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Underlying principles of the development of NCC 2022 elemental provisions

Residential Energy Efficiency-Thermal Performance

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1 Introduction

Achieving alignment with Nationwide House Energy Rating Scheme (NatHERS) 7-stars was a fundamental underpinning principle for developing the Deemed-to-Satisfy (DTS) elemental provisions for the National Construction Code (NCC) 2022. This principle helps ensure that there are different compliance paths that offer an equivalent level of performance and therefore protects energy savings for consumers, the benefits to the energy network of restrained energy demand and the policy objective of reduced greenhouse gas emissions.

As the stringency of regulation increases, it becomes much harder to achieve alignment between performance provisions and elemental provisions without adding significant compliance cost. Consequently, the structure of the elemental provisions proposed for NCC 2022 is more detailed than NCC 2019. While it is always desirable for regulation to be as simple as possible, the detailed options also offers the building industry several benefits. This paper explains the benefits to the building industry of the increased detail. Further, there are several ways in which the building industry can be assisted to navigate the greater detail, and options for this are discussed.

2 Achieving alignment with NatHERS

Before describing the need for and benefits of the additional detail introduced to NCC 2022 elemental provisions, it is essential to consider what the performance requirements of NatHERS represent.

Unlike some other rating schemes around the world, NatHERS specifies performance in terms of a specific MJ/m^2 target. By contrast, the USA HERS scheme allocates stars based on the percentage improvement over the Internation Energy Conservation Code (IECC) Standard Reference Design (a standard similar to elemental provisions) using an Energy Rating Index where 0 represents no improvement, and 100 denotes a zero-energy dwelling. Therefore, the USA rating scale does not produce dwellings that achieve an identical energy load, only a percentage improvement over a reference specification. This different structure reflects the historical development of energy efficiency regulations in the US and Australia. Elemental standards were developed first in the US, while NatHERS preceded the development of elemental standards in Australia.

While it is relatively simple to develop elemental standards representing a percentage improvement over an existing elemental specification, developing elemental standards to achieve a specific energy load is more complicated. Further, when the original elemental provisions were designed, NatHERS was transitioning between 1st and 2nd generation methodologies and star rating bands were not available. Consequently, the elemental provisions' structure could not reflect the nuance of a 2nd generation NatHERS performance calculation.

Two further factors make it difficult to achieve alignment between elemental provisions and NatHERS:

- NatHERS adds together heating and cooling loads together to achieve the star rating. In mixed climates cooling performance can be traded off with heating performance. NatHERS itself does not embody a single measure of performance in each season, and
- Smaller dwellings have a larger external surface area than larger dwellings (relative to floor area) and will not perform as well. However, smaller dwellings have a lower total energy use than larger dwellings and therefore have a lesser impact, per dwelling, on energy use and greenhouse gas emissions. An area correction is used in NatHERS to even out performance requirements across dwellings of different sizes. Despite this area correction, houses of different sizes still have subtle differences in the building fabric specifications needed to achieve 7-stars.

The factors described above make achieving alignment between elemental provisions and NatHERS star ratings a more difficult task. Despite these challenges, ratings for dwellings meeting the elemental provisions show that the proposed NCC 2022 residential energy efficiency provisions does align quite well with the NatHERS 7 stars. In general, applying the elemental requirements to three Class 1 dwellings in the 8 NCC climate zones was found to produce a rating within 0.5-stars of 7.

3 The benefits of aligning elemental provisions with NatHERS 7-stars

As described in Section 1, alignment produces a consistency of outcomes that protects the policy intent of the regulation. Two further benefits have been observed as the elemental provisions were developed and tested:

- Reduced cost of compliance, and
- Greater design flexibility.

These benefits are highly desirable outcomes for regulatory development, which may justify some increase in complexity.

Before developing the elemental provisions, compliant NatHERS 7-star solutions were developed for 18 Class 1 dwellings (nine on a slab and nine on a timber floor) and a 24 unit Class 2 building in 12 NatHERS climate zones. It was clear from this work that there were many cases where 7-stars could be achieved with ***lower building fabric specifications than the current NCC 2019 would allow***. To capture some of these cost savings and maintain consistency of outcomes with NatHERS, it was clear that the simple structure of NCC 2019 provisions could not be maintained. The design of the elemental clauses needed to be changed so that building elements that were better suited to the climate they were constructed in could be rewarded with lower specifications.

The following sections outline some of these benefits.

3.1 Ceiling Insulation

In this section, an "attic roof" refers to a roof with a flat ceiling and sloping roof where a roof space separates the roof lining and ceiling lining.

NCC 2019 requires relatively high base ceiling R-values and is based on calculating the total roof R-value. It allows lower insulation R-values for:

- A lighter coloured roofs across all climates
- Reflective foil using a fixed R-value benefit for reflective foil in an attic roof space depending on the foil emissivity, roof slope and direction of heat flow.,
- Roof ventilation: in Climates 1 to 5 NCC 2019 reduces the R-values by R0.5 where the roof is ventilated, e.g. by two wind-driven roof ventilators, and
- Insulation installed under the roof, providing the total amount of insulation under the roof is less than 50% of the total of the ceiling and under-roof insulation.

