FINAL REPORT

Resilience, durability and the National Construction Code

Economic analysis

Prepared for
Insurance Council of Australia

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THE CENTRE FOR INTERNATIONAL ECONOMICS
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Summary

Extreme weather events impose significant costs on the Australian community in a range of ways, including through the impacts on the built environment. One way that these impacts have been and can further be mitigated is through changes to building standards in the National Construction Code (NCC).

The Insurance Council of Australia (ICA) has commissioned the Centre for International Economics (CIE) to conduct a high-level economic analysis of changing the building standards to improve the resilience of buildings to three extreme weather events:

- tropical cyclones
- floods, and
- bushfires.

The analysis is intended as a high-level economic analysis of:

- the impacts that extreme weather events have on the built environment (particularly residential buildings) and the extent to which a lack of building resilience contributes to the problem; and
- opportunities to strengthen the NCC to the resilience of residential buildings to extreme weather events.

It broadly follows the framework set out in the *Regulatory Impact Analysis Guide to Ministers' Meeting and National Standard Setting Bodies.* However, as a high-level analysis, the purpose is to identify the types of changes that could be considered and to provide a high-level or indicative assessment of whether these changes could potentially pay-off, rather than to identify and assess specific changes to the NCC. The findings in this analysis could help to guide a future more comprehensive and rigorous process of changes to the NCC that fully meets the requirements of a regulatory impact statement (RIS).

Broader policy implications beyond changes to NCC are also discussed.

Limitations of the NCC in addressing building resilience

A significant proportion of the risks associated with extreme weather events relate to the built environment. The National Construction Code (NCC) addresses risks associated with cyclones, floods, and bushfires, primarily from the perspective of occupant health and safety during an event.

Building resilience

The ICA is proposing that the definition for building resilience be included in the NCC to provide a threshold test for the review of the relevant provisions and standards, based on the following:

> "Climate Resilience of Buildings is the ability of a building, structure and its component parts to minimise loss of functionality and recovery time without being damaged to an extent that is disproportionate to the intensity of a number of current and scientifically predicted future extreme climatic conditions (i.e., wildfires/bushfires, storms, hurricanes/cyclones, flooding, and heat)."

The ICA is also proposing the NCC provide an explanatory statement and updated handbook for durability, adjacent to the definition for building resilience, based on the following:

> "Durability…the capability of a building or its parts to perform a function over a specified period of time."

Or its design life, where:

> "…design life is regarded as the period for which a building, a building element or sub-system is expected to fulfill its intended function."

Limitations of the NCC

The NCC focuses on the protection of human life during an event. This may mean that, in some cases, proportionate and cost-effective options to protect buildings are overlooked because they do not also function to protect life. The ICA provided the following example to the Royal Commission into National Natural Disaster Arrangements:[1]

> Strata buildings are designed to withstand high windspeeds to ensure they don't collapse. However, window and door flashings are not designed to withstand water ingress under high windspeed. As a result, strata buildings in Australia are highly vulnerable to extensive water damage during storms.

The Royal Commission recommended that effectiveness of relevant building standards to manage natural hazard risk should be reviewed using the best available data, and better data should be commissioned if current data is inadequate.[2]

Residential building-related impacts of extreme weather events

Various studies (including those identified above) outline a range of impacts associated with extreme weather events. However, not all of these impacts relate to the resilience of residential buildings. The main impacts that could potentially be avoided through more resilient residential buildings include:

- costs associated with rebuilding or repairing damaged buildings

1 Royal Commission into National Natural Disaster Arrangements 2020, *Report*, p. 413.

2 Royal Commission into National Natural Disaster Arrangements 2020, *Report*, p. 412.

- costs associated with replacing and repairing home contents
- disruption-related costs — where dwellings become uninhabitable as a result of an extreme weather event, this can cause significant disruption to the household and the wider community. Rebuilding (and in some cases repairing) damaged dwellings can take several years. The long-term disruption-related costs can include the following:
  - In the interim, households must find alternative temporary accommodation.
  - The stress associated with living in temporary accommodation and managing the rebuild can contribute to mental health problems.
  - The location of temporary accommodation may not be conducive to continuing everyday life, including:
    - continuing with previous employment; and
    - returning to school (temporarily changing schools may be disruptive).

We estimate that the annualised residential building-related costs from the extreme weather events addressed by the NCC (bushfires, cyclones and floods) could be around $4 billion per year (table 2.1). These costs are likely to increase significantly in the period ahead.

1 Estimated annualised residential building-related costs

	Bushfire	Cyclone	Flood	Total
	$ million	$ million	$ million	$ million
Insured losses	247.58	584.04	794.56	1 626.17
Uninsured losses	61.90	146.01	198.64	406.54
Under-insured losses	60.11	431.29	190.03	681.42
Mental health impacts	80.47	577.12	200.31	857.91
Loss of housing	23.07	165.47	57.43	245.98
Employment impacts	13.71	98.31	34.12	146.13
Total	**486.84**	**2 002.24**	**1 475.09**	**3 964.16**

Source: CIE estimates.

Around half of these costs are borne by insurance, which are ultimately recovered from policy-holders through premiums. However, as risks increase insurance premiums will become less affordable and insurance coverage is likely to decrease. This will shift and even greater share of costs onto households and in some cases governments.

Extreme weather events covered by the NCC

A summary of the key findings in relation to each of the extreme weather events covered by the NCC is provided below. Note that each type of event has been considered separately, although many events involve multiple hazards and some mitigation measures improve resilience against multiple different types of events. Taking a multi-hazard resilience approach is likely to provide more favourable outcomes on a cost-benefit analysis.

Extreme winds including tropical cyclones

The NCC covers extreme winds, which includes tropical cyclones, as well as extreme winds from thunderstorms.

Despite existing NCC requirements, a lack of resilience of residential buildings to tropical cyclones imposes significant costs on the relevant communities.

- We estimate that there are currently (2021) around 530 000 dwellings in cyclonic wind regions (i.e. Wind Region C and Wind Region D) and Wind Region B2.
- Insured losses from cyclone events have increased significantly over the past 10-15 years.
- We estimate that the annual costs related to residential buildings from tropical cyclones could be in the order of around $2.0 billion per year.
- Taking into account the expected impacts of climate change (focusing specifically on the poleward shift in the maximum intensity of tropical cyclones, which would increases risks for the densely populated area of south-east Queensland) and future development in relevant areas, these costs could increase to around $4.4 billion per year by 2050 and around $27.5 billion by 2100.

Limitations of the NCC in addressing cyclone-related risks

Previous studies, including some commissioned by ICA, have highlighted several limitations of the NCC in relation to cyclone-related damage. These include the following:

- Water ingress associated with wind-driven rain is a key driver of insurance claims, even when wind speeds are well below the design speed.
- Buildings in Wind Region B are not currently designed for high internal pressure. This was a key driver of structural damage caused by Tropical Cyclone Seroja, even though wind speeds were below design levels.

Key findings

Key findings from our high-level analysis in relation to tropical cyclones are as follows.

- Several specific limitations in the current approach to mitigating risks associated with tropical cyclones through the NCC have been identified.
- The high-level estimates suggest that there may be scope to strengthen aspects of the NCC requirements to address these limitations and improve building resilience. This includes measures to:
  - reduce water ingress from wind-driven rain
  - address internal pressure in Wind Region B.

Floods

Floods impose significant costs on the community.

- We estimate that there were more than 913 000 houses or semi-detached, row or terrace houses and townhouses (i.e., Class 1a dwellings) subject to flood risks in 2022. Of these, nearly 836 000 dwellings were occupied.
- Annual average insured losses from flooding have increased significantly over recent years, which skyrocketed to $1 billion in 2022.
- We estimate that the annual flood related costs to Class 1a buildings could reach $1.5 billion (in 2022 dollars), including building related damages and disruption costs.
- Considering the expected impacts of climate change and future development in flood prone areas, these costs could rise to about $2.3 billion per year by 2050 (in 2022 dollars).

Limitations of the NCC in addressing flood-related risks

Inadequacies have been identified in current flood risk mitigation instruments including the land use planning and building regulations as follows:

- The ABCB Standard on Construction of Buildings in Flood Hazard Areas (the ABCB Flood Standard) does not consider flood resilience.
- Increasing flood risk implies that larger floods than the defined flood events - the 1-in-100 AEP floods - would occur in a more frequent and more intense way. This science and accompanying modelling should be fed into land use planning, building regulations and rainfall and runoff guidelines.
- Current building standards and codes do not achieve the desired outcomes in minimising damage when floods occur, primarily influenced by land use planning decisions.

Key findings

Key findings from our high-level analysis in relation to floods are as follows.

- The effective flood risk mitigation requires cooperative efforts of land use planning, building standards and other risk-managing instruments.
- There are opportunities for enhancing flood resilience through the building standards, including floor elevation and other non-structural options.
  - Nevertheless, the effectiveness of dwelling level options is hard to track in practice. Evidence base is missing in Australia, and observations from overseas case studies are difficult to scale to Australian conditions in general, so we adopt a range of effectiveness estimates for the proposed options.
  - The proposed options can be relatively costly, and their effectiveness depends largely on the AEP zones in which the building is located. Generally, buildings located in more frequent flood zones are more likely to benefit from flood resilient options during significant flood events, such as 1-in-100 AEP flood event or more frequent. This is aligned with results of the cost benefit analysis undertaken by the

Queensland Reconstruction Authority.[3] The analysis finds that flood resilient homes are a viable option for flood events up to and including the 1 in100 AEP, i.e., the high-risk areas. By comparison, benefits of resilient homes in lower flood risk areas are small.
  - Floor elevation appears to be a more cost-effective option compared to other non-structural measures in similar circumstances.

Bushfires

Bushfires also impose large costs on the community. These costs having been increasing significantly over recent years and are expected to continue to increase as the climate continues to change.

- We estimate there could be around 1.4 million Class 1a dwellings in bushfire prone areas (based on 2021 Census data), around 15 per cent of the total Class 1a dwelling stock (note this could overstate the number of dwellings at risk from bushfires as bushfire mapping is undertaken infrequently and in some areas, de-vegetation to support new development has reduced risks for existing dwellings).
- Over the period from 2016 to 2021, we estimate the number of Class 1a dwellings in bushfire prone areas increased at a faster rate than the Class 1a dwelling stock generally. The proportion of Class 1a dwellings in bushfire prone areas has therefore increased.
- Insured losses due to bushfires has increased significantly in recent years, from an average of around $5 million per year during the 1990s to an average of around $390 million per year over the 10 years to 2022 (in 2022 dollars).
- We estimate that total costs caused by bushfires related to residential buildings could currently be around $487 million per year (in 2022 dollars).
- These costs could increase to around $2 billion (in 2022 dollars) per year by 2050 taking into account factors such as:
  - new residential development in bushfire prone areas
  - the impact of climate change (although the impact varies across different areas, in many areas, climate change is expected to increase bushfire risk through more days with severe, extreme or catastrophic fire risk, longer heatwaves and drier vegetation)
  - an increase in properties left undefended during fires following a change to the advice provided by fire authorities.

Limitations of the NCC in addressing bushfire risks

Several weaknesses have been identified in current arrangements relating to bushfire protection, including the following:

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[3] Queensland Reconstruction Authority, 'Cost benefit analysis for flood resilient design and construction', in *Flood Resilient Building Guidance for Queensland Homes*, <https://www.qra.qld.gov.au/resilient-homes/flood-resilient-building-guidance-queensland-homes>

- Buildings that have been built to bushfire construction standards may not be resilient because the current deemed-to-satisfy building standard does not, or cannot, address all factors contributing to property loss, such as: house-to-house ignition, maintenance, compliance, landscaping and storage of combustible materials.[4]
- Although ember attack is the main source of ignition for houses lost to bushfires, the Bushfire Attack Level (BAL) which determines the bushfire protection measures that apply is based on flame contact and intensity. There is no requirement for houses more than 100 metres from vegetation to include any bushfire protection measures, even if in a designated bushfire prone area (except in Victoria).

Key findings

Key findings from our high-level analysis in relation to bushfires are as follows.

- There appear to be opportunities to improve protection from ember attack via the NCC at relatively low cost and within the 'budget' suggested by the potential benefits.
- Other measures that can be taken to reduce fire risk — some of which may be relatively cost effective — are currently outside the scope of the NCC. These include:[5]
  - separation distances between buildings to limit structure-to-structure spread
  - non-combustible fencing
  - the materials used and location of retaining walls proximal to buildings
  - fire-resistant water tanks
  - storage of combustible materials (including firewood and gas cylinders)
- As these options may be complementary to or a substitute for building-related measures, a comprehensive future ABCB RIS could consider:
  - how these approaches to bushfire mitigation could be integrated into the NCC's regulatory approach (including how relatively expensive construction-related measures could be traded off against potentially cheaper and more effective alternatives), or
  - these type of approaches (which could be applied through land use planning regulation) as alternative options to strengthening building-related measures (as required by the RIS process) — although a rigorous evidence-based assessment process is generally applied to changes to building standards, this less true of changes to planning regulation.

4 Cotter, K. *Lessons to be learned in relation to the Australian bushfire season 2019-20*, Submission to the Senate Finance and Public Administration References Committee, Bushfire Building Council of Australia Ltd, 3 May 2021, p. 9.

5 See for example: Leonard, J. Opie, K. Blanchi, R. Newnham, G. and Holland, M. *Wye River/Separation Creek Post-bushfire building survey findings*, CSIRO Land and Water, Report EP 16924, Report to the Victorian Country Fire Authority, April 2016, p. 29

Summing up

Across the extreme weather events covered by the NCC, this analysis has found that:

- costs directly related to residential buildings (including: costs associated with rebuilding, repairing or replace homes and their contents and disruption-related costs where dwellings become uninhabitable for an extended period) have increased significantly over the past 10-15 years
- this trend is likely to continue in the longer term due to factors such as climate change and new residential development in hazard prone areas.

Our analysis has also shown that costs relating to long-term displacement (i.e. mental health impacts, loss of housing services and employment impacts) make up a significant share of the total costs (~20-40 per cent depending on the type of event). This also excludes potential disruptions to schooling. Avoiding the costs associated with long-term displacement is a key focus of improving resilience of residential buildings, although more resilient homes would also reduce building-related costs.

As the costs associated with displacement are generally harder to measure than the more tangible building-related costs (i.e. the cost of rebuilding, replacing and/or repairing the damaged buildings and their contents), these costs can sometimes be excluded from cost-benefit analyses. Our analysis suggests that this would significantly understate the benefits from improving building resilience.

The high-level analysis indicates that there are likely to be cost-effective measures to improve the resilience of residential buildings to these extreme weather events, through changes to either: building standards; and/or land use planning regulation.

- In some cases, there are likely to be cost-effective opportunities to improve building resilience through changes to the NCC.
- In other cases, changes to building standards may not be the most cost-effective approach, particularly in relation to bushfires where the NCC does not cover some of the key sources of property damage.
  - In these cases, changes to land use planning regulation may provide a more cost-effective approach to mitigating risk, particularly in relation to floods and bushfires.
  - Nevertheless, these alternative options (or in some cases complementary options) could be considered in a future RIS in the context of:
    - Options to better integrate land use planning regulations with
    - Alternative options to strengthening building standards (as required in a RIS)

1 Background and introduction

Natural disasters and the National Construction Code

Natural hazards impose significant costs on the Australian community in a range of ways, including through the impacts on the built environment.

One way that these impacts can be mitigated is through building standards. Although building regulation is a state issue, for several decades building standards have been specified in a nationally consistent Building Code of Australia (BCA), which now forms part of the National Construction Code (NCC).

The NCC prescribes the minimum necessary requirements for safety and health, amenity and accessibility, and sustainability in the design, construction, performance and liveability of new buildings, as well as new building work in existing buildings (although in some cases it is impractical to apply some new standards to existing buildings).[6] Although the NCC is a national code, it is given effect through state government regulation, which allows for state-based variations.

The NCC currently contains provisions to address risks from natural disasters, including those arising from:[7]

- tropical cyclones
- floods, and
- bushfires.

In general, these provisions apply in areas that are vulnerable to the relevant extreme weather events, although the mechanisms for how this is achieved varies depending on the type of weather event.

The focus of these provisions is on occupant health and safety, consistent with the principal objective of the NCC. However, other objectives are also relevant, including sustainability and liveability. In the case of bushfires there is provision for a Class 1a building to perform beyond this threshold and in all cases the performance of a buildings structure to perform beyond an extreme weather event is enhanced as a by-product of the principal objective.

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6 Royal Commission into National Natural Disaster Arrangements 2020, *Report*, p. 401.

7 The NCC also addresses risks associated with earthquakes.

The impacts of climate change

Climate change is projected to increase the vulnerability of buildings constructed to current codes and standards in various ways, including:

- changes to the frequency of extreme weather events
- changes to the intensity of extreme weather events
- changes to the geography of extreme weather events
- changes to the compounding effects of weather (e.g. more intense rain within cyclones, higher flood levels due to sea level rise etc.).

In most cases, climate change is expected to increase the vulnerability of the built environment to extreme weather events.

Other factors, such as population growth and development in areas affected by extreme weather events will compound the vulnerability of the built environment to natural hazards and increase the costs incurred over time.

Review of the NCC

The costs incurred by a number of recent extreme weather events and the escalating future risks as a result of climate change and other factors has highlighted the need to review the NCC to ensure that the approach to mitigating the risks posed by extreme weather events remains fit for purpose (and fit for purpose over the lifespan of the building).

In March 2020, the Council of Australian Governments directed what is now the Building Ministers' Meeting (BMM) intergovernmental body to consider how the NCC could be updated to enhance climate and disaster resilience.[8] We understand that the Australian Building Codes Board (ABCB) is currently reviewing how to better account for future climate risks.

The Royal Commission into National Natural Disaster Arrangements supported a review of the NCC in the context of changing risks associated with climate change. In particular, the Royal Commission recommended (Recommendation 19.4) that the ABCB, working with other bodies as appropriate, should:[9]

- Assess the extent to which AS 3959:2018 Construction of buildings in bushfire prone areas, and other relevant building standards, are effective in reducing risk from natural hazards to lives and property, and
- Conduct an evaluation as to whether the NCC should be amended to specifically include, as an objective of the code, making buildings more resilient to natural hazards.

8 Royal Commission into National Natural Disaster Arrangements 2020, *Report*, p.413.

9 Royal Commission into National Natural Disaster Arrangements 2020, *Report*, p.414.

The built domain is one of four connected domains that underpins the National Climate Resilience and Adaptation Strategy (along with natural, social and economic).[10] The Strategy notes that improved approaches are needed to enable clearer recognition of health and wellbeing outcomes of adaptation and integrate these into built environment policies and standards.[11]

More recently, at the National Cabinet meeting of 9 December 2022, First Ministers tasked Planning Ministers with developing a national standard for considering disaster and climate risk, as part of land use planning and building reform processes. Planning Ministers will report back to National Cabinet in 2023.[12]

Any changes to the NCC must be subject to the regulatory impact analysis process to ensure that regulatory decisions are consistent with the stated principles for policymakers (see box 1.1).

1.1 Principles for policy makers[13]

All governments will ensure that regulatory decisions will be consistent with the following principles:

1 Policy makers should clearly demonstrate a public policy problem necessitating government intervention, and should examine a range of genuine and viable options, including non-regulatory options, to address the problem.

2 Regulation should not be the default option: the policy option offering the greatest net benefit — regulatory or non-regulatory — should be the recommended option.

3 Every major decision to regulate must be the subject of a Regulation Impact Statement.

4 Policy makers should consult in a genuine and timely way with affected businesses, community organisations and individuals, as well as other policy makers to avoid creating cumulative or overlapping regulatory burdens.

5 The information upon which policy makers base their decisions must be published at the earliest opportunity.

6 All regulation should be periodically reviewed to test its continuing relevance

This process involves preparing a Regulation Impact Statement (RIS) — including both a Consultation RIS and a Decision RIS — that complies with the *Regulatory Impact Analysis*

10 Australian Government, 2021, *National Climate Resilience and Adaptation Strategy 2021-2025, Positioning Australia to better anticipate, manage and adapt our changing climate*, p. 11.

11 Australian Government, 2021, *National Climate Resilience and Adaptation Strategy 2021-2025, Positioning Australia to better anticipate, manage and adapt our changing climate*, p. 23.

12 Media Statement, Meeting of National Cabinet, 9 December 2022, https://www.pm.gov.au/media/national-cabinet-2022-12-09, accessed 5 June 2023.

13 Regulatory Impact Analysis Guide for Ministers' Meetings and National Standard Setting Bodies, May 2021, p.7.

Guide to Ministers' Meeting and National Standard Setting Bodies. A RIS must answer the seven RIS Questions (see box 1.2). The adequacy of RISs is assessed by the Commonwealth Office of Impact Assessment (formerly the Office of Best Practice Regulation).

1.2 The Seven RIS Questions[14]

1 What is the problem?
2 Why is government action needed?
3 What policy options are to be considered?
4 What is the likely net benefit of each option?
5 Who was consulted and how was their feedback incorporated?
6 What is the best option from those considered?
7 How will the chosen option be implemented and evaluated?

This report

This report is intended as a high-level economic analysis of:

- the impacts that some extreme weather events have on the built environment (particularly residential buildings) and the extent to which a lack of building resilience contributes to the problem, and
- opportunities to strengthen the NCC to the resilience of residential buildings to extreme weather events.

The focus of the analysis in this report is on residential buildings. However, a more comprehensive analysis could also consider resilience issues in relation to non-residential buildings.

General approach

To identify the types of measures that could address identified limitations with current NCC requirements, CIE, RLB and ICA consulted with a number of stakeholders, including representatives from: ABCB, Standards Australia, Master Builders Australia, the Housing Industry Association, the Cyclone Testing Station at James Cook University, the Resilient Building Council and the insurance industry.

Consistent with the high-level nature of the analysis, we have generally relied on publicly available information and previous modelling/analysis of the impacts of similar measures. A more comprehensive approach would involve modelling specific measures.

14 Regulatory Impact Analysis Guide for Ministers' Meetings and National Standard Setting Bodies, May 2021, p. 12.

Limitations

The analysis broadly follows the framework set out in the *Regulatory Impact Analysis Guide to Ministers' Meeting and National Standard Setting Bodies.* However, as a high-level analysis, the purpose is not to identify specific changes to the NCC and assess whether the benefits of those changes are likely to outweigh the costs with the rigour required of a RIS.

Rather, the intention is to identify the types of changes that could be considered and to provide a high-level or indicative assessment of whether these changes could potentially pay-off. This could help to guide a future more comprehensive and rigorous process that fully meets the requirements of a RIS.

Report structure

The remainder of this report is structured as follows:

- Chapter 2 sets out:
  - the nature of the problems caused by residential buildings lacking resilience,
  - some high-level estimates of the average annual costs incurred by the community as a result of this lack of resilience of residential buildings (including details on the assumptions underpinning these estimates), focusing on the main extreme weather events covered by the NCC: cyclones, floods and bushfires
  - future projections of these costs
- The remaining chapters focus on the types of extreme weather events covered by the NCC — cyclones (chapter 3), floods (chapter 4) and bushfires (chapter 5) — including:
  - additional details on estimates of the costs incurred by the community relevant to residential buildings (which could potentially be avoided through improved building resilience), including future projections
  - identifying limitations of the NCC in addressing these risks, including some potential options to address these limitations
  - a high-level assessment of the potential costs and benefits.
- Some more detailed discussions are provided in the appendix – estimation of the number dwellings in bushfire prone areas (appendix A).

2 Statement of the problem

The cost of extreme weather events in Australia

Extreme weather events impose significant costs on the Australian community and these costs are increasing.

- A report by Deloitte Access Economics for the Australian Business Roundtable for Disaster Resilience & Safer Communities estimated that the total cost of natural disaster in Australia was currently around $13.2 billion per year and this is expected to increase to $39.3 billion per year by 2050.[15]
- A report by the McKell Institute (with the support of the ICA) estimated that the costs incurred from natural disasters are currently (2023) around $9 billion per year (although this estimate did not include social or intangible costs). Extrapolating from recent trends, the McKell Institute estimated that these costs would increase to around $35 billion by 2050.[16]

Addressing risks through the National Construction Code

A significant proportion of the risks associated with extreme weather events relate to the built environment. The National Construction Code (NCC) addresses risks associated with:

- Cyclones
- Floods, and
- Bushfires.

Limitations of the NCC

The NCC focuses on the protection of human life. This may mean that, in some cases, proportionate and cost-effective options to protect buildings are overlooked because they do not also function to protect life. The ICA provided the following example to the Royal Commission into National Natural Disaster Arrangements:[17]

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15 Deloitte Access Economics, *Building resilience to natural disasters in our states and territories*, Prepared for the Australian Business Roundtable for Disaster Resilience & Safer Communities, p.15.

16 The McKell Institute, The Cost of Extreme Weather: Building Resilience in the Face of Disaster, September 2022, p.18.

17 Royal Commission into National Natural Disaster Arrangements — Report, p.413.

> Strata buildings are designed to withstand high windspeeds to ensure they don't collapse. However, window and door flashings are not designed to withstand water ingress under high windspeed. As a result, strata buildings in Australia are highly vulnerable to extensive water damage during storms.

The Royal Commission recommended that effectiveness of relevant building standards to manage natural hazard risk should be reviewed using the best available data, and better data should be commissioned if current data is inadequate.[18]

Building resilience

The ICA is proposing that the definition for building resilience be included in the NCC to provide a threshold test for the review of the relevant provisions and standards, based on the following:

> "Climate Resilience of Buildings is the ability of a building, structure and its component parts to minimise loss of functionality and recovery time without being damaged to an extent that is disproportionate to the intensity of a number of current and scientifically predicted future extreme climatic conditions (i.e., wildfires/bushfires, storms, hurricanes/cyclones, flooding, and heat)."

The ICA is also proposing the NCC provide an explanatory statement and updated handbook for durability, adjacent to the definition for building resilience, based on the following:

> "Durability…the capability of a building or its parts to perform a function over a specified period of time."

Or its design life, where:

> "…design life is regarded as the period for which a building, a building element or sub-system is expected to fulfill its intended function."

Building-related impacts of extreme weather events

Various studies (including those identified above) outline a range of impacts associated with extreme weather events. However, not all of these impacts relate to the resilience of residential buildings. The main impacts that could potentially be avoided through more resilient residential buildings include:

- Costs associated with rebuilding or repairing damaged buildings
- Costs associated with replacing and repairing home contents
- Disruption-related costs — where dwellings become uninhabitable as a result of an extreme weather event, this can cause significant disruption to the community. Rebuilding (and in some cases repairing) damaged dwellings can take several years. The long-term disruption-related costs can include the following:
  - In the interim, households must find alternative temporary accommodation.

18 Royal Commission into National Natural Disaster Arrangements, Report, p. 412.

- The stress associated with living in temporary accommodation and managing the rebuild can contribute to mental health problems.
- The location of temporary accommodation may prevent people from returning to their previous job.

We estimate that the annualised residential building-related costs from the extreme weather events addressed by the NCC (bushfires, cyclones and floods) could be around $4 billion per year (table 2.1). Our approach to estimating these costs is set out below.

2.1 Estimated annualised residential building-related costs

	Bushfire	Cyclone	Flood	Total
	$ million	$ million	$ million	$ million
Insured losses[a]	247.58	584.04	794.56	1 626.17
Uninsured losses	61.90	146.01	198.64	406.54
Under-insured losses	60.11	431.29	190.03	681.42
Mental health impacts	80.47	577.12	200.31	857.91
Loss of housing service	23.07	165.47	57.43	245.98
Employment impacts	13.71	98.31	34.12	146.13
Total	**486.84**	**2 002.24**	**1 475.09**	**3 964.16**

[a] Averaged over the past 10 years, based on the ICA Historical Catastrophe list inflated to 2022 dollars using the National Consumer Price Index (CPI) published by the Australian Bureau of Statistics. b Based on catastrophe modelling for the Northern Australia Insurance Taskforce (as losses over a decade are unlikely to be an accurate indicator of risk).

Source: CIE estimates based on various sources. Further details on the approach to estimated costs are provided below.

Other costs that have not been quantified could include:

- disruptions to schooling, where the location of temporary accommodation is not close the previous school
- long-term displacement can delay community recovery
- carbon emissions associated with damaged and destroyed buildings and the emissions associated with repair and/or rebuild.

An important observation is that costs relating to long-term displacement (i.e. mental health impacts, loss of housing services and employment impacts) make up a significant proportion of the total costs (~20-40 per cent depending on the type of event). Avoiding the costs associated with long-term displacement is a key focus of improving resilience of residential buildings, although more resilient homes would also reduce building-related costs.

Furthermore, the approach to measuring mental health costs focuses on the most severe cases, which affect only a relatively small proportion of people affected by disasters. To the extent that all displaced households would incur some general inconvenience costs associated with living out of their homes for an extended period, our focus on only the most severe mental health conditions caused by displacement is likely to understate the impact on households.

As the costs associated with displacement are generally harder to measure than the more tangible building-related costs (i.e. the cost of rebuilding, replacing and/or repairing the damaged buildings and their contents), these costs can typically be excluded from cost-benefit analyses. Our analysis suggests that this would significantly understate the benefits from improving building resilience.

Rebuilding, replacement and repair costs

A key building-related impact of extreme weather events are the costs associated with:

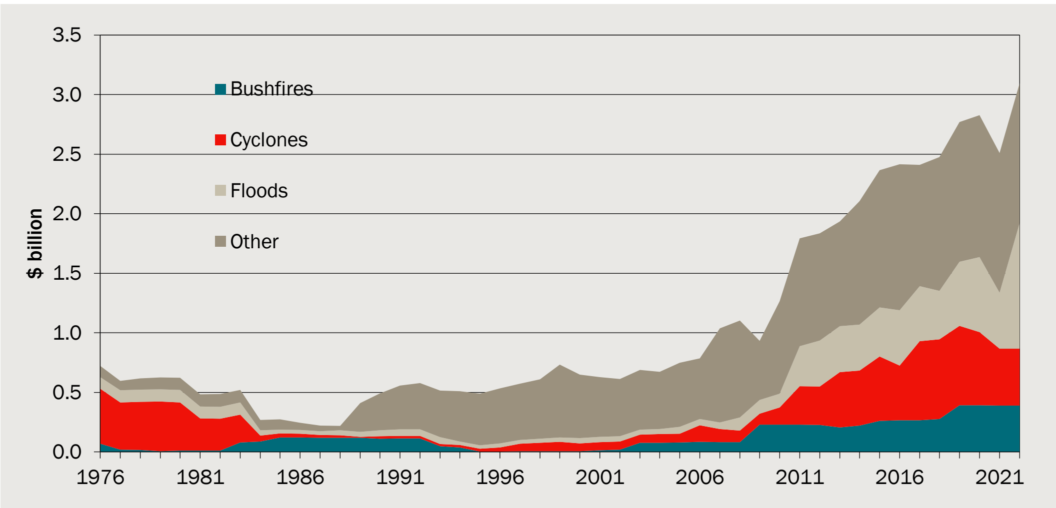
- rebuilding or repairing damaged buildings
- repairing or replacement building contents (that may have been avoided through more resilient buildings).

Insured losses

There has been a sharp increase in insurance costs associated with extreme weather events over recent years (chart 2.2). This is based on the ICA historical catastrophe list, with 'original losses' inflated to 2022 dollar terms, using the national consumer price index (CPI) published by the Australian Bureau of Statistics (ABS). On average, insurance costs associated with natural hazards have increased from $0.5-1 billion per year through the 1990s and early 2000s to around $2.5 to 3.0 billion per year in the early 2020s (in 2022 dollar terms).

Changes in flood coverage is likely to be one factor that has contributed the sharp increase in insured losses from flooding. Flood insurance was not generally included in general insurance policies until 2010/11, so coverage was low prior to that date. Nevertheless, an increase in the frequency and severity of extreme weather events and greater development in vulnerable areas are also key factors that have contributed to the observed increase.

2.2 Insured losses from extreme weather events (2022 dollars) — 10 year moving average



Data source: Based on the ICA Historical catastrophe list. The 'original loss' estimates are inflated to 2022 dollar terms using the national CPI published by the ABS.

To estimate insured losses:

- We use the 10-year average for **bushfires** and **floods** as an indicator of annual losses. However, not all insured losses relate to residential buildings, which are the focus of this report. The proportion that relates to residential buildings (including contents) is likely to vary across different events. To estimate insured losses relating to residential buildings, we use data provided by ICA for several sample events. This data suggested:
  - around 60-65 per cent of total losses (we assume 62.5 per cent) for bushfires relate to residential buildings and contents (based on the 2019-20 bushfires and the Perth Hills bushfires),
  - 65-80 per cent of total losses (we assume 75 per cent) for floods relate to residential buildings and contents (based on the various floods in 2021 and 2022).
- As damaging cyclones are relatively infrequent but high-cost events, losses over a decade (or several decades) are unlikely to be an accurate indicator of risk. We therefore use catastrophe modelling for the Northern Australia Insurance Taskforce (see chapter 3 for further details).

Uninsured losses

Not all of the costs associated with rebuilding, replacing or repairing damaged buildings and their contents are covered by insurance. Buildings may not be covered by insurance where:

- the building owner and/or occupant is not insured
- the building owner and/or occupant is under-insured (i.e. the insured amount would not meet the full cost of rebuilding/repairing a home that is lost as a result of an extreme weather event or is insufficient to repair or replace damage contents).

As noted by the 2009 Victorian Bushfires Royal Commission (into the Black Saturday bushfires), a proportion of homes are not covered by building insurance, a much greater proportion of households do not have contents insurance, and many households are under-insured. That said, there was a lack of definitive evidence about the extent of both non-insurance and under-insurance.[19]

There will be a compounding issue related to uninsurance or underinsurance. As climate change drives an increase in the severity and frequency of extreme weather events, there will be implications for both the affordability and availability of insurance. This highlights the importance of resilience measures to reduce the underlying risk.

For example, the ACCC reported evidence of insurance premiums declining when insurers moved to address level pricing for flood in 2011–12. Insurers reported that it is inevitable that insurance premiums that reflect the underlying risk for properties with a high and extreme risk of flood will not be affordable for policyholders.[20]

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19 2009 Victorian Bushfires Royal Commission 2010, *Final Report*, p.339.

20 Australian Competition and Consumer Commission, 2020, *National Australia Insurance Inquiry — Final Report*, p. 69.

Homes without insurance

As noted above, there are no definitive data sources on the proportion of dwellings that have building and/or contents insurance. In general, the evidence on insurance coverage is mixed.

- The recent Northern Australia Insurance Inquiry estimated:[21]
  - the rate of home building non-insurance in northern Australia (where home insurance premiums are higher, reflecting higher natural peril risk) is around **20 per cent**
  - the rate in the rest of Australia was around **11 per cent**.
- Recent surveys by comparison/aggregation websites have reported that uninsurance rates could be around **40 per cent** for buildings.
  - A recent (2022) survey by comparison website Finder (based on representative sample of more than 1000 people) found that around 60 per cent have some form of home insurance policy.
  - A similar survey by financial comparison site Savvy (based on 1000 NSW and Queensland residents) had broadly similar results, finding that:[22]
    - 62 per cent had home insurance (54 per cent with home and contents insurance plus 8 per cent with home insurance only)
    - 70 per cent had contents insurance (54 per cent with home and contents insurance plus 16 per cent with contents insurance only)
    - 22 per cent of those with some insurance are uninsured against extreme weather events, such as flood, bushfire or storms.
- Earlier surveys suggest uninsurance rates may be much lower. In particular, a 2012 survey by the Sapere Research Group for insurer IAG found the following (these results were similar to an earlier 2001 survey).
  - Among homeowners, insurance rates were found to be high.[23]
    - Only around 4 per cent did not have building insurance (with a further 4 per cent not able to say)
    - Around 7 per cent did not have contents insurance (as above, 4 per cent were not able to say).
  - Insurance rates among rental properties (and holiday homes) was generally significantly lower.[24]
    - 19 per cent of rental properties did not have building insurance
    - 44 per cent of renters did not have contents insurance.
  - Together, this implies that around:

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21 Australian Competition and Consumer Commission, 2020, *Northern Australia Insurance Inquiry*, Final Report, p. 289.

22 Savvy website, https://www.savvy.com.au/survey-shows-22-percent-of-nsw-and-qld-residents-uninsured-against-extreme-weather-events/, accessed 21 March 2023.

23 Sapere Research Group 2012, *Australian Household Insurance: Understanding and Affordability*, February 2012, p.18.

24 Sapere Research Group (2012), op.cit., p.23.

  - 10 per cent of dwellings do not have building insurance
  - 20 per cent do not have contents insurance.
- An ASIC report on under-insurance in the aftermath of the 2003 Canberra bushfires referred to evidence that estimated that the proportion of uninsured homes could range between 2 per cent and 15 per cent.[25]

It is not clear to what extent the different time periods explains the discrepancy between these survey results; however, it seems unlikely that insurance rates would have declined from around 90 per cent to 60 per cent over 10 years.

Some of the variation in the estimates across these sources could reflect higher premiums for properties at higher risk from extreme weather events leading to lower insurance coverage in these properties.

For the purposes of this analysis, we assume around **20 per cent** of dwellings in high-risk areas are not insured (i.e. the building). Anecdotally, insurance rates are lower for properties at risk of flooding. However, as we were unable to obtain reliable data, we assume 20 per cent as per bushfires and cyclones, although this is likely to be conservative.

Under-insurance

Even when households have some insurance on the building and/or contents, there are several reasons why insurance payouts would understate the full cost of damage caused by extreme weather events. Table 2.3 summarises of losses not covered by insurance due to under-insurance, with further details provided below.

2.3 Estimated losses due to under-insurance

	Bushfire	Cyclone	Floods
	$ million	$ million	$ million
Excess	4.95	23.36	31.78
Unclaimed losses	1.14	20.56	23.79
Underinsurance	54.01	387.37	134.45
Total	**60.11**	**431.29**	**190.03**

Source: CIE estimates.

One reason why insurance losses understate the full costs associated with extreme weather events is that insurance policies typically have an excess (the amount of money a policyholder is required to pay towards the costs of a claim[26]). Higher excesses reduce the insurance premium the policyholder pays.

The ACCC recently found that average excess levels selected by policyholders in north Queensland and north Western Australia (areas vulnerable to cyclone damage) are

25 Australian Securities and Investments Commission 2005, *Getting Home Insurance Right*, September 2005, p.17.

26 See Australian Competition and Consumer Commission, 2020, *Northern Australia Insurance Inquiry*, Final Report, p. 41.

around $1200, around 50-60 per cent higher than the rest of Australia.[27] This suggests that consumers in areas at higher risk of damage from extreme weather events are choosing higher excesses to reduce their premiums.

Based on data provided by ICA for some sample events, the average domestic insurance claims was around $30 000 for cyclones and floods and $60 000 for bushfires. Assuming an average excess of $1200 in areas at higher risk of damage from extreme weather events, this suggests that insured losses understate total costs by between 2 per cent (bushfires) and 4 per cent (cyclones and floods) as a result of the excess.

2.4 Impact of excess on average claim

	Average claim[a]	Impact of excess[b]	Estimated insured losses[c]	Claims not covered by excess[dc]
	$	Per cent	$ million	$
Bushfire	60 000	2.0	247.6	4.95
Cyclone	30 000	4.0	584.0	23.36
Flood	30 000	4.0	794.6	31.78

[a] Based on data provided by ICA for some sample events. [b] Assumes average excess of $1200 based on: Australian Competition and Consumer Commission, 2020, *Northern Australia Insurance Inquiry*, Final Report, p. viii. [c] See table 2.1 above. [d] Impact of excess multiplied by estimated insured losses.

Source: CIE, Australian Competition and Consumer Commission, 2020, *Northern Australia Insurance Inquiry*, Final Report, p. viii.

In addition, the excess means that policyholders are unable to claim for minor damage.

- The Northern Australia Insurance Inquiry found that around 25 per cent of residents who had some insurance when their most recent event occurred, did not make a claim. A high excess was the main reason why some did not claim.[28]
- The information provided in the report suggests that the average loss not claimed for was around $2500 (i.e. around 60 per cent was less than $1000 and around 40 per cent between $1000 and $9999).

Based on this information, the estimated value of unclaimed damage is shown in table 2.5

2.5 Estimated value of unclaimed damage

	Average claims per year[a]	Estimated number that did not claim[b]	Estimated value of unclaimed damage[c]
	No.	No.	$ million
Bushfire	1 369	456	1.14
Cyclone	24 672	8 224	20.56
Floods	28 552	9 517	23.79

27 Australian Competition and Consumer Commission, 2020, *Northern Australia Insurance Inquiry*, Final Report, p. viii.

28 Australian Competition and Consumer Commission, 2020, *Northern Australia Insurance Inquiry*, Final Report, pp. 288-289.

[a] Based on publicly available ICA data averaged over the 10 years to 2022. Where the number of claims was not reported for some events, we apply the average number of total losses per building claims for the events where the relevant information is available. [b] Assumes that 25 per cent of residents with insurance did not claim. [c] Assumes the average loss not claimed for was around $2500.
Source: CIE, Australian Competition and Consumer Commission, 2020, *Northern Australia Insurance Inquiry*, Final Report, pp. 288-289.

The annual number of domestic building claims for each type of event (cyclone, flood and bushfire) is based on publicly available ICA data over the 10 years to 2022. Note that the number of claims was not reported for all events. Where the number of building claims is not reported we apply the average number of total losses per building claim for the events where the relevant information is available.[29]

There is also evidence from previous events of relatively high-levels of under-insurance. Reasons for under-insurance include the following.

- One reason for high levels of under-insurance in the context of a mass disaster is that the cost of rebuilding can increase significantly due to a spike in the demand for services in the relevant location.[30]
- Analysis by the ACCC also suggested that in high-risk areas (specifically northern Australia), some consumers appear to have frozen or even lowered their sums insured to manage premium increases.[31]

Specific evidence of under-insurance includes the following.

- Several studies after natural disasters have revealed inadequate levels of insurance.
  - Following the 2003 Canberra bushfires, ASIC conducted an investigation into underinsurance.
    - A survey of ACT homeowners undertaken by ASIC found that consumers were underinsured by 27 per cent on average (where they had rebuilt similar homes enabling a comparison with cover before and after the fire to be made).[32]
    - ASIC's report also notes that the Insurance Disaster Response Organisation reported that the homes destroyed in the ACT bushfires were underinsured by 40 per cent of the replacement cost, on average.[33]
    - The Insurance Council also gave evidence to the Commonwealth Parliament that the rate of underinsurance in the Canberra bushfires was around 40 per cent for property and 30 per cent for home contents.[34]
  - The Financial System Inquiry also reported research undertaken by Legal Aid NSW in relation to the Blue Mountains bushfires of 2013. This research found that of the 68 survey participants who were insured and had suffered a total loss of their

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29 The data for cyclones is also scaled up as modelled average annual losses are significantly higher than the average over the past 10 years (see chapter 3 for further details).

30 ibid.

31 Australian Competition and Consumer Commission, 2020, *Northern Australia Insurance Inquiry*, Final Report, p. 40.

32 Australian Securities and Investments Commission (2005), op.cit., p. 12.

33 ibid.

34 Australian Securities and Investments Commission (2005), op.cit, p.15.

home at the Blue Mountains, a total of 82 per cent experienced some level of underinsurance for their home building policy and/or home contents policy.[35]

- The ASIC investigation also reported survey evidence of high levels of under-insurance. In particular, a 2000 survey of 1000 randomly selected homeowners by a company specialising in estimating rebuilding costs found that the average level of underinsurance was 34 per cent.[36]

Based on this evidence, we assume under-insurance is around **35 per cent**. However, under-insurance is likely to be an issue only for properties with severe damage.

Based on the estimated number of uninhabitable buildings (see below), the estimated under-insured losses are estimated in table 2.6.

2.6 Estimated annual under-insured losses

	Number of uninhabitable buildings[a]	Rebuild costs[b]	Estimated under-insured losses[c]
	No.	$ million	$ million
Bushfire	441	154.33	60.73
Cyclone	3 162	1 106.77	122.91
Flood	1 098	384.14	134.45

[a] See table 2.6 below. [b] Assumes the average cost to build a home is $350 000, based on information provided by Master Builders Australia. [c] Assumes 35 per cent under-insurance.

Source: CIE estimates, MBA, ICA.

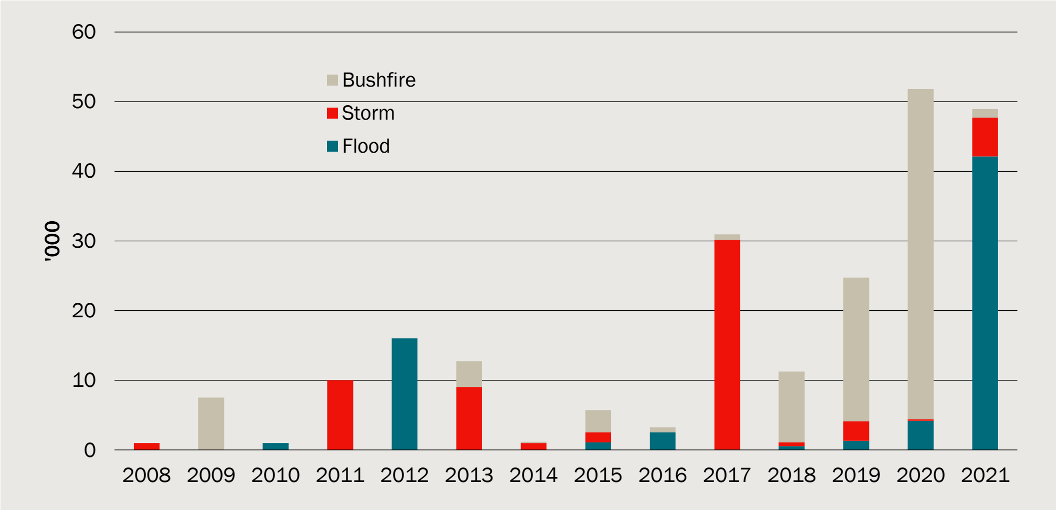
Long-term displacement

In addition to the costs associated with rebuilding, repairing and/or replacing buildings and contents, many households are displaced from their homes. The UN reports that around 50 000 Australians were displaced due to natural disasters in 2020 (mostly bushfires) and 2021 (mostly floods) (chart 2.7).

[35] Commonwealth of Australia 2014, *Financial System Inquiry — Final report*, 7 December 2014, p.228.

[36] Australian Securities and Investments Commission (2005), op.cit., p.12.

2.7 Number of people displaced by selected natural disasters



Data source: Internal Displacement Monitoring Centre.

In many cases, people return to their homes after a few days and these types of emergency evacuations are less likely to be affected by the resilience (or lack of resilience) of the dwellings themselves. Improved resilience would avoid longer-term displacements and the associated costs.

Number of uninhabitable dwellings

There is no systematic publicly available data on the number of households that are displaced from their homes for an extended period of time as a result of extreme weather event. Our indicative estimates are based on the following.

- We estimate the average number of domestic building claims for each type of event (cyclone, flood and bushfire) over the 10 years to 2022 based on publicly available ICA data. Note that the number of claims was not reported for all events. Where the number of building claims is not reported we apply the average number of total losses per building claim for the events where the relevant information is available.
- For cyclones this estimate is scaled up (approximately doubled) on the basis that modelled insured losses are higher than the 10 year average (see chapter 3 for further details).
- We then estimate the share of total domestic building claims that are likely to be uninhabitable based on an event (of each type), where an estimate the number of uninhabitable dwellings has been reported.
- We also estimated the number of uninhabitable dwellings based on assumed rates of uninsured dwellings.

Estimates based on this approach are shown in table 2.8. Further details are provided in the relevant chapters.

2.8 Estimated number of uninhabitable dwellings

	Estimated number of domestic building claims per year[a]	Share of claims for uninhabitable buildings[b]	Estimated number of insured uninhabitable dwellings	Estimated number of uninsured dwellings[c]	Estimated number of uninhabitable dwelling
	No.	Per cent	No.	No.	No.
Bushfires	1 369	32	441	110	551
Cyclones	24 672	13	3 162	791	3 953
Floods	28 552	4	1 098	274	1 372

a Estimates based on the average number of domestic building claims for each type of event (cyclone, flood and bushfire) over the 10 years to 2022 based on publicly available ICA data. Where the number of building claims was not reported for some events we apply the average number of total losses per building claim for the events where the relevant information is available. [b] See relevant chapters for more details. [c] Assumes 20 per cent of dwellings are uninsured in high-risk areas.

Source: CIE estimates.

Duration of displacement from homes

The costs of long-term displacement also depend on the period of time the household is displaced from their home. There is limited data available on the duration of long-term displacements following an extreme weather event.

- The NSW 2022 Flood Inquiry refers to the need for emergency housing for up to 2 years.[37]
- The International Displacement Monitoring Centres reports that in Australia it takes people who have lost their homes in a disaster between 1 and 4 years to rebuild.[38]
- Master Builders Australia have estimated that recovery from the Tathra bushfires will take 3-5 years.[39]

A range of factors can affect the duration of displacement. For example, in past events, rebuilding has been delayed by local shortages of labour and other building materials.

For the purposes of the high-level assessment, we assume households are displaced from their homes for **2 years**.

Loss of housing service

When a dwelling becomes uninhabitable for a period of time, one of the direct costs is the loss of services provided by the dwelling while it is being repaired or rebuilt.

37 NSW Government, 2022 Flood Inquiry, Volume Two: Full report, 29 July 2022, p. 299.

38 International Displacement Monitoring Centre 2020, *The 2019-2020 Australian Bushfires: From Temporary Evacuation to Longer-Term Displacement*, September 2020, p. 13.

39 Chalmers, S. 2020, *Australian bushfire rebuild could take five years, builders warn, citing Tathra example*, ABC News website, https://www.abc.net.au/news/2020-02-04/bushfire-rebuild-could-take-five-years-tathra-two-years-on/11922002, 4 February 2020, accessed May 2023.

During this period, households must find alternative accommodation. This includes alternative rental accommodation, staying with family or friends; temporary accommodation, such as a caravan or other types of temporary housing.

In some cases, the cost of alternative accommodation is covered by insurance. This implies that these costs have already been covered in the insured losses estimates above. However, in many cases, this is an additional cost borne by the households themselves (or in some cases governments or charities).

Regardless of the cost of alternative accommodation, the best measure of the services provided by a dwelling is the rental value. Using this approach, we estimate that the average cost for each household displaced from their home for an extended period is around **$41,863** in present value terms (using a discount rate of 7 per cent), based on the following assumptions:

- The loss of housing services is an additional cost (i.e. not covered by insurance)
- Where houses become uninhabitable as a result of an extreme weather event, the average time the household is displaced is 2 years (see above)
- The annual rent is assumed to be $21 639 based on average weekly rent of $415 (based on the average housing costs for renters renting from a private landlord).[40]

Building-related mental health impacts

The link between natural disasters and mental health impacts is well-established in the Australian and international literature. According to the Black Dog Institute, it is normal for many people to experience intense stress reactions in the immediate aftermath of a disaster. Most disaster survivors recover without professional intervention within a number of months; however, a significant proportion will experience mental health problems in the months or even years after the initial event.

The most common mental health conditions reported across a range of disaster events are post-traumatic stress disorder (PTSD), depression, anxiety, substance abuse, and complicated grief. Some may also experience heightened suicidal risk, intense negative affect, acute stress, physical health or somatic concerns, and poor sleep quality.[41]

Prevalence of mental health issues following natural disasters

There are various estimates of the prevalence of PTSD and other mental health conditions for direct victims, generally in a range of around 20-60 per cent.[42] However,

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40 Australian Bureau of Statistics, *Housing Occupancy and Costs 2019-20*, Table 3.1 Mean Weekly Housing Costs, Released 25 May 2022.

41 The Black Dog Institute, *Mental Health Interventions Following Disasters*, February 2020, p.3.

42 See for example: Cerda, M. Bordelois, P.M. Galea, S. Norris, F. Tracy, M. and Koenen, K.C., 2013, The course of posttraumatic stress symptoms and functional impairment following a disaster: what is the lasting influence vs. ongoing traumatic events and stressors?, *Soc Psychiatry Psyciatr Epidemiol*, p. 2; Golitaleb, M. Mazaheri, E. Bonyadi, M and Sahebi, A. 2022, Prevalence of Post-traumatic Stress Disorder After Flood: A Systematic Review and

not all of these mental health impacts can be attributed to a lack of building resilience. In particular, various studies have found that factors unrelated to building resilience contribute to these adverse mental health outcomes. For example, a study of the mental health impacts of the Black Saturday bushfires found that people who either lost someone in the bushfire, or feared for their lives in the bushfire, were more likely to have: general (non fire-related) post-traumatic stress disorder (PTSD), fire-related PTSD; major depressive episodes; and severe mental illnesses.[43] It is less likely that these mental health impacts could be avoided through more resilient dwellings (although a more resilient home could possibly prevent loss of life and provide better protection for subsequent events in the context of multi-hazard events).

On the other hand, various studies have suggested that mental health issues are caused or exacerbated by the following inter-related factors:

- Property losses
- Ongoing post-disaster stressors, including:
  – challenges associated with rebuilding, and
  – related financial stresses[44]
- Disruptions to everyday life associated with living in temporary accommodation.[45]

Furthermore, there is some evidence that suggests 'ongoing stressors' contribute to worsening of mental health after disaster and that the relative impact of these stressors can increase over time.[46] On the other hand, people suffering from mental health issues (including PTSD, depression and psychological distress) caused by more direct effects of the disaster (including bereavement, fear and property loss) were more likely to recover over time.

This suggests that dwellings that are not resilient to extreme weather events are causing or exacerbating the mental health impacts on the community associated with extreme weather events.

Meta-Analysis, Frontiers in Psychiatry, p. 1; Ji-Min Park and Sung-Man Bae, 2022, Impact of depressive, anxiety and PTSD symptoms in disaster victims on quality of life: The moderating effect of perceived community resilience, International Journal of Disaster Risk Reduction, Volume 69, p. 2;

43 Bryant, R.A. Waters, E., Gibbs, L. Gallagher, C.G. Pattison, P. Lusher, D. MacDougall, C. Harms, L. Block, K. Snowdon, E. Sinnott, V. Ireton, G. Richardson, J. and Forbes, D. 2014, "Psychological outcomes following the Victorian Black Saturday bushfires", *Australian & New Zealand Journal of Psychiatry*, Volume 48, Issue 7, pp. 634-643.

44 See for example: The Black Dog Institute, *Mental Health Interventions Following Disasters*, February 2020, p. 3.

45 See for example: Cerda, M. Bordelois, P.M. Galea, S. Norris, F. Tracy, M. and Koenen, K.C. 2013, "The course of post-traumatic stress symptoms and functional impairment following a disaster: what is the lasting influence of acute v ongoing traumatic events and stressors, *Social Psychiatry and Psychiatric Epidemiology*, March 2013 48(3): pp. 385-395; or

46 See: Bryant, R.A. Waters, E., Gibbs, L. Gallagher, C.G. Pattison, P. Lusher, D. MacDougall, C. Harms, L. Block, K. Snowdon, E. Sinnott, V. Ireton, G. Richardson, J. and Forbes, D. 2014, "Psychological outcomes following the Victorian Black Saturday bushfires", *Australian & New Zealand Journal of Psychiatry*, Volume 48, Issue 7, pp. 634-643.

Of particular relevance to building resilience is the finding that people displaced from their homes are more likely to have post-traumatic stress symptoms. Cerda et. al. (2013) conducted several surveys of a random sample of 658 adults in Galveston, Texas over an 18-month period following Hurricane Ike. Survey respondents that were displaced from their homes (for more than 1 week) in the intervening period were more likely to have post-traumatic stress symptoms (see table 2.9 for estimates of the relative risk).[47]

2.9 Estimated relative risk of post-traumatic stress symptoms due to displacement

	Relative risk	95% CI: low	95% CI: high
First interview	1.67	1.28	1.5
Second interview	1.43	1.07	1.9
Third interview	2.00	1.02	3.94

Source: Cerda, M. Bordelois, P.M. Galea, S. Norris, F. Tracy, M. and Koenen, K.C. 2013, "The course of post-traumatic stress symptoms and functional impairment following a disaster: what is the lasting influence of acute v ongoing traumatic events and stressors, *Social Psychiatry and Psychiatric Epidemiology*, March 2013 48(3): pp. 15-16.

Valuing mental health impacts

A standard economic approach to measuring health-related impacts (including mental health impacts) in cost-benefit analysis is summarised in box [48].

47 Cerda, M. Bordelois, P.M. Galea, S. Norris, F. Tracy, M. and Koenen, K.C. 2013, "The course of post-traumatic stress symptoms and functional impairment following a disaster: what is the lasting influence of acute v ongoing traumatic events and stressors, *Social Psychiatry and Psychiatric Epidemiology*, March 2013 48(3): pp. 385-395.

48 2.10

2.10 Measuring health-related impacts

A standard approach to measuring health-related impacts is based on the concept of a disability-adjusted life year (DALY). This is a measure of healthy life lost, either through premature death or through living with disability due to illness or injury.[49] One DALY represents the loss of the equivalent of one year of full health. DALYs for disease or health condition are the sum of:

- the years of life lost due to premature mortality (YLLs) and
- the years lived with disability (YLDs) — YLDs are measured using a 'disability weight', a factor that reflects the severity of health loss from a particular health state on a scale from 0 (perfect health) to 1 (equivalent to death).[50]

In regulatory impact analysis (and cost-benefit analysis more generally), DALYs can be converted to a monetary value to enable health related impacts to be compared with other types of costs and benefits. DALYs can be converted to a monetary value using an estimate of the value of a statistical life year (VSLY), which refers to the notional value individuals place on each additional year of life.

The Commonwealth Government Office of Impact Analysis – OIA - (formerly the Office of Best Practice Regulation) recommends using:[51]

- a VSLY of **$227 000** (in 2022 dollar terms), and
- a discount rate of 3 per cent (for health-related impacts).

These recommendations were based on an earlier review of research into VSL and VSLY and international guidelines for life and health values (inflated to account for inflation).[52]

There are various disability weights used to value mental health impacts. The disability weights used by the Australian Institute of Health and Welfare (AIHW) for some relevant mental health conditions are shown in table 2.11.

49 Australian Institute of Health and Welfare, https://www.aihw.gov.au/reports-data/health-conditions-disability-deaths/burden-of-disease/glossary#:~:text=disability%2Dadjusted%20life%20years%20(DALY)%3A%20A%20measure%20of%20healthy,used%20synonymously%20with%20health%20loss., accessed 28 March 2023.

50 World Health Organisation, https://www.who.int/data/gho/indicator-metadata-registry/imr-details/158#:~:text=Definition%3A-,One%20DALY%20represents%20the%20loss%20of%20the%20equivalent%20of%20one,health%20condition%20in%20a%20population., accessed 28 March 2023.

51 Department of the Prime Minister and Cabinet, Office of Best Practice Regulation, *Best Practice Regulation Guidance Note Value of statistical life*, August 2022.

52 Abelson, P. 2008, *Establishing a Monetary Value for Lives Saved: Issues and Controversies*, Working papers in cost-benefit analysis, WP 2008-02.

2.11 Disability weights and annual cost of mental health condition

	Disability weight	Annual cost[a]
		$
Anxiety disorders		
Mild	0.030	6 810
Moderate	0.133	30 191
Severe	0.523	118 721
Major depressive disorders		
Mild	0.145	32 915
Moderate	0.396	89 892
Severe	0.658	149 366

[a] Disability weight multiplied by $227 000 (the value of a statistical life year as recommended by the Office of Impact Analysis).

Note:

Source: Australian Institute of Health and Welfare, Source: https://www.aihw.gov.au/reports/burden-of-disease/abds-methods-supplementary-material-2018/contents/estimating-burden-of-disease-measures/years-lived-with-disability-yld#Disability, accessed April 2023; Office of Impact Analysis, https://oia.pmc.gov.au/sites/default/files/2022-09/value-statistical-life-guidance-note.pdf, accessed April 2023.

The total cost of a mental health condition caused (or exacerbated) by displacement from the home also depends on the duration of the mental health condition. Table 2.12 shows the cost of relevant severe mental health conditions at different durations, using the approach recommended by the OIA.

The mental health impact of a lifelong severe anxiety order could be as high as **$2.8 million** assuming a further 40 years of life (this is the assumption used by OIA in estimating the average value of a statistical life).

2.12 Cost of mental health impacts by duration

Duration	Severe anxiety disorders	Major depressive disorder — severe episode
Years	$	$
1	118 721	149 366
2	233 984	294 382
3	345 890	435 173
4	454 537	571 864
5	560 019	704 574
6	662 428	833 419
7	761 855	958 510
8	858 386	1 079 958
9	952 106	1 197 869
10	1 043 096	1 312 346
40 (life)	**2 826 535**	**3 556 138**

Source: CIE estimates.

Various studies show that the mental health impacts of extreme weather events can be ongoing, so the average duration is not known. However, as this study relates specifically to building resilience and the costs associated with displacement from the family home, it makes sense to link the duration of the mental health condition to the period the household is unable to live in the home.

Expected mental health costs per displaced household

Based on the above information, we estimate that the expected mental health costs per displaced household is around $146 000 (table 2.13).

2.13 Expected mental health costs per displaced household

	Probability of mental health condition	Expected number of people per household[a]	Expected mental health cost per household[b]
		No.	$
Household that has not been displaced	0.30	0.78	182 508
Displaced household	0.54	1.40	328 514
Impact of displacement	**0.24**	**0.62**	**146 006**

Source: CIE estimates.

- We estimate that displacement (due to buildings lacking resilience) could cause around **24 per cent** of affected people to suffer from post-traumatic stress symptoms. This estimate assumes:
  - A base case of 30 per cent of people exposed to an extreme weather event suffering from related mental health conditions (consistent with various studies cited above).
  - A relative risk of suffering from post-traumatic stress symptoms of 1.8 for displaced households, consistent with the findings of Cerda et. al. (2013) (see table 2.9 above).
- This implies that on average an additional 0.6 people per household will suffer from post-traumatic stress symptoms, based on an average of 2.6 people per household.
- We focus specifically on PTSD as this appears to be the most common mental health condition associated with disasters.
  - Although there are other serious mental health conditions associated with disasters, there is a strong overlap between PTSD and both depression and alcohol use. This is consistent with much evidence of a strong overlap between these conditions.
  - Where there are comorbidities, the costs from mental health conditions are not additive. Therefore estimating the costs of other mental health conditions without adjusting for comorbidities would overstate the costs.
  - Nevertheless, the specific focus on PTSD is likely to understate mental health impacts.
- The average cost of the additional mental health condition is **$234 984** per person, based on:
  - an average displacement period of **2 years** (see above).
  - an average cost **of $118 721 per year** (see above).

Loss of productive capacity

Extreme weather events can impact on employment and other economic outcomes in various ways, including through:

- The impact on **demand** for labour — this can occur in various ways, including:
  - decreasing the demand for labour through firm disruptions and closures
  - increasing the demand for labour from reconstruction activities.
- The impact on the supply of labour, including:
  - Decreasing the ability of displaced households to work in their existing jobs.
    - In the short-term, households that are unable to return to their dwellings may temporarily be unable to work the same number of hours, due to the burden of finding alternative accommodation and preparing and submitting insurance claims.
    - In the longer term, their temporary accommodation may not be located in a location that would enable them to return to their previous job.
    - Where people work from home (which has become more prevalent following the COVID-19 pandemic), losing their also means losing their workplace.
    - Some people may lose their tools and other equipment necessary for their work (which may have been avoided through more resilient buildings).
  - Some members of the community could choose to increase the number of hours worked, for example to offset income losses where another member of the household has lost their job (i.e. this effect could offset reduced employment due to other effects).

As this study focuses specifically on impacts caused by a lack of building resilience, the primary relevant impact relates to the supply of labour (although there would also be an impact on the demand for labour). In particular, the lack of building resilience could reduce the supply of labour due to:

- The burden of finding alternative accommodation and preparing and submitting insurance claims. Note that improved building resilience is unlikely to avoid the need for an insurance claim; however, an insurance claim may be less onerous where there is less damage.
- The location of temporary accommodation may not be conducive to returning to a previous workplace. This is particularly relevant where a household is required to relocate to another town. In smaller communities where multiple dwellings are lost in a disaster, there may be limited capacity to absorb displaced households within the town.

The loss of commercial buildings can also affect labour market outcomes in several ways. In particular:

- The destruction of workplaces can affect demand for labour.
- The loss of schools or childcare centres could mean that some workers need to reduce the number of hours worked.

These outcomes are relevant to building resilience more generally. However, this study primarily focuses on residential buildings.

The Australian studies that have investigated the impacts of natural disasters on labour market outcomes have generally found limited impact on household employment and incomes.

- Hickson and Marshan (2022) found that in Australia:[53]
  - Floods tend to **increase** the labour supply of both men and women.
  - Bushfires increase male employment, but reduce female employment. This is partly explained by the expansion of industries that are generally male-dominated and the contraction of industries that tend to be dominated by females.
- Johar et. al. (2020) found that the destruction of homes due to natural disasters had no average impact on employment or income, but increased financial hardship.[54]

However, it is not necessarily clear from observing labour market outcomes which mechanism(s) are causing any change. It is possible that there are several effects working together and sometimes in opposite directions.

This implies that even though the evidence suggests the net impact of natural disasters *generally* on employment outcomes appears to be limited (or possibly positive), it is plausible that the lack of building resilience *specifically* could still be having a negative impact on labour supply (i.e. the impact of natural disasters on employment may be more positive with improved building resilience).

In this regard, several international studies have suggested households that were displaced from their homes as a result of natural disasters generally had poorer employment outcomes than those that were not.

- Chang-Richards et. al. (2019), found that following the Canterbury earthquakes in New Zealand, workers who moved out of the region and who are employed elsewhere were more likely to have lower rates of labour force participation and employment and higher rates of unemployment than those who did not move.[55]
- Several US studies find that there are significant temporary impacts on labour market outcomes for those that are displaced from their homes, compared to those that are not.
  - Groen, Kutzbach and Polivka (2015) studied the responsiveness of individuals' employment and earnings to the damages and disruption caused by Hurricanes Katrina and Rita, which struck the US Gulf Coast in 2005. Key findings of this study included the following.
    - Groen, Kurtzbach and Polivka found a modest, but statistically significant reduction in income in the first year for those affected. On average, the

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53 Hickson, J. and Marshan, J. 2022, "Labour Market Effects of Bushfires and Floods in Australia: A Gendered Perspective", *Economic Record*, Vol. 98, September, 1-23.

54 Johar, M. Johnston, D.W. Shields, M.A. Siminsi, P. and Stavurova, O. 2020, *The Economic Impacts of Direct Natural Disaster Exposure*, Discussion Paper Series, IZA Institute of Labor Economics.

55 Chang-Richards, A. Seville, E. Wilkinson, S. and Walker, B. 2019, "Effects of Disasters on Displaced Workers", Chapter in *Resettlement Challenges for Displaced Populations and Refugees*, p. 193.

reduction in incomes was estimated at around **2.2 per cent**, reflecting a shift from employment to non-employment.
  - Importantly, individuals that were forced to take up temporary residence in other areas due to damage to their homes were estimated to experience a much larger reduction in earnings in the first year of around **16 per cent**.[56]
  - In the longer-term, average earnings for those affected by the event were higher than those that were not.[57] These longer-term positive effects could reflect increased demand and/or reconstruction activities in the impacted areas.
- Vigdor (2007) also found that Hurricane Katrina had a strong negative impact on the labour force participation of evacuees, particularly those who were unable to return to their initial address within a few weeks. Evacuees on the whole lost 3 weeks of work, on average, in 2005; the effect is concentrated particularly among those who did not immediately return to their pre-Katrina address; this group averaged a loss of nearly 10 weeks of work in the last four months of 2005.[58]

If the results of these US studies apply in Australia, displacement due to severe damage (which may be a result of the lack of resilience of residential buildings) could be around **$24 870** for every displaced household. This estimate is based on the following assumptions.

- The loss per worker is estimated at around **$14 946** based on:
  - Average annual earnings of **$94 000 per year** (based on average weekly earnings of **$1807** as reported by the ABS)
  - Each worker loses **16 per cent** of their income as a result of displacement. This assumption is based on the estimated reduction in income for those displaced from their dwelling.[59]
- Each displaced household contains **1.66** workers based on:
  - an average of **2.6** people per household
  - an employment to population ratio of **64 per cent**.

[56] Groen, J.A. and Kutzbach, M.J. and Polivka, A.E. 2015, *Storms and Jobs: The Effect of Hurricanes on Individuals' Employment and Earnings over the Long Term*, US Bureau of Labour Statistics, p. 26.

[57] Groen and et al (2015), op.cit., pp. 29-33.

[58] Vigdor, J. 2007, *The Katrina Effect: Was There a Bright Side to the Evacuation of Greater New Orleans*, National Bureau of Economic Research Working Paper 3022, p. 3.

[59] Groen and et al (2015), op.cit., pp. 29-33.

3 Cyclones

Current arrangements

Cyclone Tracy, which hit Darwin on Christmas Day in 1974, was a watershed event for building standards in cyclonic regions of Australia. At that time, there was no requirement for houses to be fully structurally engineered to withstand high winds. As a result, Cyclone Tracy destroyed 50-60 per cent of dwellings in Darwin and only 6 per cent were classified as intact apart from minor damage to wall cladding or windows.[60]

Although preceding the nationally consistent Building Code of Australia (BCA), these events led to a significant strengthening of building standards across Australia.[61]

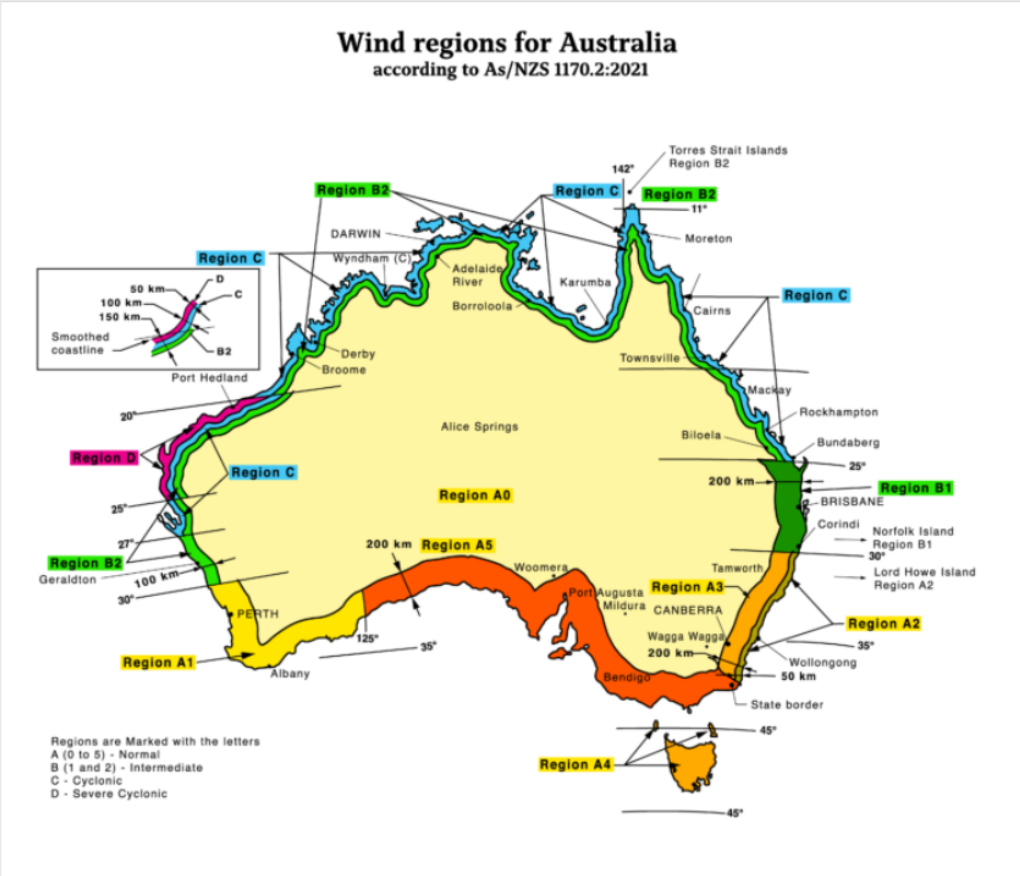
Under current requirements, Australia is divided into four main wind regions and several sub-regions (specified in the Standard AS/NZS 1170.2.2021 — see chart 3.1):

- Wind regions C and D are considered cyclonic
- Wind regions A and B are considered non-cyclonic.

60 Walker, GR 2010, A review of the impact of cyclone Tracy on building regulation and insurance, *Australian Meteorological and Oceanographic Journal*, No. 60, p. 199.

61 Walker, GR 2010, A review of the impact of cyclone Tracy on building regulation and insurance, *Australian Meteorological and Oceanographic Journal*, No. 60, pp. 199-206.

3.1 Wind regions



Data source: Standard AS/NZS 1170.2.2021.

BCA Volume One provides requirements for buildings of Class 2-9 buildings (all buildings except houses and small non-habitable buildings). The requirements are based on specified design wind speeds affecting structural and glazing design. The design wind speeds are specified in terms of the annual probability of exceedance and vary depending on:

- the wind region ; and
- the Importance Level of the building — the BCA has adopted a four Importance Level classification (table 3.2).

3.2 Design events for safety

Importance Level	Building types	Annual probability of exceedance	
		Non-cyclonic	Cyclonic
1	Buildings or structures presenting a low degree of hazard to life and other property in the case of failure	1:100	1:200
2	Buildings or structures not included in Importance Level 1, 3 or 4	1:500	1:500
3	Buildings or structures that are designed to contain a large number of people	1:1000	1:1000

Importance Level	Building types	Annual probability of exceedance	
		Non-cyclonic	Cyclonic
4	Buildings or structures that are essential to post-disaster recovery or associated with hazardous facilities	1:2000	1:2000

Source: NCC, https://ncc.abcb.gov.au/editions/2019-a1/ncc-2019-volume-one-amendment-1/section-b-structure/part-b1-structural-provisions-dts, accessed 4 May 2023.

BCA Volume Two sets requirements for buildings of Class 1 and 10 (houses and non-habitable buildings). These buildings are designated Importance Level 2. However, in practical application, design wind speeds are modified to account for site characteristics, including terrain, topography and shielding.

Size of the problem

Aspects of the size of the problem caused by cyclones in Australia are set out below.

Number of dwellings

One aspect of the size of the problem is the number of dwellings in cyclonic and transitional wind regions. Based on 2021 census data, we estimate there are around 2.8 million dwelling in cyclonic or transitional regions.

- These are mostly in south-eastern Queensland (Wind Region B1).
- There are around 490 000 dwellings in cyclonic, mostly in north Queensland (table 3.3).
- Perth (Wind Region A1) is also affected by cyclones, but has not been included in dwelling estimates.

3.3 Number of dwellings in relevant areas

	Wind Region B1	Wind Region B2	Wind Region C	Wind Region D	Total
	No.	No.	No.	No.	No.
Western Australia					
Separate houses	0	21 560	7 854	14 959	44 373
Multi-dwelling	0	3 600	1 514	5 711	10 825
Total	**0**	**25 160**	**9 368**	**20 670**	**55 198**
Queensland					
Separate houses	1 229 909	11 678	322 978	0	1 564 565
Multi-dwelling	889 559	789	73 150	0	963 498
Total	**2 119 468**	**12 467**	**396 128**	**0**	**2 528 063**
Northern Territory					
Separate houses	0	1 628	41 174	0	42 802

	Wind Region B1	Wind Region B2	Wind Region C	Wind Region D	Total
	No.	No.	No.	No.	No.
Multi-dwelling	0	296	21 844	0	22 140
Total	**0**	**1 924**	**63 018**	**0**	**64 942**
New South Wales					
Houses	114 717	0	0	0	114 717
Multi-dwelling	31 576	0	0	0	31 576
Total	**146 293**	**0**	**0**	**0**	**146 293**
Australia					
Houses	1 344 626	34 866	372 006	14 959	1 766 457
Multi-dwelling	921 135	4 685	96 508	5 711	1 028 039
Total	**2 265 761**	**39 551**	**468 514**	**20 670**	**2 794 496**

Source: ABS Census, CIE.

These are approximate estimates based on the estimated population of 'mesh blocks' within each Wind Region. Mesh blocks are the smallest geographic areas under the ABS's Australian Statistical Geography Standard (ASGS) and are designed (where possible) to contain between 30 and 60 dwellings (the current edition of the ASGS contain 368,286 mesh blocks).[62]

- Mesh blocks were allocated to wind regions based on the latitude and distance from the coast of the centre of the mesh block (see table 3.4).
- Estimates of the number of dwellings in each mesh block were based on 2021 Census data.

3.4 Wind regions

	Latitude	Distance from coast
Western Australia		
B2	<20°	50 – 100 Km
	20° – 25°	100 – 150 Km
	25° – 27°	50 – 100 Km
	27° – 30°	0 – 100 Km
C	<20°	0 – 50 Km
	20° – 25°	50 – 100 Km
	25° – 27°	0 – 50 Km
D	20° – 25°	0 – 50 Km
Northern Territory		
B2	All	50 – 100 Km

62 For more details, see https://www.abs.gov.au/statistics/standards/australian-statistical-geography-standard-asgs-edition-3/jul2021-jun2026/main-structure-and-greater-capital-city-statistical-areas/mesh-blocks, accessed 6 June 2023.

	Latitude	Distance from coast
C	All	0 – 50 Km
Queensland		
B1	>25°	0 – 200 Km
B2	<25°	50 – 100 Km
C	<25°	0 – 50 Km
New South Wales		
B2	<30°	0 – 200 Km

Source: See chart 3.1, CIE.

Average annual cost

We estimate that the residential building-related costs from tropical cyclones could be around $1.2 billion per year based on catastrophe modelling for the Northern Australia Insurance Taskforce. This is around double the estimated costs based on the 10-year average (table 3.5).

3.5 Estimated residential building-related costs from tropical cyclones

	Estimated cost based on 10-year average	Estimated cost based on catastrophe modelling
	$ million	
Insured losses	292.28	584.04
Uninsured losses	73.07	146.01
Under-insured losses	215.84	431.29
Mental health impacts	288.82	577.12
Loss of housing	82.81	165.47
Employment impacts	49.20	98.31
Total	**1 002.02**	**2 002.24**

Source: CIE estimates.

Insured losses

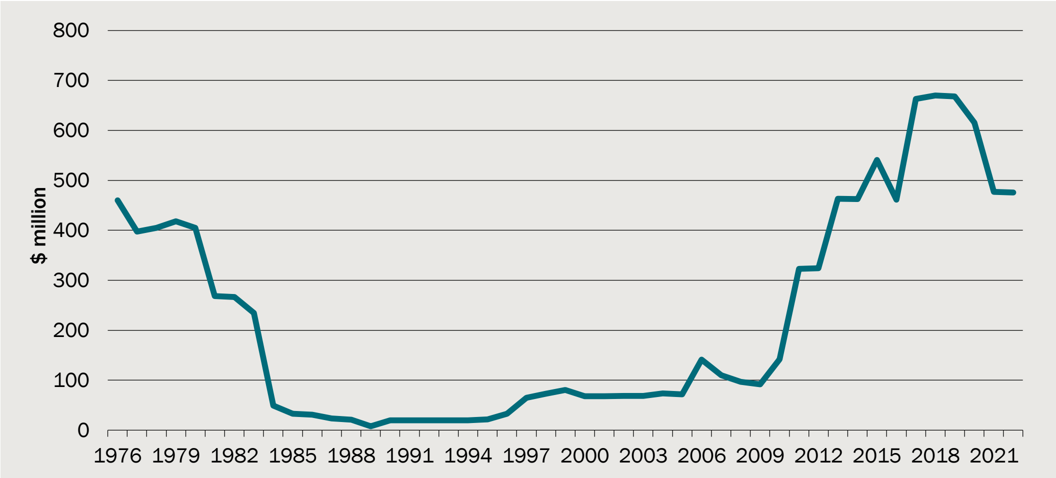
According to ICA data, insured losses from cyclones have increased significantly in the past 10-15 years (chart 3.6). This reflects the impact of a number of significant cyclone events during this period (including Tropical Cyclones Yasi, Larry and Debbie).

- Over the 10 years to 2022, average insured losses from cyclones were $487 million per year (in 2022 dollars) and have been in a range of around $500-700 million per year in recent years.
- This compares to average insured losses of less than $100 million per year from the mid-1980s through to the mid-2000s.

- In 10-year moving average terms, cyclone-related insurance losses has been higher in period prior to the mid-1980s reflecting the impacts of Cyclone Tracy (1974), which remains Australia's most costly cyclone event (in normalised terms) and several other costly cyclones during the 1960s and 1970s.

Close to 60 per cent of aggregate cyclone costs reportedly relate to residential buildings (47 per cent relate to home, 9 per cent to contents and 3 per cent to strata), which are the primary focus of this report.[63] This implies the average annual insured losses relating to residential buildings (and their contents) from cyclones is around $292 million.

3.6 Cyclone-related insurance losses — 10 year moving average



Data source: Based on the ICA Historical catastrophe list, inflated to 2022 dollar terms using the national CPI published by the ABS.

However, as damaging cyclones are relatively infrequent but high-cost events, losses over a decade (or several decades) are unlikely to be an accurate indicator of risk. Insurers therefore use catastrophe models to estimate risk.

Modelling for the Northern Australia Insurance Premiums Taskforce (in 2015) estimated average annual losses of around $494 million per year (table 3.7). This is around $584 million in 2022 dollar terms (inflated using the national CPI).

3.7 Average annual losses implied by catastrophe models

	Home	Contents	Strata	Total
	$ million	$ million	$ million	$ million
Northern Australia	235	29	21	285
Other	177	21	11	209
Total (2015 dollars)	**412**	**50**	**32**	**494**
Total (2022 dollars)	**487**	**59**	**38**	**584**

Source: Finity Consulting, *Financial Impact of Proposed Cyclone Schemes*, Northern Australia Insurance Premiums Taskforce, Reference No. 37002027, October 2015, p. 36.

63 Infinity Consulting, Financial Impact of Proposed Cyclone Schemes, Northern Australia Insurance Premium Taskforce, Reference No. 37002027, October 2015, p. 22.

Losses not covered by insurance

The approach to estimating losses not covered by insurance (due to no insurance or under-insurance) are as set out in chapter 2. For the central case estimates based on catastrophe modelling, losses not covered by insurance have been scaled up accordingly.

Long-term displacement costs

As set out in chapter 2, we use an estimate of the average number of domestic building claims as an indicator of the number of insured dwellings damaged each year over the 10 years to 2022. As the central case estimate is based on catastrophe modelling, we scale up the average over the past 10 years accordingly.

The assumed share that are uninhabitable each year is based on an analysis of insurance claims for Cyclones Yasi and Larry (by JCU for Suncorp Group Limited). Insurance claims were categorised as shown in table 3.8.

3.8 Claim categories

Loss ratio	Damage type	Typical damage
0 – 0.09	Minor damage	Minor roofing issues and water ingress, minor tree damage, fencing, shade sails, whirly birds, etc.
0.1 – 0.49	Moderate damage	Roofing and water ingress, ceiling damage, broken windows, wall cladding, etc.
0.5 – 0.99	Severe damage	Major roofing failures, water ingress damages and broken windows etc.
>1.0	Severe+ damage/underinsurance	Major roofing failures, water ingress damage, etc.

Source: Smith, D.J. and Henderson, D. Insurance Claims Data Analysis for Cyclones Yasi and Larry, Technical Report, Report for Suncorp Group Limited, April 2015, p. 9.

We estimate the number of uninhabitable dwellings (as a share of total claims) as follows.

- It is reasonable to assume that for claims where the damage is categorised as 'severe' or 'severe+', the building is uninhabitable.
- For claims where the damage is categorised as 'moderate', part of the dwelling will generally be uninhabitable and will need to be vacated while repairs take place. Even dwellings with moderate damage can take longer than 6 months to repair in a post-disaster environment. As a conservative estimate, we assume that 50 per cent of claims where the damage is categorised as moderate, the building is uninhabitable.
- For claims categorised as 'minor damage', we assume the dwelling remains habitable.

The share of claims in each category varied across the different regions. Based on a simple (unweighted) average across the 3 regions, these assumption imply around **13 per cent** of insurance claims are likely to relate to an uninhabitable building (table 3.9).

3.9 Estimated share of insurance claims where the building is uninhabitable — cyclones

Claim category	Assumed share of claim category uninhabitable	Share of claims by region			
		North Queensland Coastal Region	Townsville	Tully/Mission Beach	Simple average
	Per cent	Per cent	Per cent	Per cent	Per cent
Minor	0	86.1	94.2	55.2	78.5
Moderate	50	11.7	5.4	35.4	17.5
Severe	100	1.8	0.4	7.5	3.2
Severe+ or underinsured	100	0.5	0.1	1.9	0.8
Estimated uninhabitable		**8.2**	**3.2**	**27.1**	**12.8**

Note: Assumes that claims categorised as Severe or Severe+ are uninhabitable.

Source: Insurance Claims Data Analysis for Cyclones Yasi and Larry, p.12.

The costs associated with long-term displacement are estimated as set out in chapter 2.

New development in relevant areas

Comparing Census data on the number of dwellings in relevant areas between 2016 and 2021, indicates an additional 233 539 dwellings, mostly in Wind Region B1 (table 3.10). This is an additional 46 700 dwellings per year.

3.10 Additional dwellings in relevant wind regions — 2016 to 2021

	Wind Region B1	Wind Region B2	Wind Region C	Wind Region D	Total
		No.	No.	No.	No.
Western Australia					
Houses	0	251	365	-826	-210
Multi-residential dwellings	0	1553	160	1729	3442
Total	**0**	**1804**	**525**	**903**	**3232**
Queensland					
Houses	99 550	209	16 096	0	115 855
Multi-residential dwellings	93 976	118	5 307	0	99 401
Total	**193 526**	**327**	**21 403**	**0**	**215 256**
Northern Territory					
Houses	0	50	2911	0	2961
Multi-residential dwellings	0	11	1351	0	1362
Total	**0**	**61**	**4262**	**0**	**4323**

	Wind Region B1	Wind Region B2	Wind Region C	Wind Region D	Total
		No.	No.	No.	No.
New South Wales					
Houses	7 734	0	0	0	7 734
Multi-residential dwellings	2 995	0	0	0	2 995
Total	**10 729**	**0**	**0**	**0**	**10 729**
Australia					
Houses	107 283	510	19 372	- 826	126 339
Multi-residential dwellings	96 971	1 682	6 818	1 729	107 200
Total	**204 255**	**2 192**	**26 190**	**903**	**233 539**

Source: ABS Census of Housing and Population, CIE.

In percentage terms, this indicates an average annual increase in the dwelling stock within relevant regions of around 1.8 per cent (table 3.11).

- There was relatively rapid growth (1.9 per cent per year) in Wind Region B1.
- However, growth in the number of dwellings in the other Wind Regions was relatively slow.

3.11 Annual average increase in dwelling stock — 2016 to 2021

	Wind Region B1	Wind Region B2	Wind Region C	Wind Region D	Total
		Per cent	Per cent	Per cent	Per cent
Houses	1.7	0.3	1.1	-1.1	1.5
Multi-residential dwellings	2.2	9.3	1.5	7.5	2.2
Total dwellings	**1.9**	**1.1**	**1.2**	**0.9**	**1.8**

Source: ABS Census of Housing and Population, CIE.

If future development patterns are broadly reflective of development patterns over the 2016-2021 period, the number of dwellings at risk from tropical cyclones would increase by 1.8 per cent per year.

For the purposes of this analysis, we therefore assume that the costs from cyclones increases by around 1.8 per cent per year into the future, although we acknowledge that the risks for new buildings are lower than the average from the building stock.

Impact of climate change

A recent IAG report, *Severe Weather in a changing climate*, summarises the latest science in relation to the impact of climate change on various extreme weather events, including tropical cyclones. The report identified a number of emerging trends based on observations, theory and modelling simulations, that on balance are likely to increase the risks associated with tropical cyclones. The emerging trends highlighted in the report include the following:[64]

- Tropical cyclone frequency has declined slightly, but the proportion of intense tropical cyclones has increased markedly.
- The latitude at which cyclones reach their maximum lifetime intensity has shifted poleward, with the poleward shift expected to continue.[65]
- Tropical cyclone rainfall is already increasing and reaching further inland. For example, the area experiencing more than 600 mm of rainfall during a cyclone passage over south-eastern Queensland and north-eastern New South Wales has nearly doubled in the last decade. Further increases are expected with future warming.
- Tropical cyclone translational speed appears to be slowing at higher latitudes.
  - The IAG report argued that these slower speeds, combined with increasing intensity and rainfall, lead to a potential for substantial increases in cyclone impacts from wind (including wind-borne debris), rain and water ingress into buildings.
  - However, recent observations have suggested that faster moving events have strong wind speeds that penetrate further inland into wind regions where buildings are not designed for cyclones (this is more of an issue in WA).
- Sea levels are rising at an accelerating pace. Combined with increasing river runoff and more intense cyclones, this points towards substantial increases in storm surge impacts and coastal erosion.

The report also noted that socio-economic factors are placing more people and property at risk.

Under a 3 degrees warming scenario, South-East Queensland and North-East NSW will experience the largest relative (not absolute) change in the frequency of mostly high-intensity (Category 3-5) tropical cyclones, although are expected to be uncommon events.[66]

Although the IAG report suggested an increase in projected wind hazard, the recent Geoscience Australia report, *Severe Wind Hazard Assessment for South East Queensland*, noted there was also as significant body of research that points towards a general decline in wind hazard.[67] This ambiguity is reflected in their modelling, with one group of

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64 Bruyere, C. Buckley, B. Prein, A. Holland, G. Leplastrier, M. Henderson, D. Chan, P. Done, J. and Dyer, A. 2020, *Severe Weather in a changing climate*, 2nd edition, IAG, p. 15.

65 Bruyere, C. Buckley, B. Prein, A. Holland, G. Leplastrier, M. Henderson, D. Chan, P. Done, J. and Dyer, A. 2020, *Severe Weather in a changing climate*, 2nd edition, IAG, p. 102.

66 Bruyere, C. Buckley, B. Prein, A. Holland, G. Leplastrier, M. Henderson, D. Chan, P. Done, J. and Dyer, A. 2020, *Severe Weather in a changing climate*, 2nd edition, IAG, p. 35.

67 Edwards, M.R. Arthur, C. Wehner, M. Allen, N. Henderson, D. Parackal, K. Dunford, M. Mason, M. Rahman, M. Hewison, R. Ryu, H. Corby, N. and Butt, S., Severe Wind Hazard Assessment for South East Queensland: Technical Report, Record 2022/45, eCat 147446, Geoscience Australia, p. 117.

models suggesting a significant reduction in 1:500 average exceedance probability (AEP) and the other group suggesting a small increase.[68]

A concerning aspect of the poleward shift in the latitude at which cyclones reach their maximum lifetime intensity is the increase in risk in relatively densely populated areas in south-east Queensland and northern NSW. The recent hazard assessment for south-east Queensland by Geoscience Australia assessed the risk posed by severe winds by valuating the impact of extreme winds with different levels of probability on the residential building stock. Annual exceedance probability (AEP) wind speeds (incorporating tropical cyclone, thunderstorm and synoptic storm sources of extreme winds) were derived from the regional hazard analysis and combined with site exposure multipliers in the study areas.[69]

The report considered several plausible tropical cyclone scenarios. Across the scenarios, the average number of dwellings with damage classified as moderate or greater was around 182 500 (table 3.12).

3.12 Estimated number of dwellings damaged in south-east Queensland under plausible cyclone scenarios

	Moderate damage	Extensive damage	Complete damage	Total moderate damage or greater
	No.	No.	No.	No.
Scenario 1	105 300	135 801	1 180	242 281
Scenario 2	179 800	170 770	114	350 684
Scenario 3	155 400	81 181	11	236 592
Scenario 4	44 367	3 936	0	48 303
Scenario 5	30 200	4 429	1	34 630
Average	**103 013**	**79 223**	**261**	**182 498**

Source: Edwards, M.R. Arthur, C. Wehner, M. