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FUTURE PROOFING RESIDENTIAL DEVELOPMENT TO CLIMATE CHANGE

ADDENDUM TO THE STAGE 1 REPORT - ADAPTATIONS TO RESIDENTIAL BUILDING DESIGNS

APRIL 2021

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Future Proofing Residential Development to Climate Change
Addendum to the Stage 1 report - Adaptations to Residential Building Designs

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GLOSSARY

Baseline Year / Baseline Year (2020)	In the context of this report, references to Baseline Year relate to the BASIX and NatHERS software tools as approved for regulatory use in 2020.
BASIX	NSW planning legislation in the State Environmental Planning Policy (Building Sustainability Index: BASIX) 2004, known as the BASIX SEPP, enabled under the EP&A Regulation 2000, and implemented through the BASIX online tool https://www.planningportal.nsw.gov.au/basix
COAG	Council Of Australian Governments
DCP	Development Control Plan
DGU	Double Glazed Unit – describes the combined framing and glass components making up a window/façade system with two panes of glass (inner and outer) separated by a gap filled with air or noble gas such as Argon.
DPIE	NSW Department of Planning, Industry and Environment
FR5	Common abbreviation for the NatHERS-approved FirstRate5 modelling software.
IES VE	Integrated Environmental Solutions (IES) is a software vendor. The VE software is an in-depth suite of integrated analysis tools for the design and retrofit of buildings.
Insolation	INcoming SOLar radiATION – portmanteau term commonly used in technical and passive design-related literature to describe solar radiation that strikes the external surfaces of a building.
$kgCO_2$-e	Kilograms of CO_2 equivalent. A typical measure of Greenhouse Gas Emissions that accounts for CO_2, the benchmark greenhouse gas, as well as the many other greenhouse gases that can contribute to global warming.
LEP	Local Environment Plan
Low-E glass	Low emissivity glass has a treatment or coating to one of the surfaces, that helps to limit the transmission of heat through the glass in the direction determined by the coated side. This effectively improves the insulative performance of the glass, and depending on the type of treatment can be tuned to suit higher or lower solar control as well as substantial or subtle amount of heat transfer control.
MJ/m^2	Megajoules per square metre – measure of load or energy consumption per unit area of a dwelling
MUD	Multi-Unit Development. A typical term used to describe larger apartment buildings
NARCLiM	“NSW and ACT Regional Climate Modelling”
NatHERS	“Nationwide House Energy Rating Scheme” https://www.nathers.gov.au/ Accredited modelling performed in accordance with the NatHERS protocol/technical notes is used to determine heating and cooling loads for a given location, associated with maintaining acceptable dwelling thermal comfort through use of air conditioning.

NCC	National Construction Code is a performance-based code that sets the minimum requirements in relation structure, fire safety, access and egress, accessibility, health and amenity, and sustainability.
SEPP	State Environmental Planning Policy. These legislated policies are environmental planning instruments that deal with matters of State or Regional environmental planning significance.
SGU	Single Glazed Unit – describes the framing and glass components making up a window/façade system with a single pane of glass.
SHGC	Solar Heat Gain Coefficient – this is the measure of glass or a window system's ability to transmit or limit incoming solar radiation ('*insolation*') to the interior of a building. Lower SHGC results in less solar heat gain to the interior space. Expressed as a decimal fraction between 0 and 1. Being a coefficient, SHGC is unitless.
Thermal Comfort	A measure of the internal thermal conditions of a building considered to be representative of comfort responses for the majority of occupants. BASIX thermal comfort assessment considers the heating and cooling loads on a dwelling against benchmark thresholds for each NatHERS climate zone considered to result in acceptably comfortable conditions. Buildings with effective passive design features will require less energy for air conditioning to achieve thermal comfort than buildings that do not consider passive design elements, and will be likely to remain more comfortable without air conditioning than buildings that do not have effective passive design features.
Thermal Performance	An indicator of a material or construction's properties in terms of heat transfer / thermal mass / solar admittance. For example, an insulating material achieves good thermal performance by limiting heat transfer effectively.
U-value	This is a measure of the thermal conductivity of a construction, typically used for describing the thermal properties of glass or window systems. Lower U-value represents less thermal conductivity and therefore better insulation performance. Standard metric units for U-value are $W/m^2 \cdot K$
VVVF motor	Variable voltage variable frequency motor – a higher efficiency option for lift motors

ACKNOWLEDGEMENTS

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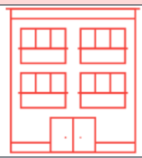
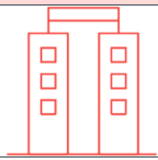
EXECUTIVE SUMMARY

This supplemental study to the *Future Proofing Residential Development to Climate Change* research project arose in response to the results of the Stage 1 study, which found that most residential designs that currently receive approval under BASIX would fail to satisfy the cooling energy limits required for thermal comfort compliance.

The aim of the Stage 1 Addendum: Adaptations to Residential Building Designs is to document Compliance Design Treatments that are required in order for current BASIX compliant buildings in the Eastern Beaches to comply with existing BASIX Thermal Comfort standards in future climate scenarios - 2030 and 2070.

Table ES.1 The five residential building types assessed

Building Types				
				
Detached	**Attached (duplex/semi/townhouse)**	**Low-rise (up to three storeys)**	**Mid-rise (four to five storeys)**	**High-rise (six storeys & above)**

The focus of treatments for the 2030 and 2070 climate scenarios was to manage the modelled cooling energy load in NatHERS software. Heating energy demand, having already been demonstrated as negligible under future climate, has been discounted from the results, however in all treatment cases there was no material rise in heating demand observed that would confound the intended outcomes of treatment.

Table 1.1 Summary of Compliance Design Treatments

TREATMENT APPROACH	DESCRIPTION
Building Fabric and Glazing Improvements	Improving on the baseline glazing thermal performance, insulation levels, material selections and adjusting cross ventilation opportunity by increasing the amount of operable window percentage.
Shading Design Improvements	Improving and adding shading elements (eaves, shade fins, vertical shading elements such as awnings, external venetians), reducing the solar absorptance of the external fabric through lighter colours than baseline, reducing or removing skylight area, shading skylights, increasing the amount (%) of operable windows.
Glazing Area Reductions and Deletions	Reducing the area of glazing compared to the baseline, or deleting windows and/or skylights entirely
Modelling of Ceiling Fans	Adding ceiling fans to conditioned day and/or night time zones in combination with the above treatments where they do not achieve compliance alone
Combined Treatment Elements *	Where compliance with the baseline BASIX targets for thermal comfort could not be achieved by any one of the design treatment approaches (including addition of ceiling fans), a combination of them was tested.

The compliance threshold adopted is the cap on NatHERS cooling load imposed under the current BASIX requirements:

- 29.5 MJ/m² for Class 1a dwellings (the Detached and Attached housing types)
- 26 MJ/m² for Class 2 dwellings (the MUD building types – low-rise, mid-rise and high-rise apartment buildings)

Glazing reduction and/or deletion was discounted from the final selection of effective design treatment solutions, due to the impractical levels of reduction required and the counterproductive impacts on ventilation and daylighting opportunity this imposed.

For the 2030 scenario, the majority of dwellings were able to achieve compliance with the application of any of the treatment approaches. For low-rise dwellings, in some cases addition of ceiling fans was required to make up the small shortfall in cooling load reductions that were achieved by the design treatments.

Compliance was achievable in the 2070 scenario for all dwelling types once a combined treatment approach was taken, applying the individual approach that yielded the overall best improvement in cooling load, then selecting additional elements of the other treatment approaches sufficient to deliver a compliant result.

Currently approved residential dwelling designs may struggle to achieve the required planning approval targets for cooling energy in the future.

They can be treated with fabric, glazing, shading and air movement improvements to deliver compliant results under 2030 and 2070 future climate scenarios.

The treatments involve judicious application of fundamental, sound passive design and thermal envelope performance principles. While they may not be cost neutral in all cases, the treatments do avoid the need for wholesale re-design of the buildings.

1 INTRODUCTION

For the full study 'Future Proofing Residential Development to Climate Change', modelling and analysis was undertaken for five different residential building types, as shown in Table ES.1 above. Buildings representative of typical Eastern Suburbs housing were chosen, comprising a detached, attached, low, mid and high-rise building, where they were compliant with current NSW residential development sustainability requirements – known as BASIX commitments.

The modelling reviewed the performance of each building type against three criteria:

- Thermal comfort of the dwelling i.e. estimated heating and cooling loads
- Energy consumption and greenhouse emissions
- Water consumption

Each building type was then assessed for these criteria under three different climate scenarios:

- Present day 2020 (to serve as a Baseline Year)
- Near future change 2030 (average 2020 – 2039)
- Far future change 2070 (average 2060 – 2079)

The analysis used existing modelling tools to assess the performance of these building types under each climate scenario. These included the Nationwide House Energy Rating Scheme (NatHERS) accredited software and IES VE software for thermal comfort, and the Building Sustainability Index (BASIX) online tool for energy and water consumption.

The main study indicated that as the climate warms in 2030 and 2070, the subject dwellings will have negligible heating needs. However, the study found that despite a relatively mild climate, all BASIX compliant dwellings in the Eastern Beaches failed the current BASIX Thermal Comfort requirements for cooling by 2030, and by 2070 cooling loads increased on average 308% above the Baseline Year for all building types. BASIX modelling results demonstrated an increase in electricity demand to meet these extra cooling needs.

Further analysis was then carried out to identify potential design modifications which would enable the dwellings to pass the BASIX Thermal Comfort cooling load requirements under the future climate scenarios of 2030 and 2070.

This report summarises the result of this additional investigation.

2 PROJECT OBJECTIVES

2.1 BACKGROUND

With the ten hottest years globally being recorded since the turn of the millennium (NOAA National Centers for Environmental Information, 2020), it is evident now more than ever that measures must be taken to prepare for a hotter climate. The residential building industry is no exception to this, with a global temperature rise of 2.5°C forecast for the next century. Homes will need to be more resilient not only to hotter temperatures, but drier climates and more extreme weather. With good design practices, homes can be energy and water efficient, have low greenhouse footprints, and be safe and comfortable for occupants.

Residential buildings will also play a large role in Local, State and Federal Government policies addressing climate change. Existing commitments to reducing climate impacts include the NSW Government's target for net zero emissions by 2050, and the Trajectory for Low Energy Buildings, a COAG-developed pathway towards zero carbon buildings. Carbon offsetting may also be pursued with home solar generation, which aligns with the National Energy Productivity Plan to improve energy productivity by 40 per cent by 2030. By ensuring that building controls encourage good building design, NSW residential developments can increase their preparedness for future conditions while also reducing their greenhouse gas emissions and water footprint.

This supplemental study to the *Future Proofing Residential Development to Climate Change* research project arose in response to the results of the Stage 1 study, which found that most residential designs that currently receive approval under BASIX would fail to satisfy the cooling energy limits required for thermal comfort compliance.

2.2 AIMS

The aim of the study is to identify and document design solutions that will enable the BASIX-compliant buildings to meet the Thermal Comfort cooling targets in future climate scenarios (2030 and 2070).

These design solutions will enable buildings to remain cooler and more comfortable for occupants, without the need for excessive air conditioning use as the climate warms.

The findings of this study are provided to help inform the design and policy response actions recommended in the main Stage 1 report.

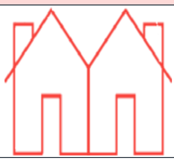
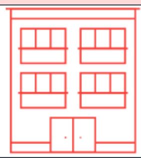
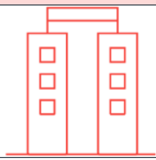
3 DETAILED METHODOLOGY

Design Sources

This supplemental study re-examined the five residential building designs that were investigated in the main Stage 1 report. A subset of the full range of modelled dwellings from the original study were selected against which to test design treatments, in accordance with the following criteria for selecting representative designs:

- For the Class 1a detached and attached dwellings, assess and document treatments on each individual dwelling for compliance.
- For the Class 2 MUDs, assess and document treatments from across the low-rise, mid-rise and high-rise cases, including the worst-performing dwellings based on cooling loads.
- Three design treatment approaches were analysed per dwelling model tested, to address
  - building fabric improvements (insulation, materials and glazing performance),
  - shading design improvements, and
  - glazing area reductions and deletions

Table 3.1 The five residential building types assessed

Building Types				
				
Detached	**Attached (duplex/semi/townhouse)**	**Low-rise (up to three storeys)**	**Mid-rise (four to five storeys)**	**High-rise (six storeys & above)**

Design Configurations

Refer to *Section 5.1-BASIX Commitments for each Building Type* of the main Stage 1 report for details of the complying design commitments of the five building types investigated here.

These designs met the BASIX thermal comfort requirements for heating and cooling load caps in effect in 2020, and form the baseline configuration of each building against which the tested design treatments were applied. The architectural designs of each of the building types are similarly available in Appendix A of the main report.

Modelling and Compliance Criteria

The selected subset of dwellings was modelled in the same FirstRate5 NatHERS accredited software used for the main Stage 1 study.

The 2030 and 2070 climate scenario weather data were used, to implement the compliance design treatments progressively, until each dwelling model was able to meet the BASIX thermal comfort requirements under the 2030 and 2070 conditions.

The thermal comfort compliance threshold was the currently in-force cap on NatHERS cooling load under BASIX:

- 26 MJ/m² for Class 1a dwellings (the Detached and Attached housing types)
- 29.5 MJ/m² for Class 2 dwellings (the MUD building types – low-rise, mid-rise and high-rise apartment buildings)

Compliance Design Treatments

The types of treatment approaches tested are described in **Error! Reference source not found.**.

Table 3.2 Summary of Compliance Design Treatments

TREATMENT APPROACH	DESCRIPTION
Building Fabric and Glazing Improvements	Improving on the baseline glazing thermal performance, insulation levels, material selections and adjusting cross ventilation opportunity by increasing the amount of operable window percentage.
Shading Design Improvements	Improving and adding shading elements (eaves, shade fins, vertical shading elements such as awnings, external venetians), reducing the solar absorptance of the external fabric through lighter colours than baseline, reducing or removing skylight area, shading skylights, increasing the amount (%) of operable windows.
Glazing Area Reductions	Reducing the area of glazing compared to the baseline, or deleting windows and/or skylights entirely
Modelling of Ceiling Fans	Adding ceiling fans to conditioned day and/or night time zones in combination with the above treatments where they do not achieve compliance alone
Combined Treatment Elements	Where compliance with the baseline BASIX targets for thermal comfort could not be achieved by any one of the design treatment approaches (including addition of ceiling fans), a combination of them was tested.

The Results section summarises the resultant design treatment solutions that were able to achieve compliance, and discusses the relative merits and shortcoming of the treatment approaches tested and recommendations for future residential design guidance and policy.

3.1 CLIMATE-RELATED SOURCES OF HEAT IN DWELLINGS

There are two main sources of heat build-up in the dwellings as a result of the thermal envelope

- heat exchange due to temperature differences between the interior and exterior, and
- heat gain due to the effects of solar radiation on the opaque and glazed parts of the building.

The approaches to design treatment seek to address these two sources of heat build-up through a range of measures.

3.2 BUILDING FABRIC AND GLAZING IMPROVEMENTS

The measures grouped under this compliance design treatment approach are aimed at improving the thermal performance of components that make up the thermal envelope of the dwellings and the building.

- By being more insulative, some of these measures help to reduce the rate of heat exchange between the outside and inside of the dwelling.
- Other measures relate to the improved thermal performance of glazing, which address
  - the insulative properties of the windows (referred to commonly as the 'U-value', with lower values being better at insulating), and
  - the solar control properties of the window, indicated by a thermal factor known as the Solar Heat Gain Coefficient (SHGC), with lower SHGC resulting in less transmission of solar radiation through the glazing that is responsible for heating the interior of the dwelling.
- The relative mass of building constructions and the positioning of that mass relative to the exterior or interior surfaces of the dwelling can have a mediating effect on daily temperature swings within the residence (also known as the 'diurnal range').
  Higher mass construction, having a slower response to absorption and retransmission of heat energy compared to lightweight construction, can offer two benefits when employed with careful design consideration:
  - mitigate extremes of temperature to varying extent and
  - spread the swings of temperature across 24 hours, seeking to keep temperatures lower than the outside during the day and potentially slightly warmer at night.

Table 3.3 summarises the range and extent of measures that were adopted for testing the Thermal Envelope (Fabric and Glazing) Improvements approach to produce the results in this report.

Table 3.3 Summary of measures tested for the Building Fabric Performance Improvements

BUILDING FABRIC PERFORMANCE IMPROVEMENT MEASURES	
High performance DGU – thermally broken frame, ultra-low solar gain low-e tinted glass, Argon gaps.	— Very insulative (for windows) — Very low solar transmission. — May have an associated lack of visual clarity due to tint. — Expensive Typical performance ranges: U value ≤ 2.0, SHGC ≤ 0.18
High performance DGU – thermally broken frame, low solar gain low-e glass, Argon gaps.	— Very insulative (for windows) — Low solar transmission. — Noticeable tint or 'finish' to the glass. — Expensive Typical performance ranges: U value ≤ 3.0, SHGC ≤ 0.27
Performance SGU or DGU – typical frames, low solar gain low-e glass	— Good insulative performance — Low solar transmission. — Noticeable tint or 'finish' to the glass. — More expensive than generic aluminium systems Typical performance ranges: U value ≤ 4.0, SHGC ≤ 0.4
Highly insulated external walls	— Insulation values of R2.7 to R4.0 added to the wall construction (typical added insulation of conventional constructions might only be R2.0)
Increased wall and roof insulation.	— Insulation values of R2.2 to R3.5 added to the wall construction. — Roof added insulation of R3 to R5 (typical roof added insulation might only be R2.5)
Fire stairs/lift lobby/corridor walls added insulation	Improves resistance to heat transmission from internal but typically unconditioned or tempered spaces
Skylight - performance ventilated model	Performance skylights use double glazed, low solar gain low-e glazing systems, typical performance ranges: U value ≤ 3.0, SHGC ≤ 0.25. A ventilated skylight can be opened, providing an additional path for cross ventilation airflow and potentially may encourage a level of buoyancy or 'stack' ventilation
Make all windows openable	Improves the number of paths for cross ventilation airflow. Must consider other constraints including safety, acoustics, security and weathertightness.

3.3 SHADING DESIGN IMPROVEMENTS

The measures grouped under this compliance design treatment approach are aimed at improving the ability to limit the impact of solar radiation on the building opaque and glazed surfaces in the design of the dwellings and the building.

- By providing external features that prevent sunlight directly impacting the façade, shading elements help to mitigate heat gains arising from absorption or transmission of solar energy into the building.
- Lightening the colour of external finishes to walls and roofs reduces the solar absorptance of the surfaces, which reduces the rate at which the materials heat up in response to sunlight that strikes the surfaces.
- Overhangs such as balconies, roof eaves and shade fins that project horizontally provide shading of the building envelope from higher sun angles, typical between mornings and afternoons, and in Australia most effective when applied on northerly-oriented elevations.
- Shade elements that are positioned vertically in front of windows and walls, such as pull-down awnings, perforated metal screens, external venetians and blinds, are more effective for shading from early morning and late afternoon radiation associated with low-angle easterly and westerly sunlight

Table 3.4 summarises the range and extent of measures that were adopted for testing the Shading Design Improvements approach to produce the results in this report.

Table 3.4 Summary of measures tested for the Shading Design Improvements approach

SHADING DESIGN IMPROVEMENT MEASURES	
Wall finishes changed to light colour	Solar absorptances 0.3-0.2
Wall & roof finished changed to very light colour	Solar absorptances 0.2-0.1
Skylight area substantially reduced	Skylights are a prime source of solar heat gain
External vertical shades to east/west oriented windows	Awnings or external blinds or screens applied to east and west give the best shading control of low-angle solar radiation. 
Maximised eaves and overhang shading	Horizontal projecting shades provide more effective control for high angle sun to a northern elevation, as well as some incidental shading to the other orientations
Make all windows openable	Increase potential for air movement

3.4 VENTILATION & AIR MOVEMENT

Increasing air movement within the dwellings can greatly improve thermal comfort in hot conditions.

More operable windows in a dwelling improve cross ventilation opportunity, higher level apartments have better access to prevailing breezes than low level, ceiling fans increase room air movement.

3.4.1 MODELLING OF CEILING FANS

Due to BASIX restrictions in place at the time of commencement, ceiling fans were not modelled in the original study. Ceiling fans if included in the design were only permitted as inputs to the Energy section of the BASIX tool. While this provided a benefit to the Energy scoring, it was not available as a modelling option and could not be employed as a measure towards meeting the BASIX thermal comfort compliance requirements.

Since this study was completed, a revision to the BASIX tool and rules means it is now possible to include ceiling fans in NatHERS modelling, in place of including them in the BASIX Energy section inputs.

Addition of ceiling fans assists with reducing the modelled NatHERS cooling energy requirement and is an additional design tool tested for achieving satisfactory thermal comfort under the future climate conditions. Fans confer a benefit to improving the cooling energy load in modelling, but rarely have any impact on heating.

Three fan sizes are available in the NatHERS software, and these can be applied per zone.

- Small ceiling fans - 900mm diameter
- Nominal sized ceiling fans – 1,200mm diameter
- Large ceiling fans – 1,400mm diameter

The larger the fan, the greater the effective air movement it provides, and this generally leads to better cooling energy results. Consideration should be given however to the practicalities of what size and number of fans can be reasonably installed in each room.

Applying ceiling fans to living areas (kitchen / living / family / dining / study rooms) would be a typical first approach, aiming to improve daytime occupant comfort in warm conditions.

A further measure is to apply ceiling fans to bedrooms as an additional treatment to address night-time occupant comfort during warm periods. This is more relevant under the future climate scenarios due to the increase in minimum temperatures seen throughout the year.

4 RESULTS

Results from the larger study Future Proofing Residential Development to Climate Change helped us to understand that, as the climate warms, houses will need to be designed to focus on minimising the cooling demands of the building. Hence, the focus of Compliance Design Treatments for the 2030 and 2070 was to ensure the BASIX Thermal Comfort cooling loads were met.

4.1 NATHERS THERMAL COMFORT RESULTS

Heating energy demand, having already been demonstrated as negligible under future climate, has been discounted from the results, however in all treatment cases there was no material rise in heating demand observed that would confound the intended outcomes of treatment.

The detailed individual dwellings NatHERS Thermal Comfort results of the Compliance Design Treatments for 2030 and 2070 are presented in Appendix A below.

4.2 GLAZING REDUCTION LIMITATIONS

Of the five treatment approaches towards cooling load compliance that were listed in **Error! Reference source not found.**, the third option involved selective reduction or removal of glazing from the baseline designs, on the premise that glazing is the least insulative element in the thermal envelope and is also the primary source of heat load in the dwelling from solar heat gains.

In the majority of cases tested, no reasonable amount of glazing reduction was capable of delivering the required improvement in cooling load that could result in compliance, neither in isolation or in combination with other treatments.

In particular for the 2070 scenario, reducing glazing areas by 50 - 90% still resulted in non-compliant buildings. This level of glazing removal is not appropriate from an architectural, daylighting and amenity perspective, and additionally results in the opposite outcome to that sought, due to the loss of cooling benefit from cross ventilation.

Therefore, reducing or deleting glazing area was determined to be an unacceptable design treatment solution for this project. Results from reducing/deleting glazing areas are included in Appendix A below

4.3 2030 FUTURE CLIMATE COMPLIANCE TREATMENT

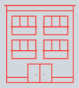
For the 2030 scenario, most dwellings were able to achieve compliance with the application of one of the two treatment approaches. For low-rise dwellings, in some apartments addition of ceiling fans was required to make up the small shortfall to reach compliance.

KEY

● Elements from each treatment approach that were applied in pursuit of compliance are indicated by a black dot in the relevant column and row of Table 4.1.

✓ A green tick mark shown in the compliance outcome row indicates that the combination of design treatments applied resulted in compliance for that dwelling type and treatment approach.

Table 4.1 Sydney Eastern Suburbs 2030 Compliance Design Treatments for future climate scenarios

2030 DESIGN TREATMENT OPTIONS						
Building Fabric Performance Improvements	Compliance outcome:	✓	✓	✓	✓	✓
	High performance DGU – thermally broken frame, ultra-low solar gain low-E tinted glass, Argon gaps.					
	High performance DGU – thermally broken frame, low solar gain low-E glass, Argon gaps.				●	●
	Performance SGU or DGU – typical frames, low solar gain low-E glass	●	●	●		
	Highly insulated external walls					
	Increased wall and roof insulation.	●	●			
	Fire stairs/lift lobby/corridor walls added insulation				●	
	Skylight - performance ventilated model	●	●	N/A	N/A	N/A
OR						
Shading Design Improvements	Compliance outcome:	✓	✓	✓*	✓	✓
	Wall finishes changed to light colour			●	●	
	Wall & roof finishes changed to very light colour	●	●			●
	Skylight area substantially reduced	●		N/A	N/A	N/A
	External vertical shades to east/west oriented windows	●	●	●	●	●
	Maximised eaves and overhang shading	●	●	●	●	●
+ Air Movement Increases	Make all windows openable	●	●	●	●	
	Nominal size ceiling fans, all day and night zones			●*		
	Nominal size ceiling fans, day zones only					
	Large diameter ceiling fans, day zones only					

* Note the low-rise building dwellings required additional modelling of ceiling fans combined with the Shading Improvements to reach compliance in the 2030 conditions.

‡ Mid rise top level dwellings did include skylights, but majority of the dwellings in this building type did not.

4.4 2070 FUTURE CLIMATE COMPLIANCE TREATMENT

For the MUD building types (low-rise, mid-rise and high-rise apartments), compliance was achievable with the addition of ceiling fans in living areas and bedroom areas in conjunction with either the Building Fabric Performance or Shading Improvement treatments. For Detached and Attached dwelling types under the 2070 climate scenario, there was no compliant solution found by applying either of the individual treatment approaches, with or without the application of ceiling fans in the modelling.

Compliance was achievable in the 2070 scenario however for ***all*** dwelling types once a combined treatment approach was taken. The combined strategy applied the individual approach that yielded the best improvement in cooling load, then selected additional elements of the other treatment approach sufficient to deliver a compliant result.

KEY

- ● Elements from each treatment approach that were applied in pursuit of compliance are indicated by a black dot in the relevant column and row of Table 4.2.
- ✓ A green tick mark shown in the compliance outcome row indicates that the combination of design treatments applied together resulted in compliance for that dwelling type and treatment approach.

Table 4.2 Sydney Eastern Suburbs 2070 Future Climate Compliance – combined design treatment solutions

2070 COMBINED DESIGN TREATMENTS						
	Combined treatment compliance outcome:	✓	✓	✓	✓	✓
Building Fabric Performance Improvements	High performance DGU – thermally broken frame, ultra-low solar gain low-E tinted glass, Argon gaps.	●	●			●
	High performance DGU – thermally broken frame, low solar gain low-E glass, Argon gaps.			●		
	Performance SGU – typical frames, low solar gain low-E glass				●	
	Highly insulated external walls				●	
	Increased wall and roof insulation.	●				
	Internally exposed mass with heavily insulated walls					●
AND	Fire stairs/lift lobby/corridor walls added insulation				●	
Shading Design Improvements	Skylight – area substantially reduced, performance ventilated model	●		N/A	N/A ‡	N/A
	Wall & roof finished changed to very light colour	●	●	●		●
	Skylight deleted		●	N/A	N/A ‡	N/A
	External vertical shades to east/west oriented windows.		●	●	●	●
AND	Maximised eaves and overhang shading		●	●	●	
Air Movement Increases	Make all windows openable.	●	●	●	●	
	Nominal size ceiling fans, all day and night zones	●	●	●	●	
	Nominal size ceiling fans, day zones only					●
	Large diameter ceiling fans, day zones only					●

‡ Mid-rise top-level dwellings did have skylights, but majority of the dwellings in this building type did not.

5 DISCUSSION AND CONCLUSIONS

The results of the design treatment study show that, for currently compliant dwellings in a range of building types, it is possible to apply individual or combined types of design treatments to achieve compliance against BASIX Thermal Comfort benchmarks in future climate scenarios 2030 and 2070.

From our modelling, two main design compliance treatments were successful, due to their practical application:

- Building Fabric Performance improvements
- Shading improvements

These treatments can be incorporated into the existing compliant designs without the need to fundamentally alter the building massing, siting or configuration.

Glazing reduction was deemed largely unsuitable as a compliance design treatment due to the associated negative impacts on daylighting and ventilation opportunity and architectural and amenity constraints.

For the 2030 climate scenario, most dwellings were able to achieve compliance with a relatively 'light-touch' application of one of the two treatment approaches described (improvements to either building fabric or shading).

All design treatment cases benefitted from improvements to air movement opportunity, firstly through improving the amount of operable windows in the design, and then the inclusion of ceiling fans to day time and/or night time occupied zones as required to further improve air movement and thus improve the experience of cooling thermal comfort.

For the 2070 climate scenario, most dwellings needed all of the following: building fabric improvements, shading improvements and increased air movement through increased openable windows and ceiling fans to day and night zones.

Inclusion of ceiling fans in modelling is not a compliance solution by itself but should form part of any key planning control aimed at design compliance recommendations for future climate conditions.

These approaches to compliance design treatment for future climate thermal comfort have shown that existing residential designs **are capable of meeting future demands for cooling comfort**.

The key conclusion from the Future Proofing Residential Development to Climate Change project is that by including a future (eg 2030) climate file into the BASIX tool and the NatHERS software residential buildings will be better designed and built to withstand future climate conditions. This addendum has demonstrated that, if future climate files are adopted in NatHERS Software used to meet the BASIX Thermal Comfort targets, then **climate appropriate building design outcomes would be secured for the NSW housing stock.** Importantly, improvements to building fabric, shading and ventilation would be delivered for all building types, delivering thermally comfortable dwellings that can be cooled efficiently in a warming climate. Critically, it would deliver thermally safe dwellings that could stay cool during heatwave and blackout events.

The design improvements that have been recommended by this study align to fundamental passive design elements. By applying these passive design elements in future residential building design, to better enable cost-effective housing construction that can deliver acceptable comfort, and to minimise the future cost of maintaining comfort through use of air conditioning.

- Siting & orientation
- Shading to control solar gains
- Selection and placement of thermal mass
- Provision of optimal cross ventilation
- Effective levels of insulation
- Finishes and colours tuned to minimise heat load
- High thermal performance glazing tuned to climate
- Construction systems that avoid thermal bridging
- Sizing and positioning of glazing for optimal daylighting without excessive solar load

This WSP report recommends that:

i) the NSW Government consider these results during the finalisation of the Design and Place SEPP.

ii) the Federal Government consider these results for the next upgrade of the National Construction Code’s 2022 residential energy efficiency update.

iii) A future climate scenario is used in minimum compliance assessment (ie NatHERS modelling for NCC compliance) to improve the resilience of dwellings to the hotter, more extreme weather expected in the near future. A 2030 climate file is recommended as a minimum, however the impacts of residential dwelling performance under future climate scenarios must be investigated in more climate zones and cost implications determined, to enable the requisite regulatory changes to secure future proofed residential development and controls as soon as possible. We recommend the following investigation to be able to inform regulatory changes:

- Repeating the assessment conducted here in more climate zones around NSW, to gain an understanding of the extent of impact expected in different areas
- Including a 2050 climate file to test sensitivity and to be able to assess which future climate file is most appropriate to include in regulatory compliance

APPENDIX A

Design Treatments - Detailed Thermal Comfort Results

A1 INDIVIDUAL DWELLINGS NatHERS TREATMENT SCORES

The following tables present the individual dwelling results for heating and cooling loads in each BASIX sample building modelled.

The design treatment approaches are abbreviated in the treatment notes as follows:

- FGP – Fabric and Glazing Performance improvement treatments
- SHD – Shading Improvement treatments
- GR – Glazing Reduction / deletion treatment
- +FANS – inclusion of ceiling fans with the associated treatment approach.

30.8 A red filled cell indicates a non-complying cooling load.

26.0 Green filled cells represent solutions that result in complying cooling loads

Note that not all cases involved a Combined treatment approach where it could be demonstrated that at least one of the approaches combined with fans could deliver a compliant cooling load outcome.

This demonstrates however that it should be possible to derive a combined treatment that adopts elements of the other approaches taken to also deliver a compliant result.

A1.1 DETACHED (SINGLE) DWELLING

COOLING LOAD COMPLIANCE LIMIT: 26 MJ / M²

Dwelling	Treatment	Stars	Cooling Load (MJ / m²)	Treatment Notes
Detached	**Baseline in 2030**	**6.4**	**37.3**	**U=5.4 & SHGC=0.56 / 0.63 windows.**
	2030 FGP	**7.2**	**25.4**	U=3.7 & SHGC=0.35 / 0.38 windows (representative of timber single low-E, low solar gain). Skylight improved to ventilated Velux spec U=2.53, SHGC = 0.21
	2030 SHD	**6.4**	**26.0**	Awnings to all east & west facing windows. Doubled eave depth north side (to boundary). Skylight improved to ventilated Velux spec U=2.53, SHGC = 0.21, area of skylight reduced to 63% (~2.5m²). Close off stair to garage with door at garage level. Garage external walls, all ground level east/north/west walls v. light colour. Roof to be light colour (medium for baseline). Window above entry at L1 change to operable type.
	2030 GR	**7.3**	**25.9**	Reduce all large east and west facing windows GF and L1 by 20%, plus family room window and L1 window above entry door by 30%. Delete skylight. Increased openable percentage on windows throughout.
	Baseline in 2070	**3.8**	**91.6**	
	2070 FGP	6.3	44.6	Sliding/fixed windows U=2.59 & SHGC=0.12 (performance thermally broken frames, double glazed low-e both panes, tint, Argon gap). Awning windows U=2.16, SHGC=0.1 (PVC frames, double glazed low-E, supergrey tint, argon gap). Reduce skylight area by 40%. Maximised openability of all windows. Reflective layer added to roof insulation, added R-value R3.
	2070 FGP + FANS	7.4	30.8	Add 1,200mm fans all day and night occupied zones, 3no. to kitchen/living, 2no. to family rm
	2070 SHD	4.8	64.0	Delete skylight. Awnings to all windows. Doubled depth of east/west eaves (3.5m/4.3m!)
	2070 SHD + FANS	5.9	44.2	Add 1,200mm fans all day and night occupied zones, 3no. to kitchen/living, 2no. to family rm
	2070 GR	5.9	48.9	Reduce all windows east/west/north + bed 1 & 2 windows 75-80%. Delete WIR, pantry windows and window above entry.
	2070 GR + FANS	7.4	31.1	Add 1,200mm fans all day and night occupied zones, 3no. to kitchen/living, 2no. to family rm
	2070 COMBINED	**7.8**	**26.0**	FGP+SHD+FANS: As for 2070 FGP treatment, plus all walls very light (SA 0.2), roofs light (SA0.3).

A1.2 ATTACHED DWELLINGS (SEMIS, DUPLEXES)

COOLING LOAD COMPLIANCE LIMIT: 26 MJ / M²

Dwelling	Treatment	Stars	Cooling Load (MJ / m²)	Treatment Notes
Attached Unit A	**Baseline in 2030**	**6.4**	**40.1**	
	2030 FGP	**7.6**	**25.5**	U=3.7 & SHGC=0.35 / 0.38 windows (representative of timber single low-E, low solar gain). Skylight improved to ventilated Velux spec U=2.53, SHGC = 0.21
	2030 SHD	**7.4**	**24.9**	Awnings to all west facing windows. Extend FF eave depth north side to boundary, GF & FF east side double depth.
	2030 GR	**7.6**	**25.7**	Reduce all windows of rumpus, kitchen/living and east study window by 20%. Delete skylights.
	Baseline in 2070	**3.4**	**103.4**	
	2070 FGP	5.9	52.2	All windows U=1.81 & SHGC=0.1 (Custom InFrame DGU uPVC frame supergrey/Argon/high-performance low-e). R3.5 to non-slab roofs, reflective roof layer, reflective blanket on ceiling.
	2070 FGP + FANS	6.9	37.6	Add 1,200mm fans all day and night occupied zones, 3no. to kitchen/living
	2070 SHD	5.4	51.7	Shading as for 2030 plus: Delete skylights. Awnings to all windows. Add GF north side eave, depth to boundary, GF & FF west side eave 2,400 deep, extend east side eaves/overhangs to 2400. All walls very light colour, roofs very light colour.
	2070 SHD + FANS	6.6	36.7	Add 1,200mm fans all day and night occupied zones, 3no. to kitchen/living
	2070 GR	5.6	55.0	Delete N master bed, study E, garage N, rumpus E windows. Reduce master bed W window by 50%, Bed 2 & Bed 3 windows by 33%, study N window by 50%, FF stairwell window 50%, reduce living W window and rumpus N by further 50% on 2030 reduction. Best practical limit of glazing reduction. Make all windows operable.
	2070 GR + FANS	6.9	39.1	Add 1,200mm fans all day and night occupied zones, 3no. to kitchen/living
	2070 COMBINED	**7.3**	**24.8**	SHD+FANS+FGP: As for 2070 shading + Sliding/fixed windows U=2.59 & SHGC=0.12 (performance thermally broken frames, double glazed low-e both panes, tint, Argon gap). Awning windows U=2.16, SHGC=0.1 (PVC frames, double glazed low-E, supergrey tint, argon gap).

Dwelling	Treatment	Stars	Cooling Load (MJ / m²)	Treatment Notes
Attached Unit B	**Baseline in 2030**	**6.0**	**41.6**	
	2030 FGP	**6.9**	**24.2**	U=3.7 & SHGC=0.35 / 0.38 windows (representative of timber single low-E, low solar gain). Skylight improved to ventilated Velux spec U=2.53, SHGC = 0.21
	2030 SHD	6.7	30.7	Awnings to all west facing windows. Extend FF eave depth north side to boundary, GF & FF east side double depth.
	2030 SHD + FANS	**7.2**	**23.7**	1200mm fans all day zones (3no. to kitchen/living)
	2030 GR	**6.9**	**24.7**	Reduce all windows of rumpus, kitchen/living and east study window by 20%. Delete skylights.
	Baseline in 2070	**3.5**	**101.5**	
	2070 FGP	6.0	45.3	All windows U=1.81 & SHGC=0.1 (Custom InFrame DGU uPVC frame supergrey/Argon/high-performance low-e). R3.5 to non-slab roofs, reflective roof layer, reflective blanket on ceiling.
	2070 FGP + FANS	7.1	32.6	Add 1,200mm fans all day and night occupied zones, 4no. to kitchen/living
	2070 SHD	5.0	59.4	Shading as for 2030 plus: Delete skylights. Awnings to all windows. GF & FF west side eave 2400 deep, extend east side eaves/overhangs to 2400. All walls, roofs very light colour. Make all windows operable
	2070 SHD + FANS	6.1	43.3	Add 1,200mm fans all day and night occupied zones, 4no. to kitchen/living
	2070 GR	5.7	49.6	Delete study E window, garage window, rumpus E window. Reduce master bed W window to 50%, Bed 2 & Bed 3 windows by 33%, FF stairwell window 50%, living W window by further 50% on 2030 reduction. Make all windows operable.
	2070 GR + FANS	6.9	39.1	Add 1,200mm fans all day and night occupied zones, 4no. to kitchen/living
	2070 COMBINED	**7.4**	**24.0**	FGP+FANS+SHD: all of FGP + FANS + delete skylights, all walls/roof v. light colour, all windows operable.

A1.3 LOW-RISE MULTI UNIT DEVELOPMENT

COOLING LOAD COMPLIANCE LIMIT: 29.5 MJ / M²

Dwelling	Treatment	Stars	Cooling Load (MJ / m²)	Treatment Notes
Low-rise Unit 4	**Baseline in 2030**	**6.7**	**31.0**	
	2030 FGP	**7.3**	**22.2**	U=4.9 & SHGC=0.33 windows (representative of aluminium double glazed low-e, low solar gain).
	2030 SHD	**7.2**	**26.0**	Eaves 1200 depth added to east and west elevations, East / West walls light colour.
	2030 GR	**6.7**	**26.0**	Reduce all east/west windows by 30%, south windows 20%. West walls light colour.
	Baseline in 2070	**4.1**	**74.9**	
	2070 FGP	6.8	39.7	Sliding/fixed windows U=2.59 & SHGC=0.12 (performance thermally broken frames, double glazed low-e both panes, tint, Argon gap). Walls added R2.5, reflective gap.
	2070 FGP + FANS	**7.6**	**28.4**	Add 1,200mm fans all day and night occupied zones, 2no. to kitchen/living
	2070 SHD	4.9	61.5	Eaves 1,200 depth added to east and west elevations, East / west walls light colour.
	2070 SHD + FANS	5.8	47.8	Add 1,200mm fans all day and night occupied zones, 2no. to kitchen/living
	2070 GR	5.5	54.2	Reduce all east/west windows by 50% on baseline, south windows by 30%. All walls very light colour.
	2070 GR + FANS	6.5	41.1	Add 1,200mm fans all day and night occupied zones, 2no. to kitchen/living

Dwelling	Treatment	Stars	Cooling Load (MJ / m²)	Treatment Notes
Low-rise Unit 8	**Baseline in 2030**	**5.4**	**43.3**	
	2030 FGP	**7.6**	**23.8**	U=2.3 & SHGC=0.25 windows.
	2030 SHD	6.6	30.9	Awnings to all windows. Doubled eave depth, extended N/S to same distance as dwelling width. Roof very light colour.
	2030 GR	5.6	33.3	Reduce all windows by 50%. Delete outermost kitchen/living window.
	Baseline in 2070	**3.3**	**106.2**	
	2070 FGP	7.0	35.7	U=2.59 & SHGC=0.12 sliding/fixed windows (performance thermally broken frames, double glazed low-e both panes, tint, Argon gap). Awning windows U=2.16, SHGC 0.1 (PVC frames, double glazed low-e, supergrey tint, Argon gap). Roof R2 added.
	2070 FGP + FANS	**7.7**	**26.9**	1200mm fans (2no.) to kitchen/living zone
	2070 SHD	4.3	70.0	All of 2030 shading +: Vertical shade all of external corridor wall west facing and extend eave (this is a rooftop unit). Extend vertical shading to all east facing wall, 75% opaque.
	2070 SHD + FANS	5.1	52.8	1200mm fans to all night and day time zones (2no.to kitchen/living)
	2070 GR	4.8	65.2	Reduce all windows including corridor by 75% on baseline (unrealistic). Delete outermost kitchen/living window.
	2070 GR + FANS	6.2	45.8	1,200mm fans to all night and day time zones (2no.to kitchen/living)
	2070 COMBINED	**7.4**	**28.4**	SHD+FANS+FGP: As for shading, with uPVC double glazed units low-E, argon gap U=2.0/SHGC=0.23 (between 2030 and 2070 FGP treatment)

A1.4 MID-RISE MULTI UNIT DEVELOPMENT

COOLING LOAD COMPLIANCE LIMIT: 29.5 MJ / M²

Dwelling	Treatment	Stars	Cooling Load (MJ / m²)	Treatment Notes
Mid-rise Unit 2.3	**Baseline in 2030**	**5.4**	**49.0**	
	2030 FGP	**7.8**	**21.2**	U=3.1 & SHGC=0.27 windows (representative Al thermally broken double glazed low-e, low solar gain).
	2030 SHD	**7.1**	**25.1**	Awnings to all W windows. Doubled eave depth to west, added N oriented window head fins 450mm deep / 1400mm deep. Walls N/E/W very light colour. Added eave to Bed 1 W window to match 1,400mm fin on kitchen window.
	2030 GR	**7.5**	**25.9**	Reduce all North & West windows by 30%, living west by 40%. Make all windows operable. Walls light colour.
	Baseline in 2070	**3.3**	**112.0**	
	2070 FGP	6.8	41.0	Sliding/fixed windows U=2.59 & SHGC=0.12 (performance thermally broken frames, double glazed low-e both panes, tint, Argon gap). Walls added R2.5, reflective gap.
	2070 FGP + FANS	**8.1**	**24.0**	1200mm fans to all night and day time zones (2no.to kitchen/living)
	2070 SHD	4.6	69.0	Awnings to all windows. Doubled eave depth to west, added N oriented window head fin 450mm deep / 1400mm deep.. All walls very light colour . Added eave to bed 1 W window to match 1400mm fin on kitchen window. Insulated walls to firestair / lift lobby to R2
	2070 SHD + FANS	5.8	50.2	1200mm fans to all night and day time zones (2no.to kitchen/living)
	2070 GR	5.4	58.5	Reduce all windows to 50%. Make all windows operable.
	2070 GR + FANS	6.7	41.7	1200mm fans to all night and day time zones (2no.to kitchen/living)
	2070 COMBINED	**8.1**	**24.3**	SHD+FANS+FGP: Glazing U=3.7 & SHGC=0.38 windows. .Highly insulate external walls (R3.0 added)

Dwelling	Treatment	Stars	Cooling Load (MJ / m²)	Treatment Notes
Mid-rise Unit 4.1	**Baseline in 2030**	**5.8**	**34.8**	
	2030 FGP	**6.4**	**27.2**	U=3.1 & SHGC=0.27 windows (aluminium thermally broken double glazed low-E, low solar gain).
	2030 SHD	5.8	30.5	Awnings to all E&W windows. Added N eave 300mm deep. Increased E/W eave depths. Walls/roof very light colour
	2030 SHD+FANS	**5.9**	**27.7**	1200mm fans to day time zones
	2030 GR	**6.2**	**29.3**	reduce all east & west windows by 15%. Delete living rm skylight
	Baseline in 2070	**4.0**	**79.6**	
	2070 FGP	6.7	36.6	U=2.59 & SHGC=0.12 sliding/fixed windows (performance thermally broken frames, double glazed low-E both panes, tint, Argon gap). Performance ventilated skylights. Maximised all windows operability. Increased roof added insulation to R2.7+reflective gap, walls to R2.5+reflective gap, insulate walls to lift/stair.
	2070 FGP + FANS	7.2	30.3	1200mm fans to day and night time zones (3no. To kitchen/living)
	2070 SHD	4.3	67.3	Awnings to all windows. Added N eave to depth of blg edge. Maximised E/W eave depths. Walls/roof very light colour. Delete bathroom skylight.
	2070 SHD + FANS	5.3	46.0	1200mm fans to day and night time zones (3no. To kitchen/living)
	2070 GR	5.8	45.7	Reduce all east, north & west windows by 50%. Delete living rm and bathroom skylights.
	2070 GR + FANS	6.4	38.1	1200mm fans to all night and day time zones (2no.to kitchen/living)
	2070 COMBINED	**7.2**	**29.5**	FGP+FANS+SHD: include awnings to W & E windows in addition to all FGP+FANS treatment.