The proposed NCC 2022 includes all these factors but treats them in a different way that better reflects their impact on NatHERS simulated energy demand:

- the benefit for roof solar absorptance is calibrated to the climate zone, e.g. lighter roofs allow lower R-values in cooling dominated climates and darker roofs allow lower R-values in heating-dominated climates. A greater range of roof solar absorptance is provided, allowing builders to take advantage of lower ceiling R-values for the product they use where this is justified in the climate. Light coloured roofs have benefits in reducing global warming. However, this benefit has not been expressed in financial terms, and a darker roof in a heating-dominated climate leads to lower heating requirements and lower GHG emissions today.
- The effect of reflective membranes in a roof varies according to roof ventilation, temperature difference, and heat flow direction. It can change from hour to hour and is not accurately represented by a single R-value for the dominant heat flow direction. Computation Fluid Dynamics

(CFD) modelling by the University of Wollongong found that the R-value of an attic space is highly variable and can effectively be negative under some circumstances. The proposed NCC 2022 specifies the ceiling R-value required if foil is installed based on NatHERS simulation results and removes the need to calculate the roof space's total R-value. This approach provides a more straightforward R-value calculation for attic roofs than in NCC 2019. The benefit of reflective foil in roofs in hot climates is much greater than the current fixed R-value of reflective attic spaces in NCC 2019, providing lower-cost options for the industry in these climates.

- Similarly, roof ventilation has a highly variable impact. Rather than provide a simplistic single benefit for roof ventilation, the reduction allowed in ceiling R-value depends on the climate zone. In hot climates, in conjunction with a lighter coloured roof, the benefit of roof ventilation exceeds the simple R0.5 allowance provided by the proposed NCC 2022. The number of roof vents required is aligned with the ventilation impacts simulated in NatHERS and require more roofs vents for larger dwellings. Again, deriving requirements from simulation results leads to much more significant reductions in ceiling insulation in hot climates than NCC 2019 would provide.
- NatHERS simulations show that in an attic roof in cooler climates, placing insulation under the roof has a negligible effect. No reward is given for under-roof ventilation in these climates in the proposed NCC 2022. Conversely, in hotter climates, because under roof insulation is more effective, the reduction in ceiling insulation sometimes exceeds the R-value of the under-roof insulation.

In summary, the calculation of the total R-value for attic roofs is simplified, more paths to lower R-values are legitimately allowed, and the insulation requirements of roofs are now more consistent with the outcomes predicted by NatHERS hourly simulation. The added insulation R-value options provided will enable the industry to avoid making a total R-value calculation. This outcome is critical because thermal bridging requirements now require much more complex calculations of Total R-value.

One further benefit of the new provisions is that, by showing an extensive range of compliant options, they help the building (and assessor) industry better understand what roof/ceiling properties deliver the lowest cost solutions in each climate zone.

3.2 Wall insulation

NCC 2019 provides four different wall total R-value requirements depending on the climate zone. A complex set of ten qualifying clauses (each with various subclauses) then offer multiple ways of reducing the insulation R-value required for some climate zones. These dispensations depend on the wall's mass, the mass of internal walls and floors, and the wall's shading by overhangs, and some clauses apply only to specific climate zones. These clauses provide a way for insulation to be significantly reduced or eliminated for concrete block walls (common in climates zones 1 and 3) or brick cavity walls (common in Perth in climate zone 5) because these wall constructions have higher insulation costs than framed walls.

Investigating the clauses offering dispensation to reduce R-values found that they did not necessarily lead to equivalent outcomes when simulated with NatHERS. In the worst cases, the application of some clauses could lead to a difference of as much as one star.

The wall insulation requirements proposed for NCC 2022 eliminate the complex range of dispensations for lower R-values. In their place, the wall insulation required to be installed is shown given the wall height, shading and solar absorptance for the most common wall types used in each climate zone with different thermal mass levels. These R-values are calibrated using AccuRate to produce equivalent outcomes and assist the elemental provisions to better align with a 7-star rating.

Allowance for wall height is a new factor that has been added to the proposed NCC 2022. Wall height affects thermal performance in two ways:

- Surface area: the higher the surface area, the greater the heat flow, and
- The impact of shading by overhangs: a taller wall will be less shaded by a given overhang than a wall with a lower height.

Wall insulation requirements for two storey dwellings are have been set to higher levels to reflect their geater external wall area.

Allowing for wall height and surface area was critical in achieving a better alignment of outcomes between elemental provisions and the NatHERS simulation. Wall height is not the only factor that affects wall surface area. A more articulated plan with courtyards will also have a greater wall surface area. While an allowance for wall perimeter could be added to the proposed NCC 2022, it was felt that, on balance, this would add too much complexity. Calculating perimeter and multiplying this by the wall height to derive a wall area to floor area ratio would be required to allow for wall surface area. In contrast, wall height is quickly taken from plans. Calculating wall to floor area ratios is requiredin Class 2, where the calculation of wall areas is far more straightforward due to the reduced number of walls in this housing type.

