Glazing for non-residential buildings under NCC2019 – products, costs, and market insights

Final Report

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Executive Summary

This report contains the results of research into glazing products used in non-residential buildings. It has a particular focus on products likely to be used following energy performance requirements in the National Construction Code (NCC) Volume 1, Section J. The current requirements were introduced in 2019 (NCC2019), with the next regulatory window for review and potential update scheduled for 2025.

The report identifies specifications, performance levels and prices for products typically used in non-residential construction. These results are provided in section 4.1.

Modelling and analysis for the development of requirements for NCC2025 draws particularly on results for fixed frame windows. *Table 1: Aluminium complete fixed frame systems - performance and costs* on page 12 contains this information. This report also provides insights into the market and industry response to NCC2019.

An important observation is that the glazing industry is well-positioned to supply products for buildings designed to NCC2019. Standard aluminium double glazed frames using glass with relatively good insulative properties (indicated by U-value) and good control of solar heat gain (indicated by Solar Heat Gain Co-efficient – SHGC) are readily available and will become more widely used.

Similarly, thermally broken frames coupled with high performance glass are available and are expected to achieve greater market penetration as buildings designed to NCC2019 are constructed.

We find that improvement in glazing performance standards within the Australian construction industry is driven by Code changes. Innovation and investment tend to follow, rather than lead, the Code, as Code requirements have a major impact on the products and specifications demanded by the market. This, in turn, has an important impact on the riskiness of, and return on investment on, innovation. Examples were provided to the research team whereby companies invested in high-energy-performance capacity in anticipation of Code changes, which then did not materialise, leading to that capacity sitting idle or under-utilised for many years.

At the same time, the glazing industry has strong capacity to innovate when the Code and market is supportive of this. There is sufficient competition to ensure products are supplied at cost-effective prices.

A common view in the glazing industry is that a lack of a rigorous Code compliance and enforcement impacts negatively on the further development of the local glazing industry, particularly at the high-performance end of the market. The glazing industry supplies what its customers demand. If Code compliance and enforcement is not rigorous, then below-specification glazing can be a profitable choice for the construction industry. As a consequence, opportunities for growth of the local glazing industry that would bring increased investment and employment are being foregone, while below-specification glazing will contribute to unnecessarily high energy use and carbon emissions, along with reduced building occupant comfort and wellbeing.

1. About this report

1. Purpose

The NCC, Volume 1, Section J deals with energy efficiency in commercial buildings.

The next scheduled opportunity for updates to Section J is expected in 2025.

In preparation, the Department of Industry, Science, Energy and Resources is managing a suite of research and analysis projects for completion by mid-2021 to ensure inclusion in the ABCB work plan.

A key area of Section J is glazing. Significant changes to the glazing requirements occurred under NCC2019. The 2019 settings were determined back in 2017. Since then, there have been shifts in building designs, glazing product options, and glazing costs.

This project examines the state of play in non-residential glazing products so that potential settings for the 2025 version of the Code (NCC2025) can be based on a sound understanding of product availability and costs.

A key task in the development of NCC2025 settings is cost-benefit analysis to assess the cost-effectiveness of potential settings. This project will support the cost-benefit analysis with data on common specifications of products, and their costs, that are used in the construction of non-residential buildings in Australia.

The second purpose is to capture industry data and insights into glazing and construction practices and trends related to glazing. This information will support development of the NCC and buildings policy more generally.

1.1 Context

Glazing is intrinsic to the functionality, as well as to the energy performance, of most building types. Retail, office, apartment, education, and health spaces all need glazing to provide visibility and natural light. At the same time, glazing provides a ready pathway for heat and cold to pass in and out of buildings – particularly when compared to walls, floors, or other building elements. It can also admit unwanted glare. Heating, ventilation, and cooling services then need to work harder to maintain occupant comfort. This means that changing glazing specifications can be a very effective strategy to improve overall building energy performance – albeit that it is only one amongst many.

The latest version of the energy efficiency requirements in the Code (Section J of NCC 2019) included significant changes to thermal performance requirements for non-residential buildings, and specifically for wall and glazing systems. The new approach recognises that the performance of the whole wall system should be considered, including window-to-wall ratios, glazing U and Solar Heat Gain Co-efficient (SHGC) values, thermal bridging and whole-of-wall system R-values for different façade aspects, climate zones and building classes. At the same time, the intent was to simplify and address shortcomings in the previous glazing calculator used in NCC2016 and earlier versions of the Code.

In addition to Code changes, the Australian and international markets for glazing products – and construction practices more generally – continue to evolve, impacting on energy performance outcomes and costs. In the short-to-medium term at least, the current coronavirus pandemic may be having additional impacts on practices and costs.

The department is keen to gather information on these issues to assist in its twin roles of providing information to all three levels of government related to buildings policy and informing the evolution of the NCC.

2. An overview of glazing market dynamics

This section gives a brief overview of the elements of glazing systems and how the glazing industry in Australia combines to supply products for the construction market.

2.1 Glazing systems and components

A glazing system is defined here as the windows, doors, or walls of buildings, which contain glass.

The three main components of the glazing system are the glass; the framing material which holds the glass in place; and hardware – such as locks and handles.

An example of a simple glazing system is a single glazed, fixed aluminium frame window. This product offers a high level of clarity and visibility, but limited performance on light control, solar heat control and thermal efficiency grounds.

An example of a highly sophisticated glazing system is a double glazed, low-e, thermally broken framed product. Here the glazing product serves several purposes - allowing light, visibility, and access to the building in a controlled thermal efficiency.

Some of the main terms and components used by the glazing industry are defined below[1].

U-value is a measure of the non-solar heat gain through the glazing system. The lower the U-value, the better the resistance to heat flow. U-values can be applied to glass only products (expressed as U_g or U_{glass}) or whole glazing systems (expressed as U_w). This project restricted scope to whole-system U-values.

Solar Heat Gain Coefficient (SHGC) is a measure of the extent to which heat from direct sunlight flows. The lower the number, the less heat that is transmitted. SHGC can be applied to glass only or whole-system products. Again, this project looked at whole system performance only – which is fully expressed as $SHGC_w$.

Visible Light Transmission (VLT) or Visible Transmittance (T_v) is the percentage of visible light that passes through the system. Lower numbers indicate less light transmittance.

Float Glass is the glass sheets that are produced in the plant that combines raw materials (mainly silica), melts them in a furnace, floats the molten glass onto a molten tin bath to form a sheet which is then gradually cooled (annealed). It is also called annealed glass.

Low-E Glass or low emissivity glass is float glass which has a thin metal coating on one side which improves the thermal and solar heat control properties of the glass.

Tinted Glass is float glass with metal oxides added to produce tints such as blue, grey, bronze and green. Tinted glass can influence SHGC and VLT but not U-value.

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[1] These definitions are drawn (approximately rather than precisely) from *A Guide to Glass and Glazing: A Handbook to AS1288, Version 3, October 2017* published by the Australian Window Association (now Australian Glass and Window Association). We recommend this publication to those wanting more technical detail on glazing componentry and characteristics.

Low-e hard coat glass (HC) is also called pyrolytic low e glass. It is a type of float glass where the surface layer that gives the glass the improved U-value and SHGC is hard and fairly durable. It can be used in single or double-glazed products as the coating can be exposed to air and cleaned.

Low e soft coat glass (SC) is also called sputter coat glass. Sputter coatings are extremely thin layers that offer substantial gains in U-value and allow low SHGC ratings while still admitting high levels of visible light. They are relatively fragile and not suitable for use in single glazed products. Soft coats are used in double-glazed units with the sputter coating facing the inside of the unit, thus protected.

DGUs are Double Glazed Units.

IGUs are Insulated Glass Units – which can be double or triple glazed. The sheets of glass are separated by a spacer and sealed. The gap can be filled with air, or argon gas is commonly used as this improves U-value. IGUs provide superior U-value to a single-glazed unit. The U-value and SHGC of the IGU is then further influenced by the choice of glass.

Frame – the support structure that surrounds the glass unit.

Float glass plants produce float glass in clear, tints and low-e forms in a variety of thicknesses and widths. There is just one plant in Australia. It can produce clear, tinted and low-e hard coated float glass – but not low-e soft coats.

Glass processors purchase float glass and process it into IGUs. They also strengthen and laminate glass to improve wind ratings and acoustic control. There are several processors in Australia who buy a combination of locally produced and imported float glass.

Aluminium extrusions are the lengths of aluminium extruded into lengths of particular shapes, ready to be cut and fabricated into frames.

Fabricators take aluminium extrusions to make a frame, insert glass units and hardware to make the complete glazing product. Fabricators can also use timber, uPVC or fibreglass as the frame material instead of aluminium.

Curtain walls are non-load bearing panels that can be used to make the façade of a building. Generally aluminium framing is used to surround glazed and non-glazed panels. Construction of stick build curtain walls occurs mainly on-site, with the wall being assembled piece by piece – or stick by stick. Unitised curtain walls combine large, one storey, units that include the frame, glazing and other panels. The units are assembled in a factory and then installed on-site. Unitised construction is more efficient than stick build and allows faster on-site construction times. We understand that stick build curtain walls are becoming rare in Australia. The curtain wall prices and specifications in Table 4 are for unitised curtain walls.

2.1.1 Overview of the glazing supply industry in Australia

There is a multitude of firms with widely varying roles and sizes comprising Australia's glazing industry.

A summary of the major steps and roles in the manufacture of glazing products is shown below:

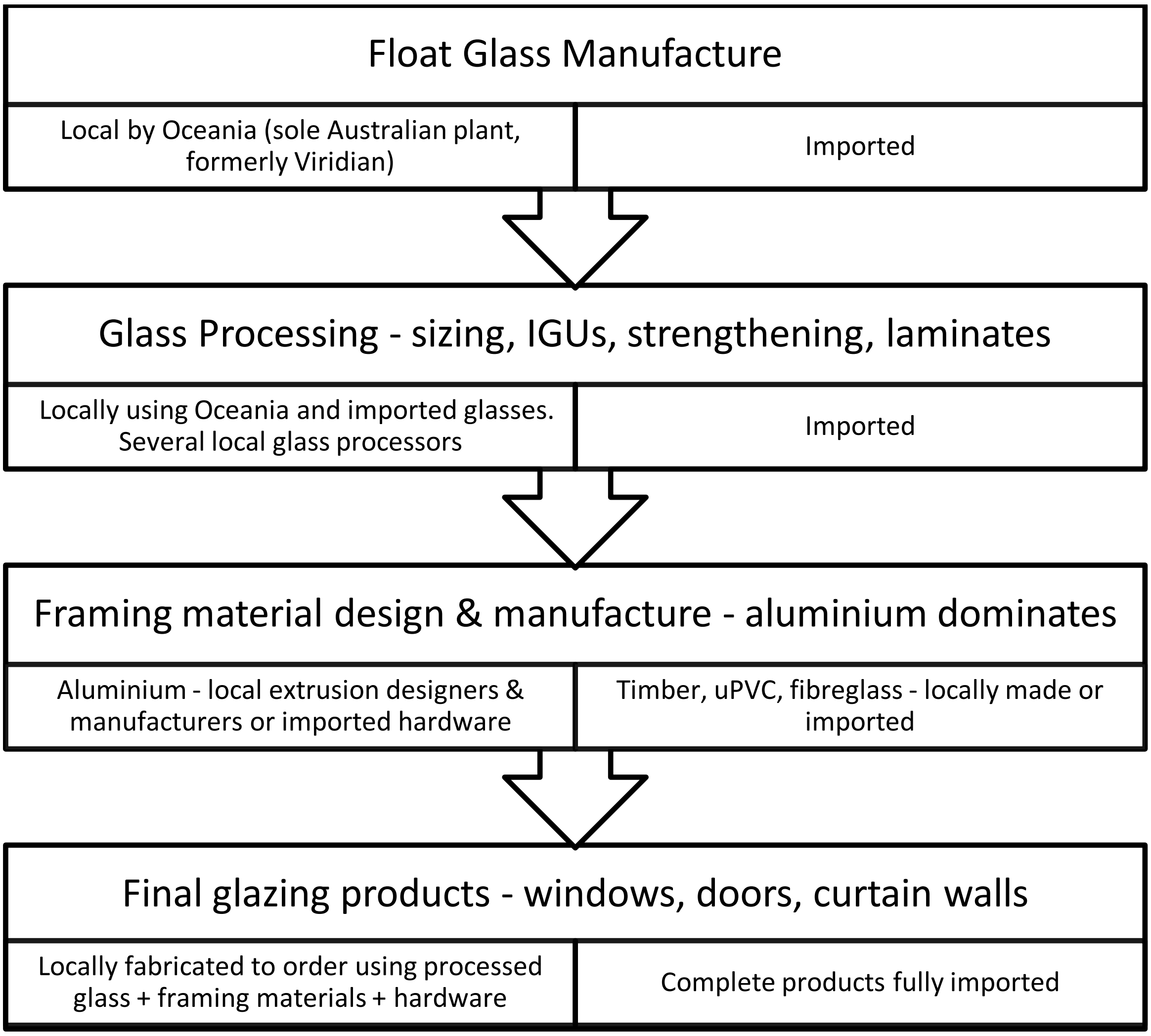

Figure 1: Roles and steps in the supply of Australian processed glazing products

3. Methodology

Close collaboration with Australian Glass and Windows Association (AGWA) was a feature of this project. Both SPR and the department would like to express their gratitude to AGWA for their project guidance and assistance with member engagement.

A summary of the project's approach and method is illustrated in Figure 2, followed by further explanation and detail.

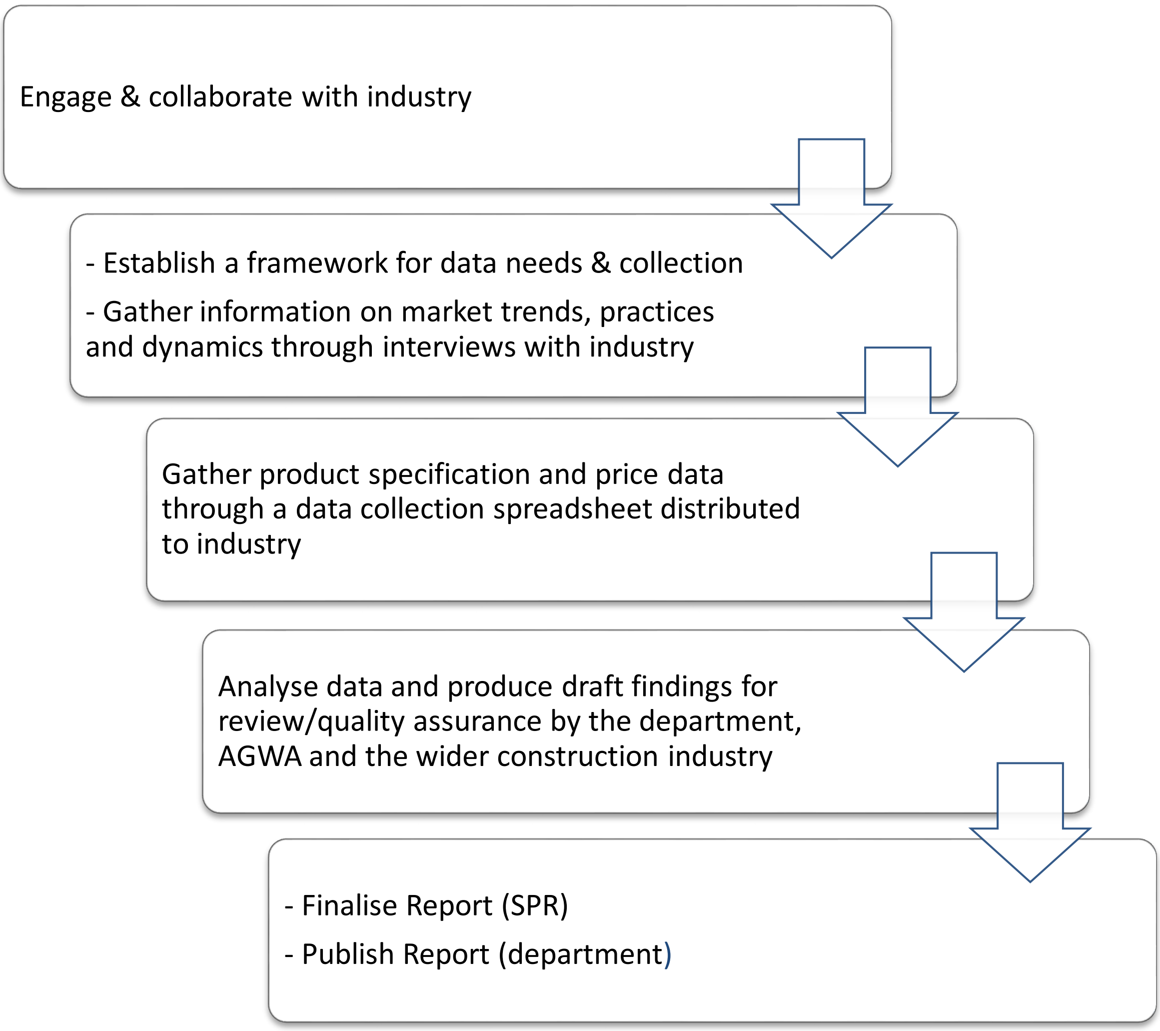

Figure 2: Glazing research project - process summary

This project was designed to be highly collaborative from the outset. The department was aware of the need for industry input and gained AGWA's agreement to participate prior to the commissioning of SPR as the research consultant. The department had also established potential information pathways into the wider construction industry with support from the NSW Government's Department of Planning, Industry and Environment, and the Better Buildings Partnership.

Project inception established an informal project committee with members from the department, the NSW Government, AGWA and SPR. It was agreed that the key challenges were to:

- Establish *what* information was required. Given the extensive variation in precise product specifications, a method of narrowing focus onto more approximate product types was required. Sufficient types were needed to provide a reasonable picture of common glazing product types and prices. Broader market information requirements also needed to be defined.
- Establish *how* to gather that information.

SPR then worked with AGWA to develop a three-stage request to industry.

Stage 1 was a call for interviews. AGWA kindly forwarded our request to their members. Requests to the wider construction industry also went out via LinkedIn channels, NSW Government industry contacts and industry groups such as the Better Buildings Partnership.

Eleven glazing industry participants and two construction industry participants agreed to discuss the 'what and how' of product specification and prices. The results reported in section 3 draw on the information provided in these interviews, especially the qualitative findings discussed in section 3.5. Industry also provided broader information on glazing market dynamics and trends – these are discussed in sections 4 and 5.

Stage 2 was a call to the glazing and construction industries to complete a data collection spreadsheet, comprising a products specification matrix and a short questionnaire. The collected data is the basis of our findings in section 3.1 to 3.4.

Both the interviews and spreadsheet data collection were conducted on a confidential basis. The contributors agreed to provide confidential data on the condition that it was de-identified and not linked to any specific source. Several glazing industry participants provided data, and a single construction/developer provided a small amount of information.

The third stage was data verification. We provided interim performance and cost results to AGWA for discussion with their members. The interim sheet was also provided to the Better Buildings Partnership, NSW Government construction industry contacts and a small number of individual constructors. AGWA provided feedback on behalf of their members. Unfortunately, no comments were received from the wider construction industry.

The department facilitated the sharing of cost and performance data from Tony Isaacs Consulting on glazing products used in residential buildings. This data was used to sense-check the non-residential results rather than as a direct input into the analysis.

The process of analysing the collected data is explained below.

3.1 Analytical Method

The three main goals of the data collection and analysis were to:

1) Identify commonly used glazing products – those that can be considered typical.

2) Establish the energy efficiency performance of those products – with approximate U-Values and Solar Heat Gain Coefficients (SHGC).
3) Establish the approximate cost per square metre of those products in different locations.

