FINAL REPORT

STAGE 3 CONDENSATION MITIGATION MEASURES

Phase Two: Impact Analysis

February 2024

Natural Capital Economics

Alluvium recognises and acknowledges the unique relationship and deep connection to Country shared by Aboriginal and Torres Strait Islander people, as First Peoples and Traditional Owners of Australia. We pay our respects to their Cultures, Country and Elders past and present.

Artwork by Melissa Barton. This piece was commissioned by Alluvium and tells our story of caring for Country, through different forms of waterbodies, from creeklines to coastlines. The artwork depicts people linked by journey lines, sharing stories, understanding and learning to care for country and the waterways within.

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Executive summary

The Australian Building Codes Board (ABCB) has been addressing condensation in residential building through amending the National Construction Code (NCC) to include various condensation mitigation measures. Stage 1 condensation mitigation measures were included in the NCC 2019, and Stage 2 measures in NCC 2022.

The ABCB is now considering Stage 3 of the condensation mitigation project. For residential or residential-like commercial buildings (NCC Building Classes 1, 2, 3, 4 and 9c), the condensation mitigation measures being considered for inclusion in NCC 2025 target improving building drying, with measures comprising:

- addition of vapour permeance requirements for Climate Zones 1, 2 and 3[1]
- drained and vented cavity dependent permeance requirements in Climate Zones 1-5
- mandatory drained and vented cavity requirements in Climate Zones 6-8.

This report provides the results of a cost-benefit analysis undertaken of the Stage 3 condensation measures that are being considered for inclusion in NCC 2025.

Approach to the CBA

The CBA used an 'avoided cost' type methodology. This required:

- determining the costs attributable to condensation occurring in buildings (the base case)
- then comparing those costs to the costs that would arise if those buildings had been built to a higher NCC standard inclusive of the Stage 3 condensation mitigation measures (the counterfactual scenario)
- determining the difference between the costs under the base case and counterfactual scenarios, or 'avoided costs', which reflect the benefits of the condensation mitigation measures
- comparing the determined benefits to the cost of implementing the various mitigation measures to arrive at an overall assessment of whether the measures deliver an expected net benefit.

The CBA of the Stage 3 condensation mitigation measures required an extensive amount of data across a number of areas, these being:

1. population forecasts (by Climate Zone over 2025–2064)—used to determine the stock of Building Class 1, 2, 3, 4 and 9c type dwellings going forward
2. the stock of dwellings (by Climate Zone and Building Class over 2025–2064)—the physical stock of housing assets at risk from exposure to condensation
3. share of dwellings that are impacted by condensation and mould (by Climate Zone and Building Class over 2025–2064)—used to establish the number of dwellings exposed to condensation and mould in the 'base case'
4. costs arising from/attributable to condensation and subsequent mould—establish the direct (damage to asset itself) and indirect (adverse health impact) costs associated with condensation, and condensation occasioning mould, occurring in dwellings

[1] For a map of ABCB Climate Zones, see https://www.abcb.gov.au/resources/climate-zone-map, accessed 7 August 2023.

5. impact of potential Stage 3 condensation mitigation measures on reducing the share of housing assets experiencing condensation—used to determine the extent of condensation and mould in the 'counterfactual scenario'
6. the additional construction costs (by Building Class) associated with meeting the Stage 3 condensation measures—the various Stage 3 condensation mitigation measures will increase (new building) construction costs under the counterfactual scenario.

As can be seen, the CBA was a data intensive exercise. While the data was of high quality in some areas, in other areas it was of a lessor quality, necessitating numerous assumptions having had to be made in using the available data/information. Sensitivity and breakeven analysis have been undertaken to account for areas of data uncertainty.

Key results

The headline results for the external wall drained and vented cavity and no cavity measures are provided in Figure 1 and Figure 2 (respectively) for each Climate Zone (CZ) and Australia wide. The headline results reflect a number of factors.

- An assumed 10 year Stage 3 external wall measure compliance period, spanning 2025 to 2034 (inclusive).
- The Stage 3 condensation mitigation measures under consideration do not always reduce the likelihood of condensation occurring across the Climate Zones. For example, external wall drained and vented cavity has no or very little impact on condensation in Climate Zones 2, 3 and 4; while the external wall no cavity measures has no impact in Climate Zones 2, 3 (and with Climate Zones 6, 7 and 8 being exempt from the no cavity provisions). For those Climate Zones with no (or very little) impact, the Stage 3 measures will impose a net cost.
- For those Climate Zones where the Stage 3 measures are estimated to deliver a net benefit (Climate Zones 1, 5, 6, 7 and 8 in case of external wall drained and vented cavity; and Climate Zones 1, 4 and 5 in case of external wall no cavity), the benefits are dominated by the indirect (health) impacts. Australia wide, the indirect benefits account for around 85% of total benefits arising from the external wall drained and vented cavity and no cavity measures. If the indirect benefits were to be excluded from the analysis, then Australia wide, the external wall drained and vented cavity measure would impose a net (present value) cost on Australia of some $959 million and the no cavity measure a net (present value) cost of $106 million.
- The absolute 'size' of the impacts across Climate Zones reflects the number of dwellings and population in each Climate Zone.

Figure 1: Summary results—external wall drained and vented cavity

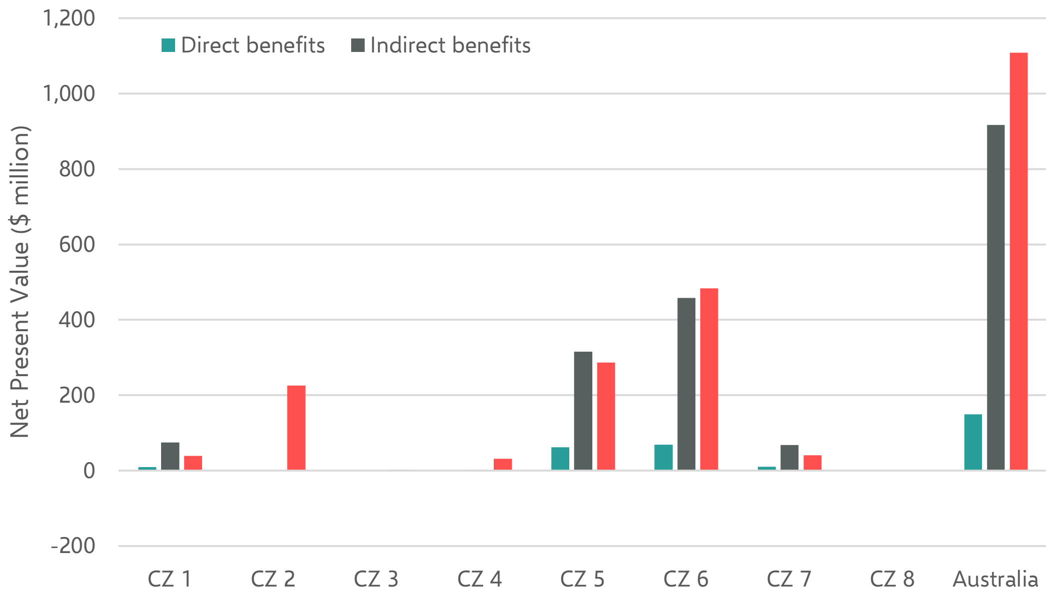
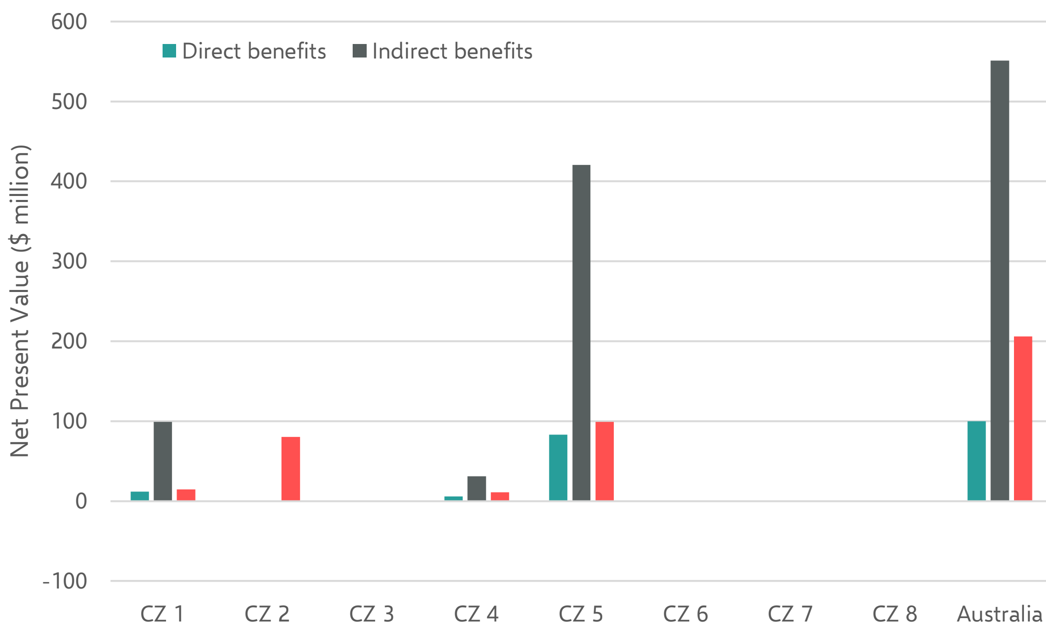


Figure 2: Summary results—external wall no cavity



Sensitivity and breakeven analysis

The CBA results presented above reflect the available data and a range of assumptions. Sensitivity analysis was undertaken around key areas of data uncertainty to quantify the impact this uncertainty has on CBA results. The CBA inputs subjected to sensitivity analysis comprised:

- share of dwellings experiencing condensation
- share of dwellings experiencing condensation that go on to experience mould

- dampness/mould and adverse health outcome relative risk factors
- condensation reducing impacts of Stage 3 measures
- cost impost of Stage 3 measures.

The sensitivity analysis (typically) took the form of adjusting the data inputs used in the central CBA (More Likely P50 case) by -/+20% (using a triangular probability distribution). Results of the sensitivity analysis are reported in Table 1, with the analysis conducted at the P90 and P10 levels.

Table 1. Sensitivity results (NPV $ million)

	Low (P90)	More Likely (P50)	High (P10)
External wall drained and vented cavity			
Climate Zone 1	23.1	44.0	69.5
Climate Zone 2	-251.5	-226.6	-201.9
Climate Zone 3	-2.4	-2.2	-1.9
Climate Zone 4	-33.9	-30.2	-26.5
Climate Zone 5	-4.9	91.0	205.6
Climate Zone 6	-97.7	43.5	206.1
Climate Zone 7	18.4	38.1	61.2
Climate Zone 8	0.1	0.1	0.1
Australia	-348.8	-42.2	312.2
External wall no cavity			
Climate Zone 1	68.6	96.1	128.7
Climate Zone 2	-89.8	-80.8	-71.9
Climate Zone 3	-0.9	-0.8	-0.7
Climate Zone 4	16.9	25.9	36.5
Climate Zone 5	282.6	404.7	549.0
Climate Zone 6	0.0	0.0	0.0
Climate Zone 7	0.0	0.0	0.0
Climate Zone 8	0.0	0.0	0.0
Australia	277.6	445.2	641.6

The sensitivity analysis also suggested that the majority of variability in results is accounted for by parameters central to calculating the size of indirect (health) benefits—the share of dwellings experiencing condensation that go on to experience mould and the adverse health outcome relative risk factors (for asthma and chronic obstructive pulmonary disease). These three factors account for nearly 64% of the variation in external wall drained and vented cavity results, and 62% in the case of external wall no cavity results.

A breakeven analysis was also undertaken to determine the (minimum) parameter values required to deliver a NPV of zero. The breakeven analysis was limited to those Climate Zones for which the external wall drained and vented cavity or no cavity measures deliver the largest net gains.

The breakeven analysis was undertaken for the CBA input parameters of:

- share of dwellings impacted by condensation

- share of dwellings experiencing condensation that go on to experience mould
- impact of the Stage 3 measures in reducing the occurrence of condensation
- cost impost of the Stage 3 measures.

Depending on the Building Class and Climate Zone being considered, the breakeven analysis suggested that the required parameter values to achieve a breakeven NPV result were typically—but not always—lower than that used in the CBA (or in the case of cost of implementing the measures, higher than that used in the CBA). For example, the CBA assumed that 78.1% of building experiencing condensation went onto experience mould (and hence occasion indirect health related costs). This figure was applied equally across all Climate Zones and Building Classes. For those Climate Zones experiencing a net gain, the breakeven analysis suggests that the required (minimum) proportion of dwellings experiencing condensation that need to then go onto experience mould was:

- external wall drained and vented cavity—30%–70% (depending on Climate Zone)
- external wall no cavity—2%–12% (depending on Climate Zone).

1 This report

This report provides the results of a cost-benefit analysis undertaken of the Stage 3 external wall condensation measures that are being considered for inclusion in NCC 2025.

1.1 Nature and extent of the problem

Condensation can occur within the building structure (floor, walls, ceilings and roofing materials) and its intermediate zones (subfloor and roof space zones) when moist air comes in contact with cold surfaces. The effects of condensation leading to building dampness and mould have been well established by academic literature both internationally and in Australia. The persistent presence of interstitial condensation and mould could compromise the structural integrity of a building whilst also damaging other components of the envelope making it inhabitable.[2] Furthermore, mould could also result in adverse health outcomes and respiratory illnesses such as asthma, and chronic obstructive pulmonary disease, all of which significantly contribute to the burden of disease in Australia.[3]

In 2011, respiratory conditions were the sixth leading contributor to the total burden of disease in Australia, with chronic obstructive pulmonary disease, asthma and upper respiratory infections being the greatest contributors to the respiratory burden.[4] It is estimated that the rate of asthma is approximately 34% higher in damp buildings[5] and the rate of respiratory infections is approximately 44% higher.[6] Another study estimates that 26.1% of Australian dwellings have dampness problems, although its unknown what percentage is attributable to condensation.[7]

In 2016 the ABCB commissioned a scoping study on condensation in residential buildings, authored by the University of Tasmania. Respondents to the ABCB's 2016 condensation survey estimate that up to 32% of Class 1 and 2 buildings are impacted by condensation.[8] In response to raising concerns about the level of condensation in residential buildings, a first stage of mitigation measures was drafted by the ABCB for inclusion in NCC 2019, and the second stage in NCC 2022. Further technical analysis and literature review undertaken by the University of Wollongong (UoW) used NCC 2022 as a baseline and identified key drivers of condensation in buildings in different climate zones and corresponding mitigation measures. The ABCB has proposed deemed-to-satisfy provisions for inclusion in NCC 2025 to align with the outcomes of this study. The proposed stage 3 provisions would apply to external walls of residential or residential-like commercial buildings (NCC Building Classes 1, 2, 3, 4 and 9c). The proposed changes for external walls include:

- addition of vapour permeance requirements in Climate Zones 1, 2 and 3[9]

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[2] Coulburn, L. & Miller, W. (2022) Prevalence, Risk Factors and Impacts Related to Mould-Affected Housing: An Australian Integrative Review. International Journal of Environmental Research and Public Health, 19(3), Article number: 1854.

[3] Commonwealth of Australia. (2018). Report on the Inquiry into Biotoxin-related Illnesses in Australia, https://www.aph.gov.au/Parliamentary_Business/Committees/House/ Health_Aged_Care_and_Sport/BiotoxinIllnesses/Report

[4] Australian Institute of Health and Welfare (2017) 'The burden of chronic respiratory conditions in Australia: a detailed analysis of the Australian Burden of Disease Study 2011'

[5] https://pubmed.ncbi.nlm.nih.gov/23144822/

[6] https://pubmed.ncbi.nlm.nih.gov/21078183/

[7] https://www.mja.com.au/journal/2018/208/7/damp-housing-gas-stoves-and-burden-childhood-asthma-australia

[8] https://www.abcb.gov.au/Resources/Publications/Research/Scoping-Study-of-Condensation-in-Residential-Buildings-Appendices

[9] For a map of ABCB Climate Zones, see https://www.abcb.gov.au/resources/climate-zone-map, accessed 7 August 2023.

- drained and vented cavity dependent permeance requirements in Climate Zones 1–5
- mandatory drained and vented cavity requirements in Climate Zones 6–8.

1.2 Impact analysis of the Stage 3 measures

An impact analysis of proposed regulatory reform is undertaken to ensure compliance with the principle of evidence-based policy formulation. In broad terms, an impact analysis requires:

- identification of the problem (and size) necessitating a government response
- identification of viable options to address the problem (including non-regulatory responses)
- to the extent possible, a cost-benefit analysis of the identified options to address the problem, and identification of the option providing the greatest net benefit
- consultation with affected businesses, community organisations, individuals and (if applicable) other areas of government
- periodic review of all regulation to ensure continued relevance.

An important component of an impact analysis is a cost-benefit analysis (CBA) of the proposed regulatory reforms. A CBA encompasses a range metrics—net present value, benefit-cost ratio, internal rate of return and breakeven analysis—which are used to assess the net merits of a policy reform/measure/program. Should some areas of costs and/or benefits not be able to be quantified (to the required level of certainty), the CBA will take on the form of a breakeven analysis. The breakeven analysis would identify, for example, the required proportion of residential dwellings experiencing condensation before the Stage 3 condensation mitigation measures 'breakeven'.

CBAs are undertaken to ensure that the proposed regulatory change(s), if implemented, would deliver a net benefit to the Australian population. Undertaking the CBA also addresses some of the other impact analysis requirements, such as identifying and quantifying the size of the problem.

1.3 This report

This report sets out the results of a CBA undertaken of the proposed Stage 3 external wall condensation mitigation measures. The approach to the CBA follows the methodology established by NCEconomics as part of the Phase One study.[10]

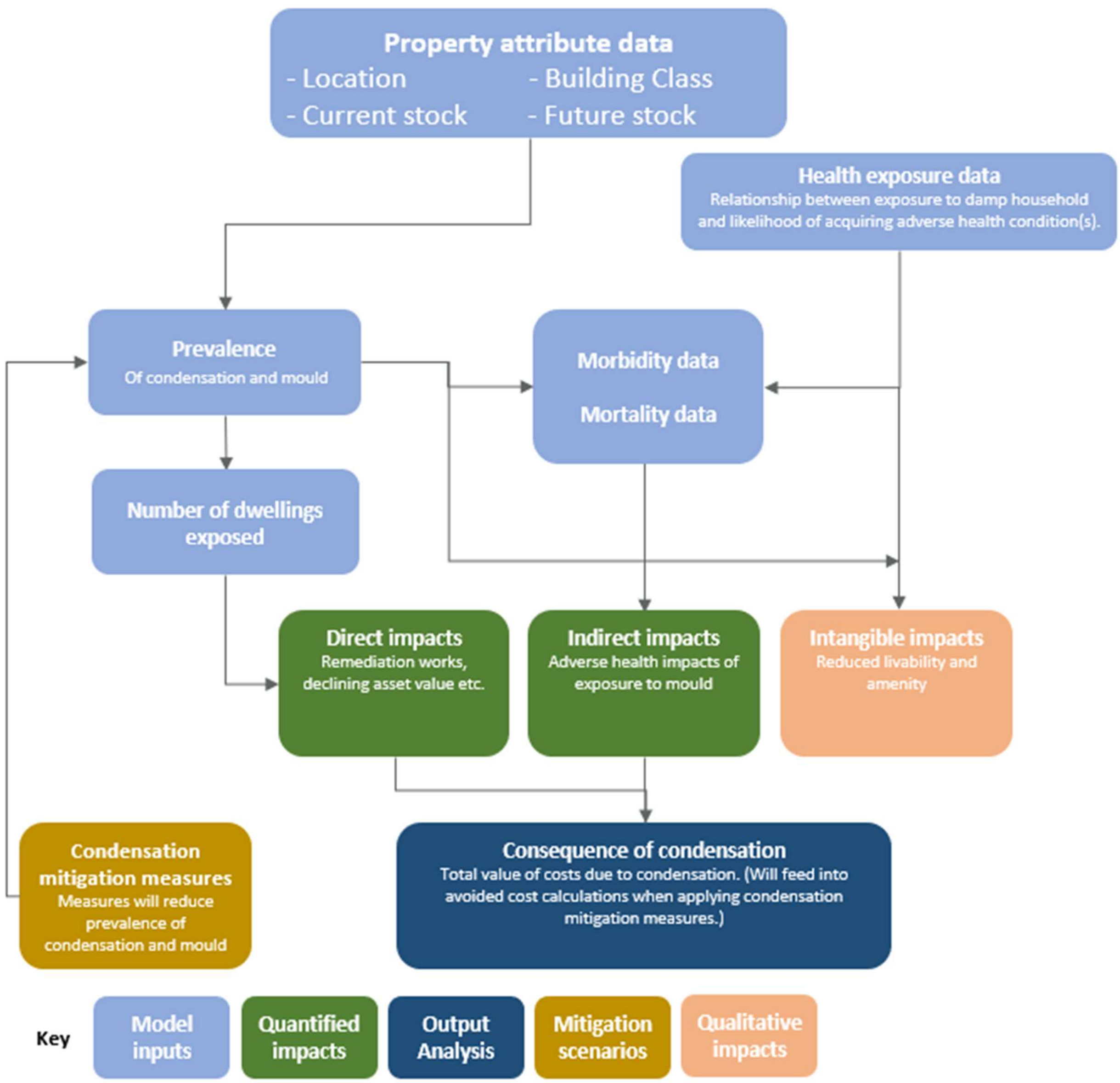
Chapter 2 details the underlying data used in the CBA, sources for this data, and required data manipulations to arrive at required data. Chapter 3 provides the results of the CBA, including sensitivity and breakeven analysis. More detailed pieces/areas of data are provided in Appendix A.

[10] See NCEconomics (2023), Stage 3 Condensation Mitigation Measures—Phase One: Impact Analysis Methodology, report prepared for ABCB, October 2023.

2 Approach to the cost-benefit analysis

The CBA utilises an 'avoided cost' type methodology. This requires determining the costs attributable to condensation occurring in dwellings constructed to a NCC 2022 (the base case), and then comparing those costs to the costs that would arise if those dwellings had been built to a higher NCC standard inclusive of the Stage 3 condensation mitigation measures (the counterfactual scenario). The difference between the costs under the base case and counterfactual scenarios, or 'avoided costs', reflects the benefits of the condensation mitigation measures. These benefits are then compared to the cost of implementing the various mitigation measures to arrive at an overall assessment of whether the measures deliver an expected net benefit. Figure 3 provides a stylised representation of the approach to the CBA.

Figure 3: Overview of CBA approach



The CBA of the Stage 3 condensation mitigation measures under consideration requires data across the following 6 areas:

1. population forecasts (by Climate Zone over 2025–2064)—used to determine the stock of Building Class 1, 2, 3, 4 and 9c type dwellings going forward
2. the stock of dwellings (by Climate Zone and Building Class over 2025–2064)—the physical stock of housing assets at risk from exposure to condensation
3. share of dwellings that are impacted by condensation and mould (by Climate Zone and Building Class over 2025–2064)—used to establish the number of dwellings exposed to condensation and mould in the 'base case'
4. costs arising from/attributable to condensation and subsequent mould—establish the direct (damage to asset itself) and indirect (adverse health impact) costs associated with condensation, and condensation occasioning mould, occurring in dwellings
5. impact of potential Stage 3 condensation mitigation measures on reducing the share of housing assets experiencing condensation—used to determine the extent of condensation and mould in the 'counterfactual scenario'
6. the additional construction costs (by Building Class) associated with meeting the Stage 3 condensation measures—the various Stage 3 condensation mitigation measures will increase (new building) construction costs under the counterfactual scenario.

The CBA spans a 10 year compliance period, with the assumption made that the NCC 2025 Stage 3 external wall provisions are introduced on 1 January 2025, with the Stage 3 external wall provisions extending to 31 December 2034 (hence a 10 year inclusive period).

Sources for the data and required data manipulations to arrive at the data needed to undertake the impact analysis are discussed below.

2.1 Working at the Climate Zone level

The data used in the CBA is largely sourced from Australian Bureau of Statistics (ABS) publications; with the data typically reported/available at the Local Government Area (LGA) or state/territory level. However, the NCC works at the Climate Zone level, which required developing an approach to move from the LGA level to Climate Zone level.

Using the Climate Zone map resource provided by ABCB, boundaries of all LGA's within Australia were compared against Climate Zone boundaries found within the map resource.[11] From these boundaries, LGA's were designated a corresponding Climate Zone that best matched these boundaries. Although ABCB highlights that climate zone boundaries are aligned with LGAs, it should be noted that some LGA's overlapped areas covering two or three Climate Zones. Where this was the case, the most populous area within the boundaries (that is, the highest dwelling count) was used to designate the Climate Zone for the LGA. The most populous regions were predominantly located along coastal areas within boundaries.

For example, the LGA of Esperance in Western Australia spans across Climate Zone 4, 5 and 6, however the most populous town within the boundaries (Esperance) is located within Climate Zone 5, therefore the LGA of Esperance was assigned to Climate Zone 5 in the analysis. See Appendix A for a comparison of the Esperance LGA across the ABCB map and the resulting NCE Climate Zone map used for analysis.

It should also be noted that LGA boundaries from the 2016 Census do not perfectly align with LGA boundaries used in the 2021 Census, and therefore correspondence data provided by the ABS was applied to apportion any changes between boundaries. This correspondence data provides ratios that, for example, assume if a

[11] See https://www.abcb.gov.au/resources/climate-zone-map

2016 LGA that contains 100 people is split into 2 LGAs in 2021 that covers 60% and 40% of the original LGA, then 60 and 40 people will be apportioned to the new LGAs respectively. This approach is consistent with ABS guidelines for analysing data over different time periods.[12]

2.2 Population forecasts

LGA level total population and population over the age of 75 years was taken from the 2021 Census. The LGA level 2021 population data was combined LGA level population projection data provided by the states/territories.[13] All states and territories provide LGA level projections for specific age groups over the short to medium term, with some states providing more projections out to 2046, while others only provided projections only to 2031.[14] Annual growth rates for each LGA were taken from the state/territory projections and were then extrapolated out to 2064. The (observed) LGA 2021 populations were then combined with the growth rate for that LGA, and population projections out to 2064 generated.

The ABS provides state and territory level population projections from 2017 out to 2066.[15] However, this projection data is based on a 2017 starting figure, and is somewhat dated (an update of the projections is expected in November 2023).[16] A comparison of the 2021 Census data against expected population projections showed an overestimation of the projected 2021 population against the verified population observed in the 2021 Census by around 930,000 people (25.37 million residents in the 2021 Census compared to 26.30 million in the projection data). Estimates at the state/territory level varied significantly, with some states such as South Australia providing accurate projections (underestimating by 0.3% of the Census data), while other areas such as the Northern Territory being relatively inaccurate (overestimated by 10.9%).

The ABS state/territory level population projections over 2021 to 2064 were scaled by the proportional difference between the 2021 Census data and the 2021 ABS projections to bring the projections into alignment with the Census population figures.

The LGA level population forecasts over 2022 to 2064 were then aggregated up to the state/territory level, and compared to the (scaled) ABS state/territory population projections. This comparison identified that the LGA population projections resulted in state/territory populations notably higher than that forecast by the ABS. For example, QGSO population projections for QLD are provided out until 2046, however when applying all LGA level growth rates and aggregating for the state, Queensland would have a population of 6.505 million. However, according to (the scaled) ABS projections, the population is expected to reach 6.316 million. Therefore, a second round of scaling of these state level projections was necessary.

Given the population overestimation, the annual LGA level population forecasts were proportionally adjusted to align with the (scaled) state/territory ABS population projections. This approach avoided overestimating the population in the long run whilst still allowing LGA growth rate relativities to be preserved. Individual LGA projections were then aggregated to the Climate Zone level.

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[12] See https://www.abs.gov.au/statistics/standards/australian-statistical-geography-standard-asgs-edition-3/jul2021-jun2026/access-and-downloads/correspondences

[13] For example, LGA level population projection data for Queensland is provided by the QGSO (2023), found at https://www.qgso.qld.gov.au/statistics/theme/population/population-projections/regions

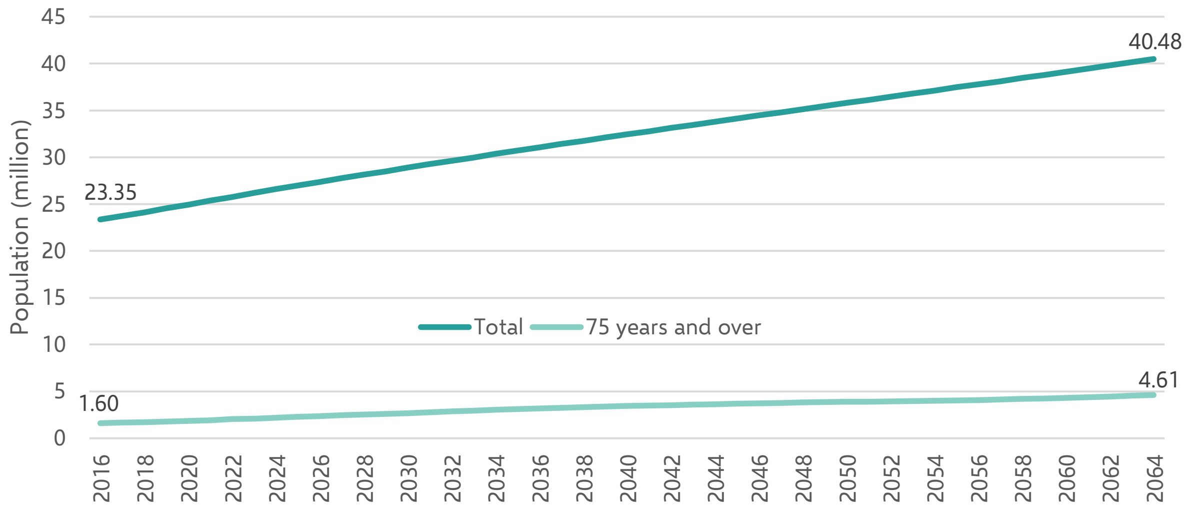
[14] State level projections at the LGA level were available for the following years: Australian Capital Territory (2021 to 2064), New South Wales (2021 to 2041), Northern Territory (2021 to 2036), Queensland (2021 to 2046), South Australia (2021 to 2036), Tasmania (2021 to 2042), Victoria (2021 to 2036), Western Australia (2021 to 2031).