Wall types that are not described in the proposed NCC 2022 tables will still have to use Total R-value calculations.

While the tables themselves are relatively simple, where dwellings have a complex range of wall constructions, heights and overhangs, a literal interpretation of the new clauses would see multiple wall insulation levels installed. Multiple wall R-values would make it hard to inspect and possibly prone to mistakes. Several potential solutions to this issue, e.g. an area-weighted average R-value, are described in later sections.

The proposed NCC 2022 provides more tables with more options than NCC 2019. The tables give the building industry a greater variety of options to legitimately lower wall R-values and reduce compliance costs. The new clauses also eliminate the more complex dispensation clauses and improve the correlation with NatHERS outcomes. Again, following the requirements shown in the tables eliminates the need to provide Total R-value calculations. Total R-value calculations are now significantly more complex given the introduction of thermal bridging requirements, so this represents a significant reduction in complexity.

The tables also provide options for legitimately eliminating the need for wall insulation in higher mass wall construction which predominate in Climates 1 and 3 and Perth in Climate 5. There has been significant resistance to requirements for wall insulation in these areas due to the higher cost, so the more detailed provisions provide a way to achieve this without loss of performance.

Wall insulation levels for wall types which are not commonly used and therefore have no table option in the proposed NCC 2022 can be inferred from the options presented in the NCC. For example, if the wall has no thermal mass the insulation R-values for a weatherboard wall may be used, and if the wall has thermsal mass exposed to the inside of the house the R-value for brick cavity walls can be used. This will be further explained in supporting documents.

3.3 Floor Insulation

NCC 2019 sets minimum total R-values that must be achieved for suspended floors in each climate zone. The added insulation R-value must then be calculated using tables that show the uninsulated thermal resistance of the floor, including the subfloor space and enclosing walls, depending on the height and material of the subfloor wall and the direction of heat flow.

Like attic spaces, the actual effective thermal resistance of the subfloor varies over time. In one day, the direction of heat flow may change, and the direction of heat flow, even in hot climates, is more often down and not up as assumed in NCC 2019 because the subfloor space can be cooler than the outdoor temperature. Therefore, similar to ceiling insulation in attic roofs, only the floor component is included in Total R-value calculations, i.e., calculation of subfloor spaces and wall R-values are eliminated. The proposed changes for NCC 2022 improves the alignment of the requirements with NatHERS by deriving added floor R-values from simulation results. Further, if the added R-values shown in the table are used, there is no need to undertake complex total R-value calculations.

The proposed NCC 2022 floor insulation requirements are given in a table showing subfloor wall height, whether reflective foil is installed under the floor and shows underfloor and subfloor wall insulation options.

The proposed NCC 2022 also adds new alternative methods of meeting the regulation other than simply using bulk floor insulation installed under the floor. Where it is beneficial, the use of reflective foil can lead to lower floor insulation R-values. The insulation of subfloor walls is also included, depending on the height of the subfloor wall. Subfloor wall insulation is an important addition. In mixed climates with significant heating and cooling requirements adding under-floor insulation increases cooling loads. While subfloor wall insulation is not as effective at reducing heating, it does reduce both heating **and** cooling requirements. Because subfloor walls often have a much smaller area than the floor itself, subfloor wall insulation is often cheaper than underfloor insulation and provides a cost-effective energy efficiency option in mild and warmer climates.

3.4 Thermal Bridging

Steel frames without thermal bridging mitigationin a dwelling with a suspended floor can reduce energy ratings by as much as 1.8 stars, depending on the climate zone as shown in the table below for Class 1 dwellings. By contrast, the imimpact of thermal bridging by timber framing is only up to 0.4 stars.

Table 1 Impact of thermal bridging on star ratings of timber floored dwellings

Climate Zone	Star Rating		
	Without Thermal Bridging	Accounting for Thermal Bridging	
		Steel Frame	Timber Frame
Darwin	7.0	6.6	6.9
Cairns	7.1	6.9	7
Brisbane	6.9	6.3	6.5
Longreach	6.9	6.4	6.8
Mildura	6.9	5.8	6.5
West Sydney	6.8	5.9	6.4
Perth	6.9	6.4	6.6
Adelaide	6.9	6.1	6.6
Melbourne	6.9	5.9	6.7
Hobart	7.1	5.8	6.7
Canberra	6.9	5.9	6.6
Thredbo	7.2	5.2	6.7

The insulation R-values shown in the proposed NCC 2022 include both the required R-value of the added insulation product (for the main types of construction used in each climate zone) and the Total R-value of the building element. Total R-values include an allowance for the thermal bridging of insulation and air space layers in a construction element by framing members. The definition of Total R-value in Volume 2 will be updated to be consistent with the definition in Volume 1 of the NCC.

The total R-values for inclusion in the NCC 2022 shown in this report are calculated using the method in NZS 4214. The NZS method is cited in the Australian standard for AS 4858.2. New Zealand and Australia share a standards process, so the use of this standard has process advantages.

The impact on building heat flows of thermal bridging due to framing members is potentially very complex. The area of building elements covered by framing is not a fixed value. It can vary considerably from dwelling to dwelling depending on the design and size of the dwelling and specific construction techniques used. The span tables which are shown in AS 1684 for timber frames and the National Association of Steel Framed

Housing (NASH) standard for steel frames demonstrate that there is a range of acceptable solutions for residential construction which would each imply a different frame ratio. Thermal bridging effects can be calculated for metal fixing to steel framing members, including brick ties and screw fixing to frames. It can also include the impact of cross framing members such as ceiling battens and bearers under floor joists.

The proposed changes to NCC 2022 are required to take into account thermal bridging due to framing members. The capacity of the residential building industry to calculate these effects varies substantially. For example, builders of high rise apartment buildings will employ engineering professionals to design the structure and services of a building who will have the require skills to make such total R calculations. In contrast, the 'kitchen table' builder who constructs only a few houses each year may not have these professional resources available. Simplifications to thermal bridging calculations in the DTS elemental provisions are recommended, at least for the next NCC 3 year cycle:

- A standard frame ratio is used for all building elements so that users of the NCC are not required to calculate the frame ratio on a case by case basis, and
- The thermal bridging impact of fixing and cross framing members like ceiling battens and bearers below floor joists be ignored.

There are physical limits to improving Total R-values in conventional construction. These limits may relate to the size of air gaps that must be maintained which limit the thickness of insulation levels that can be installed.

Brick Veneer walls are the most commonly used external walls in Australia. The CSIRO AHD dashboard shows that 53% of all external walls in Australia use Brick Veneer. Any solution for thermal bridging must accommodate this wall construction type. A Brick Veneer wall contains a cavity that, in part, provides resistance to moisture penetration. If an air-gap of at least 20mm between thermal bridging insulation and the inner surface of the brick must be maintained, there is a physical limit to the insulation that can be added. In addition, the type of insulation that can fit within this space and provide sufficient additional R-value to remediate thermal bridging is more expensive than insulation products which fit between framing members. While a 20mm air gap could be maintained at higher R-values if the overall cavity width is increased, this would also have cost implications. There are, therefore, limitations to the practicality and cost-effectiveness of minimising thermal bridging.

In some building elements, these barriers to reducing thermal bridging are not so severe. In ceilings to an attic space, thermal bridging can be remediated by using the same material as the insulation to the rest of the ceiling, and there is generally no space limitation. Insulation could be installed over ceiling joists, or strips of batt could be cut to fit over framing members. Covering framing members in attic spaces may have some Occupational Health and Safety (OH&S) implications because the position of the frames would no longer be visible. Covering ceiling level framing is not a big issue with truss framed roofs because the other structural members of the truss will indicate the position of the bottom chord. International experience with this issue may provide useful information.

Proposed solutions to thermal bridging will also be affected by the level of thermal bridging that is deemed to be acceptable. The loss of effective insulation R-value due to timber framing members is significant but is nowhere near as large as with steel frames, particularly at higher R-values.

For NCC 2022 it is proposed that thermal bridging remediation is not required for timber frames. For steel-framed elements, the additional thermal bridging for steel-framed elements should seek to match total R-values for timber framed elements subject to benefit-cost analysis.

Because the calculation of thermally bridged Total R-value is complicated, the information presented will focus on ensuring that users of the NCC will only need to calculate Total R-value where they choose to do so. Added insulation R-values for thermal bridging mitigation are given for the most common building constructions and a nu mber of alternative options are provided. If these R-values are used, there will be no need to do a Total R-value calculation.

In general terms, the additional insulation required corresponds to a continuous layer of only 10 or 15 mm of polystyrene or insulation (depending on climate) or applied to the frame only of around R0.6. This is significantly less than would be required to eliminate framing effects altogether, which is required by such regulations in other parts of the world.

3.5 Glazing

Before discussing the benefits of the increased complexity of the glazing calculations, some further background is provided below. Note that anecdotal evidence suggests that very few dwellings that use the elemental provisions calculate window performance by hand. All calculations are made using a spreadsheet, and the great majority of these use the Glazing Calculator (GC) provided by the ABCB. Because the complexity of the calculations is hidden from GC users, adding some more complexity to the calculations was considered acceptable if this led to better alignment with NatHERS. Of course, adding more data inputs may increase the number of opportunities for users to make errors and game the results. The potential downsides to greater complexity can be handled to some extent by better training and GC tool help systems and error checking.

The GC developed for the proposed NCC 2022 also responded to industry feedback:

- it would be desirable to be able to calculate multi-level dwellings within one calculator rather than producing a GC for each level, and
- using the same exposure factors for dwellings with a slab on ground and suspended timber floor did not correctly reflect the differences in how solar gains impacted the performance of buildings with the two floor types.

