance on the performance of the building envelope.

It will provide an overview of the different considerations designers should take to ensure the best design, material and product selection for the development type and climate.



What drives a building envelope's thermal performance?

How will improved Building Envelope Performance benefit me?

Whether you are an owner, occupier, builder or property developer, adopting Environmentally Sustainable Design (ESD) principles in the design and construction of buildings and renovations can result in marked benefits, both now and in the future.

As an owner/occupier you can expect:

- Lower energy bills due to less reliance on mechanical heating and cooling systems.
- Improved living comfort, health and well being.
- Future proofing of your building asset and reassurance in the quality of the construction of your investment.

While developers and builders can take advantage of:

- Enhanced market appeal to prospective purchasers.
- Higher investment returns.
- Better performing building facades result in smaller and often cheaper HVAC systems.
- A development that meets best practice standards and more importantly, community expectations.
- A point of difference in the market by demonstrating high quality building construction.

Forms of heat transfer

Heat moves through a building envelope primarily in three ways: by conduction, convection, and radiation.

Conduction occurs directly through glazing, air cavities, window's spacers, window and external wall frames, noggins and spacers and is a function of the internal and external temperature difference. Heat will always be lost to the colder side of the building envelope. In summer, conduction is heat transfer from the outside, as the inside is often colder, while the inverse is true during the winter. This results in thermal conductivity bringing external heat inside during summer, making building interiors warmer, while in winter, it results in internal heating being lost to the outside. Thermal conductivity is the most important property of an insulating material and is a strategy to produce a higher-performance building envelope.

Convection occurs at the interior and exterior building envelope surfaces, and within the air cavity between glass layers of double glazing. On the interior, a cold surface (e.g. plasterboard) cools the adjacent air. This denser colder air then falls, starting a convection current.

On the exterior, the air film against glazing contributes to the window's insulating value. Higher wind speeds result in the windows being less effective at keeping the heat in, contributing to a higher heat loss.

Within the cavity, temperature-induced convection currents also facilitate heat transfer. By adjusting the cavity width, adding more cavities, or choosing a gas fill that insulates better than air, glazing can be designed to reduce this effect.

Radiation occurs due to the movement of heat as infrared energy through the glazing and building envelope. About two-thirds of heat loss is due to heat radiation from the warm to the cold side. Improving the thermal transmittance effect is therefore based on reducing heat loss via radiation. It can be reduced through the use of double glazing, glazing with a low-E coating and ensuring a continuous insulation blanket. You could also consider thermal bridging by utilising a thermal break that will improve the thermal performance of the building envelope and minimise the effects of radiation.

Building Envelope

The exterior of a building is often referred to as the 'building envelope'. The building envelope ensures that we are protected from the elements such as heat, cold, excessive humidity, air pollution, noise, wind and rain.

To maximise the building envelope's thermal protective capabilities:

- Insulate walls, floors and ceilings, exceeding minimum building code standards.
- Minimising thermal bridging within the building envelope.
- Specify high performance windows and doors (glazing and frames).
- Target an airtight envelope by draft-proofing any gaps around doors, windows, vents, and any other openings between the interior and exterior of the building.
- Perform blower door testing to identify and address all gaps and optimise the airtightness of the building envelope.
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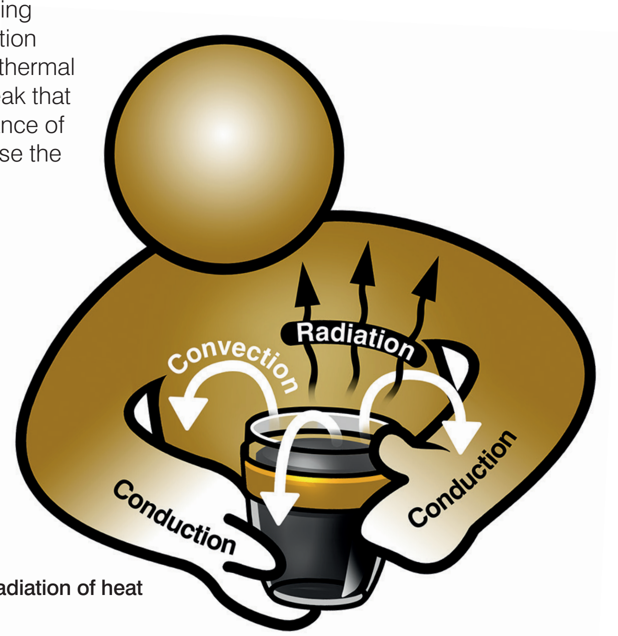
- You should also consider the use of exposed 'thermal mass' inside a building to balance a building's internal temperatures through heat storage and release.



Radiation of heat

What drives a building envelope's thermal performance?

Measuring a building's thermal performance

When considering a building's thermal performance, the two most common and important performance values are the U-value and R-value. What you need to ask yourself is whether these are being achieved for the different components of the building envelope.

The **U-value** (Wm^2/K) of a building component like a wall, roof or window, measures the amount of energy (heat) lost through a square metre (m^2) of that building component for every degree (K) difference in temperature between the inside and the outside.

When we talk about the U-Value of a component of a building such as a wall, roof or window, we're describing how well or how badly that component transmits heat from the inside to the outside. The lower the U-value, the better the thermal performance.

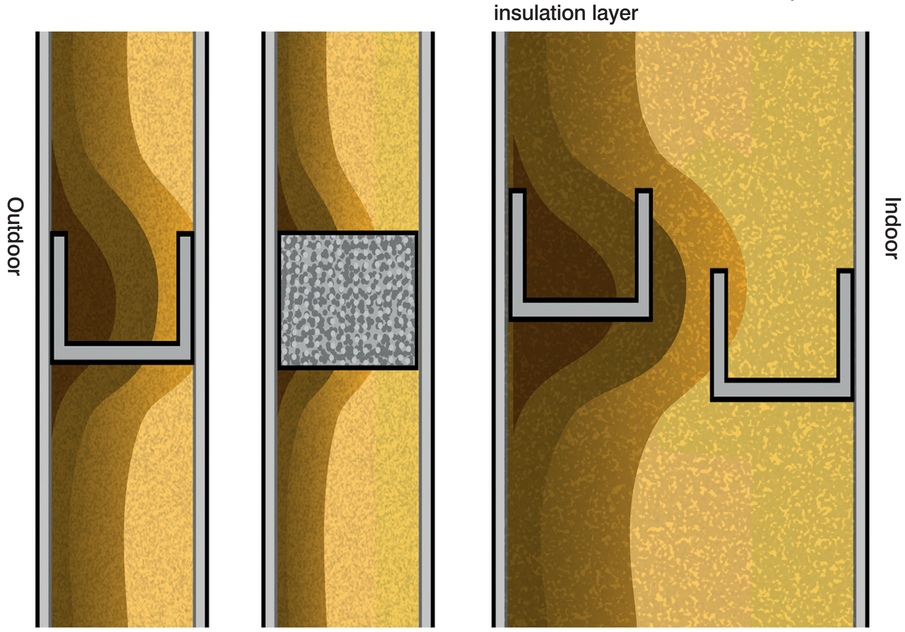
The **R-value** (reciprocal of U-value) is the thermal resistance, or how good the material is at preventing the heat passing through it, for a given thickness and area. The R-value is expressed as m K/W.

The heat flow through a building construction depends on the temperature difference across it, the conductivity of the materials and the thickness of the materials used. The temperature difference is an external factor, whereas the thickness and the conductivity are properties of the material that can be controlled. A greater thickness and lower conductivity mean less heat flow. Together, these parameters form the thermal resistance of the construction.

Thermal conductivity values are not always available from insulation suppliers or standard marketing material. Instead, thermal conductivity is multiplied by the product thickness to provide the thermal resistance value or R-value (m^{2}K/W). By adding up the R-values of all building component layers, including surface resistance values and thermal bridging effects, we can calculate the total thermal resistance or Total R-value (m^{2}K/W). The higher the R-Value achieved, the higher performing the insulation product or building component.

Comparing the U-value and R-value for different stud wall types

Steel stud wall	Timber stud wall	Double stud wall with uninterrupted insulation layer



R-value: 0.97 m2K/W U-value: 1.03 W/m2K	R-value: 1.75 m2K/W U-value: 0.57 W/m2K	R-value: 3.03 m2K/W U-value: 0.33 W/m2K

Balancing tinting with daylight

Visible light transmittance (VLT) describes the amount of visible light that passes through a window. A high VLT, such as 85% for single clear glass, means that the majority of external light enters a building's interior.

A low VLT, such as 10% for a highly reflective and tinted glass, tells us that very little of the exterior light enters a building's interior. A typical double-glazed clear window has a VLT around 54% or 0.54 This value decreases through most added coatings and tints, such as for a reduced solar heat gain coefficient, a lower emissivity or a higher reflectivity of the glass.

It is a common problem that lower SHGC glazing (good at blocking summer heat gain), will have lower VLTs and block daylight too. Different glazing products can be compared using their light-to-solar-gain (LSG) factor. LSG is the ratio of the visible light transmittance to the Solar Heat Gain Coefficient (SHGC). LSG=Transmittance (Tvis)/SHGC.

Products that can block solar radiation but allow daylight through will have a higher LSG. Spectrally Selective glazing is a specialised type of glazing that use special coatings to block solar radiation but allow daylight into a building, and typically have a LSG factor of 1.4 or better.

Selecting high performing windows

Glazing and Framing

Windows are an important element in the overall composition of a home or office. Obviously, they let in light and fresh air and offer views that connect interior living spaces with the outdoors.

At the same time, windows can be a major source of unwanted heat gain in summer and a significant heat loss in winter. Energy efficient windows make your home or office more comfortable, dramatically reduce your energy costs and help to create a healthier environment.

Better perfoming glazing

The following sections explain the key performance indicators of a window, its U-value, solar heat gain coefficient, visual light transmission, and acoustic performance.

Glazing U-Value and Thermal Performance

The thermal performance of a window is described through its U-value. The U-value stands for a material's (e.g. glass) or total system's (e.g. whole window, glazing and frame) heat transfer coefficient. It is commonly understood as the key measure of heat loss in winter.

It is also worth noting that the U-value is the inverse of the R-value, which is commonly used to describe the resistance to heat transfer of solid building materials, such as walls, roofs and floors.

Heat flows from warmer to cooler bodies. In Victoria's climate, this means that in winter it flows from the inside to the outside, and in summer, the opposite direction. This heat flow is a complex interaction of three heat transfer mechanisms - conduction, convection and radiation, that we mentioned previously.

A window unit with a low U-value between 1 and 2 (double glazed, argon filled, thermally enhanced or even broken frame) will perform much better in winter than a higher U-value of 6 or 7 (typical single glazed aluminium frame).

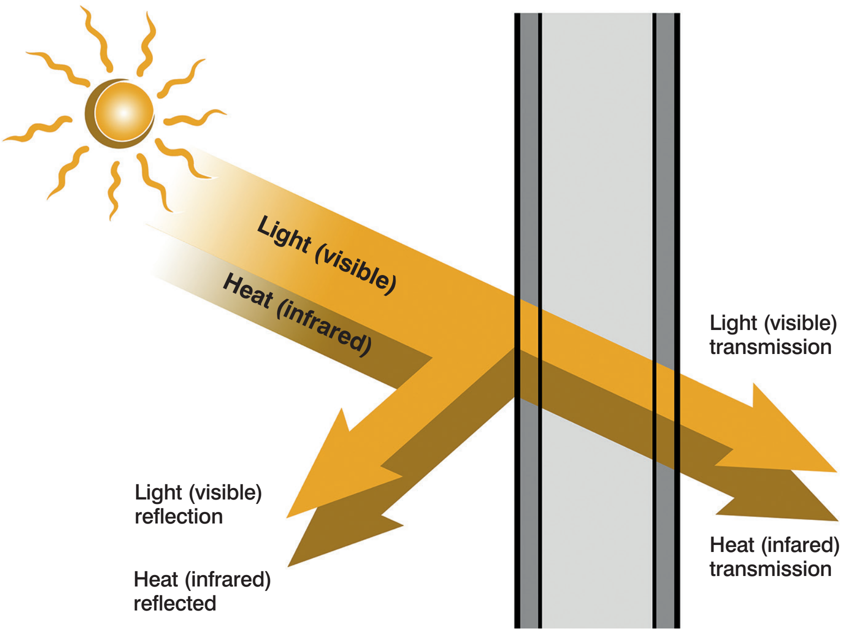
Glazing Solar Heat Gain Coefficient and Thermal Performance

Windows and glazing are also a key area for heat gain in summer. The Solar Heat Gain Coefficient (SHGC) is a measure of how much solar radiation passes through a window and is commonly expressed as a value between 0 to 1.

A high coefficient of 0.85 typical of single glazed clear glass, means that 85% of the heat can enter through the glass and is referred to as 'high heat gain'.

A low SHGC coefficient of 0.2 means that only 20% of heat will transfer through the glass and is known as 'low heat gain'.

It should be noted though that the SHGC needs to be carefully balanced between unwanted heat gains in summer and desirable heat gains in winter. As a rule of thumb, in a residential context a higher SHGC is preferred, whereas in a commercial context a lower SHGC typically leads to a better performance across the year. Furthermore, there is typically a close correlation between the SHGC and the visual light transmission (VLT) of a window. The higher the SHGC, the higher the VLT and vice versa. So choosing the right glazing product is not only about energy conversation and thermal comfort but also about internal daylight levels.



Acoustic performance

Excessive noise generated by neighbours, traffic and hard surfaces that reflect internal sounds (echo or reverb) can have an impact on an occupant's amenity and employee's productivity. In order to ensure comfortable noise levels, Council recommends considering the inclusion of acoustic insulation to internal and external walls, double-glazing to windows, landscaping that buffers traffic noise and a good balance of internal hard and soft finishes.

Windows are a key area for sound and noise to travel into and out of a building. Poor acoustics in a building can lead to reduced privacy and even a bad night's sleep. Considering the use of double or triple glazing, laminated glass, thickened glass and ensuring an airtight building envelope, is a great way to improve acoustic performance, increase thermal comfort and reduce energy consumption.

Thermal Bridges

A thermal bridge is an element of the building envelope with less insulation, or reduced insulation performance, relative to the adjacent areas of the thermal envelope. This particular location within the building envelope provides a path of least resistance (a "bridge") for heat to move through. During winter, this means additional heat will be lost through these specific locations of the building envelope. During summer it is the opposite, a thermal bridge will allow unwanted additional heat to pass through the thermal envelope into the building. In Victoria's climate which experiences extreme heat during summer contrasted with cold winters, it is very important to consider thermal bridging in the building envelope.

It is important to note that Thermal bridges not only increase energy demand and decrease occupancy comfort, but that they can also lead to construction damage as colder spots can lead to condensation of the warm moist indoor air and lead to respective corrosion and mold growth within the construction. Avoiding thermal bridges is therefore a way to reduce the risk of structural damages and health risks.

Thermal bridging is now part of National Construction Code and designers should be giving careful consideration to the different thermal bridges that can occur within a building envelope.

Thermal bridges can occur at several locations within a building envelope. Summarised below are the main types of thermal bridges:

Construction thermal bridges are the most common type of thermal bridge. A construction thermal bridge occurs when a physical material, a gap or a component passes through the insulation or thermal barrier of the building envelope. When the material or component conducts heat better than the insulation it effectively forms a bridge allowing heat to transfer between the inside and the outside. Some examples of this include:

- Any component of the building envelope that passes through the thermal envelope to the internal, e.g. bracing for shading or uninterrupted balcony slabs as per the image right.
- Gaps left between insulation board.
- Roof/Ceiling-to-wall junctions, especially where full ceiling insulation depths may not be achieved.
- Window-to-wall junctions.
- Door-to-wall junctions.
- Wall-to-wall junctions.
- Wood, steel or concrete members, such as studs and joists, incorporated in the exterior wall, ceiling, or roof construction.
- Recessed downlights that penetrate insulated ceilings.
- Windows and doors, especially frame components.

Structural elements remain a weak point in construction, commonly leading to thermal bridges that result in high heat loss and low surface temperatures on the interior side of the building envelope.

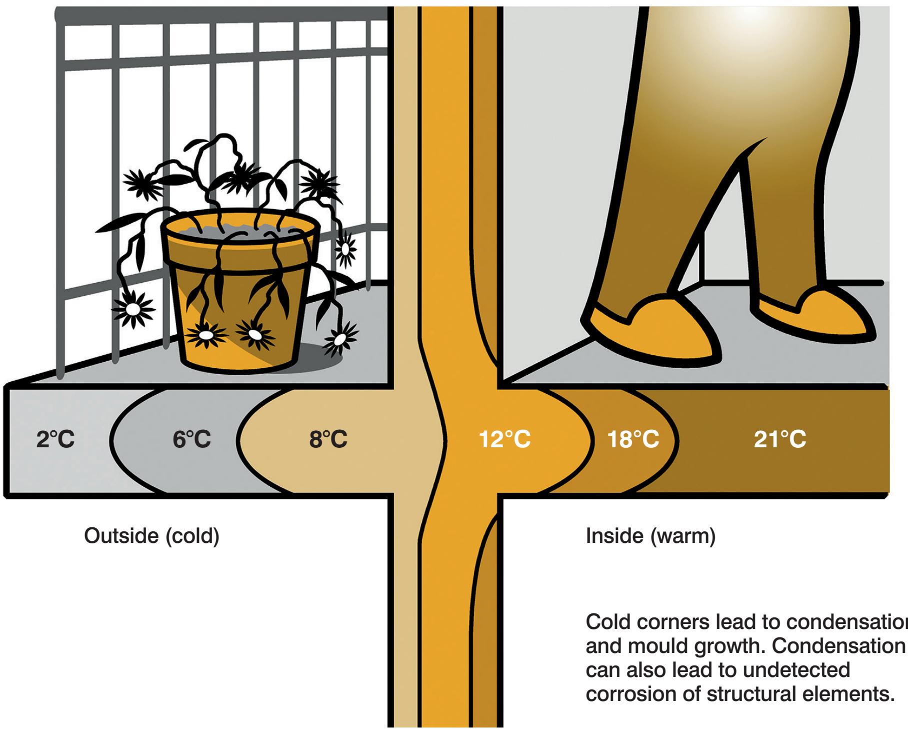
Construction thermal bridges can usually be avoided or minimised with careful design. When designing a high-performance building envelope, the consideration of thermal bridging becomes critical.

Geometric thermal bridges are where the geometry of the thermal envelope causes increased heat loss to some locations within the building envelope. Geometric thermal bridges do not form a literal bridge in the way construction thermal bridges do. And they can occur where full insulation thickness and continuity is maintained. Typically, a geometric thermal bridge is where the external heat loss area is greater than the corresponding internal area of the thermal envelope. Some examples of this include:

- External wall corners.
- The eaves junction.
- The ground floor and external wall junction.
- Around window and door openings.

Geometric thermal bridging is unavoidable. However, geometric thermal bridging increases with the complexity of the building form. Therefore, by keeping the building's design simple, geometric thermal bridging can be minimised.

Typical temperature gradient in an uninterrupted floor to balcony slab



Cold corners lead to condensation and mould growth. Condensation can also lead to undetected corrosion of structural elements.

National Construction Code Section J 2019 vs 2016 and Thermal Bridging in Non-Residential Developments

As of May 2020, the 2019 provisions of the National Construction Code of Australian Section J requirements have now been mandated in Victoria.

The biggest change within the updated provisions is the calculation of building fabric R-values and U-values, which now includes the assessment of regular thermal bridging. Thermal bridging presents the net impact of lowering the total thermal performance R-value of a construction, therefore requiring more insulation to achieve the same total R-value as a non-bridged construction.

To illustrate this change and the impact on total R-value calculations, the table on the right provides a summary of external wall constructions with total R-values calculated to both NCC 2019 Section J and 2016 version.

It should be noted that wall constructions that may have complied under NCC 2016, may no longer comply under NCC 2019. This is also possible for roofs and other elements of the building envelope.

Wall structure	Timber Framed Wall 90mm Glasswool	Metal Framed Wall 90mm Glasswool
Wall cladding	Plasterboard internal, weatherboard external	
Insulation performance (m2/KW)	R 2.0	R 2.0
Total system wall performance requirement under NCC 2016	R2.8	R2.8
Actual total system wall performance under NCC 2016	R2.9	R2.9
Total system wall performance requirement under NCC 2019 for apartments and commercial buildings	R1.0 – 1.4, depending on window to wall ratio	
Actual total system wall performance under NCC 2019 for apartments and commercial buildings	R1.75	R0.97
Total system wall performance requirement under NCC 2019 for single dwellings	As per NCC 2016. Assessment requirements are however expected to change in line with NCC 2019 for apartments and commercial buildings with the upcoming NCC 2022.	

Building Air Tightness

The practice of testing whole building's air tightness (or air permeability) is common in Europe and North America as it is recognised that well sealed buildings perform measurably better in a number of different ways.

A leaky building requires significantly more active heating and cooling to maintain comfortable indoor temperatures, just like a sieve cannot hold water!

Australian building's air tightness is comparably very poor and contributes to poor energy efficiency and thermal comfort and the increased risk of structural damages. At this point, there is no legislative requirement for whole building air tightness testing in Australia.

However, Council encourages applicants to be ahead of the curve by considering building designs and constructions that aim for airtight building envelopes.

An airtight building envelope needs to be designed into the building during the initial concept design stage. A continuous airtightness barrier system is the combination of interconnected materials, flexible sealed joints and components of the building envelope that provides the airtightness of the building enclosure and a separation of heated and unheated spaces.

The first step of designing for an airtight building envelope is to define an airtightness performance target and take into account what practices, materials and products should be used. Building air tightness can be measured as a q50 measurement, which relates to air permeability, in m3/h/m2@50Pa, or in other words the air leakage per square meter of building envelope. Alternatively, the high-performance building standard 'Passive House' requires building air tightness as

a n50 measurement, or air changes per hour (ACH) @50Pa, or in other words the number of times the volume of air within the building is changed in an hour at a pressure of 50 pascal.

The pressure of 50 pascal is comparable to a strong wind of 30km/h.

Concerned about air quality? Building airtightness can go hand in hand with effective natural ventilation or mixed mode

Ventilation systems. In our Victorian climate it is important have the ability to fully seal a building when outdoor temperatures are uncomfortable. When temperatures are comfortable though, buildings should be opened up to make the most out of the many benefits that come with natural ventilation.

Summarised below are the best practice targets recommended for both a residential and commercial development:

- Green Star best practice standard: $3.0 m^3/(h.m^2)$ at 50 Pa.
- Passive House standard: 0.6 ACH at 50 Pa.

Refer to the Green Building Council of Australia, Green Star for New Buildings guidelines for further guidance on best

practice air tightness performance targets for different building typologies development types.

Guidelines for improved Building Envelope Performance

Designing for Victoria's climate

Victoria's climate changes significantly with the seasons and often is described as having four seasons in one day. But how do you design buildings for a climate such as this?

In Victoria, dwellings are typically heating dominated, which means they benefit from combined strategies of increased solar transmittance, daylight, passive heating, heat storage and reduced thermal transmittance.

In summer though, solar transmittance control (typically through external shading) becomes more important, as does the efficiency of ventilation (natural or mechanical) and air-conditioning systems.

By considering the information and guidance provided within this fact sheet, we can create developments that are designed to not only accommodate but utilise Victoria's diverse climate in ways we never imagined.

Council's Design Advice

- A facade and building design that responds to local climate conditions.
- Minimum 7 Star NatHERS ratings for residential buildings.
- Non-residential buildings should aim to exceed minimum NCC 2019 requirements.
- Exterior shading on all north, east and west facing glazing that is adjustable and/or responds to summer and winter sun angles accordingly.
- Detailed construction methods that address thermal bridging and air leakage.
- High performance glazing that responds to orientation and optimises daylight access and thermal performance.

Where can I find out more?

Speckel: to calculate total system R-values
https://speckel.io/

Passive House Australia
https://passivehouseaustralia.org/

Technical Manual Passive Design, Your Home
www.yourhome.gov.au

Moreland Apartment Design Code
https://bit.ly/3bl8a1i

BESS Tool Notes Energy
https://bess.net.au/tool-notes/

Better Apartment Design Standards
https://www.planning.vic.gov.au/policy-and-strategy/better-apartments/better-apartments-design-standards

Sustainability VIC, Energy Smart Housing Manual
https://bit.ly/2SQeUhD

Green Building Council of Australia, Green Star for New Buildings Submission Guidelines
https://new.gbca.org.au/

Other existing CASBE Sustainable Design Fact Sheets
www.casbe.org.au/what-we-do/sustainability-in-planning

Environment Design Guide papers
Lyons, P. 2004. Properties and rating systems for glazings, windows and skylights (including atria). Environment design guide, PRO 32. Australian Institute of Architects, Melbourne. acumen.architecture.com.au/environment

Other Fact Sheets in this series are available to provide guidance on Energy efficiency and environment quality that encompass building envelope performance. Those Fact Sheets are entitled:

- 1.1 Indoor Environment Quality
- 1.2 Natural Ventilation
- 1.3 Daylight
- 2.0 Energy Efficiency
- 2.1 Sun Shading
- 9.1 Melbourne Climate

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