[15] See https://www.abs.gov.au/statistics/people/population/population-projections-australia/latest-release#data-downloads – Data explorer datasets. Note projections here assumed that rates of fertility, mortality and net overseas migration were all “medium”.

[16] See https://www.abs.gov.au/statistics/people/population/population-projections-australia/latest-release

Projected population estimates from 2025 out to 2064 have been provided for Australia in Figure 4, by both total population and the population over the age of 75. See Appendix A for a breakdown of these population estimates by individual Climate Zones.

Figure 4. Australian projected population estimates



2.3 Forecast dwelling stocks

The stock of Building Class 1, 2, 3, 4 and 9c type dwellings in each Climate Zone and over the period until 2064 has been estimated using the latest available stock data, and then:

- for Building Classes 1 and 2—growing those stocks in line with the estimated Climate Zone population growth rate whilst taking into account trend changes in population to dwelling type ratios
- for Building Classes 3 and 4—growing those stocks in line with the estimated Climate Zone population growth rate
- for Building Class 9c—growing that stock in line with the estimated Climate Zone growth rate for the 75+ population group.

Estimated dwelling stock data for Building Class 1 and 2 dwellings was provided by the ABS at the LGA level between 2016 and 2022, with the LGA level data being aggregated to arrive at Climate Zone level figures.[17] Although future estimated dwelling stocks across all class types are expected to follow population growth, by comparing the number of Building Class 1 and 2 dwellings across this time to the population within those Climate Zones, a dwelling to population ratio (i.e. building stock per capita) for each Climate Zone was able to be calculated spanning the 2016 to 2022 period.[18] The (ordinary least squares) trend over this time period was estimated, with the trend continued over the period until 2064.

The trend dwelling to population ratios were combined with the population forecasts to estimate the stock of Building Class 1 and 2 dwellings in each Climate Zone over the period until 2064. Incorporating the dwelling

[17] For estimated dwelling stock data, see https://www.abs.gov.au/statistics/industry/building-and-construction/estimated-dwelling-stock/latest-release

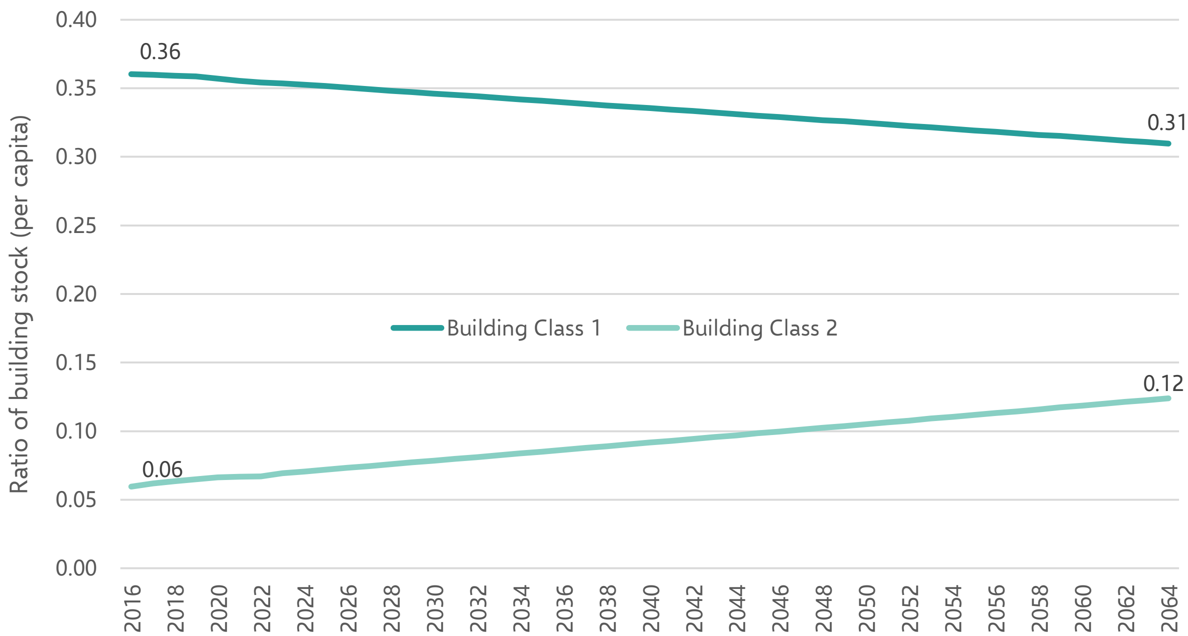
[18] Note that historical population data was extracted by ABS TableBuilder for the 2016 and 2021 Census in order to estimate historical population. This data was disaggregated at 5-year age bracket intervals and was combined to provide the total population as well as the population of residents over the age of 75. Population growth between the 2016 and 2021 Census data was assumed to follow a linear growth trend, increasing by a consistent growth rate each year.

type to population trends into the stock estimation allows any shifts in preferences between Building Class 1 and 2 dwellings (for example, an increasingly higher proportion of residents residing in apartments in urban areas) to be taken into consideration.

Figure 5 shows the trended ratio of building stock per capita between 2016 and 2064 for Class 1 and Class 2 buildings. Aggregated across all Climate Zones, this trend demonstrates a long-term gradual decline for Class 1 buildings per capita, likely due to factors such as urbanisation and changing housing preferences towards higher density, apartment type living necessary for growing population. The opposite (increasing) relationship for Class 2 buildings also suggests that the population is shifting towards higher density apartment living over time.

Appendix A provides a breakdown of both Class 1 and Class 2 trends across all Climate Zones.

Figure 5. Trend of Building Class 1 and 2 buildings for Australia



Building Class 3 estimated dwelling stock data was extracted from the 2021 ABS Census of Population and Housing using TableBuilder. [19] A shortlist of non-residential dwelling types that aligned most closely with the Building Class 3 definition were used to estimate the count of dwellings for each LGA. This short list included boarding houses, private hotels and hostels for the disabled.[20]

As with Building Class 1 and 2, estimated dwelling stock data for Building Class 4 was provided by the ABS at an LGA level.[21] Although there is no specific data categorised as Building Class 4 within this dataset, the residual dwelling stock after subtracting all houses/townhouses/apartments is defined within the ABS methodology as 'dwellings in non-residential buildings' (for example, caretaker/manager's residence and

[19] ABS Census data from "Dwelling and Household Characteristics" – "Type of Non-Private Dwelling" indicator was used to inform Building Class 3 stock data.

[20] The following non-residential dwellings types were excluded from analysis as they either did not align with Class 3 dwellings, did not have data available on vacancy levels or were not able to be feasibly incorporated into analysis due to limitations around estimating costs of implementing new Stage 3 construction measures; hotel, motel, bed and breakfast, nurses' quarters, staff quarters, boarding school, residential college, hall of residence, public hospital (not psychiatric), private hospital (not psychiatric), psychiatric hospital or institution, nursing home, accommodation for the retired or aged (not self-contained), hostel for homeless, night shelter, refuge, child care institution, corrective institution for children, other welfare institution, prison, corrective institution for adults, immigration detention centre, convent, monastery, etc., other and non-classifiable, and not stated.

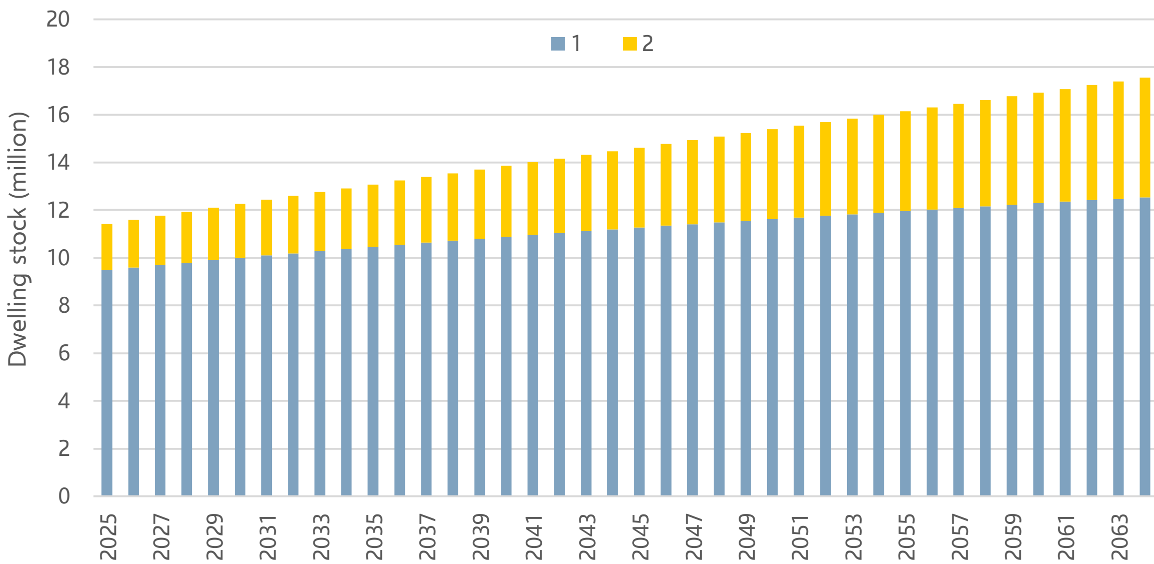
[21] See Australian Australian Bureau of Statistics 2022, 8701.0 Estimated dwelling stock: Table 01, available at https://www.abs.gov.au/statistics/industry/building-and-construction/estimated-dwelling-stock/latest-release, accessed 28 July 2023.

house/flat attached to a shop), which aligns with the description of Building Class 4 dwellings.[22] Therefore, the residual dwellings within this dataset when Building Class 1 and Building Class 2 dwellings are removed was assumed to be an estimate of Building Class 4.

Building Class 9c used estimated building stock data from Gen Aged Care Data, provided by the Australian Institute of Health and Welfare as of June 2023.[23] This data provided a comprehensive list of all aged care services within Australia by LGA, along with the service type provided by each facility. [24] Projected populations for residents aged 75 and older were used to estimate the expected future stock of Building Class 9c (see Section 2.2 for the approach used to calculate this population).

Figure 6 shows the estimated stock of dwellings for Building Class 1 and 2 for Australia over the period 2025-2064; while Figure 7 shows the estimated stock of dwellings for Building Class 3, 4 and 9c for Australia over the same period (noting use of differing axis scales between the figures). More detailed results at the Climate Zone and Building Class level can be found in Appendix A.

Figure 6: Australian dwelling stock for Building Class 1 and 2



[22] See Australian Bureau of Statistics 2022, Estimated dwelling stock methodology, available at https://www.abs.gov.au/methodologies/estimated-dwelling-stock-methodology/jun-quarter-2022, accessed August 15, 2023.
[23] See https://www.gen-agedcaredata.gov.au/Resources/Access-data/2023/September/Aged-care-service-list-30-June-2023
[24] Note that facilities within the AIHW data list were filtered to exclude home care (to avoid double counting Class 1 and 2 buildings) and included residential, transition care, National Aboriginal and Torres Strait Islander aged care program, short term restorative care and multi-purpose services.

Figure 7. Australian dwelling stock for Building Class 3, 4 and 9c

However, not all additional dwelling stocks were included in the NCC Stage 3 measure impact analysis. Several external wall types were identified as not being applicable for the measures being proposed as part of NCC Stage 3.[25] Consequently, the estimated proportion of dwelling stocks built with these non-applicable wall types needed to be removed from the analysis.

CSIRO provides external wall type data for Class 1, Class 2 and Class 4 building types as part of the data collected for the Australian Housing Database; with the data reporting the share of external wall area accounted for by various external wall types.[26] For example, the CSIRO data reports that 37.2% of the external wall area of Class 1 buildings in NSW is of a brick veneer wall type. The simplifying assumption is made that proportion of external wall area is interpreted as building share, and hence 37.2% of Class 1 buildings in NSW have a brick veneer external wall (with this assumption overlooking the potential for a dwelling to have several types of external wall). The CSIRO data was extracted at a state level across a wide range of wall types for Class 1, 2 and 4 buildings, before being converted to the Climate Zone level. CSIRO weightings were applied to each LGA at the state level, before Building Class weights (that is, total number of dwellings existing for relevant classes) from LGAs were used to aggregate up to the Climate Zone level.

These weights calculated the average external wall types across all Climate Zones, which were then combined for wall types applicable to NCC Stage 3 measures. This provided the total proportion of dwellings that were able to be included in analysis.

Table 2 provides the proportion of dwellings, by Climate Zone and Building Class, which had an external wall type of relevance to the Stage 3 external wall condensation mitigation measures. For example, a brick veneer external wall would be subject to the Stage 3 measures, whereas an external wall made from concrete blocks would not be impacted by the measures, and hence dwellings with a concrete block external wall type are excluded from the analysis. The proportions were used to scale (down) the estimated total building stock to arrive at the relevant building stock for use in the analysis.

[25] CSIRO External wall types deemed being suitable for the Stage 3 measures under consideration comprise brick veneer, clad fibre cement, clad AAC, clad weatherboard, and clad metal. External wall types considered not suitable for the measures comprise masonry cavity, clad insulated panel systems, concrete block, concrete panel, masonry single brick, party wall, plasterboard, retaining wall, and masonry other. It was assumed that unclassified wall types could not be impacted by Stage 3 measures and were also excluded from the analysis.

[26] See CSIRO 2023, Australian Housing Data, Wall Construction, available at https://ahd.csiro.au/dashboards/construction/walls/, accessed 11 September 2023.

Table 2. Proportion of wall types by Climate Zone

Climate Zone	Building Class		
	1	2*	4
Climate Zone 1	59.1%	21.6%	51.6%
Climate Zone 2	75.0%	17.6%	54.7%
Climate Zone 3	63.0%	20.0%	62.1%
Climate Zone 4	63.2%	33.9%	43.5%
Climate Zone 5	54.6%	37.4%	45.0%
Climate Zone 6	66.9%	24.6%	39.4%
Climate Zone 7	73.4%	36.2%	45.3%
Climate Zone 8	71.4%	40.5%	48.1%

* Building Classes 3 and 9c assumed to be equivalent to Building Class 2.

Note that no specific data was available for the proportion of external wall types for Class 3 and Class 9c dwellings. It was assumed that Class 2 dwellings were most comparable to these building classes and therefore equivalent proportions were applied.[27]

2.4 Share of dwellings impacted by condensation and mould

Condensation data provided by Dewsbury et al. (2016) was used to allocate the expected probability of condensation and resulting mould prevalence in new dwellings across Climate Zones.[28]

This data was collected from survey responses (2,023 responses in total) across a range of companies and individuals within the wider building industry with results reported in September of 2016. These responders included (but were not limited to) architects, builders, surveyors/inspectors, engineers, local council workers and health professional.[29] From these responses, the average proportion of new buildings affected by condensation were estimated for each state/territory, with Dewsbury et al. (2016) noting that there was a significantly disproportionate level of responses from southern-most states such as Tasmania (and highlighting that condensation is therefore likely a much bigger issue in these states).[30] It should also be appreciated that the Dewsbury et al. (2016) survey was subjective, rather than objective, in nature. To account for uncertainty with respect to the share of dwellings impacted by condensation and mould, sensitivity analysis has been carried out (see below).

This state level condensation prevalence data was then converted and calculated at a Climate Zone level to provide inputs for analysis. The same average weighted approach described in section 2.3 above was used here, whereby the state-associated condensation rates from Dewsbury et al. (2016) were proportionally weighted against the total number of dwellings existing for individual classes within LGAs. These weights when aggregated from the LGA level provided the expected average condensation prevalence rates across all Climate Zones.

[27] Note that Class 3 and 9c buildings could have multiple end-use applications and utilise different construction types. However, to control the scope and the number of variables used in modelling, it was assumed that Class 2 dwellings were most comparable.

[28] Dewsbury et al. (2016). Scoping Study of Condensation in Residential Buildings—Appendix 02: Statistical Analysis of Nationwide Condensation Survey. For the Australian Building Codes Board.

[29] Note that the highest responders from the survey were architects, builders and building certifiers (making up approximately half of results). Responses were also weighted relatively heavily towards Tasmania, New South Wales and Victoria when considering the proportional size of the industry across each state.

[30] Note that prevalence data is for overall rates and does not delineate specific condensation occurrences across areas such as external walls, roofs, bathrooms, windows, etc. Additionally, a notable portion of condensation concerns may manifest interstitially, potentially evading immediate detection.

Table 3 presents these converted prevalence rates.[31] [32]

Table 3. Prevalence rates of condensation in new buildings by Climate Zones

Climate Zone	Building Class				
	1	2	3	4	9c
Climate Zone 1	31.8%	36.5%	32.3%	29.6%	32.7%
Climate Zone 2	29.3%	29.2%	29.1%	30.3%	29.5%
Climate Zone 3	32.0%	40.6%	29.0%	32.6%	32.5%
Climate Zone 4	29.8%	23.9%	31.3%	30.4%	30.1%
Climate Zone 5	27.1%	25.7%	30.8%	30.4%	27.5%
Climate Zone 6	30.6%	29.1%	31.0%	30.7%	30.4%
Climate Zone 7	33.0%	34.5%	31.9%	33.1%	32.9%
Climate Zone 8	32.7%	34.1%	32.0%	32.3%	32.0%

Source: NCEconomics based on values taken from Dewsbury et al. (2016).

It should be noted here that estimates from Dewsbury et al. (2016) may differ from condensation rates experienced in new houses today, however, they provide the best estimates of condensation prevalence rates available in Australia within existing literature. As noted, condensation issues in external walls may go unnoticed as the condensation can occur interstitially. Whilst NCC 2022 resolved this issue partly, technical analysis undertaken by University of Wollongong (see Section 2.6) demonstrated that some wall systems are still at risk. It is therefore possible that the condensation rates provided in Table 3 may be a lower bound/conservative estimate of the current condensation rates in new buildings.

A literature review suggested that around 25% of existing Australian houses experience mould.[33] From Table 3, if (around) 32% of Australian houses experience condensation, with 25% of houses experiencing dampness/mould, then 78.1% of dwellings experiencing condensation go on to experience mould (noting the implied assumption here that all mould in housing is due to condensation, and hence overlooks mould being attributable to, for example, flood/storm damage or occupant behaviour).[34] The forecast dwelling stocks were combined with the figures in Table 3 and the condensation-to-mould rate of 78.1% to calculate the number of dwellings experiencing mould in each Building Class and Climate Zone.

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[31] Note the necessary assumption here that prevalence rates of condensation across all Building Classes within the same state are equivalent. This assumes that there is no difference in condensation rates experience by owner occupied, rented, commercially operated houses, apartments, boarding homes, aged care facilities etc. within any one Climate Zone. The slight variations in prevalence rates across Building Classes for individual Climate Zones seen in Table 3 results from differing Building Classes weights (that is, proportional differences in building counts) for the various Building Classes across LGAs, when data is converted from the state to Climate Zone level.

[32] Survey results from Dewsbury et al. (2016) were reported for Class 1 and Class 2 dwellings. With no additional literature available, it was therefore assumed that condensation prevalence rates for other classes (3, 4 and 9c) were equivalent to Class 1 and Class 2.

[33] For example, Knibbs, L., Woldeyohannes, S., Marks, G., Cowie, C. (2018). Damp housing, gas stoves, and the burden of childhood asthma in Australia. *The Medical Journal of Australia, 208*(7), 299-302, available at https://www.mja.com.au/journal/2018/208/7/damp-housing-gas-stoves-and-burden-childhood-asthma-australia, accessed 9 August 2023, find that 26.1% of Australian homes have a dampness problem, while the Healthy Housing Research Group reports that 25% of Australian homes experience dampness and mould, see Healthy Housing Research Group, University of Melbourne, https://mspgh.unimelb.edu.au/research-groups/centre-for-health-policy/healthy-housing-unit/evidence-for-action-on-cold,-damp-and-mould-in-australian-homes, accessed 8 August 2023. It is assumed that 25% of Australian homes experience mould.

[34] Note that homes built after 2019 and 2022 (that is, after implementation of NCC Stage 1 and 2 measures) may have experience a reduced occurrence of condensation, however no data is currently available to quantify this assumption.

2.5 Costs occasioned by condensation and mould

Condensation leading to building dampness, which may then in turn occasion mould growth, gives rise to two potential cost streams—structural damage to the dwellings themselves (a direct cost), and adverse health impacts for the occupants of those dwellings (an indirect cost).

Direct costs

There is a vast array of possible building configurations within Building Classes 1, 2, 3, 4 and 9c, which can in turn give rise to a wide range of costs associated with rectifying structural damage occasioned by building dampness. For example, direct costs will vary depending on the length and height of the external wall, the type of construction materials used in the external wall, and the proportion of the wall incurring damage.

The direct cost analysis is made manageable though assuming a standard (or average) building type for each Building Class, with the dampness occasioning direct costs being determined for these standard building types. Table 4 details the standard building types used when determining the direct costs arising from condensation and building dampness. Building Class 1 is representative of a 3-4 bedroom house with 2 bathrooms, while Building Class 2 is representative of a 2-bedroom apartment with 2 bathrooms. These standard building types also used when costing implementation of the Stage 3 measures (see Section 2.7).

Table 4: Standard dwelling types used in the analysis

Building Class	Nominal dwelling dimension	External wall dimension for costing	Living Area*
1	18m x 10m	56m (by 2.7m high)	180m^2
2	10m x 10m	20m (by 2.7m high)	100m^2
3	5m x 3.5m	8.5m (by 2.7m high)	17m^2
4	10m x 10m	20m (by 2.7m high)	100m^2
9c	10m x 6m	16m (by 2.7m high)	60m^2

*Note that as defined by the NCC, occupancy areas for Building Class 2, 3 and 9c refer to sole occupancy units/apartments within the building.

The construction costs for the standard dwelling types in each Building Class have been obtained from a range of sources, and are reported in Table 5.[35] These construction costs relate to state/territory capital cities. Climate Zone level construction costs have been produced through assuming that the capital city construction costs apply equally to dwellings in all LGAs of the respective state/territory of that capital city. The Climate Zone level share of dwellings (of a Building Class) accounted for by an LGA were then used as weights to arrive at Building Class construction costs at the Climate Zone level.[36]

For some Building Classes, construction cost data was not available for particular capital cities. In these cases, the assumption was made that the missing dwelling's construction cost could be approximated by the average of available capital city dwelling construction costs.

[35] Class 1 buildings sourced from websites of project home builders in each state and territory capital city (see, for example, www.hallmarkhomes.com.au, www.plantationhomes.com.au, www.kinghomesnsw.com.au, www.simonds.com.au, www.ibuildnew.com.au, www.ausbuild.com.au and so on); Classes 2, 3, 4, 9c buildings sourced from Rawlinsons Australian Construction Handbook 2023 (Edition 41 (published by Rawlinsons Publishing); Built Environment Economist (Australia and New Zealand)—Building Cost Index—December 2022 Edition (published by the Australian Institute of Quantity Surveyors); Riders Digest 2023—Queensland Edition (published by Rider Levett Bucknall Quantity Surveyors). These dwellings, and hence construction costs, would comply with NCC 2022.

[36] Note that for Class 3 and Class 9c, construction costs were calculated on a per room basis. These costs were subsequently multiplied by the expected number of rooms per building (see Table 8) at the Climate Zone level in order to arrive at the construction costs per building. For Class 3 and Class 9c, this cost therefore includes all accommodation rooms but excludes any common spaces such as kitchens and communal living rooms.

Table 5: Dwelling construction costs

Climate Zone	Building Class				
	1	2	3	4	9c
Climate Zone 1	$255,605	$277,136	$540,000	$308,747	$8,292,291
Climate Zone 2	$262,163	$319,692	$540,000	$317,885	$3,622,376
Climate Zone 3	$253,503	$262,104	$540,000	$300,556	$3,616,194
Climate Zone 4	$302,453	$299,892	$540,000	$309,560	$6,036,291
Climate Zone 5	$296,750	$304,012	$540,000	$312,122	$12,838,402
Climate Zone 6	$275,907	$299,283	$540,000	$298,764	$11,497,999
Climate Zone 7	$281,808	$302,250	$540,000	$301,339	$10,677,703
Climate Zone 8	$318,095	$300,228	$540,000	$313,487	$5,729,000

The cost arising from (interstitial) occurring dampness and mould have been estimated through determining the cost, expressed as a proportion of build cost (see Table 5), of rectifying damage at various time points. Rectification costs will increase over time as the dampness/mould becomes more extensive.

There will be variability in when the condensation occasioned damage is rectified, and the extent of damage. However, for the purpose of the CBA, the damage assumed to require rectifying at various time points (years post build) comprises:

- damage rectified in year 5—similar to year 10 but with reduced extent of damage (pro-rata assessment of percentage)
- damage rectified in year 10—removal of plasterboard wall lining, floor skirting, ceiling cornice, door and window architraves; cleanout of wall cavity; treatment of wall framing for removal of mould (if any); replacement of wall sheeting, skirting, cornices, architraves; painting of affected surfaces; if required (dependent upon location of required rectification), removal and replacement/reinstallation of joinery, wall tiling, fixtures and fittings (for example, shower screens, shelving, and the like)
- damage rectified in year 20—removal of plasterboard wall lining, floor skirting, ceiling cornice, door and window architraves, soft floor finishes (carpet and vinyl), portions of ceiling lining; cleanout of wall cavity; removal and replacement of damaged wall framing (assumed minimal replacement); treatment of remaining wall framing for removal of mould; replacement of wall sheeting, skirting, cornices, architraves, floor finishes, ceiling; painting of affected surfaces; if required (dependent upon location of required rectification), removal and replacement/reinstallation of joinery, wall tiling, fixtures and fittings (for example, shower screens, shelving, and the like)
- damage rectified in year 40—Similar to year 20 but with more extensive replacement of wall framing.

The cost associated with rectifying the above damages will vary according to the wall area of the building experiencing that damage (for example, bedroom, kitchen, bathroom etc), and the size of the impacted area. Rectification costs have been determined for all of the walls of the dwelling (including the expensive areas of kitchens and bathrooms), and then this total cost has been pro-rated to the length of the external walls. ABCB/UoW advised that the condensation/mould issues are most likely to impact the southern walls of the dwelling.[37] The total cost of rectification was then multiplied by 25% (for the assumed southern wall only), then

[37] University of Wollongong (Sustainable Buildings Research Centre), 2023, Preliminary Results: One Dimensional Hydrothermal Simulations, Version 1, August 2023.

divided by the total building cost to arrive at an appropriate percentage. For the 40 year scenario it was assumed that 50% of the external wall length will be affected.

The resulting estimated direct costs, expressed as a percentage of building costs, associated with condensation are reported in Table 6. These direct costs will be incurred by the dwellings experiencing condensation (with costs increasing over time). It is assumed that costs, and the share of dwellings addressing condensation, increase linearly between the various time points. It is also assumed that rectifying the damage provides the opportunity to (costlessly) improve air flow and building drying, and in so doing eliminating the condensation problem. The share of dwellings having addressed condensation at those time points is based on expert opinion.

Table 6: Direct cost time versus damage profile

Year in which damage rectified	Share of dwellings addressing condensation	Cost to rectify damage
5	0.1%	3.04%
10	20.0%	3.96%
20	20.0%	6.74%
40	59.9%	17.44%

Indirect costs

It is widely acknowledged that dampness and mould in buildings can adversely affect the health of its occupants.[38] The World Health Organization conducted an extensive literature review of the relationship between dampness and dampness-related agents and specific health outcomes.[39] They found evidence of an association between dampness/dampness-related agents and asthma exacerbation, upper respiratory tract symptoms, cough, and wheeze. Later studies have investigated other relationships such as the potential link of early mould exposure to development of asthma in children.[40] There is an ongoing research project at the University of Melbourne investigating the contribution of mould and other housing problems to the burden of poor health in Australia in terms of respiratory disease and cardiovascular disease.[41]

The indirect costs associated with (condensation occasioning) mould in dwellings have been quantified through using Population Attributable Fractions (PAF) in combination with Disability Adjusted Life Years (DALYs) and the Value of a Statistical Life Year (VoSLY). PAFs determine the proportion of a particular disease that could have potentially been avoided if the population had never been exposed to a risk factor.[42] DALYs measure the total burden of disease and combines years of healthy life lost due to living with ill health (years lived with disability, YLD) and the years of life lost due to dying prematurely (years of life lost, YLL), while VoSLY represents the value society places on a year of life.

The calculation of PAFs requires the input of the relative risk (RR) and prevalence of exposure in the population (P), and is given by:

$$PAF = \frac{P.(RR-1)}{P.(RR-1)+1}$$

[38] Coulburn and Miller (2022) provides an overview of research that establishes a link between dampness/mould and adverse health impacts in an Australian context.