3.5.1 Aligning glazing calculation and NatHERS 7-star outcomes is challenging

Achieving sufficient alignment between NatHERS 7-stars and the Glazing requirements of the proposed NCC 2022 is the most challenging task in developing the new regulationsThis task is further complicated for glazing because the NCC provides separate summer and winter performance targets while NatHERS adds together heating and cooling. In addition, the NCC and uses a metric for winter performance of conduction losses divided by solar gain. It isn't clear whether this metric for winter performance is ideally suited to reflecting the impacts of glazing in winter that a simulation tool would predict. Furthermore, the impact of solar gains on heating and cooling energy use is complex. The amount of solar gain is easy to predict, but the impact on heating and cooling depends on a variety of factors:

- the temperature in the space: if a space is comfortable with minimal solar gain in winter, additional solar gain does not reduce heating energy use. With higher building fabric specifications, this will occur more frequently.
- whether the room is being conditioned at the time of the solar gain and the thermostat setting if it is,
- the amount of thermal mass affects the storage of the solar gain for future hours,
- the extent of cross ventilation available to remove excess solar gain in summer, and
- one kW of solar gain can have a different impact on heating and cooling in different rooms, e.g. a one kW solar gain in winter may not impact energy use in a bedroom as if it isn't during the day but will impact heating loads in a living room, and
- many other factors.

Simulation tools take all these factors into account, and trying to replicate the nuance and sophistication of a simulation in a single whole of dwelling calculation is challenging.

3.5.2 Process of aligning glazing calculations and NatHERS

Each of the 18 houses and 24 apartments specified to achieve 7-stars was entered into the NCC 2019 Glazing Calculator in the 8 NCC climate zones. Calculations from the GC for summer solar gain, winter solar gain and winter conduction losses and the impacts of horizontal overhangs on solar gain were extracted on a window by window basis, entered into a spreadsheet and correlated with the heating and cooling loads predicted by AccuRate. An additional NatHERS simulation was run for each dwelling with all windows fully shaded to obtain a better picture of the impact of radiation gains on heating and cooling energy to allow the differences in other building fabric elements to be isolated.

The extent of compliance for the 7-star dwellings with the current GC was also evaluated.

The summer and winter solar gain exposure factors for windows of various orientations were then modified to improve alignment with NatHERS. To improve the alignment of Glazing Calculator outputs with NatHERS, additional factors were introduced. Alignment was considered to be achieved when the average score of the 7-star dwellings was 100% of the target for each season, and the range of results reflected the range of NatHERS heating and cooling loads. Factors and solar exposure values were adjusted so that the relative ranking of dwellings using the Glazing Calculator was as close as possible to the ranking of NatHERS heating and cooling loads.

Aligning outcomes from the GC and NatHERS also involved trying to align the radiation exposure with the difference between the 7-star solution and with windows fully shaded simulations. This provided a measure of the impact of radiation alone. The newly introduced factors and solar exposure values were then adjusted so that the Cshgc/Cu ranking matched the heating load ranking.

Reproducing the relative ranking of NatHERS heating and cooling loads with the Glazing Calculator scores and achieving a similar spread of results was not always possible.

3.5.3 New factors introduced to the proposed NCC 2022 GC

Exposure factors

The original exposure factors were derived from tools that predicted the total radiation incident on glazing for the three months of winter and summer. By adjusting exposure factors to align with NatHERS outcomes, the exposure factors now reflect solar gains for all months that require heating and cooling. In addition, this process means that exposure factors are not simply predicting the amount of radiation incident on windows, but the impact of this radiation on heating and cooling loads. Separate sets of exposure factors and and other factors were developed for dwellings with a suspended timber floor and a slab on ground.

In Climate Zone 5, where houses in Perth use high thermal mass brick cavity construction, a separate set of factors was developed for dwellings that use Brick Cavity construction and internal brick walls.

Level Factor

The level factor was developed to allow the GC to model all storeys in a dwelling in one calculation rather than require a separate GC for each level. To ensure that data entry errors or gaming are avoided, the GC asks for the number of storeys to be input and checks to see whether windows have been identiofied as upper floor windows.

Bedroom factor

Bedrooms are assumed to be occupied at different times and are heated and cooled to different thermostat temperatures. Therefore, solar gains and conduction through glass affect these rooms differently from daytime occupied areas in the dwelling. In NatHERS ratings, it was clear that the most cost-effective method of achieving compliance is to install higher performance glazing in living areas first. This factor ensures that a similar outcome is achieved with the GC.

The bedroom factor allows some potential for gaming, e.g. labelling a study as a bedroom. The impact is not large, and it mirrors the gaming potential that already exists with NatHERS. All rooms which can be accessed only from a bedroom, like a walk-in robe or ensuite, are included in the "bedroom" definition. This definition also includes a "parent's retreat", similar to NatHERS.

Window Frame Solar Absorptance

NatHERS ratings showed that adjusting the window frame colour (solar absorptance) to suit the climate better was not only a no-cost improvement but also facilitated the use of larger glazing areas or reduced the need for high-performance glazing. Given the higher stringency of building fabric requirements, not allowing for frame colour would have unnecessarily limited design freedom and imposed additional cost.

Window frame colours are only required to be specified as light, medium and dark using the same definition of solar absorptance definitions as NatHERS tools. These broad categories allow for some colour substitution without affecting compliance. Note that aluminium framed windows use colorbond colours and solar absorptance tables are readily available for these colours.

Introducing frame colour opens up some potential for gaming and adds another factor to be checked on site. These issues also exist for compliance achieved using NatHERS. Assumptions regarding frame is therefore displayed in GC outputs. Further, providing appropriate training on the importance of window frame solar absorptance to the building and building surveying industries will be necessary. The building and design industry will also need to explain the impacts of changing colour to clients effectively.

Hard floor surface factor

A hard floor surface on a slab on ground significantly increases the ability of the concrete slab to store solar gains through windows. The dwellings that achieved a NatHERS 7-star rating that used ceramic tiles or a polished concrete floor finish were able to use higher windows areas and use less high-performance glazing. Including the hard floor surface factor in the elemental provisions allows similar benefits of greater design flexibility and lower cost compliance found in NatHERS.

Window Openability

Cross ventilation of dwellings has significant potential to reduce cooling loads. However, predicting the effects of cross ventilation is challenging to model without computer simulation because it depends on the prevailing wind direction when external temperatures are suitable to provide a cooling effect, the internal resistance to airflow in the dwelling, and the openability of windows.

Window openability is the only factor that is easy to define for the purposes of the elemental provisions. Limiting the allowance for cross ventilation to the openable window area alone will necessarily over and underestimate the effects of cross ventilation on a dwelling by dwelling basis. The dwellings simulated at 7-stars in each climate have a significant range of openability, in part because well-ventilated building designs were deliberately selected for this purpose. Alignment of GC and NatHERS outcomes should at least help ensure that the effects of cross ventilation predicted are, on average, in a suitable range.

NCC 2019 provides some allowance for "highly ventilated" dwellings, allowing a higher target C_{SHGC} to be used. This alternate target typically allows only around 10% higher solar gain for highly ventilated dwellings. Designers of specialist, well-ventilated buildings in hot and warm climates have long criticised this allowance as inadequate.

The new allowance based on the total openable window area to floor area ratio provides a significantly greater allowance for more highly ventilated houses. For example, in Darwin (CZ01):

Table 2 Openable window area to net floor area ratio in Darwin

Openable window area to net floor area ratio	CSHGC target	Change compared to 5%
5%	0.0672	100%
10%	0.0718	107%
15%	0.0770	115%
20%	0.0827	123%

And in Sydney (CZ05):

Table 3 Openable window area to net floor area ratio in Sydney

Openable window area to net floor area ratio	CSHGC target	Change compared to 5%
5%	0.0484	100%
10%	0.0538	111%
15%	0.0569	117%
20%	0.0587	121%

The openable window area allowance proposed for NCC 2022 provides designers of specialist well-ventilated buildings with considerably more design flexibility than NCC 2019.

Highly openable windows are considerably more expensive than traditional windows. Louvre windows can be a similar cost to basic double glazed windows. Consequently, it is not likely that the take up of designs that depend on highly openable windows will be adopted in the mainstream; however, this change ensures more compliance options are available for those who want such dwellings.

It should be noted that these values were derived from AccuRate simulation results. While NatHERS tools have been criticised for not adequately allowing for cross-ventilation, it is clear that they certainly show significantly more significant benefits for ventilation than the current NCC 2019 elemental provisions.

Calculating the openable area of each window would be an onerous task. While those who wish to do so should be allowed to enter the openable percentage, it is proposed to simplify this data input to three options:

- Fixed, i.e. 0%,
- Default: the user will specify the opening style (e.g. awning, sliding, louvre etc.), and the openable percentage will be set according to research based on investigating window industry window sizing charts, and
- Highly openable: set to 90%, typical for a louvre window or bi-fold door, or
- The user may input the openable percentage.

Overall impacts and benefits

To help the industry better understand the impact of the new glazing calculations on construction specifications and cost, the level of compliance achieved by the 7-star dwellings with 2019 and 2022 GC is compared.

The table below shows the average compliance levels achieved for the 7-star Class 1 dwellings on a slab floor for summer and winter performance with the 2019 and 2022 GC. Compliance levels are expressed in percentages:

- 100% represents exactly meeting the GC target.
- Below 100% implies that the dwellings, on average, exceed the target, and
- Above 100% implies that the dwellings fail to meet the requirements of the target.

The 2019 Glazing Calculator is intended to achieve a level of performance consistent with 6-stars. The 7-star dwellings should have a compliance level below 100% in the 2019 GC if alignment with 6-star performance were achieved. The table below shows the average compliance with the 2019 and proposed 2022 GC in each of the NCC climate zones.

Table 4 Average compliance with the 2019 and proposed 2022 GC in the NCC climate zones

Climate Zone	Average Compliance %			
	% 2019 Summer Limit Slab	% 2022 Summer limit Slab	% 2019 Winter Limit Slab	% 2022 Winter limit Slab
1	128%	101%	NA	NA
2	125%	99%	65%	100%
3	128%	100%	105%	91%
4	89%	100%	123%	100%
5	75%	101%	80%	100%
6	67%	100%	146%	100%
7	53%	77%	164%	100%
8	37%	75%	230%	100%

The table above shows that for the dwellings tested, the 2019 GC generally does not achieve ideal alignment with 6-stars. In warmer climates 1 to 3, the 7-star dwellings exceeded the 2019 summer performance limit. In the proposed 2022 version, these same dwellings, on average, achieve 100% of the required limit. The closer alignment with NatHERS will allow significant cost savings compared to the 2019 elemental provisions in these climates, despite the higher stringency that applies to the proposed NCC 2022. Similarly, the 2019 GC evaluates the 7-star dwellings in climates 4, 6, 7 and 8 to, on average, fail to meet winter performance targets. In some cases by very significant amounts. Again, better alignment with NatHERS reduces the glazing costs for compliant dwellings in these climates.

The one outlier from the observations above is Climate Zone 5, where the GC requirements are consistent with a 6-star level, and compliance with the proposed 2022 GC will increase compliance costs as expected.

The performance targets in the 2022 GC were set at a level so that dwellings with the average heating and cooling energy loads of the 7-star sample exactly met the GC target performance. In Climate Zone 3 (e.g. Longreach), heating is such a small part of the total load that a lower level of heating performance than that of the 7-star dwellings could be permitted without significantly affecting star rating outcomes. Similarly, in climates 7 and 8, cooling loads are so low that a lower level of performance than that achieved by the 7-star sample could be allowed without affecting alignment with 7-stars. An argument could be made for deleting the summer seasonal requirement in these climates due to their very low cooling energy loads. However, because these climates represent a large geographical area with diverse conditions, e.g. Canberra ins in Climate 7, only eliminating cooling performance requirements for Alpine regions could be supported.

The development of the 2022 GC not only sought to set the stringency of the GC to represent the average compliance level of the 7-star sample, but it also sought to limit the range of compliance levels across the sample to broadly reflect the variation in heating and cooling loads found in the 7-star sample. The newly developed factors were particularly helpful in limiting the range of compliance levels. The table below shows results obtained for the 7-star sample in each climate zone expressed as a percentage above and below (+/-) the average compliance level.

Table 5 Percentage differences of 7-star results compared with the average compliance level

Climate Zone	Range of results +/- % from average			
	% 2019 Summer Limit Slab	% 2022 Summer limit Slab	% 2019 Winter Limit Slab	% 2022 Winter limit Slab
1	27%	14%	NA	NA
2	43%	24%	24%	20%
3	55%	27%	57%	23%
4	35%	14%	43%	14%
5	18%	21%	24%	11%
6	21%	23%	65%	25%
7	17%	15%	57%	20%
8	8%	10%	89%	27%

The table above shows that the range of outcomes delivered by the 2019 GC would generally be much greater than that achieved by the 2022 GC without the new factors.

Note that summaries of outcomes for suspended timber floors and each dwelling are available.

3.5.4 Conclusion

The new design of the GC algorithms has made them more complicated than those for the 2019 GC. This complexity is embodied in the 2022 GC, so all that users will see of this complexity are a few more data inputs. As explained above, ensuring that tool help functions and training adequately covers these new data inputs will help ensure that inadvertent mistakes are not made. A greater range of data inputs will always open the further potential for gaming. The risk of gaming can be mitigated to some extent by constructing internal error correction, e.g. check where the dwelling has two storeys, but windows are only entered on the ground floor. New data inputs also add additional items that need to be checked to ensure compliance at the certification and construction stages. Therefore, it will be critical to ensure that the GC report highlights these areas and that the industry receives training on the implications of product substitution.

Note that all the new data inputs proposed are already data input into NatHERS ratings. Therefore, the industry is already familiar with checking these requirements, even though the quality of this checking may not always be of a high standard.

While greater complexity is accepted as a less than optimal regulatory solution, the benefits of the greater complexity are substantial. As shown above, the new factors open the door to new cost-saving options or greater design flexibility that have previously only been available through NatHERS. Better alignment with NatHERS outcomes will also deliver significant glazing cost savings over the 2019 GC in every climate zone except climate 5.

3.6 Ceiling fans

Ceiling fans facilitate significant reductions in the use of artificial cooling and industry is already installing them in significant numbers.

The benefits of air movement provided by higher areas of openable windows in DTS elemental are proposed to be significantly increased compared to NCC 2019. This increase is made to reflect the benefits of air movement found in NatHERS simulation.

Ceiling fans also enhance comfort in summer by providing air movement. NatHERS ratings show that using ceiling fans leads to significant cost-effective increases to star rating in hot climates, and smaller, but still cost-effective improvement in warm climates. Furthermore, data on the use of ceiling fans shown in the CSIRO dashboards based on NatHERS universal certificates demonstrate the extensive use of ceiling fans in the field, particularly in NCC climate zones 1 and 2 (around 8 in Climate Zone 1 and 5 in Climate zone 2 as shown in the CSIRO AHD portal).

Minimum requirements for the provision of ceiling fans is proposed for NCC 2022 in climate zones 1, 2, 3 and living areas in Climate 5. In Climate zones 1 and 2 these requirements include both daytime and night-time occupied spaces. In Climate zone 5 ceiling fans are only required in daytime occupied spaces. This reflects the 7-star ratings developed for this project. In both climates ceiling fans in bedrooms did not significantly change the the rating. In Climate 3, the high daytime temperatures showed that a significant amount of cooling could be avoided through the use of ceiling fans in living rooms. On average 5 ceiling fans were installed in living areas of Class 1 dwellings in Climate Zone 3. In Climate Zone 5, higher datytime temperatures, and in locations like Sydney, higher daytime humidity, also showed that ceiuling fans could allowed significant amount of cooling to be avoided. . On average 3 ceiling fans were installed in living areas of Class 1 dwellings in Climate Zone 5.

Ceiling fans are not required in circulation spaces like hallways and entry foyers.

In Climates 1 and 2 the higher humidity levels and lower diurnal range of temperatures (i.e., overnight temperatures are higher than in other climates) mean that significant benefit is derived through the installation of ceiling fans in bedroom areas. In Climate zones 3 and 5 lower humidity and overnight temperatures mean that comfort can be achieved by opening windows to let in cooler outside air and provide air movement. Consequently, the benefit of ceiling fans in bedroom areas is much lower in terms of the improvement to the star rating. In addition, the installation of ceiling fans found in these climate zones is significantly lower than for Climate zones 1 and 2. Not requiring ceiling fan installation in bedrooms in Climate zones 3 and 5 is therefore consistent with current industry practice.

Minimum ceiling fan number and diameter for the propoised NCC 2022 provisions was set according to the 7-star rating solutions developed for this project and generalised using the ceiling fan comfort algorithms embedded in Chenath.

In each dwelling the additional comfort (in °C) provided by air movement for the installed ceiling fans was calculated using the algorithms embedded in Chenath. This additional comfort is dependent on the number and diameter of ceiling fans and the area of the space they serve. The average minimum additional comfort provided in daytime and night-time spaces by ceiling fans was established and set as a minimum benchmark. The number and diameter of ceiling fans required to deliver this minimum comfort benchmark was calculated for rooms of various size to develop the minimum requirements.

4 Assisting industry to deal with the increased complexity of proposed NCC 2022 elemental

4.1 Insulation requirements

Insulation requirements are embodied in a series of tables that show the added insulation required given the building element's other properties that affect heat flow. An insulation selector spreadsheet could fulfil a similar role to the Glazing Calculator. The tool would ask for details:

- climate zone,
- what type of building element it is (walls, roof/ceiling or floor),
- the construction of the component, and
- the key factors that determine heat flow accounted for by the regulation, e.g. for walls, number of stories, height, colour and eave overhang.

The tool would then show the required added R-value. If the building were constructed using a steel frame, the options for thermal bridging mitigation would be given, and the user could select which option they wish to use. The tool would then produce a report outlining the assumptions and the required R-value.

There are some other features that an insulation tool could include:

- Dwellings with multiple wall height/colour/overhang: the calculator could provide an area-weighted R-value for the whole dwelling so that the same R-value can be installed over the entire building.
- Where added insulation R-value exceeds practical limits, a suggestion that lower insulation R-values would be possible by using:
    - a NatHERS rating, or
    - using other building element properties like lighter colours/deeper eaves in hot climates or darker colours smaller eaves in cool climates.
- For more unusual constructions, a total R-value calculator could be provided. This calculator would ensure that the correct building material and air space values are used to eliminate error and gaming. A similar product is provided for façade calculations in Volume 1.

4.2 Glazing requirements

Like the suggestions above for insulation, the Glazing Calculator should highlight the new features that have been included in the calculation in its outputs to facilitate checking and installation. The GC should provide warnings regarding product substitution.

4.3 General strategies

Much of the complexity comes from providing options for lower R-values. An alternative to this would be to set the maximum R values from the tables in the NCC, then put the more complex tables in an NCC standard document like that developed for load limits.

It will also be important that the output of all tools are structured to help certifiers/inspectors by making underlying assumptions about the insulation R values explicit and providing warnings about product substitution.

Most building industry bodies require Continuing Professional Development training. It may also be important to ensure that training is developed for other key trades such as carpenters/insulation installers, plumbers, and electricians delivered through their member associations.

The greater detail of calculations means that compliance will depend on a broader range of factors than just the headline performance parameters line R-value or U-value and SHGC. The building industry will need to fix aspects such as colour earlier in the design process than it currently does. Consequently, the building industry needs more time to adapt its processes to the new requirements. All of the new features in the elemental provisions are also covered in NatHERS ratings, so the industry already has experience with this. Nevertheless, for those builders who routinely use elemental provisions some adjustment will be needed.