The resulting list of products, performance levels and costs can be used to estimate the approximate glazing costs for widely ranging building designs in different climate zones.

3.1.1 Identifying common products

It is important to recognise that the research was not aiming to establish a full and precise picture of all the glazing products used in Australian buildings.

There is an almost infinite number of building design and glazing combinations that apply in the Australian construction landscape. Non-residential building designs are unique, varying according to use, site, and regulatory requirements. Then there are a huge number of possible glazing options, with an abundance of choice in construction method, glass types and specification, framing types, size, etc.

Accordingly, there are no standardised glazing systems (such as a complete window) for which specifications and prices are published on a catalogue.

Instead, there is a many-step process of reaching the final product and price list. Many suppliers publish specifications of glazing product series (rather than complete units). These specifications are for various combinations of glass and frame. The Windows Energy Rating Scheme (WERS) database contains 20,209 different product series that are registered and rated for use in the commercial building sector. Each of those series can come in different sizes – so the total number of final product options is huge.

The wider construction industry (designers, energy efficiency and Ecologically Sustainable Design (ESD) consultants, builders, etc.) can select options from the suite of products. Typically, the options are developed on a project-by-project basis and refined with interaction between a few glazing suppliers and the client, until a preferred set of solutions that best meets the building client's performance and price criteria is selected.

The final set of specifications, sizes and prices are only known by the building client and the successful glazing supplier.

Given this situation, we asked industry to identify relatively common product types, where similar versions, with approximately equivalent specifications, are produced by many competing suppliers.

The products are shown in section 4.

3.1.2 Establishing performance levels related to energy efficiency

The project focused on the two aspects of glazing product performance that play a role in the energy efficiency of a building.

The U-values and SHGC measures cited in section 4 were provided by glazing industry sources, as representing typical results for common glass types within fixed aluminium centre glazed frames.

SPR then used a combination of other data provided direct by industry, WERS search results and advertised product specifications to develop the approximate impact of different frame types on U Values and SHGC.

Visible Light Transmission

The U-value and SHGC of a glazing system affects Visible Light Transmission (VLT), another aspect of glazing performance. VLT can influence energy consumption as the use of natural light can reduce the use of electric internal lighting. This project reports glass only VLT measures, as VLT changes significantly depending on frame type and size.

Several glazing industry sources noted that it is important to understand the general relationship between VLT and heat flows.

In simple terms a lower SHGC necessitates a lower VLT – but this is not a fixed relationship. High-performance double-glazed systems that use low-e sputter coated glass can achieve low U-values and SHGC while allowing high levels of light transmission. Low e hard coated glass can provide good U-values and SHGC but VLT and clarity is not as well controlled as by their soft coat equivalents. Non-low-e tints control light and solar heat gain, but not U-value.

Selectivity

Selectivity or Light to Solar Gain (LSG) is a performance factor used in the US in the commercial glazing sector.

Selectivity shows the relationship of SHGC and VLT through the LSG ratio with VLT divided by SHGC.

Higher numbers indicate better performance – good transmission of light with low solar heat gain. Hard coat low-e products will generally have a LSG of below 1.25. Soft coat low e products will have a LSG of 1.25 up to 2.44.

Given the benefits of combining good solar heat control performance with high levels of visible light, it would be useful for the LSG performance measure to become more widely used in Australia.

Non-energy related glazing performance

Other aspects of glazing product performance include wind load resistance, impact resistance and acoustic performance.

Broadly speaking, these areas of glazing performance are somewhat independent from U-value and SHGC.

The thickness and use of laminated glass (sheets of glass joined with an interlayer) are the factors that influence strength and acoustic performance. Additional thickness adds strength, while the interlayer (typically PVB – polyvinyl butyral) which bonds the glass sheets together also prevents shattering into large and sharp pieces. The PVB also improves acoustic performance – providing a sound insulating effect.

These thickness and laminating factors work separately to the hard coat or soft coat low-e coatings that are used to influence U-Value and SHGC.

For example, two double-glazed systems using different glass thickness and laminate specifications, but the same low-e coatings will have very similar U-value and SHGC, but different strength and acoustic properties.

Performance measurement - rating methods

The U-values, SHGC and VLT scores shown in the report are results obtained under the Window Energy Rating Scheme (WERS). WERS is accredited by the Australian Fenestration Rating Council (AFRC) and follows the AFRC rating protocols. Those protocols largely follow the US system, developed by the National Fenestration Rating Council (NFRC) which is based on ISO15099.

The NFRC/AFRC protocols are used in Australia, the US and Canada. However, in Europe, a different set of glazing performance tests and rating protocols are followed. These deliver different U-value and SHGC values for the same product. Generally speaking, the European system delivers lower U-values and higher SHGC than the AFRC system – therefore ratings produced under the different systems are not comparable.

This issue is discussed further in section 5 as it is an ongoing issue of concern for the Australian glazing and construction market.

3.1.3 Estimating Costs

The costs shown in the following section were estimated using a two-step process.

The first step was to develop interim estimates using the various data provided by industry. We also gathered data on the extent of discounts for large orders. Medium orders were roughly defined as those worth a total of $100,000 to $500,000 delivered. Large orders are those with a value over $500,000. Small orders are under $100,000. We did not collect pricing on small orders as they represent less than 20% of the total non-residential market.

The interim version of costs and prices was then sent out to industry for review and feedback. The results are provided below.

Note that we aimed to estimate a competitive price for a reasonable sized order of a typically used product. This is not necessarily an average price. Smaller orders would come at a greater cost. Also, there is likely to be variability in pricing for some products as the market becomes accustomed to NCC2019. For instance, in some parts of Australia, such as QLD and WA where the market has not previously demanded large quantities of double-glazed products, average prices in those locations might lag behind the national competitive price point as the local industry tools-up for the shift in product demand.

4. Glazing Products and Costs – summary of findings

This section presents a summary of findings across the main areas of research.

4.1 Complete Glazing Systems - Specifications and Costings

The four tables below show typical performance and prices for several generic frame types and construction methods.