[39] World Health Organization (2009). WHO Guidelines for Indoor Air Quality: Dampness and Mould.

[40] See for example Knibbs, L. D., Woldeyohannes, S., Marks, G. B., & Cowie, C. T. (2018). Damp housing, gas stoves, and the burden of childhood asthma in Australia. The Medical journal of Australia, 208(7), 299–302. https://doi.org/10.5694/mja17.00469

[41] Project: 'Evidence for action on cold, damp and mould in Australian homes.' Funded by NHMRC Ideas Grant from 2021 to 2024. Research group: Healthy Housing at the Centre for Health Policy, Melbourne School of Population and Global Health.

[42] PAFs are used to calculate DALYs in the Australian Burden of Disease Study, as well as in the Global Burden of Disease Study.

In this case, the prevalence of exposure in the population (P) can be measured by the prevalence estimates of condensation occasioning mould in Australian dwellings (see Section 2.4 above). The relative risk (RR) is the relative risk of disease for people exposed to dampness and mould (the risk factor).

A literature review was undertaken to identify estimates of relative risks for various respiratory diseases, with estimates then assessed as to whether they were suitable for use in the CBA. This involved looking at whether the diseases used for the estimation of relative risk aligned with the diseases used in the Australian Burden of Disease Study (ABDS). In certain papers, the estimation of relative risk is based on the *onset* of a disease rather than *prevalence* of the disease. Such estimates were considered not suitable for use as the ABDS uses *prevalence* of disease as a basis for its DALY estimates. Based on this assessment, relative risk factors for people exposed to mould for three respiratory diseases—asthma, chronic obstructive pulmonary disease (COPD) and upper respiratory conditions—have been identified as suitable for use in the analysis. Table 7 reports the relative risk factors used in the PAF calculations.

Table 7: Relative risk factors used in the PAF calculations and CBA

Source	Disease	Estimated RR (95% CI)	Notes
Fisk et al (2010)[43] Meta-analysis of 23 studies. Exposure based on reports of visible dampness and/or mould odour as risk factors	Bronchitis[44]	1.45 (1.32–1.59)	The umbrella category of COPD includes bronchitis and emphysema. The ABDS only reports DALYs for COPD.
Fisk et al (2007)[45] Meta-analysis of 33 studies. Exposure based on reports of visible dampness and/or mould odour as risk factors.	Asthma (current)	1.56 (1.30–1.86)	Good match with the ABDS data. Fisk et al. use asthma prevalence in the last 12 months. The ABDS data measures asthma prevalence based on self-reported symptoms of diagnosed asthma in the previous 12 months.
	Upper respiratory tract symptoms	1.70 (1.44–2.00)	Apparent match between the upper respiratory diseases used in Fisk et al. and the ABDS data, but lacking detailed information about what is included in the ABDS data.

The relative risk factors identified in Table 7 were used to calculate the PAFs for asthma, COPD and upper respiratory tract disease in each Building Class in each Climate Zone.

The PAFs were then combined with the DALY and VoSLY to estimate the health related costs arising from condensation occasioning mould in each Building Class in each Climate Zone. This calculation required several prior data manipulations.

The ABDS produces DALYs for each of asthma, COPD and upper respiratory tract diseases. The 2022 DALY figures are produced at the Australia wide level; whereas the CBA needs DALY at the Building Class and in each Climate Zone level. State and territory level DALYs for the three respiratory diseases being considered are available for 2018 (the most recent year for which state/territory level data is available).[46] To arrive at estimates

[43] See Fisk, W.J., Eliseeva, E.A. & Mendell, M.J. (2010). Association of residential dampness and mold with respiratory tract infections and bronchitis: a meta-analysis. Environ Health 9, 72. https://doi.org/10.1186/1476-069X-9-723

[44] The studies included in the meta-analysis reflected indicators of both acute and chronic bronchitis. As described in Mudarri (2016), this could however represent a reasonable estimate for acute bronchitis.

[45] See Fisk, W. J., Lei-Gomez, Q., & Mendell, M. J. (2007). Meta-analyses of the associations of respiratory health effects with dampness and mold in homes. Indoor air, 17(4), 284–296. https://doi.org/10.1111/j.1600-0668.2007.00475.x.

[46] Australian Burden of Disease Study: Impact and causes of illness and death in Australia 2018. Available from: https://www.aihw.gov.au/reports/burden-of-disease/abds-impact-and-causes-of-illness-and-death-in-aus/data

of disease burden for each state/territory (and ultimately each Climate Zone), the relative proportions of state/territory disease burden from 2018 have been applied to the 2022 disease burden estimates.

The state/territory level 2022 asthma, COPD and upper respiratory tract DALYs were then allocated across the LGAs in a particular state/territory is proportion to population shares. The LGA level 2022 asthma, COPD and upper respiratory tract DALYs were then aggregated to the Climate Zone level.

The Climate Zone level asthma, COPD and upper respiratory tract DALYs were then allocated across the various Building Classes with a Climate Zone in proportion to the share of population residing in dwellings of that Building Class type. This calculation required combining the number of Building Class dwellings with data, or an assumption, about the average number of occupants per dwelling in each Building Class. Table 8 reports the number of occupants per dwelling in each Building Class across Climate Zones used in the analysis. [47]

Table 8: Number of occupants per Building Class type

Climate Zone	Building Class				
	1	2	3	4	9c
Climate Zone 1	2.72	1.89	12.00	1.00	53.17
Climate Zone 2	2.68	1.75	12.00	1.00	88.89
Climate Zone 3	2.63	1.59	12.00	1.00	23.43
Climate Zone 4	2.44	1.57	12.00	1.00	37.99
Climate Zone 5	2.67	1.95	12.00	1.00	81.31
Climate Zone 6	2.79	1.91	12.00	1.00	78.30
Climate Zone 7	2.46	1.64	12.00	1.00	62.52
Climate Zone 8	2.37	1.88	12.00	1.00	33.70

The above steps allow calculation of the DALYs associated with asthma, COPD and upper respiratory tract disease, in each Building Class and across each Climate Zone in 2022. Population growth rates were used to grow these DALYs over the period to 2064. Using population growth rates alone to grow the DALYs over time assumes that the DALY per capita remains constant at 2022 levels. However, and as can be seen from Table 9, the DALY per capita appears to be increasing for asthma and COPD, while decreasing for upper respiratory tract diseases. To the extent that DALY per capita are being help constant at 2022 levels, and especially for the far more important asthma and COPD, the indirect costs associated with condensation occasioning mould may be conservative.

[47] Occupancy rates for Building Class 1, 2 and 9c were calculated using the ABS "Average persons per household" approach, found at https://www.abs.gov.au/ausstats/abs@.nsf/Lookup/2901.0Chapter23302016 . This approach uses the sum of the number of persons usually resident across all dwellings divided by the total number of dwellings. Building Class 9c data provided by the Australian Institute of Health and Welfare included bed numbers which were used via the same approach to calculate occupancy rates. Building Class 4 by definition only has 1 occupant residing within each dwelling. Building Class 3 occupancy rates required an assumption by NCEconomics based on the included non-residential dwelling types.

Table 9: DALYs over time

Year	DALY			DALY per capita		
	Asthma	COPD	Upper respiratory	Asthma	COPD	Upper respiratory
2003	96,352	132,210	17,159	0.00502	0.00688	0.00089
2011	108,064	148,481	19,639	0.00502	0.00690	0.00091
2015	120,594	167,606	18,963	0.00525	0.00729	0.00083
2018	130,876	176,882	19,769	0.00543	0.00733	0.00082
2022	138,041	203,573	20,346	0.00535	0.00790	0.00079

Source: Total DALYs per year are sourced from the Australian Burden of Disease Study 2022. Available from: https://www.aihw.gov.au/reports/burden-of-disease/australian-burden-of-disease-study-2022/data

The Office of Impact Analysis (OIA) recommends a value of $227,000 be used for the value of a statistical life year in 2022.[48] This figure has been grown in line with inflation to arrive at a VoSLY in 2023 dollar terms of $240,681, with this VoSLY being used in the analysis.[49]

The cost associated with the disease burden is estimated by applying the PAF for each disease being considered to the DALY for that disease burden, and then multiplying the attributable DALYs by the value of a statistical life year. This is consistent with the recommended approach by Ananthapavan et al. (2021).[50] The calculation being:

$$\$\, Cost_k = PAF_{j,k}^{i} * \; DALY_{j,k}^{i} * VoSLY$$

where *i* = Building Class (1, 2, 3, 4 and 9c), *j* = Climate Zone (1, 2, 3, 4, 5, 6, 7 and 8) and *k* = the respiratory disease being considered (asthma, COPD and upper respiratory).

Table 10 shows the indirect costs in 2025 under the base case scenario arising from the above calculations. The distribution of indirect costs across Climate Zones and Building Classes reflects the population in the Climate Zones and Building Classes (which in turn reflects the dwelling stock and number of people per dwelling).

The indirect costs reported in Table 10 relate to all dwellings of a particular Building Class in a particular Climate Zone experiencing mould. The figures in Table 10 were then converted to a cost per mould occurring dwelling, with these costs then being applied to the number of dwellings expected to experience mould under the base case and with Stage 3 external wall measure scenarios.

The final data manipulation saw the indirect costs arising from mould over time being scaled down to take account of the number of damp buildings that have had condensation/dampness problem addressed (see Direct costs section above). Rectifying the condensation/dampness problem is assumed to remove the occurrence of mould, and hence occupants of these dwellings are no longer exposed to the indirect health costs.

[48] Office of Impact Analysis (2023). Guidance note – value of statistical life, available at https://oia.pmc.gov.au/resources/guidance-assessing-impacts/value-statistical-life, accessed 10 August 2023.

[49] The inflation rate over 2022 to 2023 was calculated as the (percentage) change in the Australian All Groups CPI between the June 2023 and June 2022 quarters; with index figures taken from ABS 6401.0.

[50] The authors recommend a CBA framework for preventative health interventions, based on a review of CBA and other guidance documents published by Australian and NSW Government departments. See Ananthapavan, J., Moodie, M., Milat, A. et al. (2021). A cost–benefit analysis framework for preventive health interventions to aid decision-making in Australian governments. Health Res Policy Sys 19, 147. https://doi.org/10.1186/s12961-021-00796-w.

Table 10: Cost attributable to mould in dwellings in 2025 (base case)

Disease	Climate Zone 1					Climate Zone 2					Climate Zone 3					Climate Zone 4				
	Class 1	Class 2	Class 3	Class 4	Class 9c	Class 1	Class 2	Class 3	Class 4	Class 9c	Class 1	Class 2	Class 3	Class 4	Class 9c	Class 1	Class 2	Class 3	Class 4	Class 9c
Asthma ($m)	114	13	0	0	1	665	83	0	0	6	33	1	0	0	0	138	3	0	0	1
COPD ($m)	156	18	0	0	1	800	100	0	0	8	43	1	0	0	0	170	3	0	0	2
Upper respiratory ($m)	18	2	0	0	0	98	12	0	0	1	5	0	0	0	0	25	1	0	0	0

Disease	Climate Zone 5					Climate Zone 6					Climate Zone 7					Climate Zone 8				
	Class 1	Class 2	Class 3	Class 4	Class 9c	Class 1	Class 2	Class 3	Class 4	Class 9c	Class 1	Class 2	Class 3	Class 4	Class 9c	Class 1	Class 2	Class 3	Class 4	Class 9c
Asthma ($m)	922	188	2	1	10	1268	161	3	1	11	304	20	0	0	3	6	1	0	0	0
COPD ($m)	1150	234	2	1	13	1479	188	3	1	13	372	25	0	0	3	8	1	0	0	0
Upper respiratory ($m)	167	34	0	0	2	244	31	1	0	2	60	4	0	0	1	1	0	0	0	0

2.6 Impact of the Stage 3 condensation mitigation measures

The condensation reducing impact of the Stage 3 condensation mitigation measures have been taken from research conducted by the Sustainable Buildings Research Centre (SBRC) at the University of Wollongong, on behalf of the ABCB.

The SBRC undertook a number of hydrothermal modelling simulations to quantify the maximum mould index reached in 10-years of simulated operation under a number of agreed conditions and assumptions. The analysis was undertaken for 8 different external wall types/constructions, with various membrane permeance values (where appropriate), in the 8 NCC Climate Zones, and with three different Indoor Humidity Risk Ratings (IHRM). The maximum mould index was established for:

- external walls built to a NCC 2022 standard (the base case)
- external walls with ventilated cavities
- external wall membrane permeability.

SBRC notes that the data produced in the study is a product of the specific assumptions and settings agreed on for the simulations. Furthermore, the modelling results likely provide a relatively accurate indication of relative risk between different construction types and climates, but they do not indicate that all such constructions would exhibit such performance in reality, due to the vast variation in construction details and environmental conditions that occur in real buildings.

The mould index resulting from the SBRC research under the base case, and with an IHRR of 3.3, ranges between a low of 0.003 and a maximum of 4.947. The mould index ranges between 0–6, and is scaled such that increasing values are associated with greater mould incursion/severity, namely:

- 0—no mould growth and spores not activated
- 1—some growth detected with microscopy and initial stage of hyphae growth
- 2—moderate growth detected with microscopy and coverage more than 10%
- 3—some growth visually detected and new spores produced
- 4—clear visually detected and coverage more than 10%
- 5—plenty of visually detected growth and coverage more than 50%
- 6—very heavy and tight growth and coverage around 100%.

The verification method in NCC 2022 allows a maximum mould index of 3.

The mould index relates to mould occurring interstitially, with this mould (and precursor building dampness) having the potential to occasion structural damage. An assumption is made that uncontrolled airflow between walls and internal airspaces exposes the internal spaces and dwelling occupants to mould and mould spores, which in turn can occasion health costs.

The SBRC analysis is limited to Building Classes 1 and 2, with the assumption made that (any) reduction in mould index applies equally to Building Classes 3, 4 and 9c. Note that NCC 2022 requirements do not apply to Building Classes 3 and 9c. The mould index base case data for Building Classes 3 and 9c was adjusted to take account of differing starting position to NCC 2022.

For the various wall type and Climate Zone combinations, base case mould index values below 3 have been excluded from the analysis. This is based on the assumption that a mould index below 3 is not associated with the building dampness/mould being of sufficient severity to occasion structural damage nor health costs.

For those wall type and Climate Zone combinations with a mould index greater than 3, the reduction in mould index resulting from constructing external walls with ventilated cavities or increased indoor ventilation rates has been calculated as the percentage difference in mould index between the base case and the Stage 3 drained and vented cavity and no cavity measure simulations. The percentage difference calculations were adjusted such that if a Stage 3 measure lowered the mould index to below 3, then it was treated as if the index value was zero (hence a 100% reduction in the rate of mould occurrence).[51].

The SBRC analysis was undertaken for 8 differing external wall types. The CSIRO external wall type data (expressed at the Climate Zone level) was used as weights to combine the per cent reduction in mould index for the 8 SBRC external wall types into a single figure for a representative (or average) external wall type in each Climate Zone and Building Class.[52] Table 11 shows the resulting assumed reduction in probability of mould, and therefore condensation, under the Stage 3 condensation mitigation measures used in the impact analysis. The (implied) assumption is made that there is a linear relationship between reduction in mould index and reduction in condensation.

The figures reported in Table 11 are a key CBA input. It is important to appreciate that the SBRC modelling includes various assumptions, and that the condensation reducing impact of measures may differ should any of those assumptions change.

As can be seen, the Stage 3 external wall drained and vented cavity and no cavity measures only have notable impacts in select Building Classes in select Climate Zones. The instances of low figures reflect one or more of:

- the mould index being below the critical threshold value of 3 in the base case (hence a low risk to begin with)
- the Stage 3 measure not impacting the mould index for certain wall types in certain Climate Zones, or if there is an impact, it is only marginal
- the Building Classes having a high proportion of external wall types not able to be impacted by the Stage 3 measures under consideration
- the Stage 3 measure not being applicable to certain Climate Zones (namely, permeance measures are applicable to Climate Zones 1–5 only, and hence will have no impact on condensation rates in Climate Zones 6–8).

The ability of the Stage 3 external wall drained and vented cavity to reduce the occurrence of mould is also dependent on whether dwellings are already being built with drained and vented cavities. If this was the situation, then the Stage 3 external wall drained and vented cavity provision would have no impact, as the dwelling's external walls already have drained and vented cavities. While it is thought that few, if any, dwelling external walls are built with a cavity, we have assumed that 25% of new builds in the base case are built with a drained and vented cavity to err on the side of caution.

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[51] For example, assume the mould index under the base case was 4.0, and that the Stage 3 measure reduced the mould index to a value of 2.8. Strictly speaking, the per cent reduction in mould index is 30% (given by (2.8 – 4.0)/4.0). However, as the 2.8 value is below the critical threshold of 3.0 and therefore does not occasion any damage/costs, the 2.8 figure is replaced with a value of 0, with there being a 100% reduction in the occurrence of mould (of a sufficient severity to occasion damage/costs) (given by (0 – 4.0)/4.0).

[52] See CSIRO 2023, Australian Housing Data, Wall Construction, available at https://ahd.csiro.au/dashboards/construction/walls/, accessed 11 September 2023.

Table 11: Impact of Stage 3 measures in reducing occurrence of condensation

Climate Zone	Building Class				
	1	2	3	4	9c
External wall drained and vented cavity					
Climate Zone 1	47.5%	6.1%	6.1%	7.4%	6.1%
Climate Zone 2	0.0%	0.0%	0.0%	0.0%	0.0%
Climate Zone 3	0.0%	0.0%	0.0%	0.0%	0.0%
Climate Zone 4	0.5%	0.7%	41.5%	0.7%	41.5%
Climate Zone 5	33.1%	49.2%	56.4%	26.6%	56.4%
Climate Zone 6	18.7%	44.9%	100.0%	44.2%	100.0%
Climate Zone 7	30.8%	46.1%	89.3%	42.0%	89.3%
Climate Zone 8	36.7%	49.9%	69.6%	42.8%	69.6%
External wall no cavity					
Climate Zone 1	47.5%	6.1%	6.1%	7.4%	6.1%
Climate Zone 2	0.0%	0.0%	0.0%	0.0%	0.0%
Climate Zone 3	0.0%	0.0%	0.0%	0.0%	0.0%
Climate Zone 4	27.3%	54.6%	94.6%	26.0%	94.6%
Climate Zone 5	33.1%	49.2%	56.4%	26.6%	56.4%
Climate Zone 6	0.0%	0.0%	0.0%	0.0%	0.0%
Climate Zone 7	0.0%	0.0%	0.0%	0.0%	0.0%
Climate Zone 8	0.0%	0.0%	0.0%	0.0%	0.0%

2.7 Cost of implementing the Stage 3 measures

The cost of implementing the Stage 3 drained and vented cavity and no cavity measures have been estimated through determining the additional labour and material costs associated with each measure. This saw:

- obtaining material prices for vapour/water barrier from supplier websites
- costing the application of vapour/water barriers based on labour cost and productivity rates (where applicable)
- costing the material supply and labour cost to create a wall cavity between the external wall framing and the external cladding (utilising unit pricing from Rawlinsons Australian Construction Handbook 2023)
- assessing the cost differential between timber stud wall framing and metal stud wall framing
- costing the implementation of roof ventilation requirements (in Climate Zones 4 and 5 under the external wall drained and vented cavity scenario).

Implementation costs were determined for each Building Class at the state/territory capital city level, and expressed as a share of building construction costs. These state/territory level cost imposts were then assumed to apply equally to the respective Building Classes within each LGA of the state/territory of that capital city. The LGA level cost imposts were then aggregated to the Climate Zone level based on Building Class shares accounted for by each LGA. Table 12 shows the resulting cost impost, expressed as a share of building construction costs, associated with the Stage 3 drained and vented cavity and no cavity measures.

Table 12: Cost of implementing Stage 3 condensation mitigation measures

Climate Zone	Building Class				
	1	2	3	4	9c
External wall drained and vented cavity					
Climate Zone 1	1.02%	0.29%	0.90%	0.29%	0.49%
Climate Zone 2	1.04%	0.30%	0.91%	0.31%	0.51%
Climate Zone 3	1.03%	0.29%	0.91%	0.29%	0.51%
Climate Zone 4	1.01%	0.36%	1.01%	0.36%	0.54%
Climate Zone 5	1.02%	0.35%	1.04%	0.37%	0.56%
Climate Zone 6	0.90%	0.29%	0.77%	0.28%	0.46%
Climate Zone 7	0.92%	0.30%	0.82%	0.29%	0.47%
Climate Zone 8	0.90%	0.30%	0.93%	0.31%	0.48%
External wall no cavity					
Climate Zone 1	0.29%	0.10%	0.24%	0.09%	0.13%
Climate Zone 2	0.28%	0.08%	0.24%	0.08%	0.14%
Climate Zone 3	0.29%	0.10%	0.24%	0.09%	0.13%
Climate Zone 4	0.26%	0.09%	0.26%	0.09%	0.14%
Climate Zone 5	0.27%	0.09%	0.26%	0.09%	0.14%
Climate Zone 6	0.00%	0.00%	0.00%	0.00%	0.00%
Climate Zone 7	0.00%	0.00%	0.00%	0.00%	0.00%
Climate Zone 8	0.00%	0.00%	0.00%	0.00%	0.00%

Note that the estimated cost of implementing the Stage 3 condensation mitigation measures excludes other costs that may be occasioned by the measures. For example, the Stage 3 external provisions require, for any control layer, sheathing or water barrier to be incorporated between the cladding and the exterior side of the primary insulation layer. Furthermore, introduction of an external wall drained and vented cavity may trigger the need for additional insulation in accordance with AS 4859.2. Any additional implementation costs associated with these requirements have been excluded from the analysis.

2.8 Key assumptions used in the impact analysis

Sections 2.1 to 2.7 of this chapter have detailed the sources of the data and required data manipulations to arrive at the data needed to undertake the impact analysis. It is also evident that numerous assumptions have had to be made in using the available data/information and conducting the impact analysis. Table 13 provides a compiled summary of any key assumptions made.

Table 13. Key assumptions made

Assumption	Building Class	Explanation
Climate Zone mapping allocation	All	Where LGA's mapped from resources provided by ABCB (2023) overlapped areas covering two or three Climate Zones, the most populous area within the boundaries were used to designate the relevant Climate Zone for the LGA. The most populous regions were predominantly located along coastlines.
ABS correspondence data	All	Where ABS data has spanned several years and has required the collation of different geographical boundaries through ABS provided correspondence ratios, these ratios assume to apportion any changes between boundaries equally based on area.
Projected population growth	Class 1 Class 2 Class 3 Class 4 Class 9c	LGA level populations were assumed to grow in line with specific LGA growth rates retrieved from state/territory government websites. Where specific LGA growth rates were not provided out to 2064, growth rates were assumed to remain constant at reported growth rates (that is, population growth rate data was extrapolated).
Existing housing stock	Class 4	The residual dwellings within the ABS estimated dwelling stock dataset following removal of the Building Class 1 and Building Class 2 dwellings were assumed to be an estimate of Building Class 4. This assumption aligns with building definitions provided by the ABS.
Future housing stock projection	Class 1 Class 2	Future housing stock at the Climate Zone level was assumed to grow in line with projected populations of all ages between 2023 and 2064, whist taking into account trend dwelling to population ratios. Trends were estimated using ABS dwelling stock and population data for the period 2016 to 2022. The dwellings per capita trend ratios were calculated at the Climate Zone level and were assumed to continue out to 2064.
	Class 3 Class 4	Assumed to directly grow in line with projected population of all ages between 2023 and 2064.
	Class 9c	Assumed to directly grow in line with projected population of residents 75 year and over between 2023 and 2064.
Proportion of wall types used for scaling future estimated relevant dwelling stock	Class 1 Class 2 Class 4	Assumed that the wall type data provided by CSIRO between 2016 and 2022 would hold constant over the period to 2064 and could therefore be used to determine relevant building stock. As data was converted from state level to climate zone level, assumes that the proportion of wall types on average across states can be estimated based on the number of dwellings for each LGA.
	Class 3 Class 9c	As CSIRO wall type data was not available for Class 3 and Class 9c dwellings, assumed Class 2 dwellings were most comparable to these building classes, with Class 2 wall type data being assumed to apply equally to Class 3 and 9c dwellings.
Share of housing impacted by condensation	All	State level condensation prevalence data was converted to the Climate Zone level based on assumption that state level condensation rates occur equally across all Building Classes within all LGAs of the same state. A further assumption was made that condensation leads to building dampness and mould of sufficient severity to occasion costs.

Assumption	Building Class	Explanation
Condensation rates experienced in homes	All	Assumes that condensation rates are applicable as a total to homes. No differentiation or delineation is applied to condensation occurrences across distinct areas such as external walls, roofs, bathrooms, windows, etc.
Direct damages to housing	All	Assumptions made regarding the type and extent of condensation/mould damage at various year intervals. Cost of rectifying condensation/mould based on material and labour costs.
Indirect health impacts estimation of DALYs	All	Assumption made that proportion of 2018 DALYs accounted for by the various states/territories reflects the (exact same) situation in 2022. Assumptions also made that the DALYs per capita remain constant at 2022 levels, that the number of DALYs within an LGA of a particular state/territory can be determined according to LGA population shares, and that the number of DALYs across building types can be determined by population shares accounted for by those building types.
Relationship between dwellings experiencing condensation and those experiencing mould		Assumption is made that all mould in housing is due to condensation arising from construction practices, and hence overlooks mould being attributable to, for example, flood/storm damage or occupant behaviour. Assumption is also made that a percentage reduction in mould index translate into an equivalent reduction in condensation (hence linear relationship between reduction in mould index and reduction in condensation).
Occupancy rates	Class 3	Assumption made that the expected occupancy rate for Class 3 buildings was 12 occupants per dwelling (to enable calculation of the share of DALYs accounted for by Building Class 3 dwellings). This estimation was based on the various types of buildings included in Class 3 buildings; however it should be noted that the resulting impact of the Class 3 occupancy rate has an almost negligible impact on the overall result of the CBA due to the minimal number of dwellings.
Removal of mould after condensation/dampness addressed	All	Assumed that rectifying the condensation/dampness problem would remove the occurrence of mould, and hence occupants of these dwellings are no longer exposed to any indirect health costs.
Impact of Stage 3 NCC measures	All	For the various wall type and Climate Zone combinations, base case mould index values below 3 have been excluded from the analysis based on assumption that a mould index below 3 is not associated with the building dampness/mould being of sufficient severity to occasion structural damage nor health costs. The SBRC analysis relates to Building Classes 1 and 2, assumption is made that (any) reduction in mould index applies equally to Building Classes 3, 4 and 9c. Sarting (base case) mould index values for Building Classes 3 and 9c adjusted to take account of NCC 2022 not applying to these Building Classes. The SBRC analysis also makes various technical assumptions when determining condensation reducing impacts of condensation mitigation measures.
Share of new dwellings built with drained and vented external wall cavities	All	Assumption is made that 25% of new dwellings are built with drained and vented external wall cavities, and hence these dwellings are not impacted by the Stage 3 external wall provisions.
Dwelling construction costs	All	Building Class construction costs were obtained at the capital city level, with assumption that construction costs applied equally to dwellings in all LGAs of the respective state/territory of that capital city. For some Building Classes, construction cost data was not available. In these cases, assumption made that dwelling's construction cost could be approximated by the average of available capital city dwelling construction costs.

Assumption	Building Class	Explanation
Cost of implementing Stage 3 condensation mitigation measures	All	The Stage 3 external wall provisions require, for any control layer, sheathing or water barrier to be incorporated between the cladding and the exterior side of the primary insulation layer. It is assumed that (any) additional costs associated with the sheathing or water barrier are not material and hence can be excluded from the analysis. Introduction of an external wall drained and vented cavity may trigger the need for additional insulation in accordance with AS 4859.2. Any costs associated with the (potential) triggering of this requirement have been excluded from the analysis.

3 Impact analysis of the Stage 3 measures

An impact (cost-benefit) analysis of the Stage 3 external wall measures under consideration has been undertaken at the individual Building Class level in each Climate Zone. This has allowed generation of a range of cost, benefit and net impact metrics for 40 possible Building Class–Climate Zone combinations, for each of the Stage 3 measures being considered.

The impact analysis has been supplemented with a breakeven analysis to determine the minimum values needed in certain fields/parameters before the Stage 3 measures would deliver a net benefit.

It should also be noted that the results provided below rely on numerous assumptions, and that should these assumptions differ, then the results will also differ. The sensitivity and breakeven analysis provided below provides insight into what the CBA results could be with differing assumptions.

3.1 Cost-benefit analysis

High level results of the CBA are provided below for the external wall drained and vented cavity and no cavity measures. More detailed results can be found in Appendix B.

External wall drained and vented cavity

Figure 8 and Figure 9 report the Net Present Value (NPV) and Benefit-Cost Ratio (BCR) results (respectively), at the Climate Zone level, for the external wall drained and vented cavity measure. As can be seen, and Australia wide, the external wall drained and vented cavity measure has a relatively small ($42 million) net cost in present value terms, with the measure having a BCR of 0.96. However, there is variability in results across the Climate Zones.

Figure 8: Net Present Value—External wall drained and vented cavity

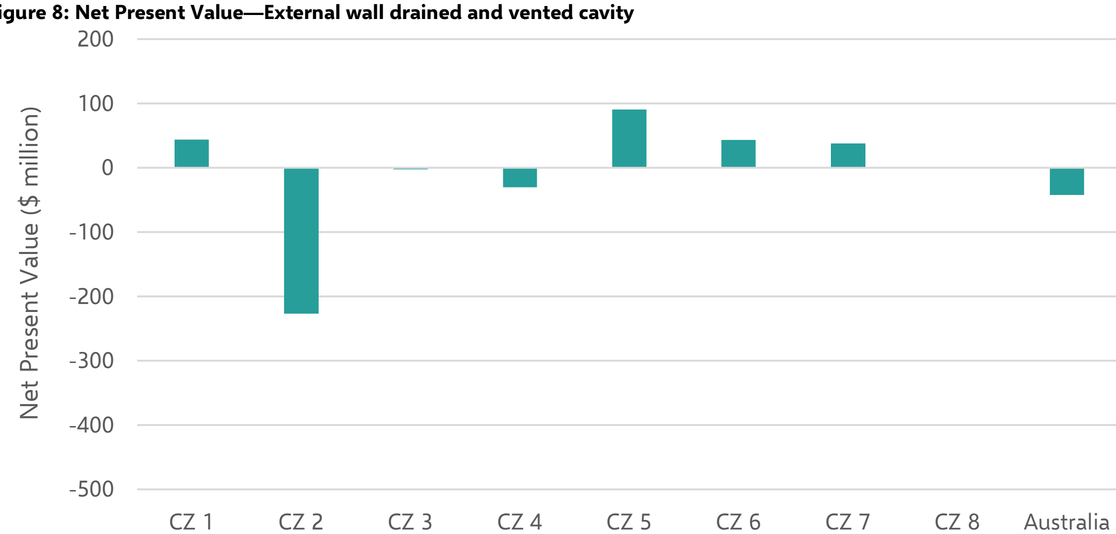
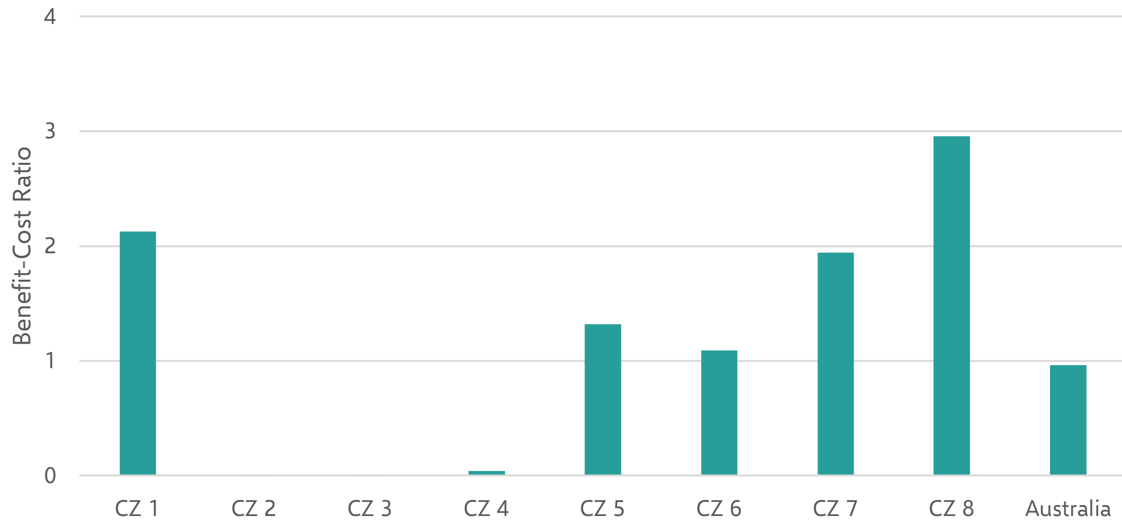


Figure 9: Benefit-Cost Ratio—External wall drained and vented cavity



The Australia wide result of a net cost is driven by Climate Zones 2, 3 and 4. In these Climate Zones, implementation of the external wall drained and vented cavity measure will come at a net cost (with a NPV of -$227 million in the case of Climate Zone 2). These outcomes reflect the fact that in these Climates Zones, the external wall drained and vented cavity delivers little by way of condensation reduction (see Table 11), and hence does not deliver any (or only small) direct and/or indirect benefits.[53] While delivering little in the way of benefits, implementation of the wall drained and vented cavity measure increases building construction costs, with these cost increases exceeding the delivered benefits.

If the Climate Zone 2, 3 and 4 results are excluded from the Australia figure, then the external wall drained and vented cavity measure would deliver an aggregate NPV benefit of $217 million and a BCR of 1.26.

The large NPV gains experienced in Climates Zones 5 and 6 simply reflects the large number of dwellings in these areas, the fact that the external wall drained and vented cavity measure has a large condensation reducing impact, which in turn drives large direct and indirect benefits. For example, external wall cavities are estimated to see Climate Zones 5 and 6 experiencing total benefits of $905 million with implementation of the cavities costing $770 million, yielding a net benefit of $135 million. The $905 million of total benefits comprises $131 million of direct benefits (avoided structural damage) and $774 million of indirect benefits (avoided adverse health impacts). The indirect benefits arising from reduced condensation (and hence mould) are the largest driver of benefit.

As noted in the above Climate Zones 5 and 6 example, the indirect benefits arising from a reduction in condensation (and mould) greatly outweigh the direct benefits. Indeed, and as can be seen from Table 14, the external wall drained and vented cavity measure would impose a NPV cost on Australia of some $700 million if the indirect benefit were to be overlooked/excluded from the analysis.

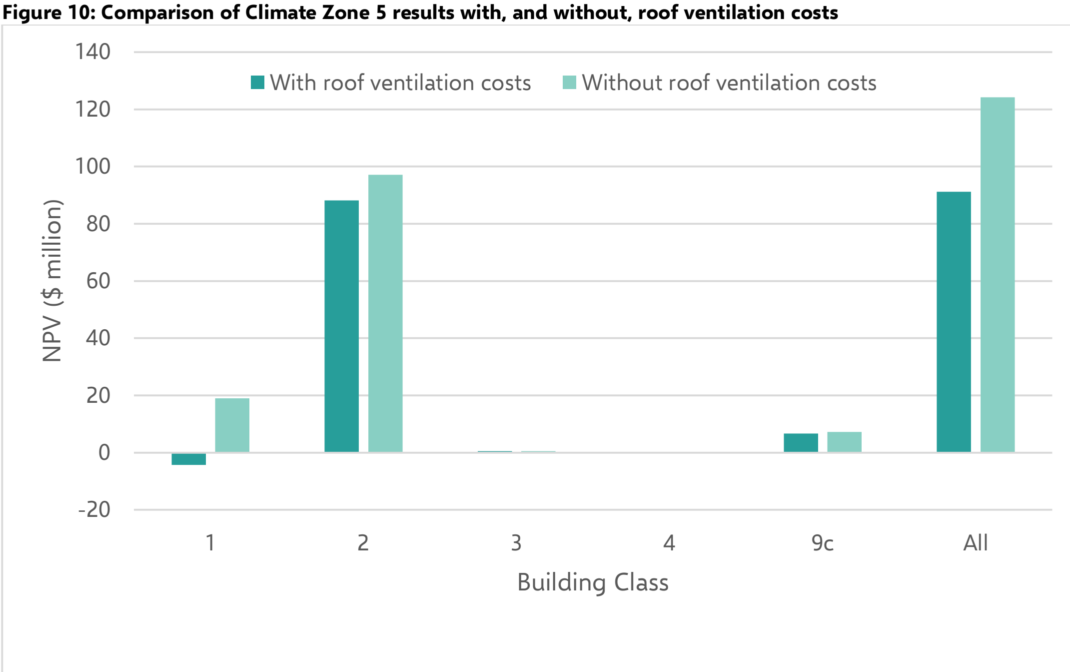
[53] It should be noted that while the implementation of an external wall drained and vented cavity measure may not deliver much in the way of condensation reduction benefits, the measure may provide other benefits such as improved weatherproofing, which may in turn act to reduce mould. Any such (indirect) condensation and mould reduction benefits have been excluded from the analysis.

Table 14: Importance of indirect benefits (Climate Zones 1, 5, 6, 7 and 8)

Benefit stream	Building Class					
	1	2	3	4	9c	All
Direct + Indirect benefits						
Net Present Value ($ million)	-4.9	192.5	2.3	0.5	26.5	216.9
Benefit-Cost Ratio	1.0	3.0	8.0	1.9	3.8	1.3
Direct benefits only						
Net Present Value ($ million)	-658.7	-36.8	-0.2	-0.3	-3.3	-699.2
Benefit-Cost Ratio	0.1	0.6	0.4	0.5	0.7	0.2

While Climate Zone 5 has an overall net benefit (NPV of $91 million across all Building Classes), there is variability between Building Classes. Specifically, Building Class 1 has a NPV of -$4 million, suggesting the drained and vented cavity measure will impose a net cost on Build Class 1 type dwellings. Drained and vented cavities are estimated to deliver net benefits to other Building Classes within Climate Zone 5. The Building Class outcomes, in part, reflect assumptions about the cost of implementing drained and vented cavities. As noted in Section 2.7, the cost of the drained and vented cavity measure includes the cost of implementing vented roof spaces in Climate Zones 4 and 5, with the latter adding another 0.6% to 0.12% (depending on Building Class) to dwelling costs. However, due to difficulties in quantifying benefits of the vented roof space provisions, the costs of vented roof spaces in Climate Zones 4 and 5 are being considered, but not any resultant benefits. Figure 10 shows the NPV results for Climate Zone 5 with, and without, the costs of the vented roof spaces. As can be seen, excluding the vented roof space costs sees the results for Building Class 1 going from a NPV cost (of $4 million) to a NPV benefit (of $19 million). Across all Building Classes the NPV is some $33 million higher.

Figure 10: Comparison of Climate Zone 5 results with, and without, roof ventilation costs



External wall no cavity

Figure 11 and Figure 12 report the Net Present Value and Benefit-Cost Ratio results, at the Climate Zone level, for the external wall no cavity measure. As can be seen, the impact of the external wall no cavity measure is more significant but is highly variable, with Climate Zones 1 and 5 driving the majority of the estimated net benefit. It is also apparent from the figures that the external wall no cavity measure only reducing the occurrence of condensation in Climate Zones 1, 4 and 5. Australia wide, the no cavity measures are estimated to deliver a net gain of $445 million (present value terms), with the measure having a BCR of 3.16.

Compared to the external wall drained and vented cavity outcomes, the no cavity measures see a reversal of outcomes for Climate Zone 4 (cavities delivering a net loss of $30 million with no cavity measures delivering a net gain of $26 million). This $56 million difference under the drained and vented cavity and no cavity measures reflect the relevance of the measures to Climate Zone 4. For example, the drained and vented cavity measure has a much lower (1%-42%) impact on reducing mould (and hence condensation due to the assumption that mould is directly attributable to dwelling condensation) in Climate Zone 4, whereas the no cavity measure has a much higher 26-95% (depending on Building Class) impact on reducing mould.

Figure 11: Net Present Value—External wall no cavity

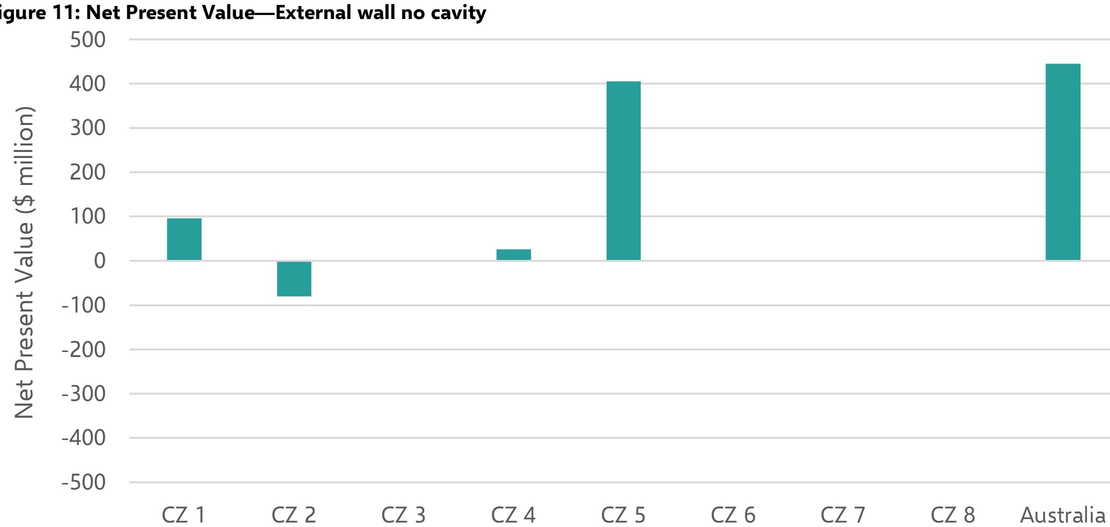
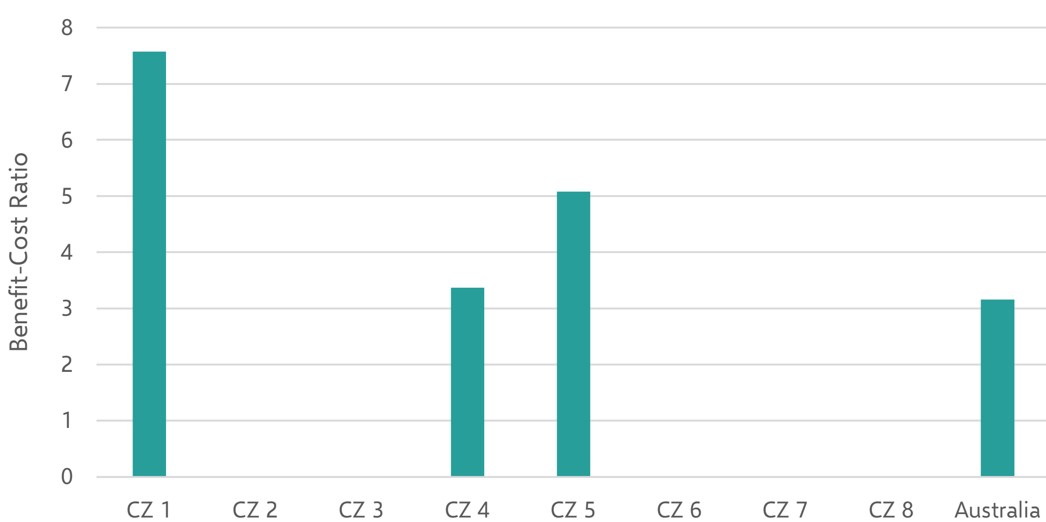


Figure 12: Benefit-Cost Ratio—External wall no cavity



Sensitivity analysis

The CBA results presented above are based on the data inputs identified in chapter 2. And as noted throughout chapter 2, numerous assumptions have been made in deriving the required data inputs (with key assumptions having been summarised in Table 13). Sensitivity analysis has been undertaken around key areas of data uncertainty to quantify the impact this uncertainty has on CBA results. The CBA inputs subjected to sensitivity analysis include:

- share of dwellings experiencing condensation—-20% to +20% of values reported in Table 3
- share of buildings experiencing condensation that go on to experience mould—-20% to +20% of figure (78.1%) identified in Section 2.4
- dampness/mould and adverse health outcome relative risk factors—95% confidence intervals as identified in Table 7
- condensation reducing impacts of Stage 3 measures—-20% to +20% of values reported in Table 11
- cost impost of Stage 3 measures—-20% to +20% of values reported in Table 12.

Sensitivity results for both the external wall drained and vented cavity and external wall no cavity scenarios have been provided in Table 15 below. Results have been calculated at the both the P90 and P10 levels, where P90 indicates a low estimate whereby 90% of the simulated results obtained a NPV greater than this value. Likewise, P10 indicates a high estimate whereby 90% of the simulated results obtained a NPV less than this value.

Under the external wall drained and vented cavity scenario, across Australia these P90 and P10 results varied across the NPV range, from $-349 million up to $312 million. Climate Zone 5 is by far the largest driver of these positive results across both scenarios, while Climate Zones 2 and 3 all display result ranges with negative NPVs. The negative NPV results reflect the fact that the external wall drained and vented cavities have no or very little impact on mould (and hence condensation) in Climate Zones 2, and 3.

The external wall no cavity scenario displayed contrasting results for Climate Zone 4, where NPV results were positive and ranged from $17 million to $37 million.

Table 15. Sensitivity results (NPV $m)

	Low (P90)	More Likely (P50)	High (P10)
External wall drained and vented cavity			
Climate Zone 1	23.1	44.0	69.5
Climate Zone 2	-251.5	-226.6	-201.9
Climate Zone 3	-2.4	-2.2	-1.9
Climate Zone 4	-33.9	-30.2	-26.5
Climate Zone 5	-4.9	91.0	205.6
Climate Zone 6	-97.7	43.5	206.1
Climate Zone 7	18.4	38.1	61.2
Climate Zone 8	0.1	0.1	0.1
Australia	-348.8	-42.2	312.2

	Low (P90)	More Likely (P50)	High (P10)
External wall no cavity			
Climate Zone 1	68.6	96.1	128.7
Climate Zone 2	-89.8	-80.8	-71.9
Climate Zone 3	-0.9	-0.8	-0.7
Climate Zone 4	16.9	25.9	36.5
Climate Zone 5	282.6	404.7	549.0
Climate Zone 6	0.0	0.0	0.0
Climate Zone 7	0.0	0.0	0.0
Climate Zone 8	0.0	0.0	0.0
Australia	277.6	445.2	641.6

Variability around key inputs was also assessed through sensitivity testing for both external wall drained and vented cavity and external wall no cavity scenarios. As presented in Figure 13 and Figure 14, key inputs have been identified which have caused significant variations in the overall NPV results. The largest contributor to variance across both scenarios is the relative risk of occupants experiencing asthma due to mould. This indicates that the value used for quantifying the risk of occupants experiencing asthma due to mould is driving 29.1% and 26.3% of variation in NPV results (for external wall cavities and external wall no cavity respectively).

Additionally, the relative risk of disease for both asthma and COPD contribute to a significant amount (over 40%) of the variation in results for both scenarios. These results indicate that further research into the indirect impacts of mould exposure, and more specifically the relative risk of disease for people exposed to dampness and mould would provide greater accuracy for future analysis.

Figure 13. Key contribution to variance inputs—External wall drained and vented cavity

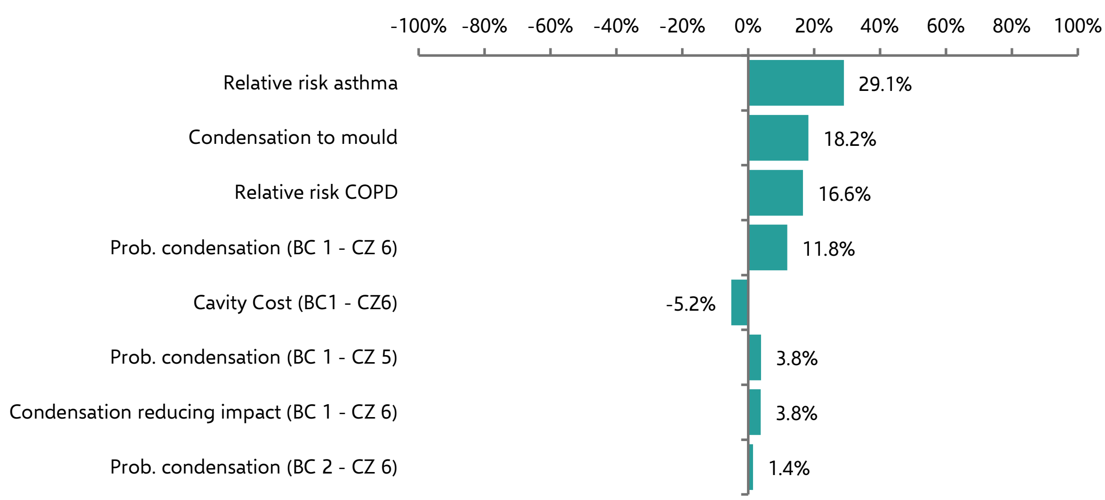
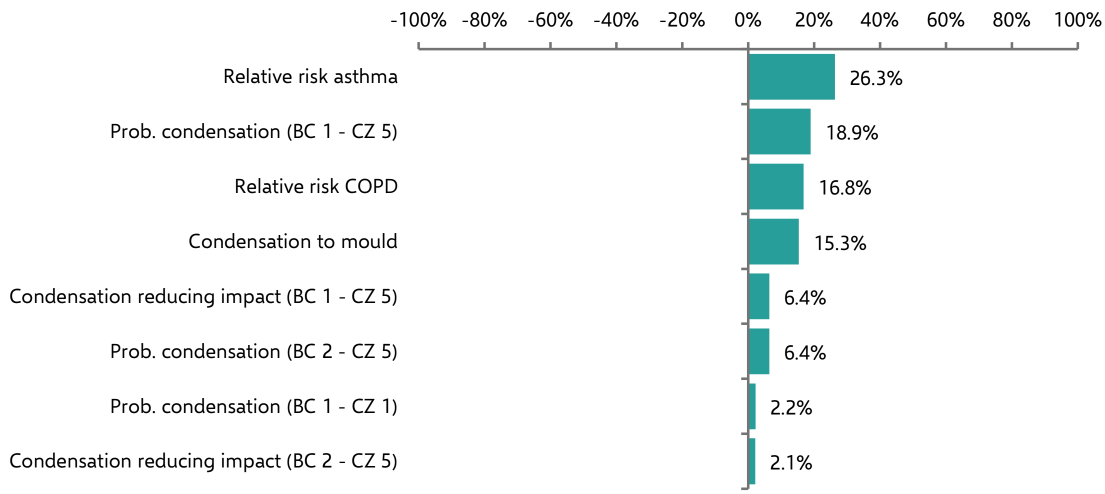


Figure 14. Key contribution to variance inputs—External wall no cavity



One key input that is critical when undertaking a CBA as part of a Regulatory Impact Statement (RIS) is the discount rate used in the CBA. The CBA results provided above (and in Appendix B) were generated using a discount rate of 7%. RIS typically also require alternative discount rates to be used to assess the sensitivity of results to the chosen discount rate. Table 16 reports the Australia-wide NPV and BCR results using the lower discount rates of 3% and 5%, and a higher discount rate of 10%. As can be seen, using the lower discount rate of 5% sees the external wall drained and vented cavity being viable, while when using the higher discount rate of 10% for the no cavity measures, results still show strong viability.

Table 16. Impact of differing discount rates on key CBA results—Australia wide impacts

Discount rate	Net Present Value ($ million)	Benefit-Cost Ratio
External wall drained and vented cavity		
3%	834	1.65
5%	279	1.23
7%	-42	0.96
10%	-296	0.70
External wall no cavity		
3%	1,063	5.44
5%	679	4.07
7%	445	3.16
10%	243	2.31

3.2 Breakeven analysis

For each of the Stage 3 measures under consideration, breakeven analysis has been undertaken around the CBA input parameters of the:

- share of dwellings impacted by condensation
- share of dwellings experiencing condensation that go on to experience mould
- impact of the Stage 3 measures in reducing the occurrence of condensation
- cost impost of the Stage 3 measures.

The breakeven analysis has been limited to those Climate Zones for which the external wall drained and vented cavity or no cavity measures deliver the largest net gains, with the breakeven analysis determining the parameter value required to deliver a NPV of zero for Building Classes within those Climate Zones. For impact type analyses, values above this (minimum required) value will see the measure delivering a beneficial outcome (NPV>0). For cost inputs, values below this (maximum required) value will see the measures delivering a beneficial outcome.

The outputs of the breakeven analysis are presented in Table 17. Also reported are the parameter values used in the CBA (and which underlie the results presented in Section 3.1 and Appendix B). As can be seen, the required breakeven figures are typically substantially lower than that used in the CBA (dwellings impacted by condensation and required reduction in condensation attributable to measures), or, in the case of cost of measure implementation, typically require costs several times the magnitude of that used in the CBA.

However, there are some exceptions to this general rule, namely Building Class 1 in Climate Zones 5 and 6 under the external wall drained and vented cavity scenario. As can be seen in the detailed results presented Appendix B, the Stage 3 external wall drained and vented cavities are estimated to come at a net cost, with NPVs of -$4m and -$62m respectively (while noting across all Building Classes within Climate Zones 5 and 6, the drained and vented cavity measure is estimated to bring a net benefit). Hence in the case of Building Class 1 dwellings in Climate Zones 5 and 6, the breakeven figures require condensation rates and the reduction in condensation to be higher than that assumed in the CBA, or the cost of implementing the measure to be lower than that assumed in the CBA.

Interpreting the results of the breakeven analysis involves understanding the critical threshold where the project's net present value (NPV) equals zero. As the NPV for the no cavity measure in Climate Zones 1 and 5 was positive, the breakeven points should be interpreted from the perspective that benefits can be reduced further until implementation of the no cavity measures becomes unviable or, likewise, costs can be increased further until implementation becomes unviable.[54]

For example, based on the no cavity scenario, in the case of Buildings Class 1 dwellings in Climate Zone 1, a condensation rate of 31.8% was assumed/used in the CBA. However, the breakeven point occurs at a much lower rate of 3.8%. That is, if 3.8% of Building Class 1 dwellings Climate Zone 1 experience condensation, then the no cavity measures will see a NPV of $0. The reduction from 31.8% to 3.8% represents the margin available before the threshold of viability is reached, indicating the degree to which condensation impacts can be decreased while maintaining Stage 3 measure feasibility.

[54] Note that breakeven analysis is conducted one variable at a time, and therefore any result shown in Table 17 assumes that all other variables are unchanged.

Additionally, under the same no cavity scenario, and all other things held equal, the cost of implementing measures for Building Class 1 in Climate Zone 1 can be increased from 0.3% to 2.2% before the economic viability threshold is reached.

The CBA assumed that 78.1% of dwellings experiencing condensation went onto experience mould (and hence occasion indirect health related costs). This figure was applied equally across all Climate Zones and Building Classes. For those Climate Zones experiencing a net gain, the breakeven analysis suggests that the required (minimum) proportion of dwellings experiencing condensation that need to then go onto experience mould is:

- external wall drained and vented cavity—30%–70% (depending on Climate Zone)
- external wall no cavity—2%–12% (depending on Climate Zone).

The required proportion of dwellings experiencing condensation that then go on to experience mould for breakeven (NPV=0) is substantially lower than the 78.1% assumed in the CBA.

Table 17. Breakeven analysis

Input parameter	Building Class				
	1	2	3	4	9c
External wall drained and vented cavity					
Dwellings impacted by condensation					
Zone 5 (used in CBA)	27.1%	25.7%	30.8%	30.4%	27.5%
Zone 5 (Breakeven)	27.4%	14.6%	13.4%	26.7%	17.0%
Zone 6 (used in CBA)	30.6%	29.1%	31.0%	30.7%	30.4%
Zone 6 (Breakeven)	33.3%	13.7%	8.4%	16.2%	10.5%
Cost of measure implementation					
Zone 5 (used in CBA)	1.0%	0.4%	1.0%	0.4%	0.6%
Zone 5 (Breakeven)	1.0%	0.9%	4.9%	0.5%	1.3%
Zone 6 (used in CBA)	0.9%	0.3%	0.8%	0.3%	0.5%
Zone 6 (Breakeven)	0.8%	1.0%	8.6%	0.8%	2.8%
Reduction in condensation occurrence					
Zone 5 (used in CBA)	33.1%	49.2%	56.4%	26.6%	56.4%
Zone 5 (Breakeven)	33.7%	18.9%	12.1%	21.5%	24.7%
Zone 6 (used in CBA)	18.7%	44.9%	100.0%	44.2%	100.0%
Zone 6 (Breakeven)	21.7%	12.6%	9.0%	15.7%	16.4%
External wall no cavity					
Dwellings impacted by condensation					
Zone 1 (used in CBA)	31.8%	36.5%	32.3%	29.6%	32.7%
Zone 1 (Breakeven)	3.8%	15.4%	22.3%	20.6%	22.9%
Zone 5 (used in CBA)	27.1%	25.7%	30.8%	30.4%	27.5%
Zone 5 (Breakeven)	4.7%	4.5%	5.3%	9.5%	6.4%

Input parameter	Building Class				
Cost of measure implementation					
Zone 1 (used in CBA)	0.3%	0.1%	0.2%	0.1%	0.1%
Zone 1 (Breakeven)	2.2%	0.2%	0.4%	0.1%	0.2%
Zone 5 (used in CBA)	0.3%	0.1%	0.3%	0.1%	0.1%
Zone 5 (Breakeven)	1.0%	0.9%	4.9%	0.5%	1.3%
Reduction in condensation occurrence					
Zone 1 (used in CBA)	47.5%	6.1%	6.1%	7.4%	6.1%
Zone 1 (Breakeven)	6.2%	2.8%	4.2%	5.3%	4.4%
Zone 5 (used in CBA)	33.1%	49.2%	56.4%	26.6%	56.4%
Zone 5 (Breakeven)	8.8%	4.9%	3.1%	5.2%	6.3%

Appendices

Supporting data A

Climate Zone mapping example

The figures below provide a mapping example for the conversion of ACBC Clime Zone boundaries to the LGA level data used for the analysis. This example is for the LGA of Esperance, in Western Australia.

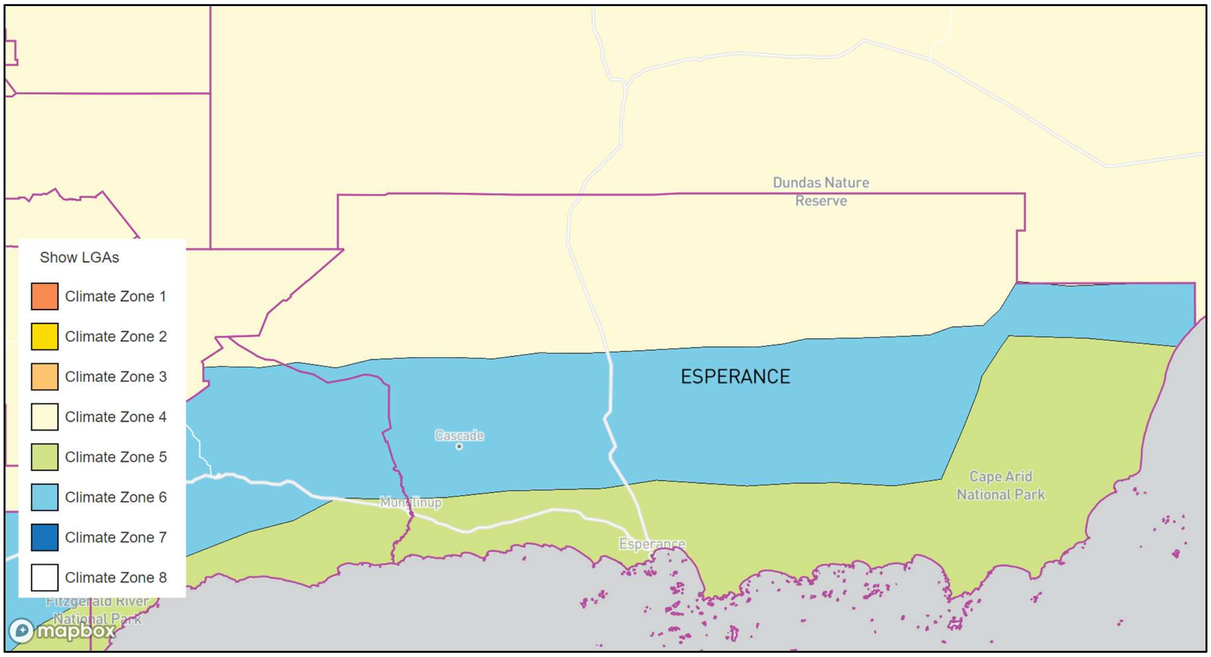


Figure 15. ABCB Climate Zone mapping for Esperance LGA

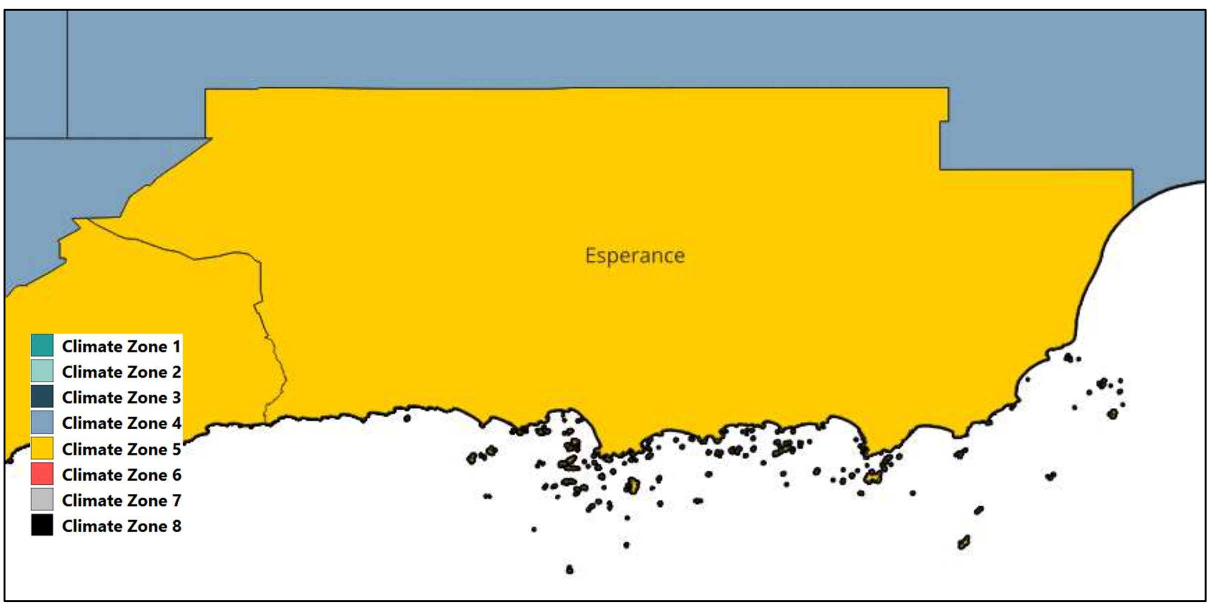
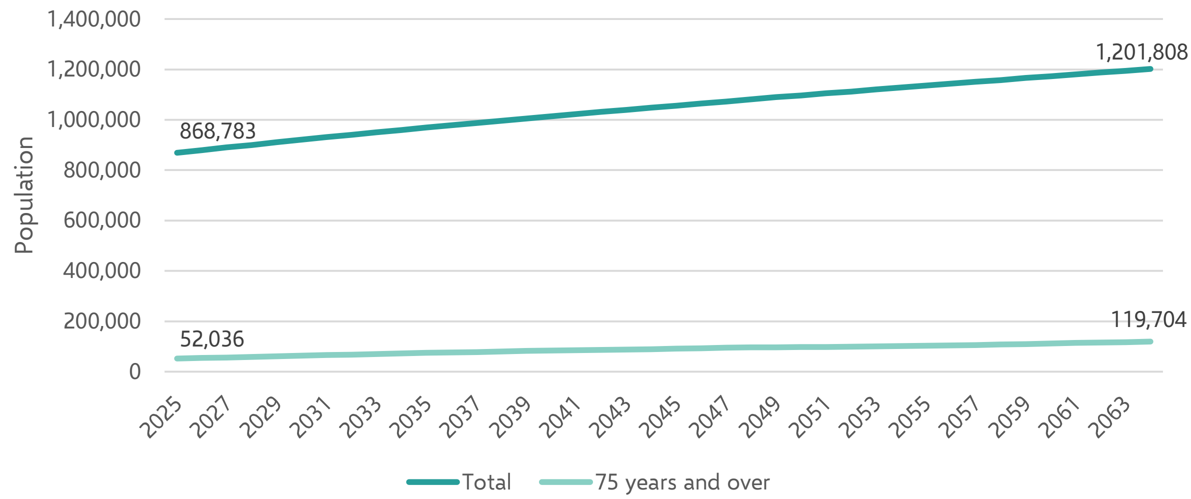


Figure 16. NCE mapping of Esperance LGA for Climate Zone analysis

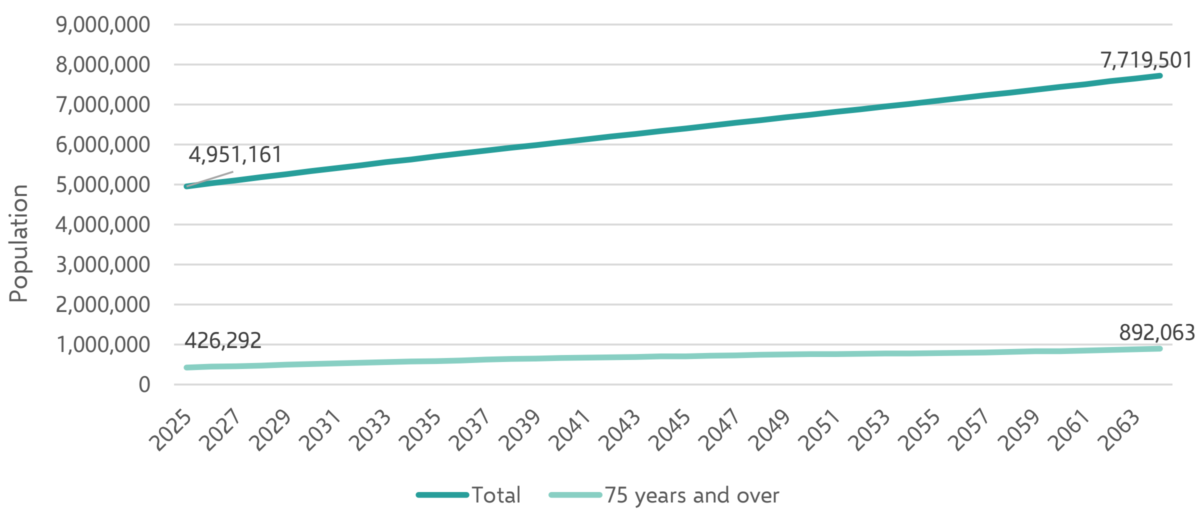
Population projections by Climate Zone

The charts below provide a breakdown of population projections from 2025 out to 2064 by Climate Zones, for both total population and the population aged 75 years and older.

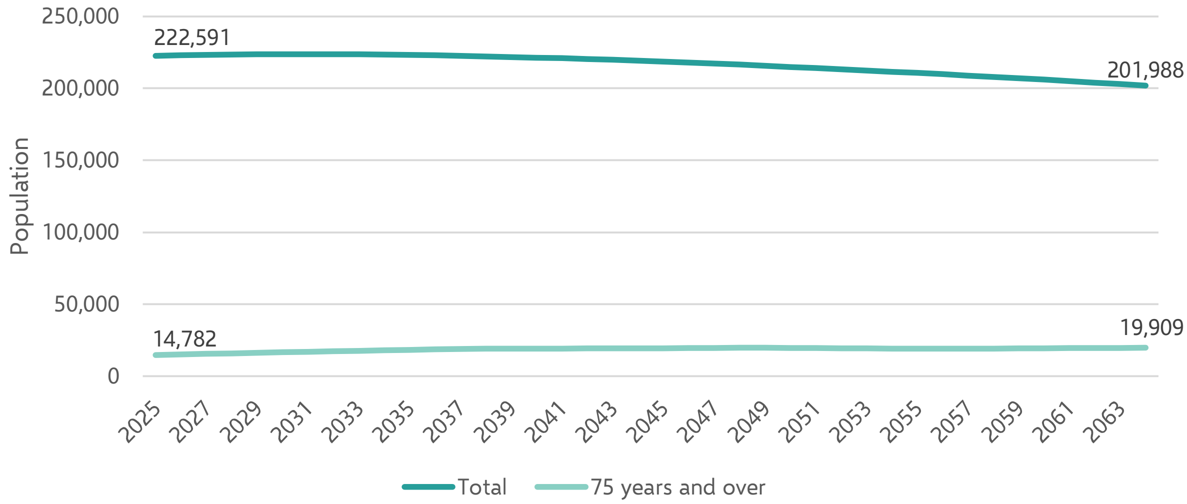
Climate Zone 1



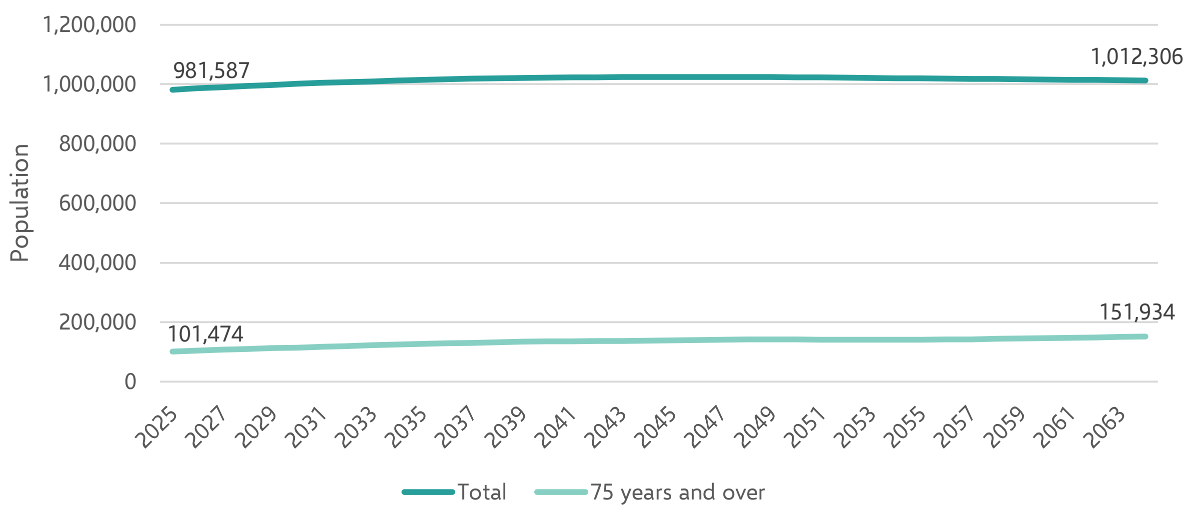
Climate Zone 2



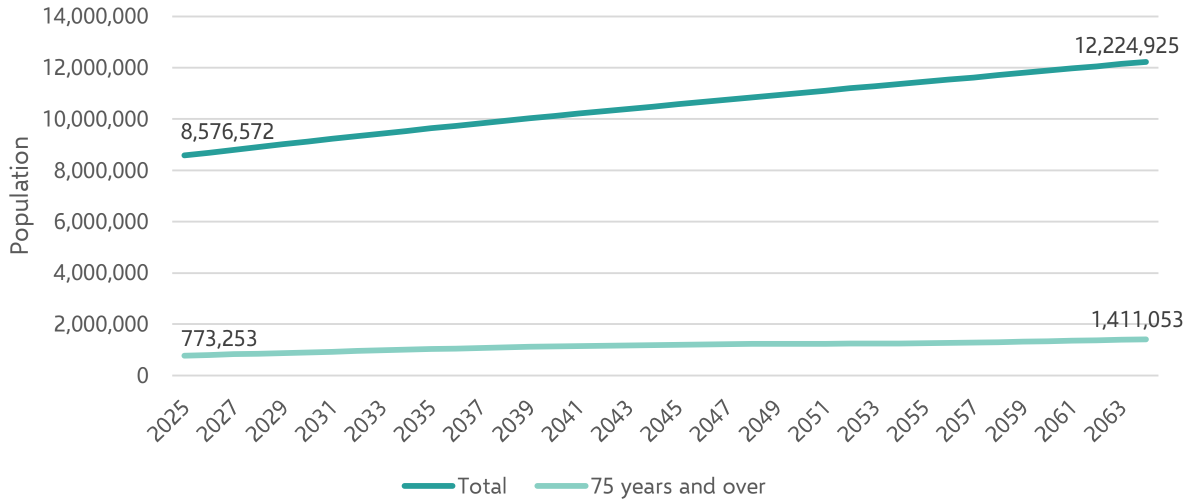
Climate Zone 3



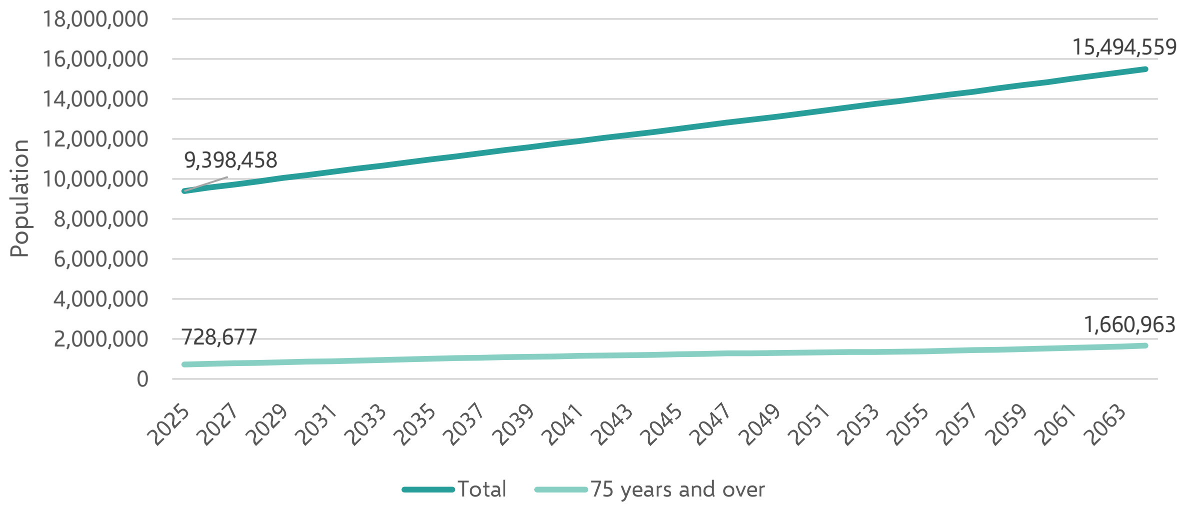
Climate Zone 4



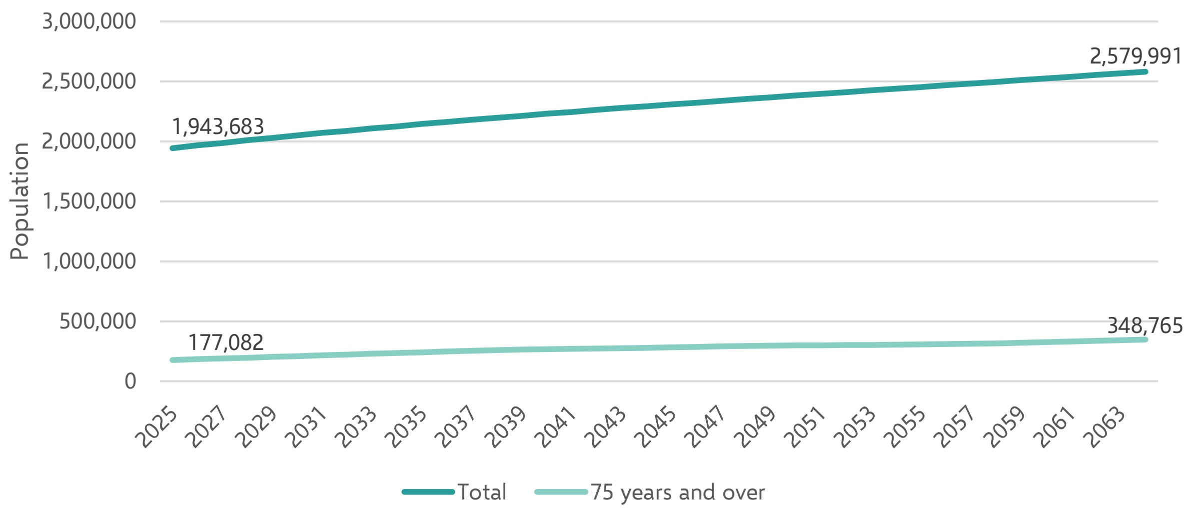
Climate Zone 5



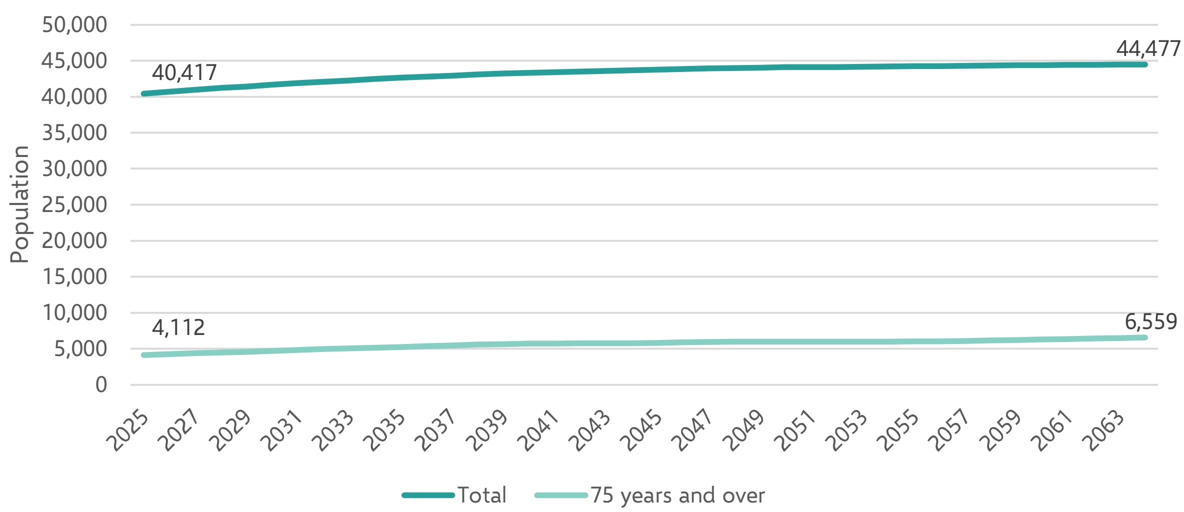
Climate Zone 6



Climate Zone 7



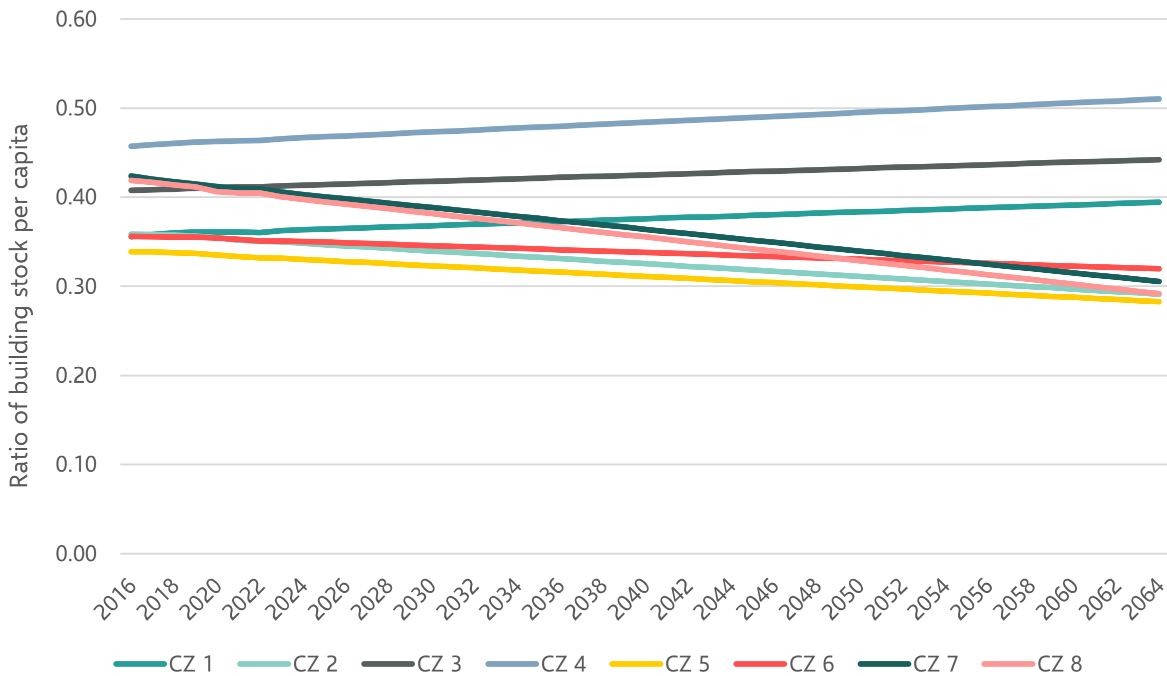
Climate Zone 8



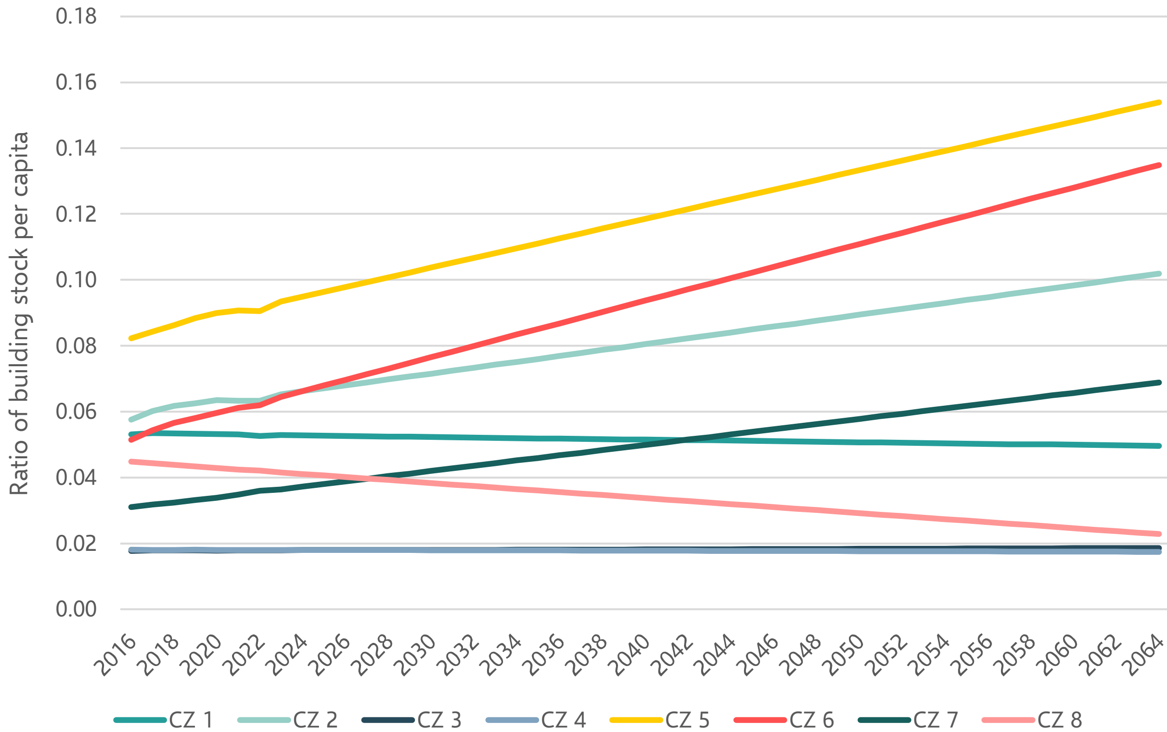
Building stock per capita trends by Climate Zone

The charts below provide a breakdown of trended ratios used for Building Class 1 and 2, across all Climate Zones.

Building Class 1



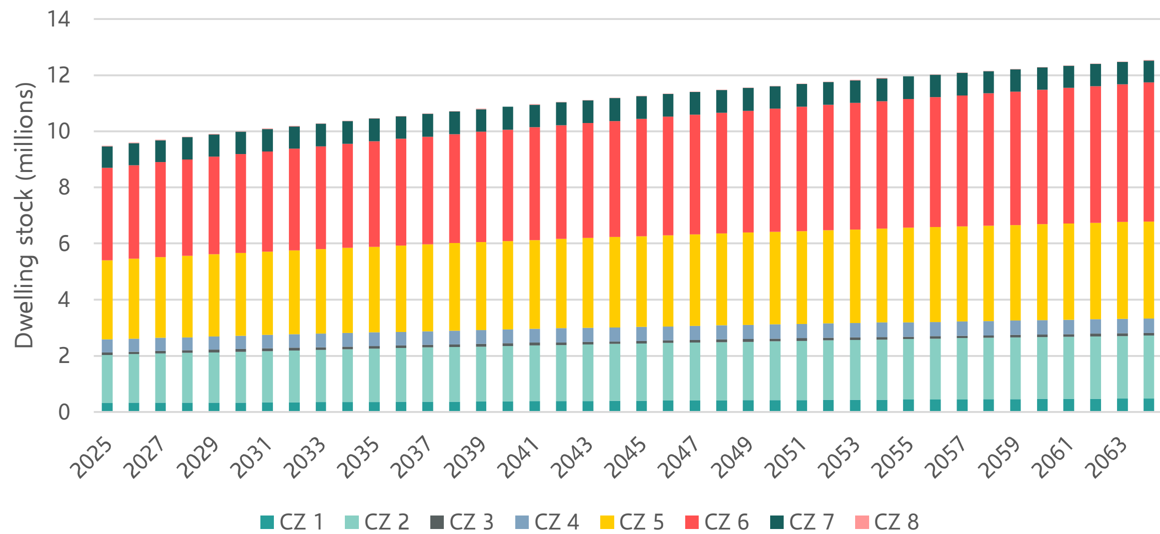
Building Class 2



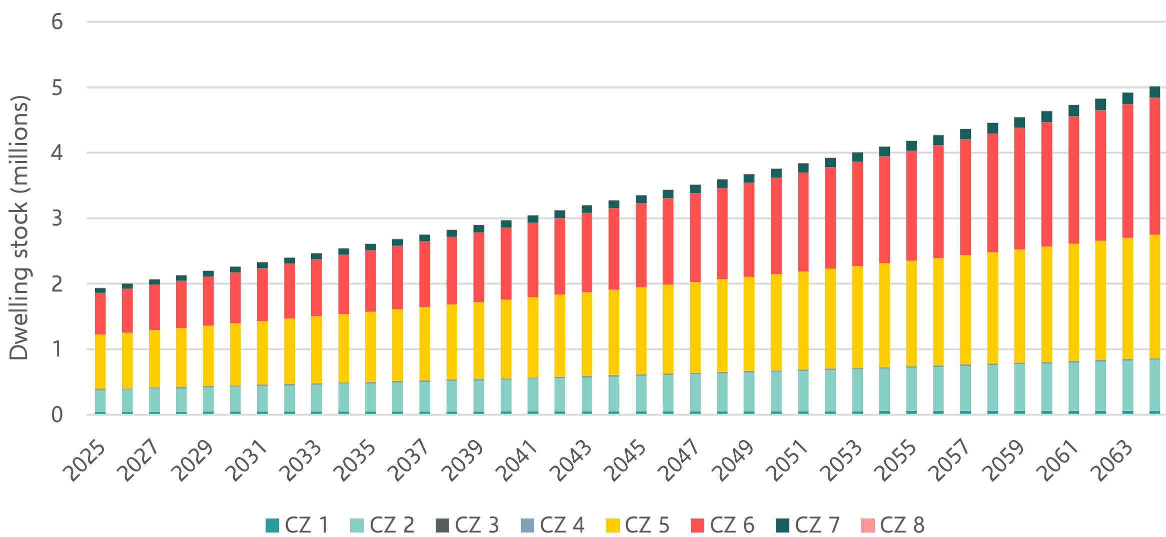
Estimated dwelling stock by Building Class and Climate Zone

The charts below provide a breakdown of estimated dwelling stocks from 2025 out to 2064 by Building Class, across all Climate Zones.

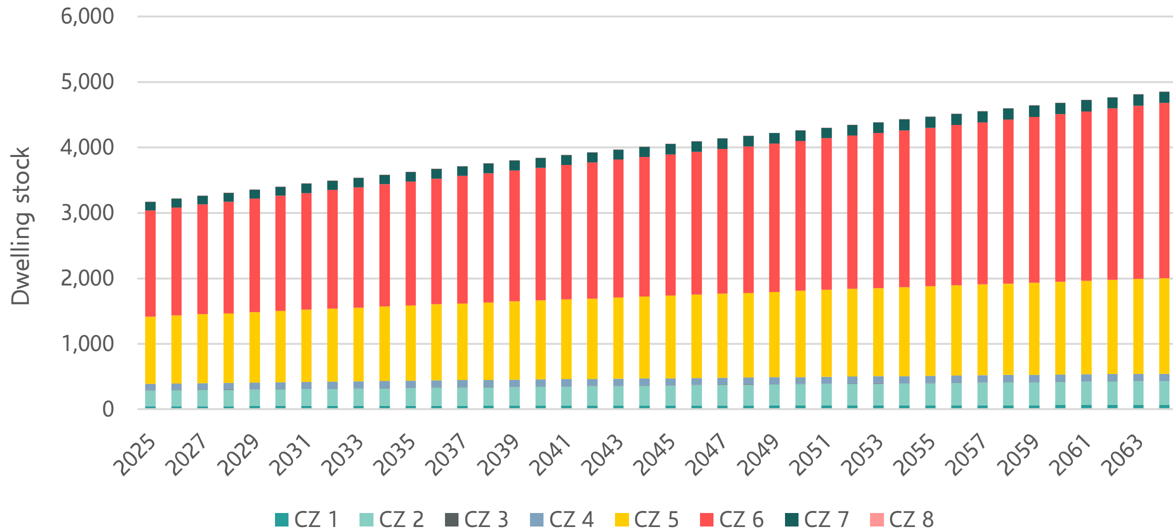
Building Class 1



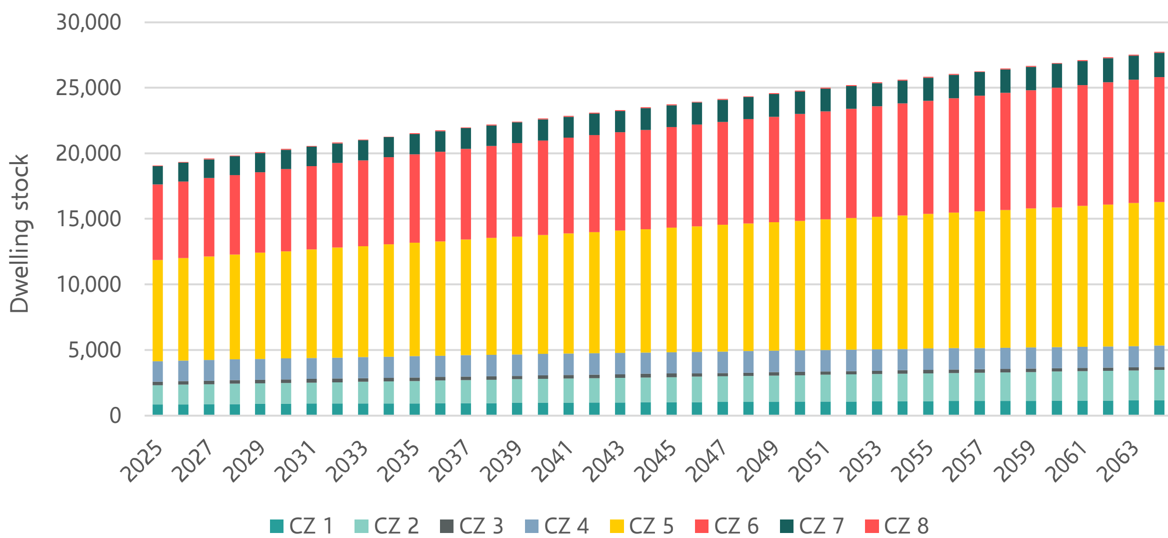
Building Class 2



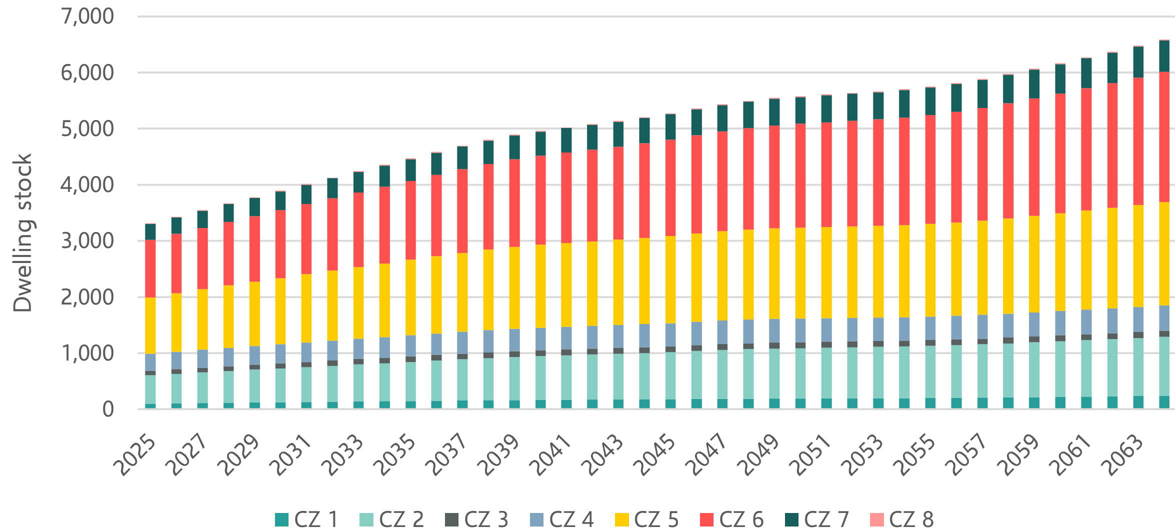
Building Class 3



Building Class 4



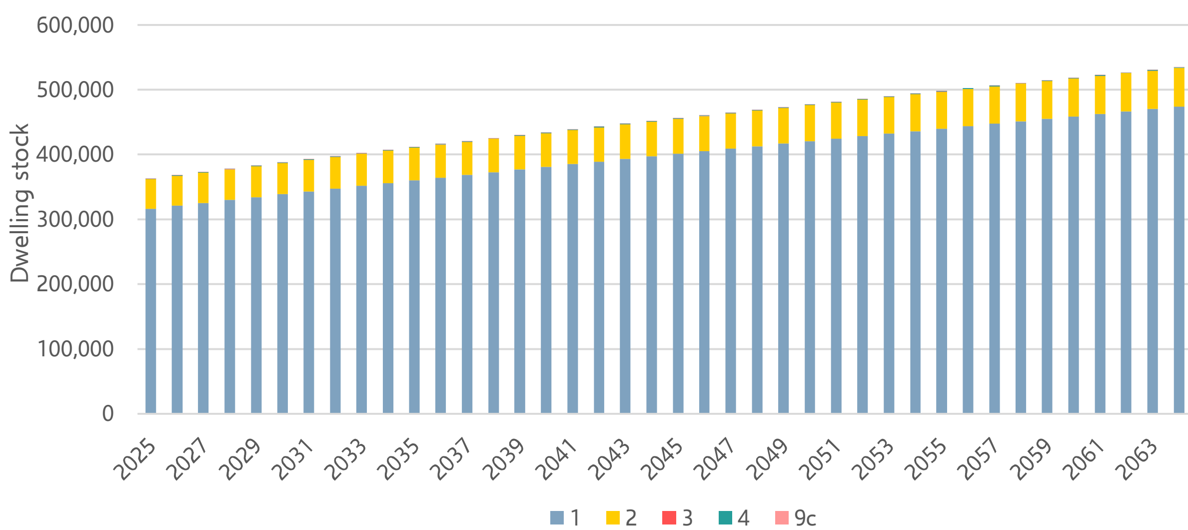
Building Class 9c



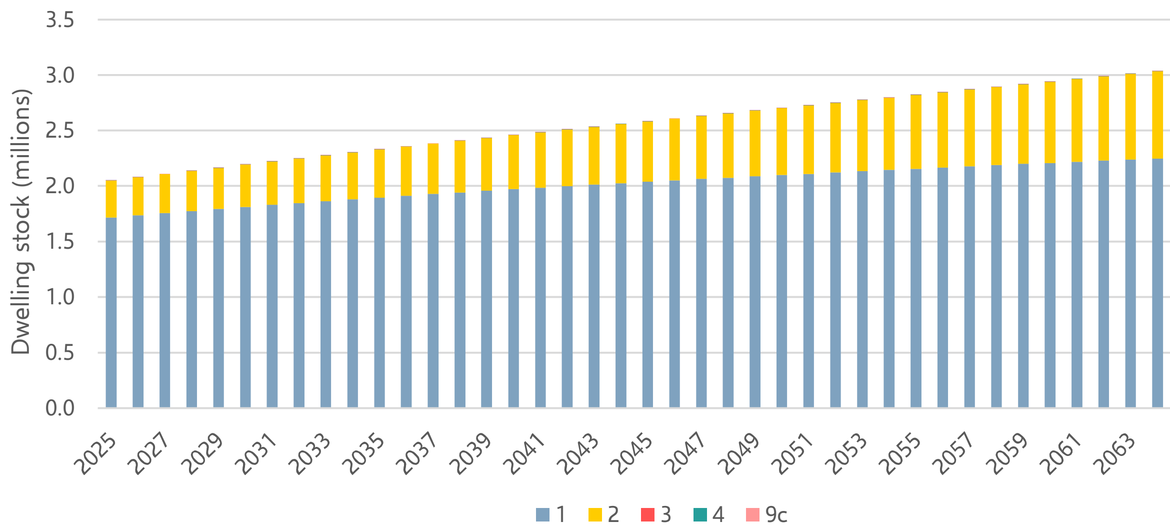
Estimated dwelling stock by Climate Zone and Building Class

The charts below provide a breakdown of estimated dwelling stocks from 2025 out to 2064 by Climate Zones, across all Building Classes.

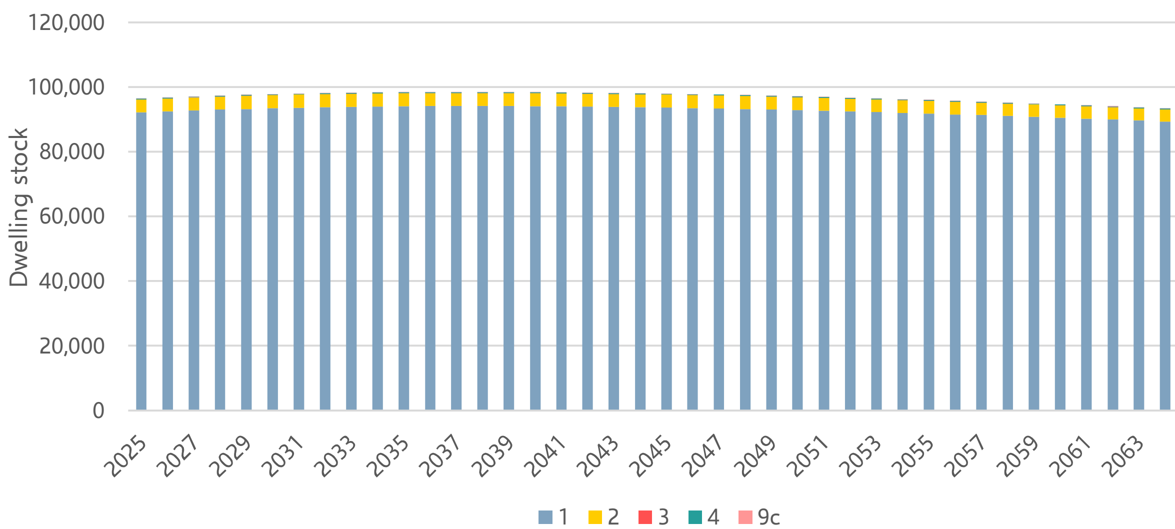
Climate Zone 1



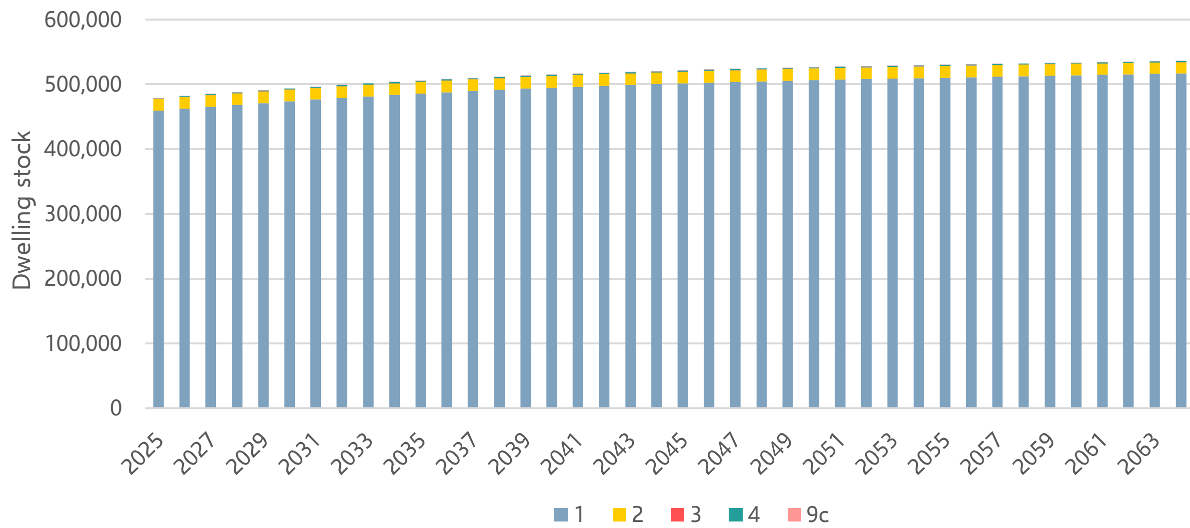
Climate Zone 2



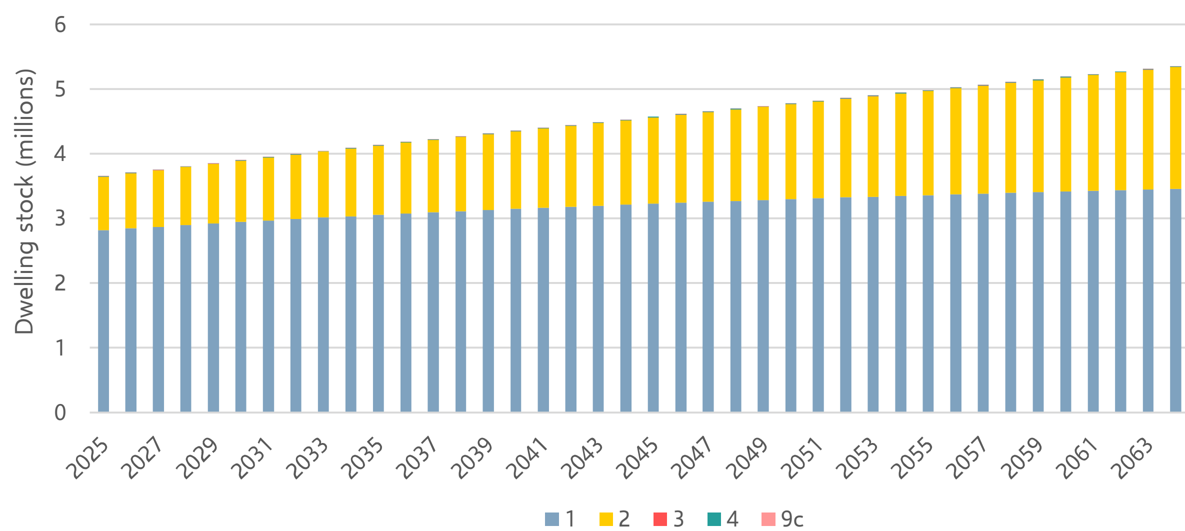
Climate Zone 3



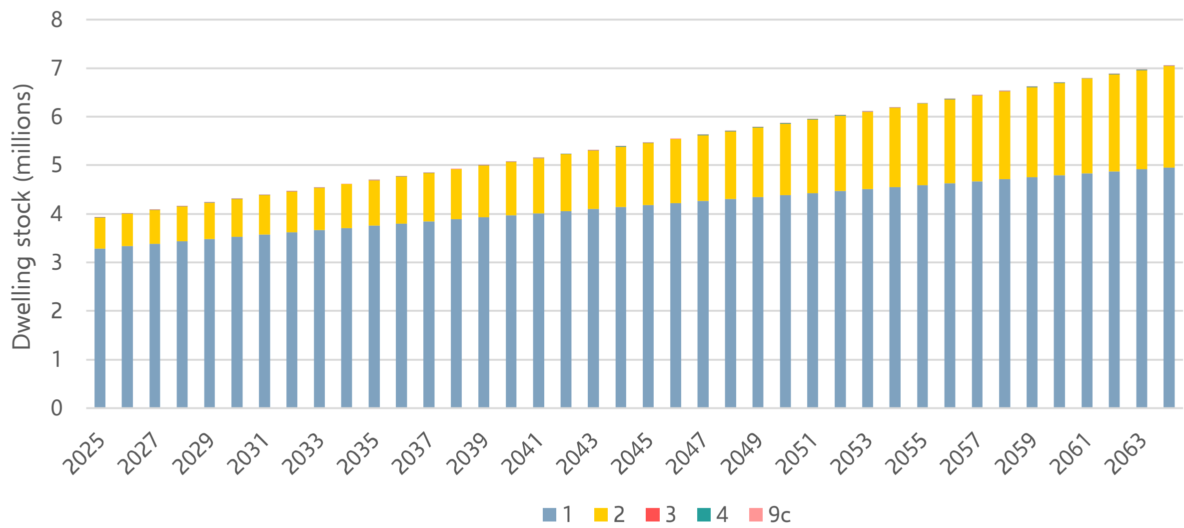
Climate Zone 4



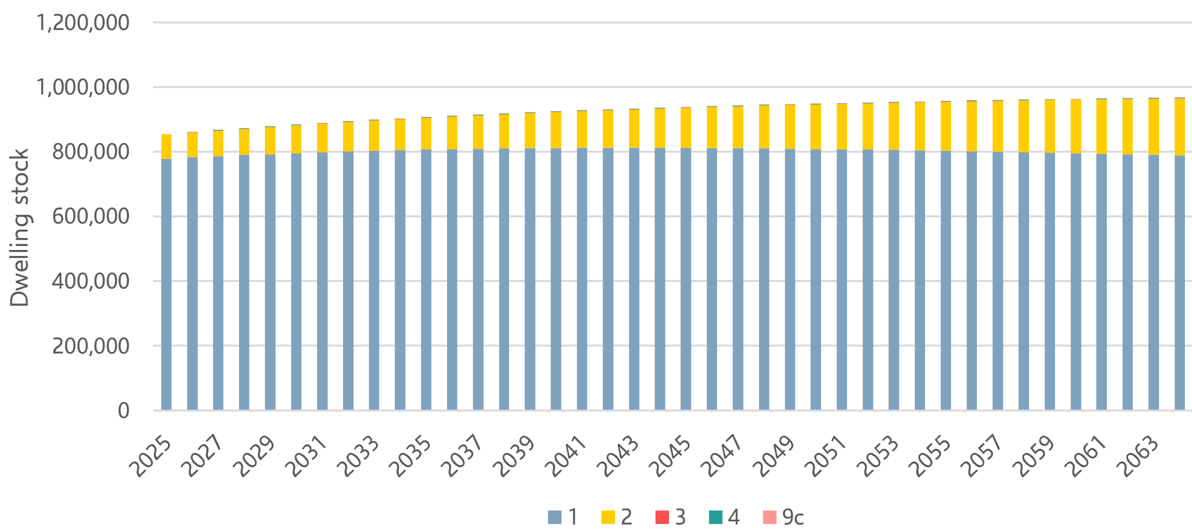
Climate Zone 5



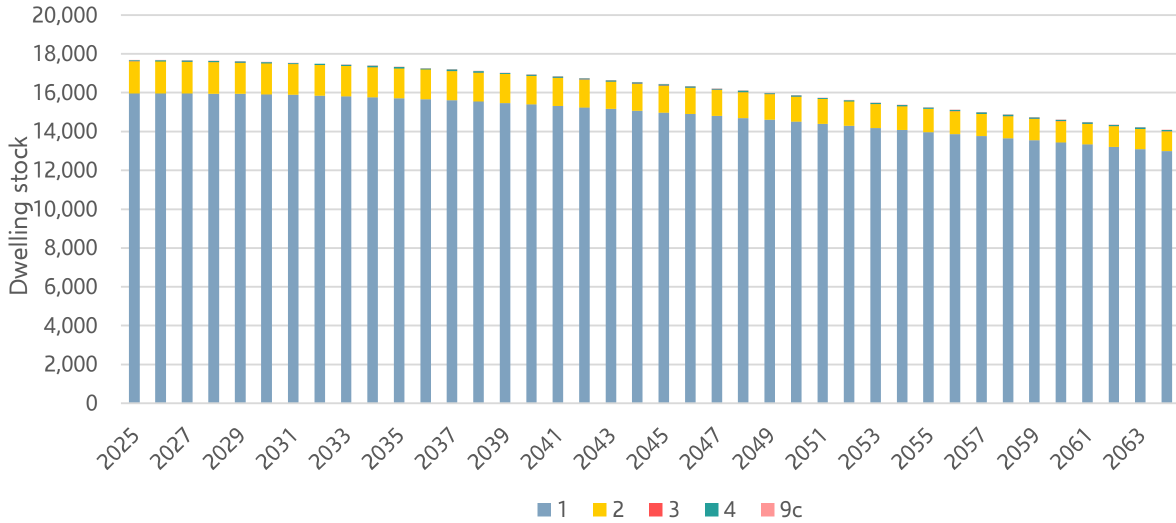
Climate Zone 6



Climate Zone 7



Climate Zone 8



Appendices

Detailed results B

Benefit and cost results by Climate Zone and Building Class (external wall drained and vented cavity) ($ millions)

The tables below provide a detailed breakdown of benefits and costs across Climate Zones and Building Classes used to calculate the NPV.

	Building Class											
	1		2		3		4		9c		Total	
	Benefits	Costs	Benefits	Costs	Benefits	Costs	Benefits	Costs	Benefits	Costs	Benefits	Costs
Climate Zone 1	82.5	38.3	0.3	0.4	0.0	0.0	0.0	0.0	0.1	0.2	82.9	39.0
Climate Zone 2	-1.0	214.6	0.0	9.5	0.0	0.0	0.0	0.1	0.0	1.3	-1.0	225.6
Climate Zone 3	0.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1
Climate Zone 4	0.3	30.8	0.0	0.1	0.0	0.0	0.0	0.0	0.9	0.5	1.3	31.4
Climate Zone 5	221.9	226.3	142.7	54.5	0.7	0.2	0.3	0.3	11.8	5.2	377.4	286.4
Climate Zone 6	383.9	445.7	123.2	34.5	1.8	0.2	0.5	0.2	17.5	2.9	526.9	483.4
Climate Zone 7	51.7	34.8	20.1	4.4	0.1	0.0	0.1	0.0	6.4	1.1	78.5	40.4
Climate Zone 8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0
Australia	739.4	992.6	286.3	103.6	2.6	0.3	1.0	0.6	36.8	11.2	1,066.1	1,108.4

Benefit and cost results by Climate Zone and Building Class (external wall no cavity) ($ millions)

	Building Class											
	1		2		3		4		9c		Total	
	Benefits	Costs	Benefits	Costs	Benefits	Costs	Benefits	Costs	Benefits	Costs	Benefits	Costs
Climate Zone 1	110.1	14.3	0.4	0.2	0.0	0.0	0.0	0.0	0.1	0.1	110.7	14.6
Climate Zone 2	-0.3	76.5	0.0	3.4	0.0	0.0	0.0	0.0	0.0	0.5	-0.4	80.4
Climate Zone 3	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8
Climate Zone 4	33.8	10.7	0.3	0.0	0.0	0.0	0.0	0.0	2.8	0.2	36.9	10.9
Climate Zone 5	296.5	78.5	190.3	18.9	0.9	0.1	0.5	0.1	15.8	1.8	504.0	99.2
Climate Zone 6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Climate Zone 7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Climate Zone 8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Australia	440.0	180.8	191.0	22.5	1.0	0.1	0.5	0.1	18.7	2.5	651.2	206.0

Direct and indirect benefit results by Climate Zone and Building Class (external wall drained and vented cavity) ($ millions)

The tables below provide a detailed breakdown of direct and indirect benefits across Climate Zones and Building Classes.

	Building Class											
	1		2		3		4		9c		Total	
	Direct	Indirect	Direct	Indirect	Direct	Indirect	Direct	Indirect	Direct	Indirect	Direct	Indirect
Climate Zone 1	8.6	73.9	0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.1	8.7	74.3
Climate Zone 2	-1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.0	0.0
Climate Zone 3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Climate Zone 4	-0.1	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.7	0.1	1.2
Climate Zone 5	29.8	192.1	29.7	113.0	0.0	0.7	0.1	0.3	2.2	9.6	61.8	315.6
Climate Zone 6	42.1	341.8	23.8	99.4	0.1	1.7	0.1	0.4	2.9	14.6	68.9	458.0
Climate Zone 7	5.9	45.8	3.6	16.5	0.0	0.1	0.0	0.1	1.0	5.4	10.6	67.9
Climate Zone 8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1
Australia	85.3	654.1	57.1	229.2	0.1	2.5	0.3	0.7	6.3	30.5	149.1	917.1

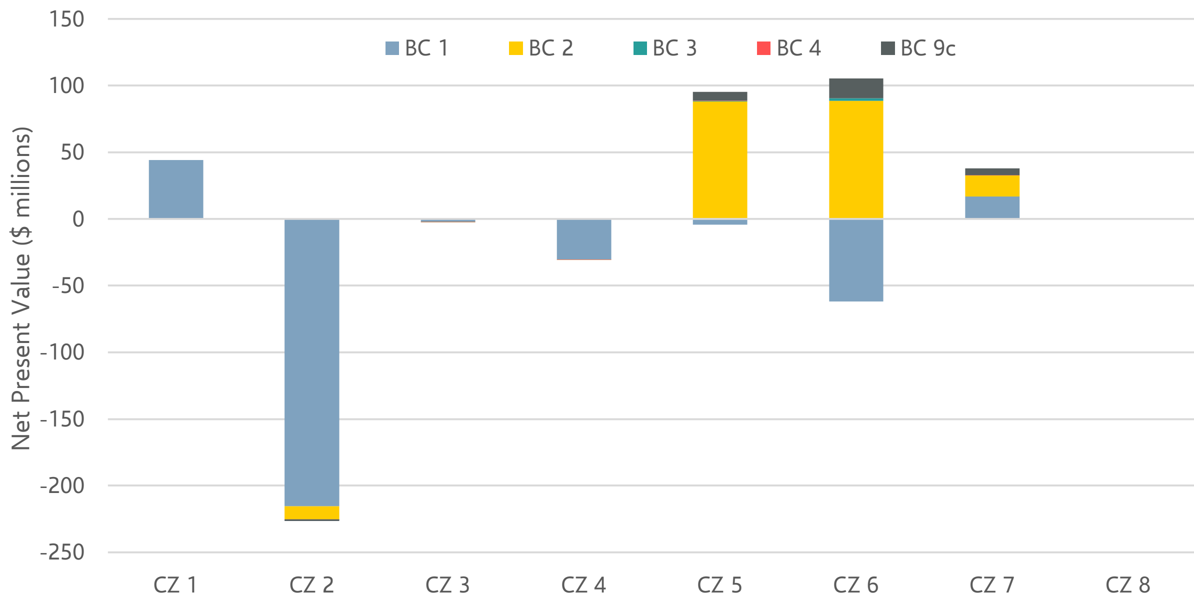
Benefit and cost results by Climate Zone and Building Class (external wall no cavity) ($ millions)

	Building Class											
	1		2		3		4		9c		Total	
	Benefits	Costs	Benefits	Costs	Benefits	Costs	Benefits	Costs	Benefits	Costs	Benefits	Costs
Climate Zone 1	11.6	98.5	0.1	0.4	0.0	0.0	0.0	0.0	0.0	0.1	11.7	99.0
Climate Zone 2	-0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.4	0.0
Climate Zone 3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Climate Zone 4	5.1	28.7	0.1	0.2	0.0	0.0	0.0	0.0	0.5	2.2	5.7	31.2
Climate Zone 5	40.4	256.1	39.7	150.6	0.1	0.9	0.1	0.3	2.9	12.8	83.1	420.8
Climate Zone 6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Climate Zone 7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Climate Zone 8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Australia	56.7	383.3	39.8	151.2	0.1	0.9	0.1	0.4	3.5	15.2	100.2	551.0

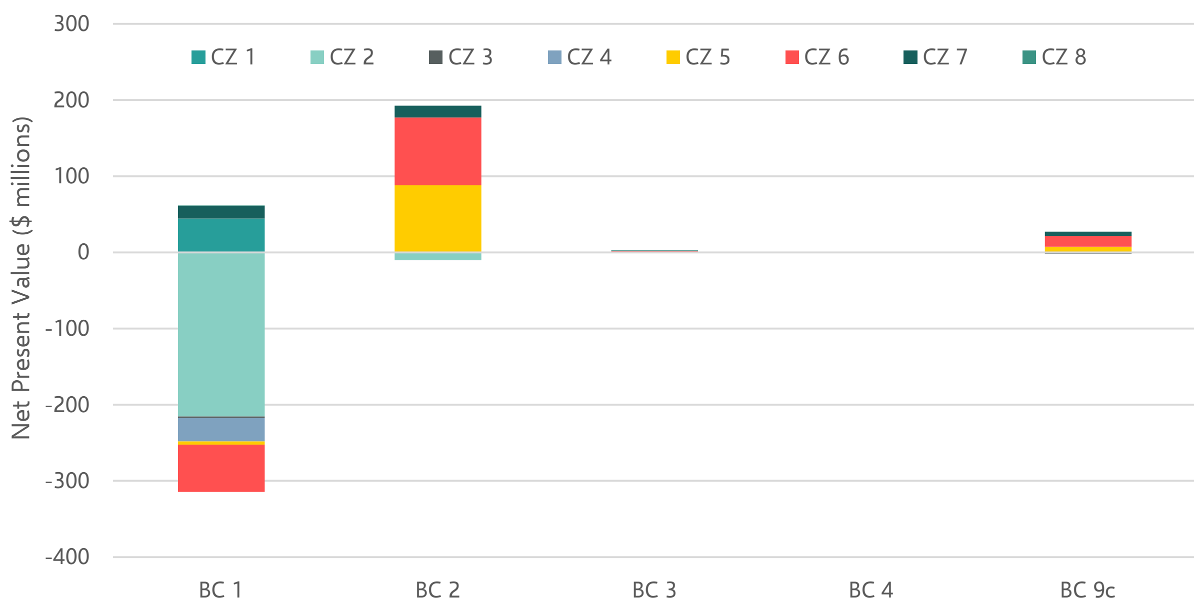
NPV results for external wall drained and vented cavity

The figures below provide a summary breakdown of NPV results for the external wall drained and vented cavity scenario across Climate Zones and Building Classes. Note that errors bars provided within figures further below represent sensitivity testing around results at the P90 and P10 level.