A1.5 HIGH-RISE MULTI UNIT DEVELOPMENT

COOLING LOAD COMPLIANCE LIMIT: 29.5 MJ / M²

Dwelling	Treatment	Stars	Cooling Load (MJ / m²)	Treatment Notes
High-rise Unit 1.09	**Baseline in 2030**	**5.9**	**41.8**	
	2030 FGP	**7.9**	**22.6**	U=2.3 & SHGC=0.19/0.25 windows (uPVC frames double glazed low-e, low solar gain).
	2030 SHD	**6.6**	**26.0**	Awnings to all W windows. 2m eave added to west (main) elevation. Fully enclosing eave/opposite wall shading scheme to N. Walls light colour. Window operability increased
	2030 GR	**7.4**	**26.0**	Delete N slit window off bedroom, reduce all windows by 40% to >50%. Make all windows operable
	Baseline in 2070	**3.8**	**91.8**	
	2070 FGP	6.2	48.6	U=2.59 & SHGC=0.12 sliding/fixed windows (performance thermally broken frames, double glazed low-e both panes, tint, Argon gap). Awning windows U=2.16, SHGC 0.1 (PVC frames, double glazed low-E, supergrey tint, argon gap). Internally exposed wall mass (concrete) 300mm thick. Hyperinsulate external walls (R4.0+ added)
	2070 FGP + FANS	7.4	32.2	1200mm fans to all night and day time zones (3no.to kitchen/living)
	2070 SHD	5.1	58.7	Awnings to all windows, all walls v. light colour.
	2070 SHD + FANS	6.2	41.7	1200mm fans to all night and day zones
	2070 GR	5.0	64.0	
	2070 GR + FANS			
	2070 COMBINED	**7.8**	**26.0**	SHD+FANS+FGP: glazing as for 2070 FGP

Dwelling	Treatment	Stars	Cooling Load (MJ / m²)	Treatment Notes
High-rise Unit 3.09	**Baseline in 2030**	**6.1**	**37.7**	
	2030 FGP	**7.6**	**24.3**	U=3.1 & SHGC=0.27 windows (thermally broken Al frames double glazed low-e, low solar gain).
	2030 SHD	**7.0**	**26.7**	Awnings to all W windows.
	2030 GR	**7.0**	**29.3**	Reduce all windows by 20% to 33%. Similar reductions for night time and day time zones.
	Baseline in 2070	**3.9**	**84.1**	
	2070 FGP	6.4	45.4	U=2.59 & SHGC=0.12 sliding/fixed windows (performance thermally broken frames, double glazed low-E both panes, tint, Argon gap). Awning windows U=2.16, SHGC 0.1 (PVC frames, double glazed low-E, supergrey tint, argon gap). Internally exposed wall mass (concrete) 300mm thick. Hyperinsulate external walls (R4.0+ added)
	2070 FGP + FANS	**7.6**	**29.4**	1200mm fans to all night and day time zones (2no.to kitchen/living)
	2070 SHD	5.6	48.6	Awnings to all W windows. Extend eaves over external façade to 3m depth (west facing). All external walls light colour (0.1 SA). Make all windows operable (can create problems in high rise for safety and also pressurisation against doors). Internally exposed wall mass (concrete, brick). Heavily insulate corridor wall to match external. Hyperinsulate external walls (R4.0+ added).
	2070 SHD + FANS	**7.3**	**27.5**	1400mm fans to all night and day time zones (2no.to kitchen/living)
	2070 GR	6.5	43.8	Reduce windows by 80%-90%. Further reductions or deletions negatively impact improvements due to removing the ventilation opportunity.
	2070 GR + FANS	**7.7**	**28.6**	1200mm fans to all night and day time zones (2no.to kitchen/living)
	2070 COMBINED			Not required

Dwelling	Treatment	Stars	Cooling Load (MJ / m²)	Treatment Notes
High-rise Unit 10.05	**Baseline in 2030**	**6.1**	**24.5**	
	Baseline in 2070	**4.9**	**58.8**	
	2070 FGP	6.9	35.0	U=2.59 & SHGC=0.12 sliding/fixed windows (performance thermally broken frames, double glazed low-e both panes, tint, Argon gap). Awning windows U=2.16, SHGC 0.1 (PVC frames, double glazed low-e, supergrey tint, argon gap).
	2070 FGP + FANS	**7.4**	**26.9**	1200mm fans (2no.) to kitchen/living zone
	2070 SHD	5.2	50.1	Awnings to all windows. Extend/add eaves to ALL of external façade. All walls to light colour (0.2 SA).
	2070 SHD + FANS	6.3	35.6	1200mm fans to daytime zones (3no. to kitchen/living) and night zones
	2070 GR	6.1	42.4	Reduce windows by 50%. Further reductions or deletions negatively impact improvements due to removing the ventilation opportunity. Maximise openability % of all windows remaining.
	2070 GR + FANS	**7.2**	**29.3**	1200mm fans to daytime zones (3no. to kitchen/living) and night zones
	2070 COMBINED			Not required

Dwelling	Treatment	Stars	Cooling Load (MJ / m²)	Treatment Notes
High-rise Unit 12.04	**Baseline in 2030**	**5.7**	**30.9**	
	Baseline in 2070	**4.4**	**68.4**	
	2070 FGP	6.7	36.9	U=2.59 & SHGC=0.12 sliding/fixed windows (performance thermally broken frames, double glazed low-E both panes, tint, Argon gap). Awning windows U=2.16, SHGC 0.1 (PVC frames, double glazed low-E, supergrey tint, argon gap). Internally exposed wall mass (concrete) 300mm thick. Hyperinsulate external walls (R4.0+ added).
	2070 FGP + FANS	**7.8**	**26.8**	1200mm fans to all night and day time zones (2no.to kitchen/living)
	2070 SHD	4.6	63.5	Awnings to all windows
	2070 SHD + FANS	5.4	50.2	1200mm fans to all night and day time zones (2no.to kitchen/living)
	2070 GR	5.6	51.7	Delete every second window on curved façade of living, make all others operable. Reduce remaining window sizes by 50%
	2070 GR + FANS	6.8	36.7	**1,400mm** fans to all night and day time zones (2no.to kitchen/living)
	2070 COMBINED	**7.4**	**26.9**	FGP+FANS+SHD: 1,200mm fans to day time zones (2no.to kitchen/living), awnings and wall colours very light