Table 1: Aluminium complete fixed frame systems - performance and costs

Frame Type	Glazing	U_w	$SHGC_w$	VLT Glass Only	$/sqm - medium order	$/sqm - large order
Fixed single glazed	Single Glazed Clear	6.1	0.75	88	200	165
Fixed single glazed	Single Glazed Tint	6.0	0.53	42	210	175
Fixed single glazed	Single Glazed HC Low-E - Clear	4.1	0.64	81	220	185
Fixed single glazed	Single Glazed HC Low-E - Neutral	4.2	0.49	63	230	190
Fixed single glazed	Single Glazed HC Low-E - Grey	4.2	0.43	40	240	195
Fixed double glazed	Double Glazed Clear	3.5	0.64	80	280	240
Fixed double glazed	Double Glazed Tint	3.5	0.42	40	300	265
Fixed double glazed	Double Glazed SC Low-E - Clear	2.5	0.53	79	310	275
Fixed double glazed	Double Glazed SC Low-E - Neutral	2.4	0.25	66	360	325
Fixed double glazed	Double Glazed SC Low-E - Grey	2.4	0.21	39	370	335
Fixed double glazed thermally broken	Double Glazed Clear	2.9	0.64	80	320	270
Fixed double glazed thermally broken	Double Glazed Tint	2.9	0.42	40	340	295
Fixed double glazed thermally broken	Double Glazed SC Low-E - Clear	1.9	0.53	79	350	305
Fixed double glazed thermally broken	Double Glazed SC Low-E - Neutral	1.8	0.25	66	400	355
Fixed double glazed thermally broken	Double Glazed SC Low-E - Grey	1.8	0.21	39	410	365

Notes: All glass is 6mm sizes, SC = Soft/Sputter Coat, HC = Hard Coat, Products are Australian fabricated

Table 2: Aluminium operating window frame systems - performance and cost

Frame Type	Glazing	U_w	$SHGC_w$	$/sqm medium order	$/sqm - large order
Operating window single glazed	Single Glazed Clear	6.4	0.73	330	281
Operating window single glazed	Single Glazed Tint	6.3	0.51	347	295
Operating window single glazed	Single Glazed HC Low-E - Clear	4.4	0.62	363	309
Operating window single glazed	Single Glazed HC Low-E - Neutral	4.5	0.47	380	323
Operating window single glazed	Single Glazed HC Low-E - Grey	4.5	0.41	396	337
Operating window double glazed	Double Glazed Clear	3.8	0.62	462	393
Operating window double glazed	Double Glazed Tint	3.8	0.4	495	421
Operating window double glazed	Double Glazed SC Low-E - Clear	2.8	0.51	512	435
Operating window double glazed	Double Glazed SC Low-E - Neutral	2.7	0.23	594	505
Operating window double glazed	Double Glazed SC Low-E - Grey	2.7	0.19	611	519
Operating window double glazed thermally broken	Double Glazed Clear	3.2	0.61	624	530
Operating window double glazed thermally broken	Double Glazed Tint	3.2	0.39	663	564
Operating window double glazed thermally broken	Double Glazed SC Low-E - Clear	2.2	0.50	683	580
Operating window double glazed thermally broken	Double Glazed SC Low-E - Neutral	2.1	0.22	780	663
Operating window double glazed thermally broken	Double Glazed SC Low-E - Grey	2.1	0.18	800	680

Notes: All glass is 6mm sizes, SC = Soft/Sputter Coat, HC = Hard Coat, Products are Australian fabricated

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Table 3: Aluminium Door Systems - performance and costs

Frame Type	Glazing	U_w	$SHGC_w$	$/sqm - medium order	$/sqm - large order
Door single glazed	Single Glazed Clear	6.4	0.73	280	231
Door single glazed	Single Glazed Tint	6.3	0.51	294	245
Door single glazed	Single Glazed HC Low-E - Clear	4.4	0.62	308	259
Door single glazed	Single Glazed HC Low-E - Neutral	4.5	0.47	322	266
Door single glazed	Single Glazed HC Low-E - Grey	4.5	0.41	336	273
Door double glazed	Double Glazed Clear	3.8	0.62	392	336
Door double glazed	Double Glazed Tint	3.8	0.4	420	371
Door double glazed	Double Glazed SC Low-E - Clear	2.8	0.51	434	385
Door double glazed	Double Glazed SC Low-E - Neutral	2.7	0.23	504	455
Door double glazed	Double Glazed SC Low-E - Grey	2.7	0.19	518	469
Door double glazed thermally broken	Double Glazed Clear	3.2	0.61	448	378
Door double glazed thermally broken	Double Glazed Tint	3.2	0.39	476	413
Door double glazed thermally broken	Double Glazed SC Low-E - Clear	2.2	0.50	490	427
Door double glazed thermally broken	Double Glazed SC Low-E - Neutral	2.1	0.22	560	497
Door double glazed thermally broken	Double Glazed SC Low-E - Grey	2.1	0.18	574	511

Notes: All glass is 6mm sizes, SC = Soft/Sputter Coat, HC = Hard Coat, Products are Australian fabricated

Table 4: Aluminium complete curtain wall systems

Frame Type	Glazing	U_w	$SHGC_w$	$/sqm - medium order	$/sqm - large order
Curtain wall single glazed	Single Glazed Clear	6.3	0.75	340	306
Curtain wall single glazed	Single Glazed Tint	6.2	0.53	357	321
Curtain wall single glazed	Single Glazed HC Low-E - Clear	4.3	0.64	374	337
Curtain wall single glazed	Single Glazed HC Low-E - Neutral	4.4	0.49	391	352
Curtain wall single glazed	Single Glazed HC Low-E - Grey	4.4	0.43	408	367
Curtain Wall double glazed	Double Glazed Clear	3.7	0.64	476	408
Curtain Wall double glazed	Double Glazed Tint	3.7	0.42	510	451
Curtain Wall double glazed	Double Glazed SC Low-E - Clear	2.7	0.53	527	468
Curtain Wall double glazed	Double Glazed SC Low-E - Neutral	2.6	0.25	612	553
Curtain Wall double glazed	Double Glazed SC Low-E - Grey	2.6	0.21	629	570
Curtain Wall double glazed thermally broken	Double Glazed Clear	3.1	0.64	544	459
Curtain Wall double glazed thermally broken	Double Glazed Tint	3.1	0.42	578	502
Curtain Wall double glazed thermally broken	Double Glazed SC Low-E - Clear	2.1	0.53	595	519
Curtain Wall double glazed thermally broken	Double Glazed SC Low-E - Neutral	2	0.25	680	604
Curtain Wall double glazed thermally broken	Double Glazed SC Low-E - Grey	2	0.21	697	621

Notes: All glass is 6mm sizes, SC = Soft/Sputter Coat, HC = Hard Coat, Products are Australian fabricated

4.2 Cost and performance variations by Location, Product Type and Origin

The costs shown above apply to product supplied in Brisbane, Canberra, Melbourne, and Sydney.

Table 5 below shows the price increase factors that can reasonably be applied to product that is ordered and delivered in other locations around Australia.

Table 6 shows the typical level of performance differentials for key variations in product specification including alternative frame types (timber, uPVC and fibreglass) and triple glazing. These alternative frame types typically result in a U-value improvement of 0.9. Triple glazing typically improves U-value by 0.5 compared to double glazing – although this depends on the combination of glass used in the triple or double-glazed units.

Table 7 shows rules of thumb for the use and cost of imported rather than Australian supplied product. This table shows that imported product is typically cheaper, and use is triggered by sizable orders. However, lead-time is much longer for imported product. Lead time at present, with the disruptions to supply chains caused by COVID and related factors may be longer than the usual 6-month period. The Table also notes that compliance with glazing standards and claimed performance specifications is not assured with the use of imports.

Table 5: Cost variations - factors by location

Price variation factors	Location examples
0%	Brisbane, Canberra, Melbourne, Sydney
10%	Regional capitals and major centres: Hobart, Adelaide, Perth, Wollongong, Newcastle, Geelong, Bunbury, Launceston, Gold Coast, Sunshine Coast, Toowoomba, etc.
15%	Regional centres: Ballarat, Bendigo, Shepparton, Albury, Dubbo, Tamworth, Wagga Wagga, Townsville, etc.
20%	Remote Centres: Darwin, Cairns, Broome, etc.
25%	Other small or remote locations

Table 6: Cost and performance variations for alternative product types

Variation	Price Premium over equivalent aluminium version	U-value improvement
Timber frames	100%	0.9
uPVC frames	30%	0.9
Fibreglass frames	50%	0.9
Triple glazed	40%	0.5

Table 7: Rules of thumb – local vs imported glazing systems

Issue	Result
Typical Discount for fully imported complete glazing systems	15%
Typical Trigger for fully imported	orders of 1000 square metres +
Lead time for fully imported	6 months + approx.
Lead time for locally fabricated	2 weeks to 4 months - depending on size and complexity
Compliance with performance and standards: imported product	Variable, may or may not perform as rated/claimed
Compliance with performance and standards: locally fabricated product	WERS rated products will perform as rated

Note: The discount for imported systems applies to orders of 1000sqm +. Smaller discounts would apply to medium orders, and a premium is likely to apply to smaller orders.

4.3 System types – extent of variability

Aluminium framed glazing systems strongly dominate the non-residential construction sector in Australia.

Aluminium provides a framing solution that is strong, durable, low maintenance, highly adaptable to variable requirements across different building designs, and scalable (suitable for projects large and small). Aluminium is a major commodity produced across the world so is widely available at competitive prices. The benefits of aluminium for use in glazing products mean that there are many industry players of different sizes. This gives the aluminium glazing industry scale along with reasonable levels of competition. This combination of factors makes aluminium glazing products widely available and relatively cost effective.

The chief drawback of aluminium within glazing systems is its intrinsic lack of insulating properties. It has a U-value of 221. The effect is that aluminium allows unimpeded transmittance of heat or cold. This is somewhat moderated using silicon rubbers within frames, but complete aluminium framed glazing systems have higher U-values than the glass element of the system.

Thermally broken-aluminium frames address this issue by blocking the thermal flow. The aluminium extrusions used in thermally broken frames incorporate struts generally made from polyamide. These struts bridge two separate aluminium profiles and restrict temperature transfer through the frame.

Table 6 above showed that alternative frame types – timber, uPVC and fibreglass systems all significantly improve the U-value of the glazing system. Timber & fibreglass are insulators while uPVC frames have insulation built into the frame. uPVC and fibreglass systems are also commonly manufactured to have excellent air-sealing properties – further improving the thermal integrity of facades. There is widespread use of uPVC and fibreglass frames in cold areas of North America and Europe, while timber is gaining popularity – albeit probably still at a boutique level internationally.

In Australia, there is very limited use of non-aluminium glazing systems. Timber is the second most available material – but a very long way behind aluminium in market share.

Some combined aluminium/timber curtain walls are starting to be used in high end developments. Fibreglass and uPVC are used on a very small scale in buildings of similar construction designs to residential buildings. This is because there is slightly more uptake and availability of these uPVC and fibreglass glazing systems in the residential sector.

We do not have strong data on the market shares of the different frame types – but Table 8 below shows the extent to which aluminium dominates product choice and availability. Note that these counts are of WERS rated products. There are additional products available in the market that are not WERS rated.

Table 8 also shows that there is reasonable availability of thermally broken aluminium frames – but that non-thermally broken products still dominate the industry offerings. Triple glazed aluminium product is available – but not common at the current time.

Table 8: WERS Rated Commercial Sector Product and Brand availability by frame material

Description of frame materials/types & product/brand	Numbers of product combination available
Aluminium (all glazing types)	16,048
Double glazed aluminium	9,926
Double glazed thermally broken aluminium	2,616
Triple glazed thermally broken aluminium	80
Triple glazed aluminium	311
Timber products	418
Timber brands	6
uPVC products	75
uPVC brands	4
Fibreglass products	545
Fibreglass brands	1

Source: Window Energy Rating Scheme (WERS) website. Searches of certified commercial products with a maximum U-value of 6.5 yielded the above results. The most recent search was 10 May 2021. See Search (awawers.net)

4.4 Industry expectations of change under NCC2019

This section provides a summary of industry views on the impact of NCC2019. These views were provided in phone discussions with a wide range of participants within the glazing industry. A small number of participants in the wider construction industry also provided some general observations. Detailed sales data was not made available for analysis. Therefore, the observations here are qualitative rather than quantitative.

Further information on Australia's glazing industry is provided in section 5. This provides further context and discussion of some of the issues introduced below.

4.4.1 Industry expectations of NCC2019 impacts on glazing product volumes

The increased stringency of NCC2019 can be met, simply speaking, via two broad methods.

One method is to specify and install a suite of higher performing glazing products within a like-for-like building design.

A second method is to change the building design so that buildings have less overall glazing – with a lower window to wall ratio. A common strategy here is to utilise large windows on the northern face of the building and restrict the use of glazing on other faces. The precise strategy depends on the building's intended use, site orientation, views and other considerations.

Glazing volumes would plateau or drop if the construction industry leaned more towards the second method of reducing glazed areas.

However, many factors apart from the NCC2019 glazing requirements influence building designs. For instance, there has been a general trend, over the last decade or so, of increasing window to wall ratios, in building classes such as offices and mixed-use buildings. This is a response to demand for buildings with more heavily glazed facades due to issues including aesthetic appeal, the desirability of naturally lit interiors and the adoption of curtain wall construction techniques that are suited to large-glazed areas.

The industry representatives that we consulted expected these trends to continue under NCC2019.

While they acknowledged that building designs with lower WWRs in response to NCC2019's Section J would occur at times, they thought a more common response would be the use of higher performance glazing products. This is because:

- Higher performance products incorporating double glazing with low e soft coats are increasingly available at competitive prices.
- Thermally broken frame types are becoming increasingly available – at a scale that allows competitive pricing.
- The consumer and architect driven demand for high window to wall ratios and use of natural light are expected to continue.

Furthermore, the glazing industry expects NCC2019 to have little effect on the overall demand for buildings in Australia. They expect other factors such as government stimulus in the wake of COVID-19 to increase activity in new buildings and major refurbishments.

The overall expectation is that demand for glazing products will increase in the short to medium term.

4.4.2 Glazing industry investment in Research & Development

We were not given precise data on the nature and extent of R&D investment in our discussions with industry. However, our overall impression is that R&D investment by the Australian glazing industry is generally modest in scale by world standards. R&D efforts tend to be reactive to wider construction industry demands and changes in the NCC – rather than taking a proactive approach of seeking to lead demand.

This is largely driven by the commercial realities of operating within the Australian construction industry.

Several industry figures advised that their experience was that early investment into products with much higher performance than the local standard had not yielded good returns. This was due to low take-up by the construction industry.

The Australian non-residential glazing sector is also dominated by imports. Estimates of the market share of imports from industry players ranged from 50% to 90% - depending on building type and location. The market domination of imports creates a situation where local suppliers are reluctant to invest heavily in R&D due to the risk that construction firms will continue to source their product from overseas based on price.

Industry participants observed that major investment into R&D or upscaling of manufacturing capacity was commercially risky in the current regulatory and compliance environment.

Major investment would be justified if it brought a significant increase in market share. This would require taking market share from imports. Significant investment could bring costs down close to the level of equivalent quality imported product. However, the capture of market share would still not be guaranteed as the market price is not necessarily set by products of equivalent performance and quality. Some international suppliers provide a claim that the product meets the required specifications – but do not back this claim with assurance in the form of certification or test results.

It is quite possible that, at least some of the time, market leading prices are based on products that are intrinsically cheaper items with lower quality and performance than certified and tested products.

No-one in the Australian glazing industry suggests that all imports are of dubious quality. Many international suppliers make excellent products that are installed in markets where minimum product performance requirements are far higher than applies in Australia. Rather the suggestion is that in the absence of a strong compliance and enforcement regime, it is entirely possible for products that do not meet Australian standards to be supplied and installed.

This has the effect of distorting the market and weakens incentives for local R&D investment.

We also heard that some of the major local players tend to invest defensively, rather than pro-actively, only investing enough to protect their existing market share. Smaller players may have greater appetite for change, yet these players generally do not have the resources to force significant change.

4.4.3 Glazing Industry capacity for innovation

The international and local glazing industry alike have a track record of developing new products in response to market and regulatory signals. This demonstrates a strong capacity for innovation.

While the relative scale of investment in R&D by the Australian glazing industry is moderate, the industry does invest in response to market expectations – developing new product variants quickly.

An example of the ability of the local industry to innovate is the reduction in price of double-glazed products.

Prices for fixed double-glazed products now come with a premium of about a third over single glazed products but bring approximately 75% improvement in U-value and up to 100% improvement in SHGC. This is on a somewhat like-for-like basis (as reported by industry and shown in Table 1).

For instance, a fixed single glazed frame using hard-coat low-e grey glass has a U-value of 4.2, a SHGC of 0.43 and a medium order price of $240. A fixed double-glazed frame with soft-coat low-e grey glass has a U-value of 2.4, a SHGC of 0.21 and a medium order price of $370.

A large order of fixed frame double glazed clear units comes at the same price ($240) as a medium order of the single glazed low-e product described above – with this basic double-glazed product bringing a 20% benefit in U-value.

The improved cost-effectiveness of double-glazed product is a result of manufacturing and labour efficiencies introduced by the glazing industry. These efficiencies partially offset the added cost of materials.

4.4.4 Industry expectations of NCC2019 impacts on triple glazed product volumes

Industry views of whether the volume of triple glazed products will increase in response to NCC2019 are somewhat mixed.

A minority of industry figures thought there would be a small increase in triple glazed product. This could occur in cooler climate zones in building designs that retain high glazing ratios in south facing walls for instance.

However, the general view was that NCC2019 requirements could be met in the great majority of cases with double-glazed and single glazed products.

Most triple-glazed aluminium windows available at the current time (which is not many) are not thermally broken. These have similar u-value performance to double-glazed windows that combine thermally broken frames with high performance IGUs using soft coated low-e glass.

There are WERS certified PVC, fibreglass and timber framed triple glazed units that offer U-values as low as 1.0 available at present. However, these items have low market penetration, used in situations where building designers are aiming for the utmost energy efficiency, beyond Code requirements.

4.4.5 Industry expectations of NCC2019 impacts on thermally broken product volumes

The industry expects uptake of thermally broken product to increase under NCC2019 requirements. However, few actual orders for new builds to NCC2019 have been received by the industry yet, so there is very limited sales data available for quantitative analysis.

The expectation for increased uptake of thermally broken product is particularly the case in the South-Eastern States and the ACT. Here the construction industry is already accustomed to using double glazed product. The move to thermally broken double-glazed product does not require much adaptation, so there are no major practical barriers to uptake.

In WA, the requirements for NCC2019 have only just come into play. WA Industry figures expect that the industry would shift, in general, from basic single glazed products to double glazed product using low-e glass. The sources we spoke with did not expect that thermally broken frames would be commonly required in Climate Zones 1 to 5 where the majority of WA construction occurs.

Similarly in Queensland, there is little expectation from industry at this stage that thermally broken frames will be extensively required under NCC2019.

The construction industry in Queensland has not yet widely adopted double glazing. Some glazing industry figures suggested that the Queensland construction industry assume that: single glazing using low e hard coated glass, combined with shade structures would be a common option under NCC2019. However, this expectation may not prove realistic. Some glazing industry participants expect designs in Queensland to shift, under NCC2019, towards use of double-glazed products using low-e soft coats with superior SHGC performance.

In all markets and climate zones, it largely remains to be seen to how industry implements NCC2019 in terms of building designs and product selection.

4.4.6 Industry expectations of NCC2019 impacts on the origin of glazing products

In broad terms, the industry expects that NCC2019 will not play a major role in influencing the market share of imports in complete glazing systems that are delivered to construction sites.

Australian and international suppliers alike can deliver a very wide range of products that will be suitable for buildings designed to NCC2019.

NCC2019 will influence the origin of the glass component of glazing systems. There is a wide expectation that demand for IGUs incorporating low e soft coated glass will increase. This is because soft-coats outperform hard coats in the areas of U-value, SHGC and VLT.

Soft coated float glass is not manufactured in Australia, therefore must be imported.

The Australian glass processors (makers of IGUs) therefore expect to increase their imports of soft-coated glass. Correspondingly orders of locally manufactured hard-coated glass could be expected to ease.

5. Glazing Practice, Product Trends, and Issues

The main trends in glazing practices and products have been discussed in the above sections. These include:

- a shift from use of single to double glazing
- the availability of triple glazed products – but limited uptake is expected
- increasing use of soft coated low-e glass in IGUs
- increasing availability and uptake of thermally broken double-glazed products
- the continued ability of the local glazing industry to meet required performance standards.

Other product developments and issues are noted below.

Dynamic or Smart Glazing

A new product type, called dynamic or smart glazing has been developed by some of the world's biggest glass makers.

Dynamic glazing uses an electrochromic coating of layers of ceramic material combined with an electric connection. Applying low voltage darkens the coating as lithium ions and electrons transfer from one layer to the next – this darkening minimises solar heat gains. When the voltage polarity is reversed, the ions and electrons return to their original layer, causing the glass to return to its clear state – so when sun is not facing the façade, clarity and visible light transfer can be maximised.

Variations of dynamic glass allow for different zones within the same pane of glass – for instance, the lower zone might be tinted to reduce glare, while the higher zone might be clear to allow visible light transfer.

We are not aware that this product is available in Australia and understand that market penetration in North America and Europe is low[2]. Presumably, this is because cost is relatively high.

Aluminium frame issues

Aluminium's dominance as the framing material used within the commercial glazing sector is expected to continue. In the Northern Hemisphere materials like uPVC are more common than in Australia, but aluminium still has the majority of the non-residential market.

There are two key issues that the aluminium extrusion industry needs to address in order to further improve the energy and environmental performance of their products and the buildings where they are used. These are:

- Thermal and air-tightness performance. Standard thermally broken aluminium frames have reasonable U-values, but do not perform as well as alternatives such as uPVC. Research is

[2] See Sage Glass Website and US Glass Magazine Website

ongoing, for instance by the US Department of Energy and industry partners to develop aluminium framing systems which have improved thermal performance. The Australian industry is expected to keep an eye on developments and introduce improvements as they become commercially proven and required under Code stringency settings[3].

- Embodied emissions. Aluminium smelters powered by renewable energy produce around 4 tonnes CO2 for every tonne of aluminium produced. Those smelters powered by coal electricity can produce up to 16 tonnes of CO2 for each tonne of aluminium. Those window manufacturers and building owners seeking to minimise embodied emissions today and into the medium term should accordingly be sourcing aluminium from smelters using green energy. In the medium to longer term, leaders in the aluminium industry are looking to move towards net zero emissions through the adoption of technologies like inert anodes that emit oxygen rather than CO2. This work has started with Alcoa for instance developing such a process. Alcoa has already supplied some product to Apple for top-level lap-tops and is now partnering with Audi on a plan to supply zero emissions aluminium for car wheels[4].

Construction industry education

The glazing industry is unanimous in their view that the wider construction industry does not have a comprehensive understanding of how glazing product choice effects building energy performance.

This view was reflected by our experience with the construction industry.

Builders appear to rely on their design managers, architects, energy assessors and ESD consultants to handle the nuances of glazing. However, the glazing industry reports that the people performing these roles are often not fully equipped with the knowledge and tools to make optimal decisions and/or are pushed by other parts of the industry to make sub-optimal design choices from a glazing and thermal performance perspective.

The lack of an effective compliance and enforcement regime

Again, the Australian glazing industry participants that we spoke with were unanimous in calling for an effective Code and products compliance and enforcement regime to be introduced.

This view is supported by numerous independent reports in recent years issuing the same call.

A lack of compliance and enforcement causes at least three major adverse outcomes:

1) increased energy costs and emissions from Australia's building stock
2) lower comfort and wellbeing for building occupants
3) lost opportunities for investment in the local glazing industry and increased employment.

[3] See for instance Berkeley Lab, Highly Insulating Commercial Framing, available at Lawrence Berkeley National Laboratories Website

[4] *Financial Times*, 25/3/2021 "Alcoa steps up battle to cut emissions in deal with Audi" and *Aluminium Insider*, 29/06/2020, "The Net-Zero Shift Starts with Low Carbon Aluminium"

These outcomes result from weak or non-existent enforcement of compliance with Code requirements and Australian standards. Builders can mistakenly (or deliberately) select products with specifications that are not Code compliant. Suppliers can deliver products that have lower performance levels than specified by the builder. The first issue reduces demand for quality products. The second issue distorts price signals. The combination impacts negatively on investment by local industry and restricts competition from quality importers. Both issues result in worse outcomes for building occupants and the community.

Glazing products sold in Australia are not always rated and tested to the same standards.

A further quality assurance and market information issue is the absence of a single, globally accepted standard to rate glazing products for U-value and SHGC.

The WERS system used by the Australian industry is based on the North American system for testing product performance. An alternative set of test standards is used in Europe. Suppliers in other regions can access either system – or none at all.

The two systems (or sets of protocols and standards), both produce legitimate and repeatable results – but those results are not comparable because they are based on different climatic settings, thermal loads, solar loads, and the points on the product where measurements are taken and applied. The European set of protocols produces U-values that can be up to 1.0 lower than the AFRC protocols. For instance, a product rated in Europe might have a U-value of 2.3 while the same product rated under WERS could score 3.1.

The Australian industry is satisfied that the NFRC system is a better fit for Australian conditions. The AFRC and WERS systems are accordingly based on NFRC protocols.

However, there is no regulatory requirement that glazing products sold in Australia are rated to AFRC protocols. The NCC references the AFRC system – but does not prescribe its use as there is no Australian standard.

The ability of suppliers to use different product rating systems is a cause of information failure in the construction market. Glazing is already complex, and most customers accept quoted U-values and SHGC at face value, rather than determining which rating system is being used.

Price distortion can follow. Suppliers of imported systems may inadvertently, or perhaps deceptively, quote products based on European rated U-value (of say 2.3) at a lower cost than competing products rated under WERS.

Non-compliance with the NCC is also the result of such circumstances. The building designer specifies the U-value of 2.3 – under the AFRC protocols – not the European protocols.

The Australian glazing industry, coordinated by AGWA, is very conscious of this problem and has commenced the process of developing an Australian standard which could then be prescribed under the NCC.

We encourage government bodies to support the development of the Australian standard. Given that standards development is not a rapid process, we also suggest that a program of awareness raising be delivered in the short-term. This could target designers, energy assessors, ESD consultants and the like. An awareness program could be part of a wider industry education process – as alluded to earlier in this section.

NCC: chief mechanism to lift glazing standards and minimum energy performance in Australia.

Many glazing industry participants vigorously observed that voluntary and glazing-industry led efforts to improve the overall energy performance of glazing are largely ineffectual. Sections of industry, locally and internationally, have always been willing and able to supply high performance product – but the demand for systems, by the wider construction industry, with performance well above Code has always been minimal.

The higher stringencies under NCC2019 will drive improvement. Further improvement will require stringencies to be lifted again in future versions of the Code.

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