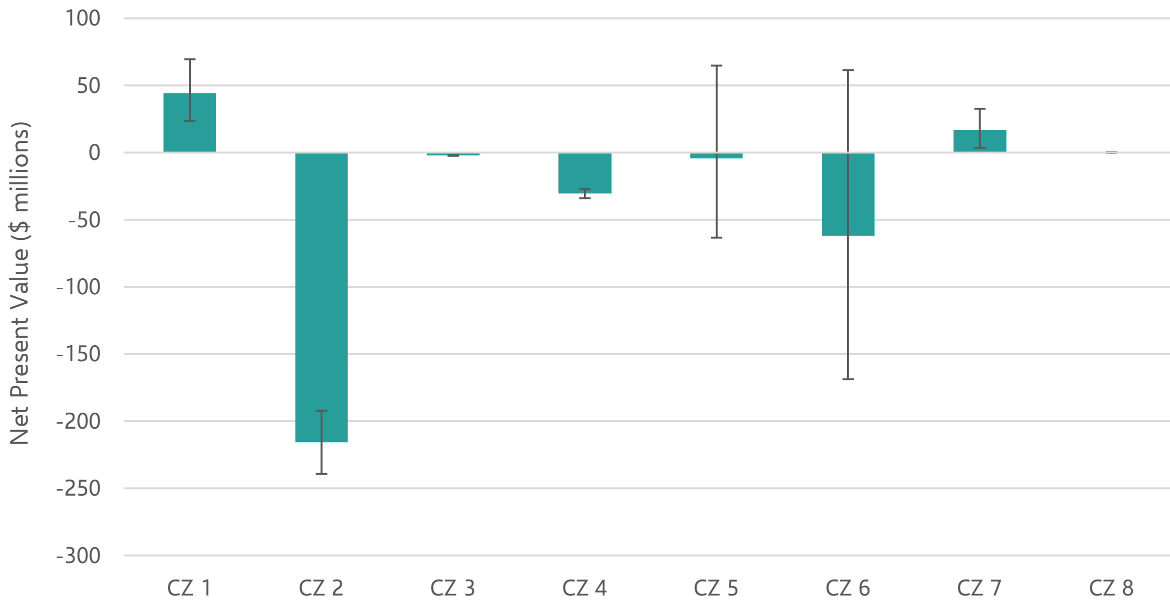
NPV summary by Climate Zone and Building Class



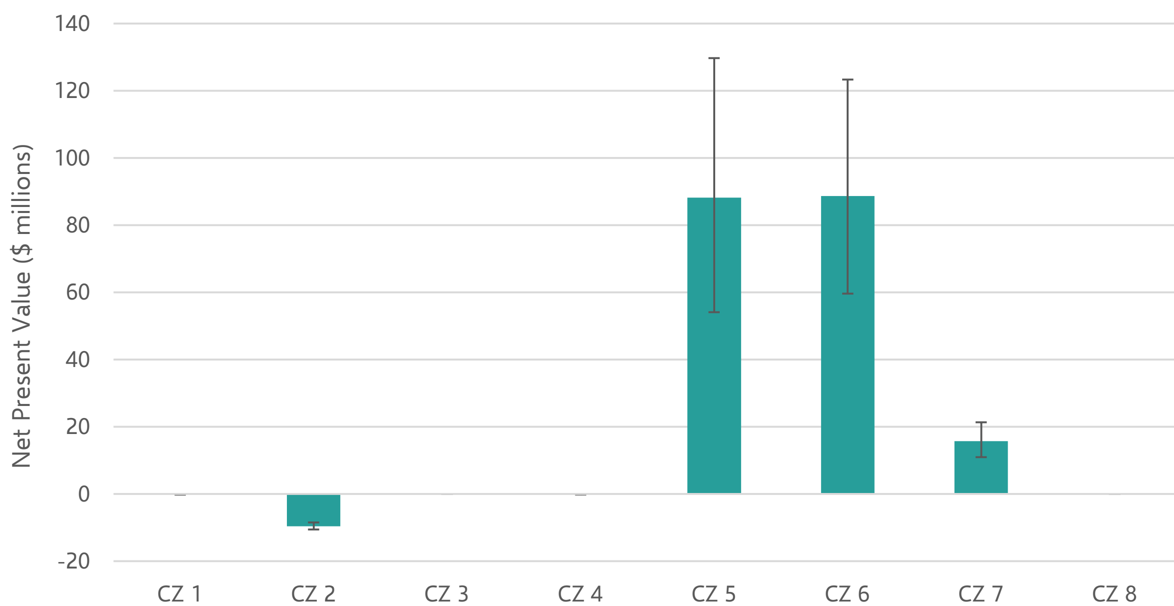
NPV summary by Building Class and Climate Zone



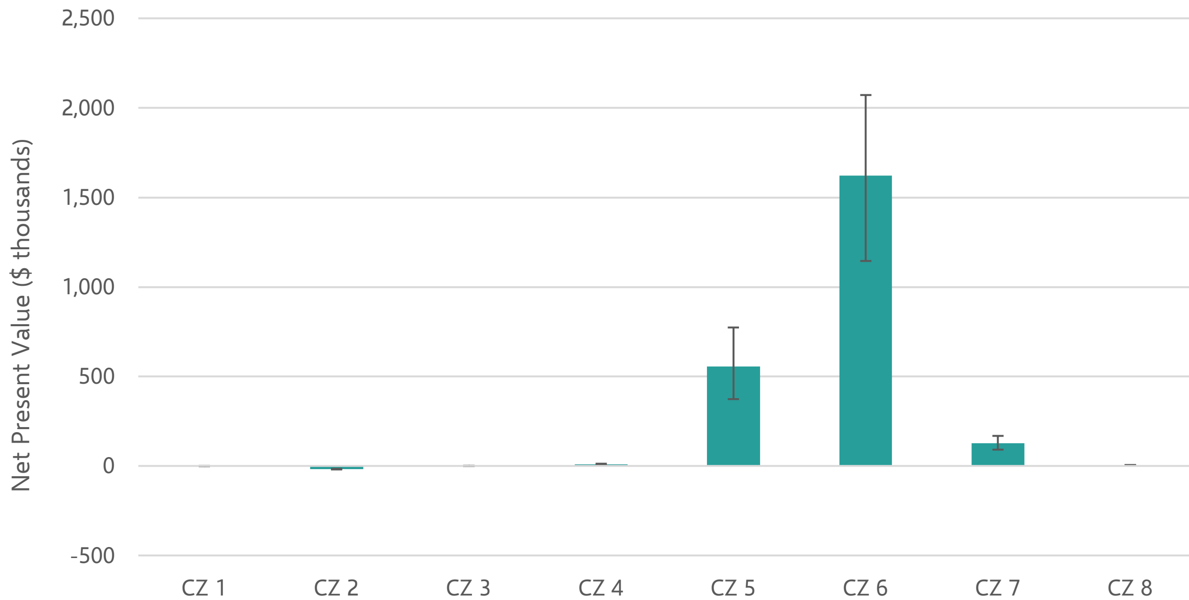
NPV Building Class 1



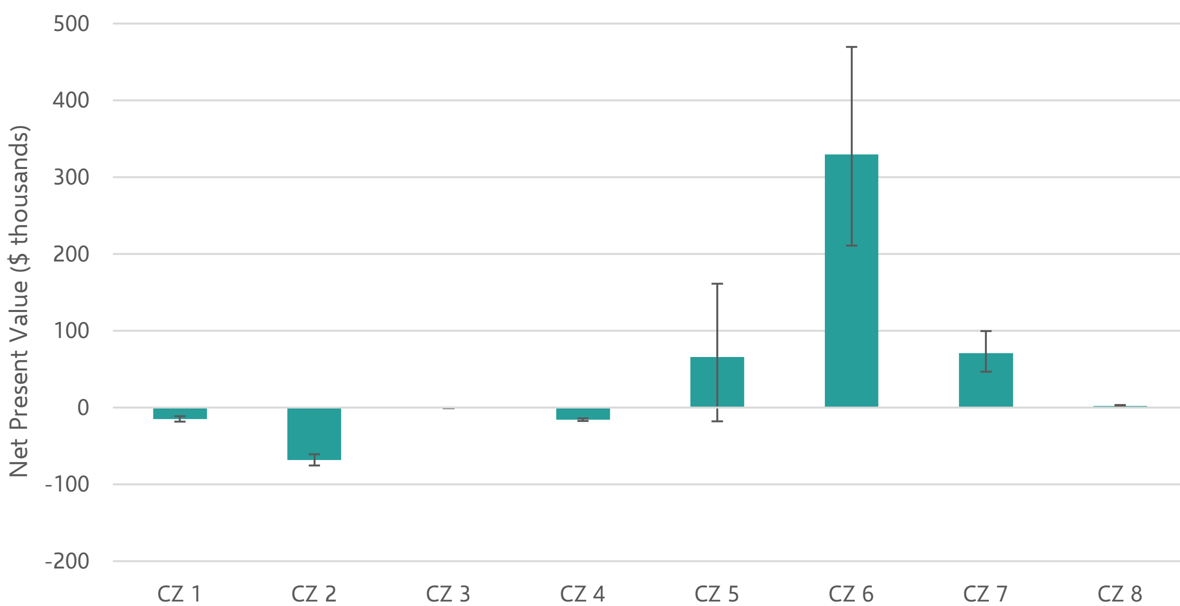
NPV Building Class 2



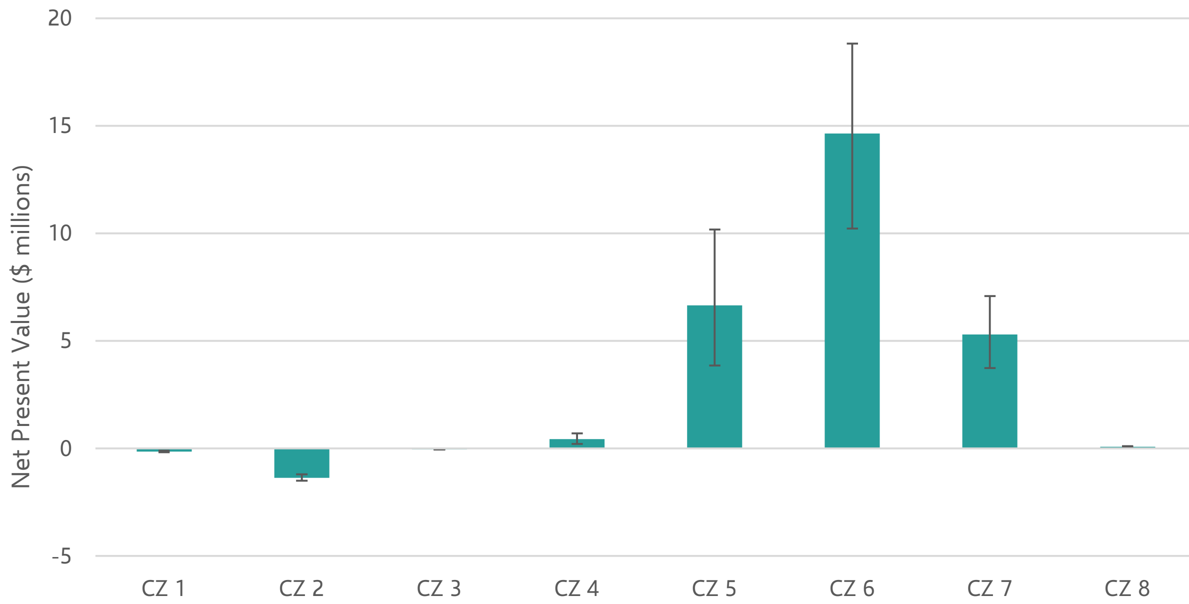
NPV Building Class 3



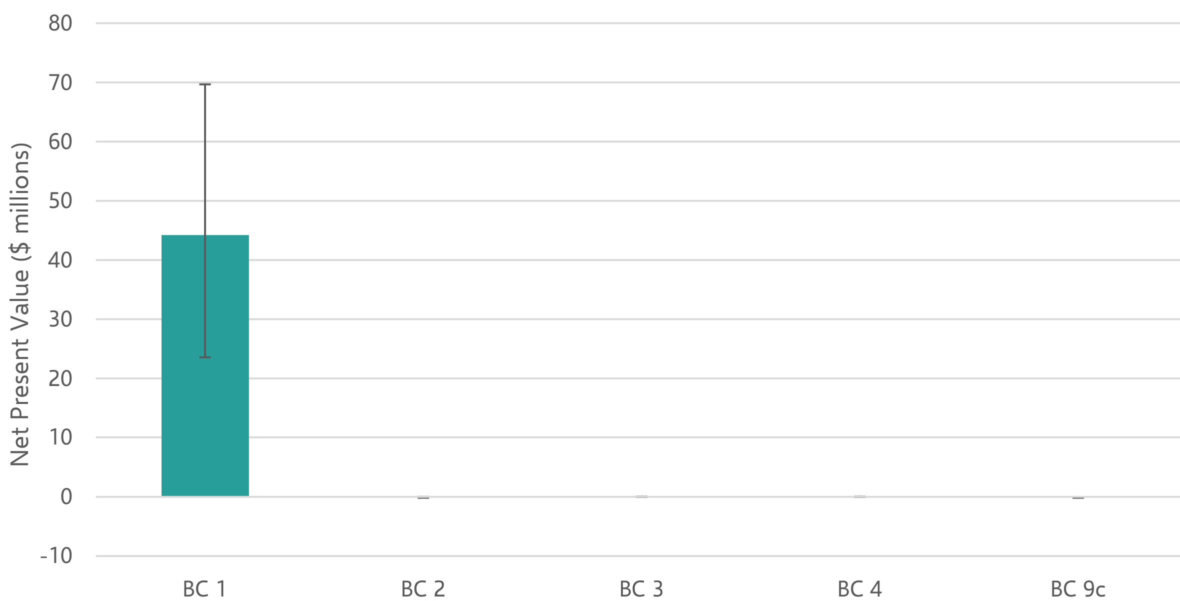
NPV Building Class 4



NPV Building Class 9c



NPV Climate Zone 1



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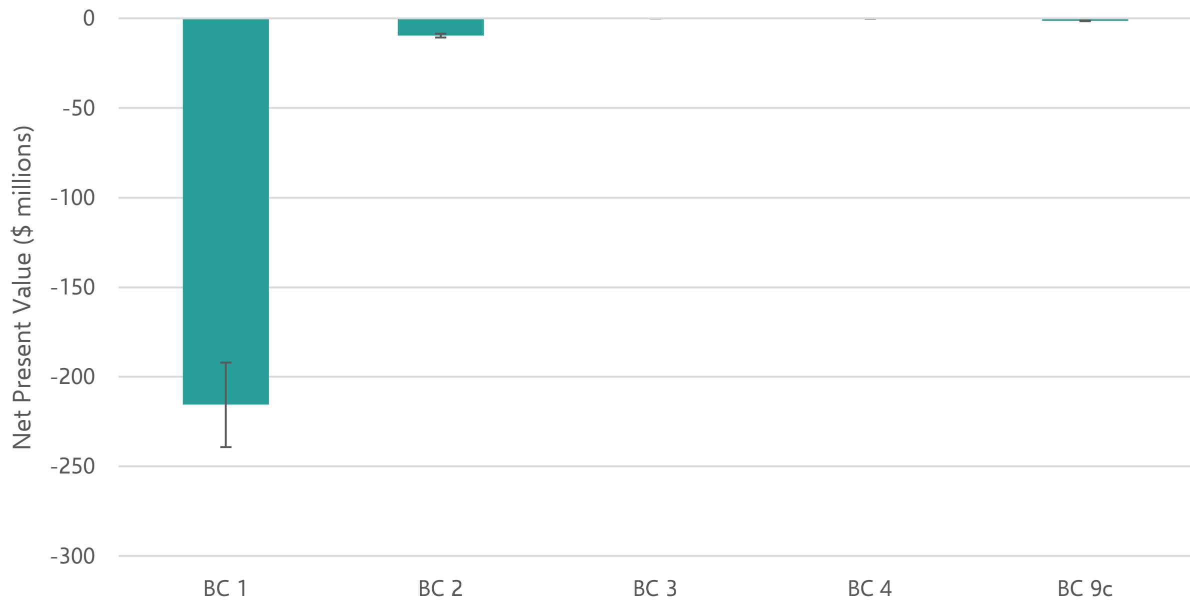

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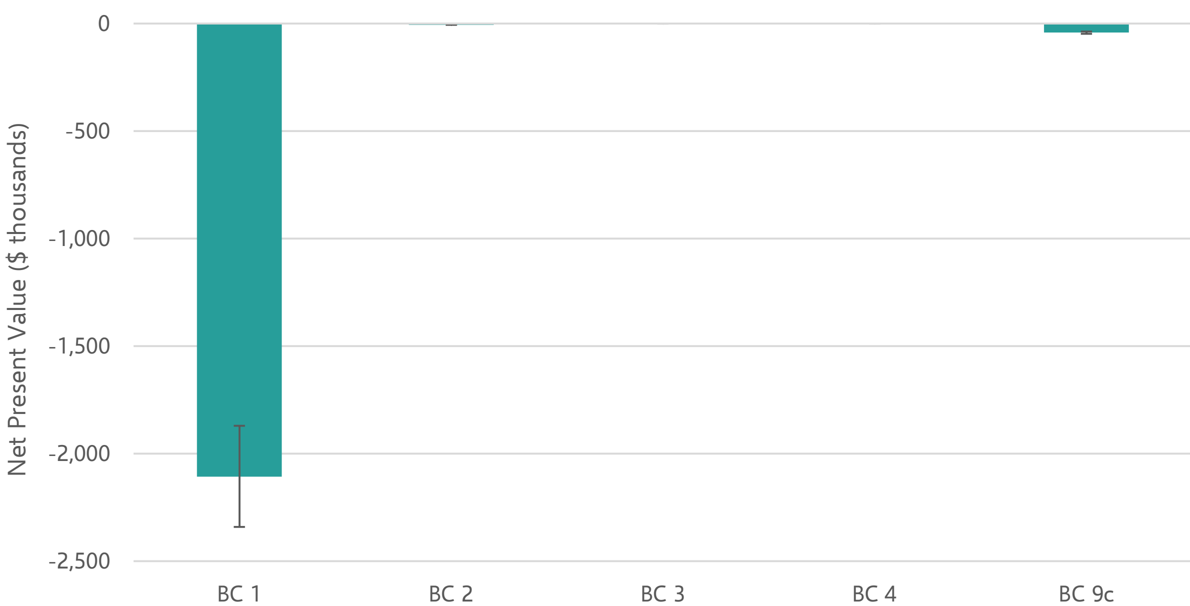

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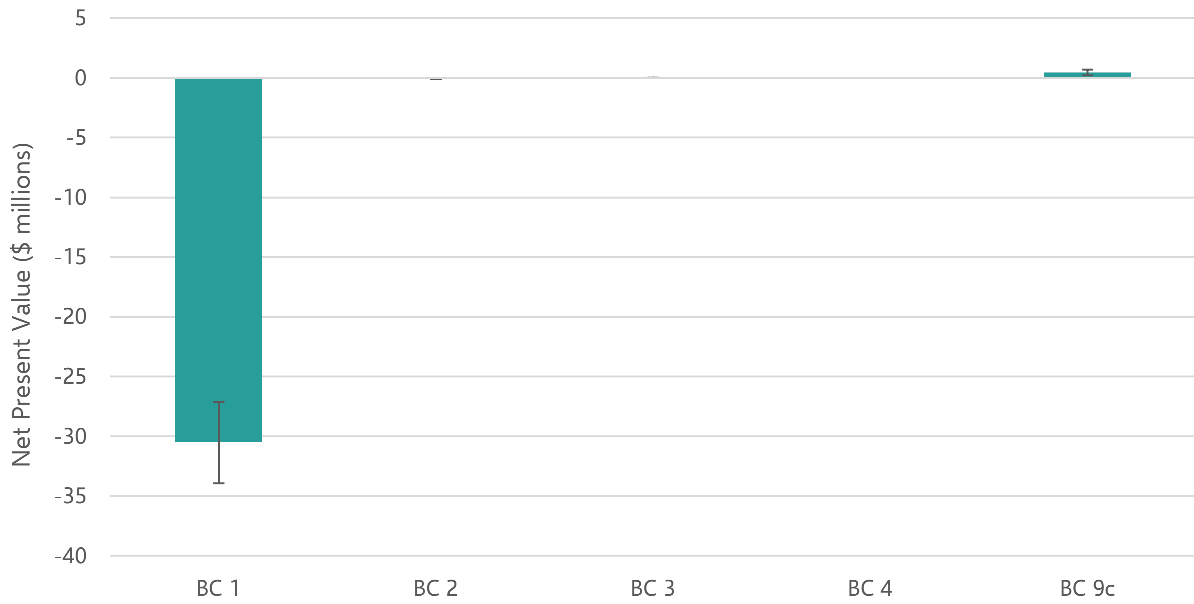
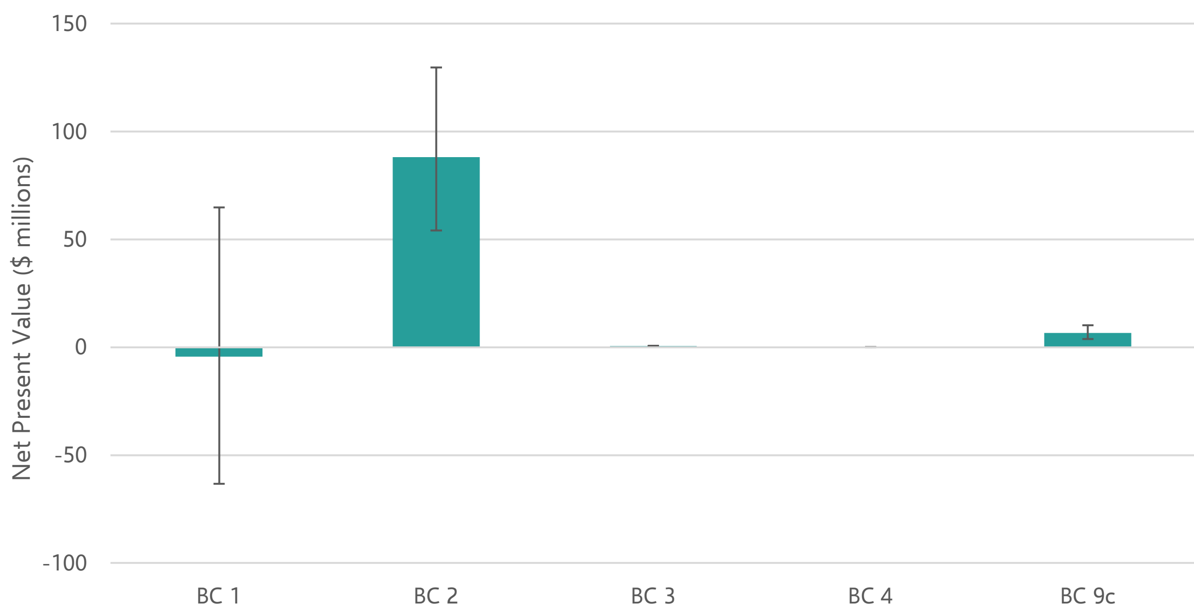
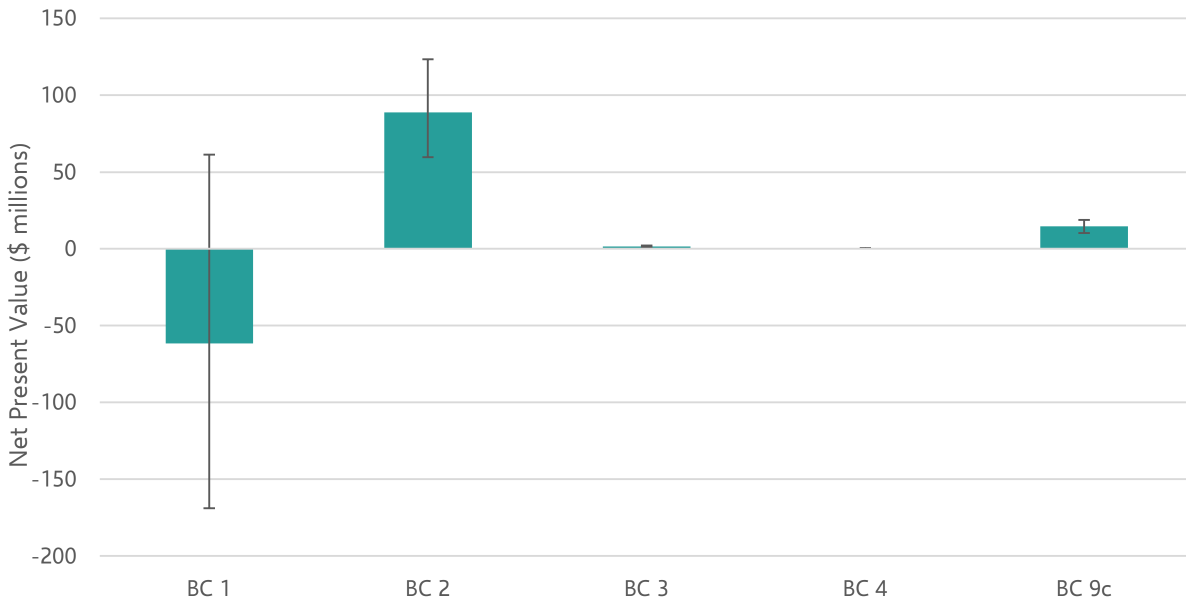


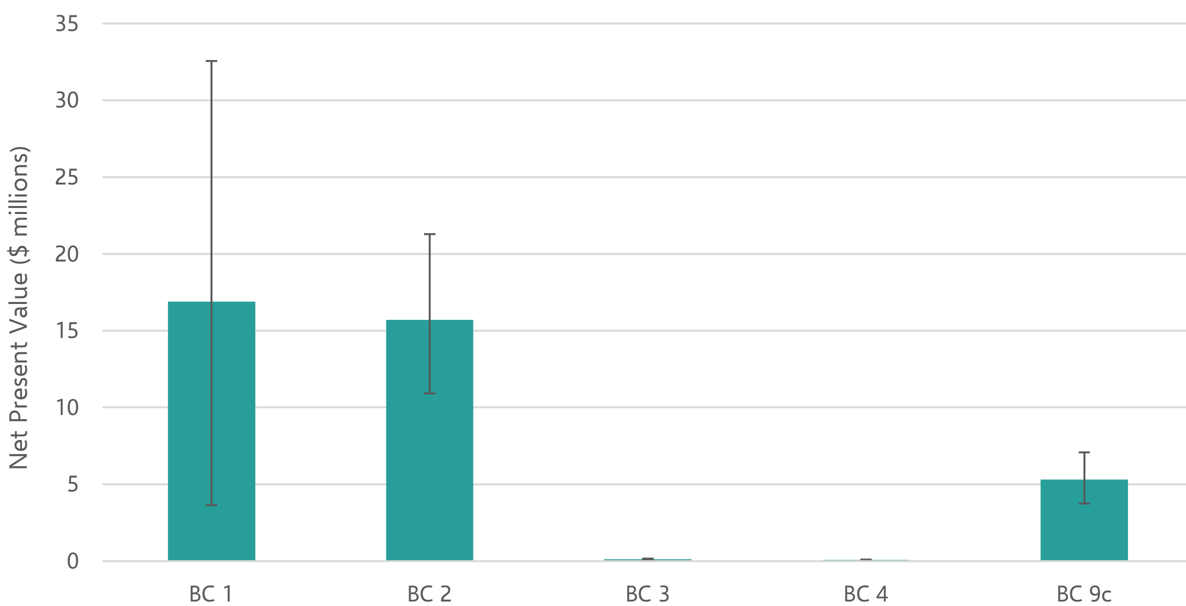
NPV Climate Zone 5



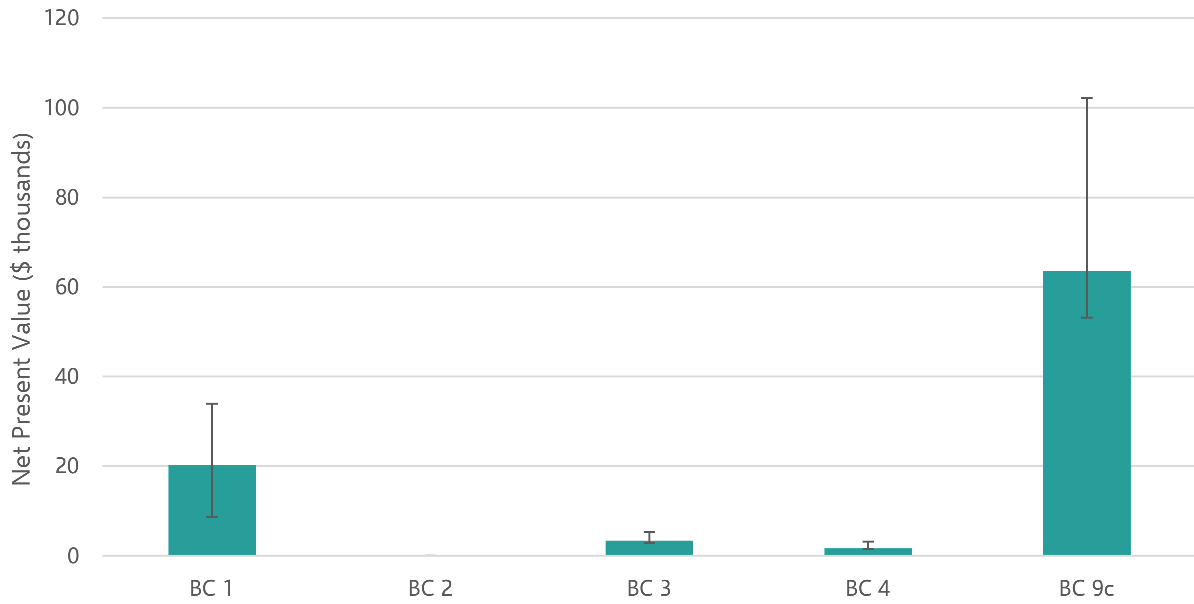
NPV Climate Zone 6



NPV Climate Zone 7



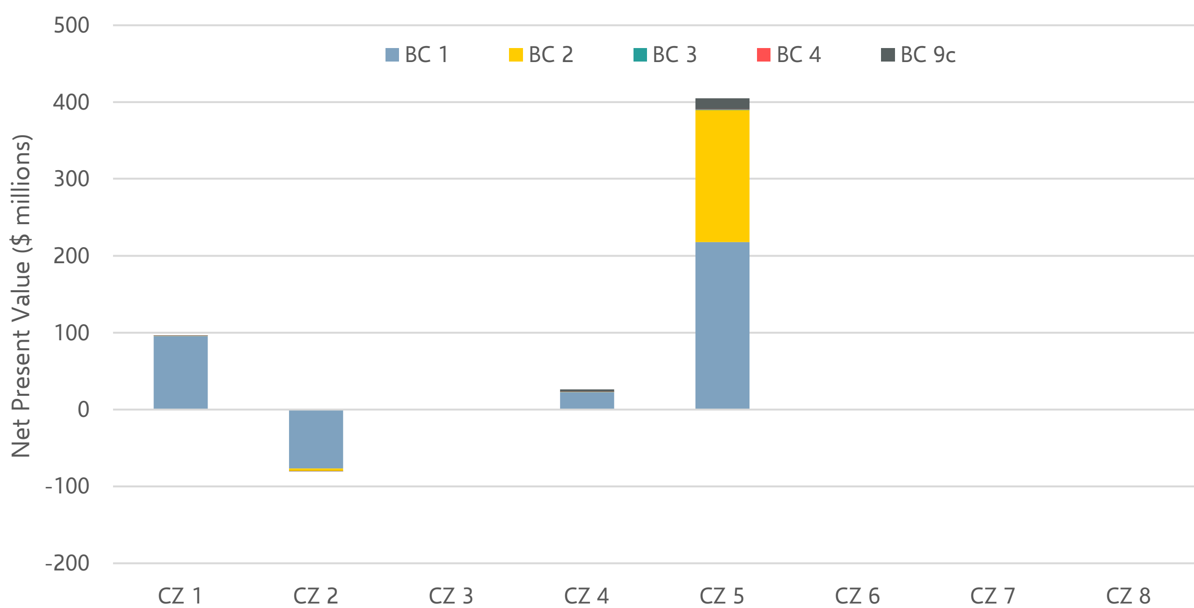
NPV Climate Zone 8



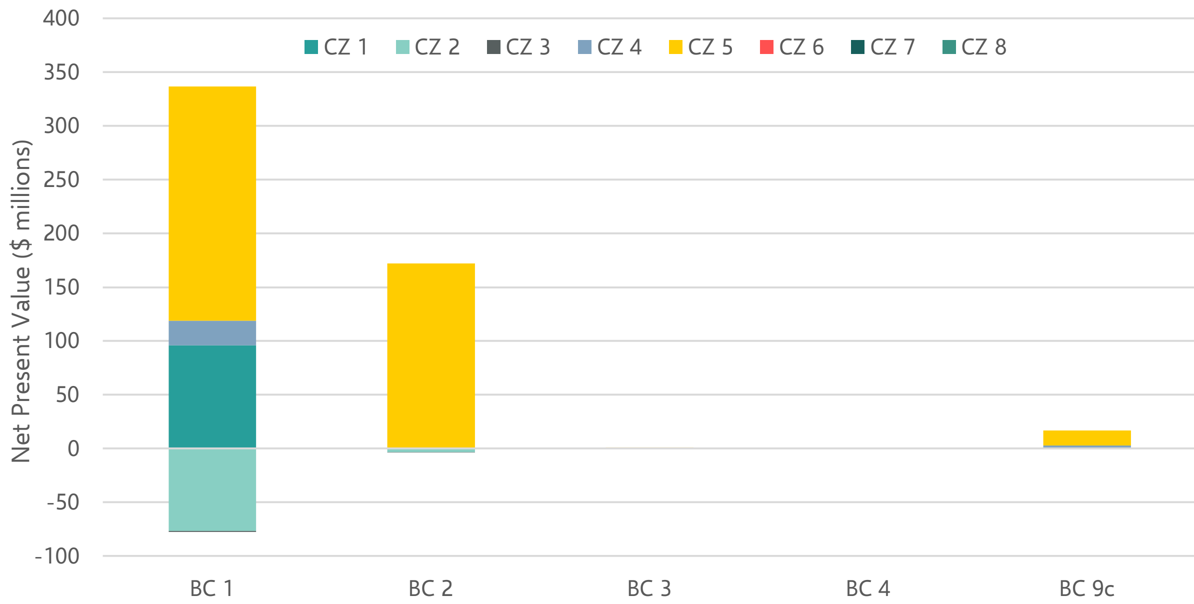
NPV results for external wall no cavity

The figures below provide a summary breakdown of NPV results for the external wall no cavity scenario across Climate Zones and Building Classes. Note that errors bars provided within figures further below represent sensitivity testing around results at the P90 and P10 level.

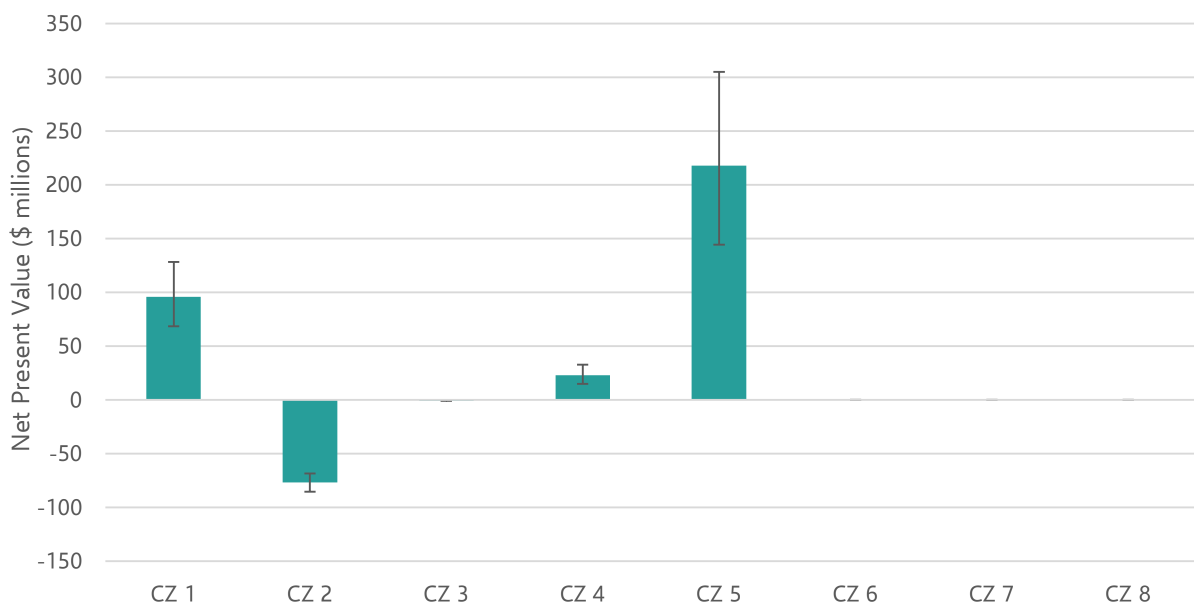
NPV summary by Climate Zone and Building Class



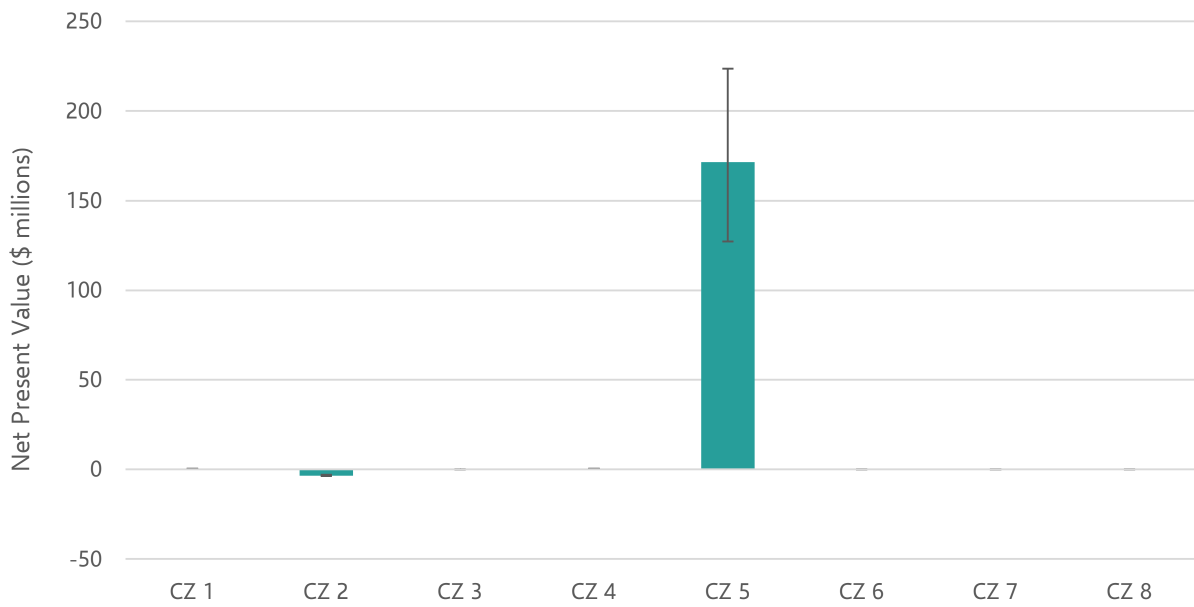
NPV summary by Building Class and Climate Zone



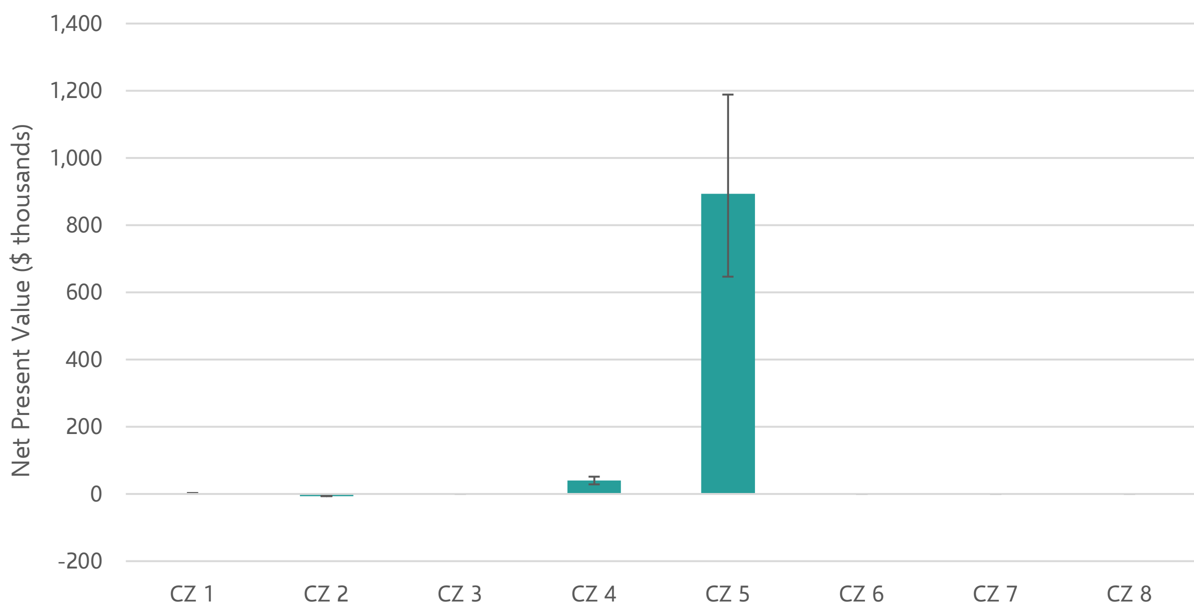
NPV Building Class 1



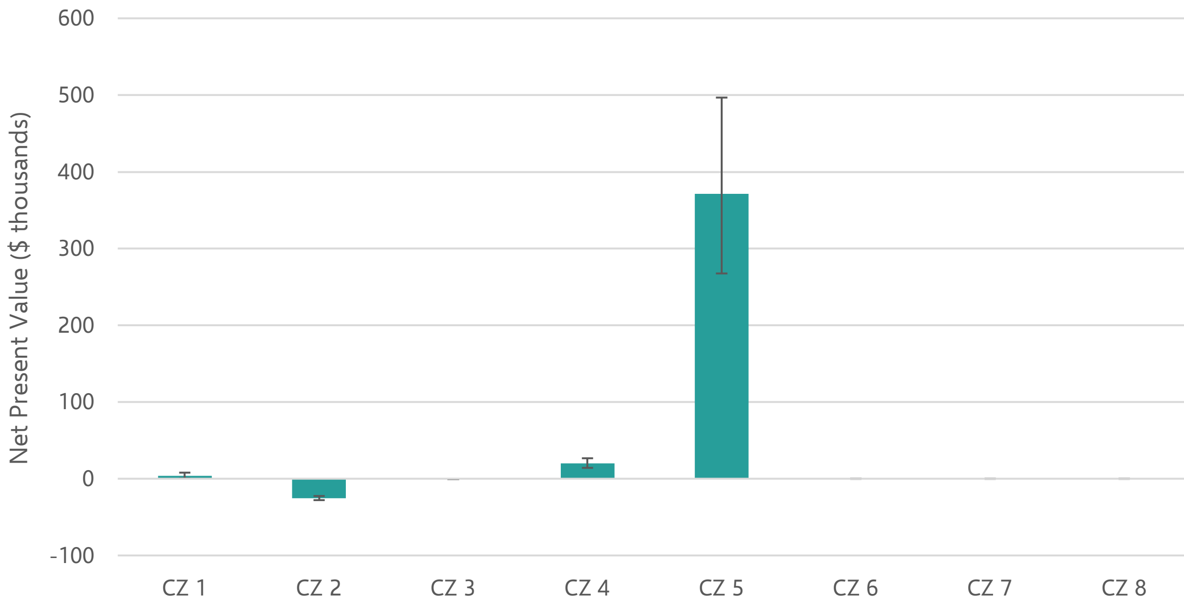
NPV Building Class 2



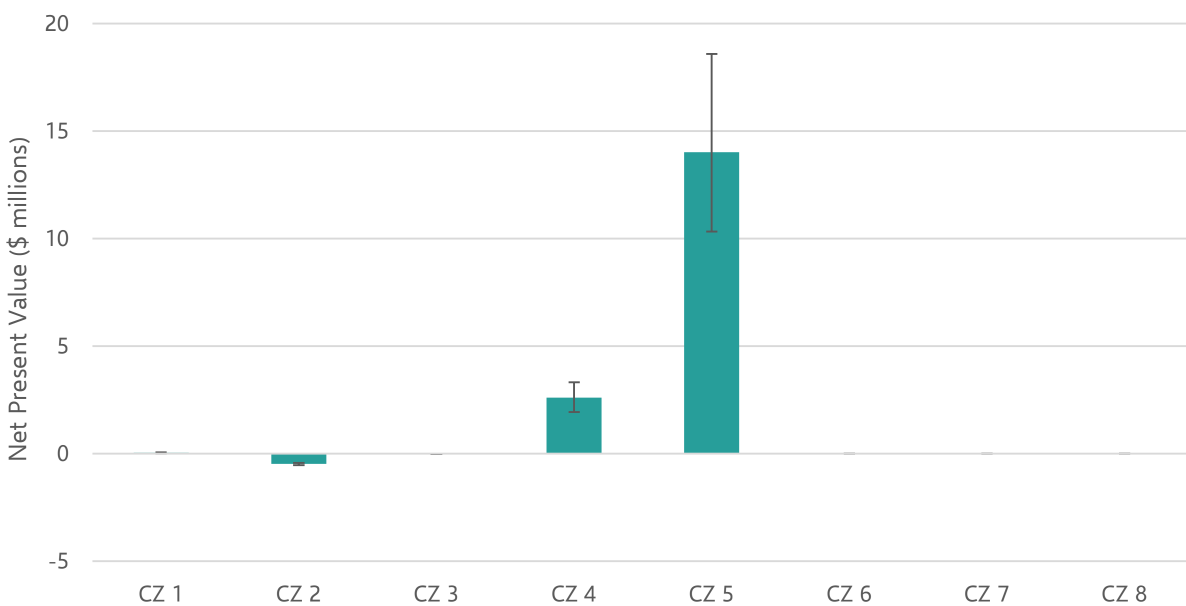
NPV Building Class 3



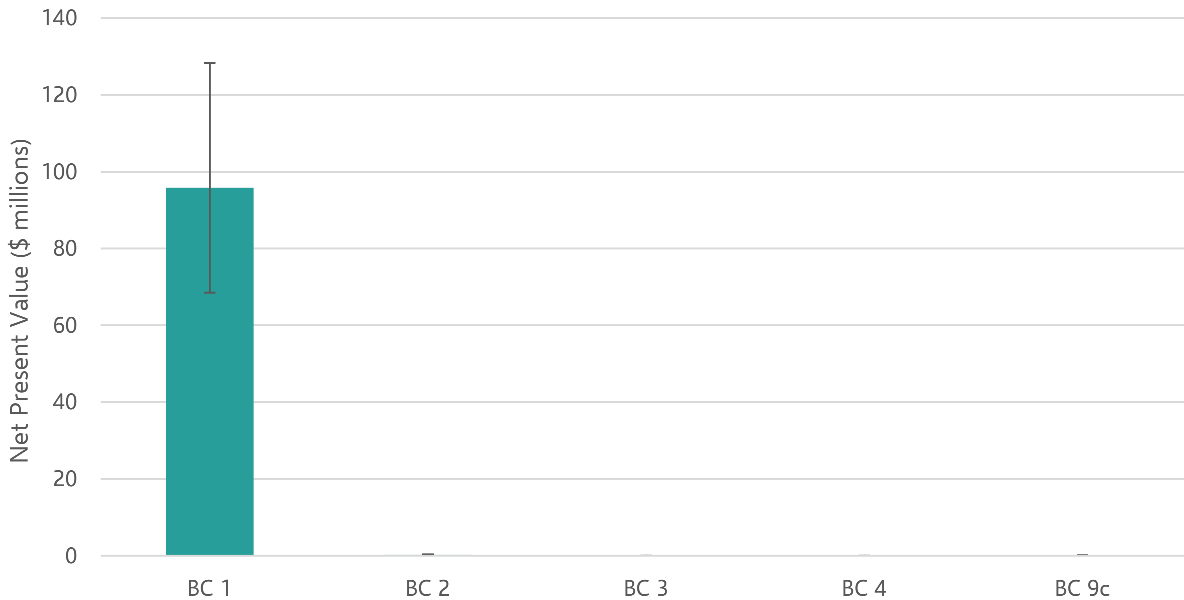
NPV Building Class 4



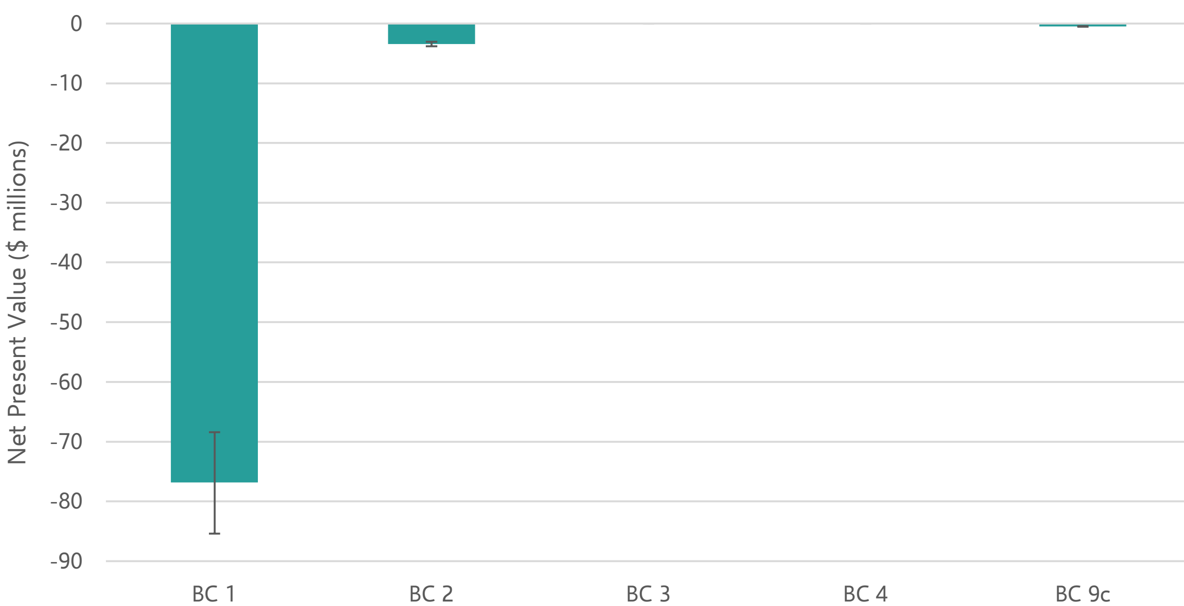
NPV Building Class 9c



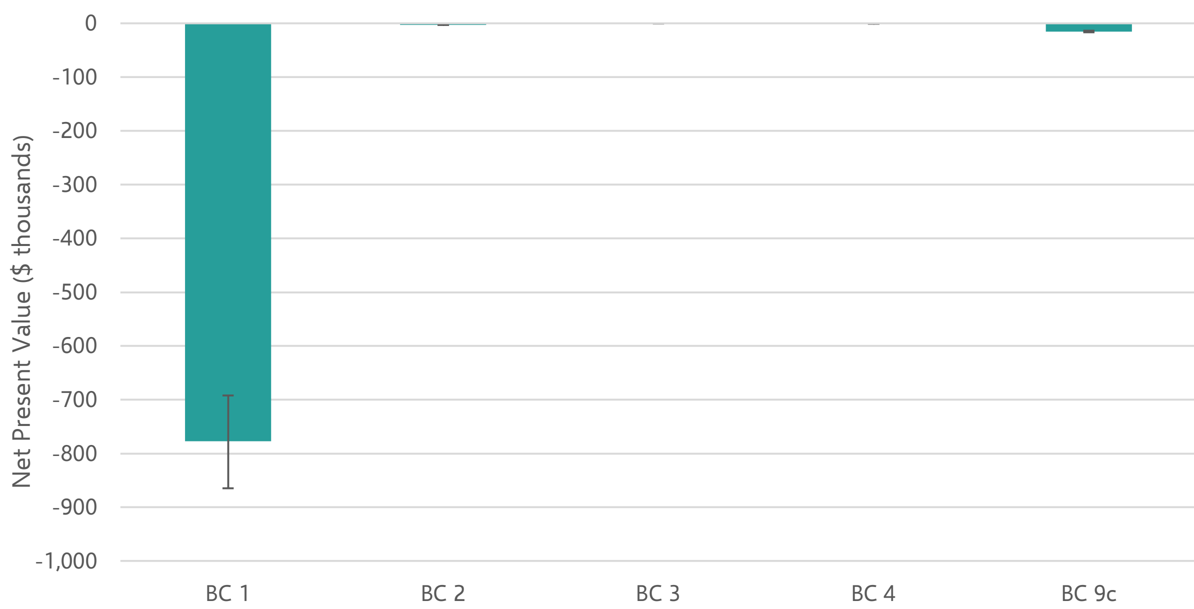
NPV Climate Zone 1



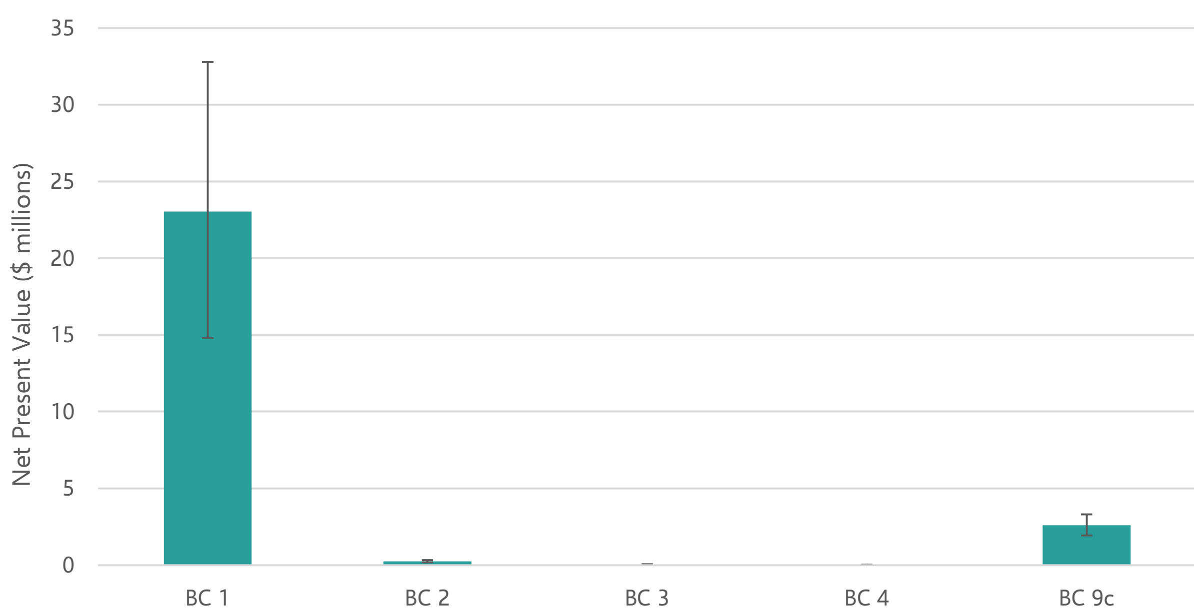
NPV Climate Zone 2



NPV Climate Zone 3



NPV Climate Zone 4



NPV Climate Zone 5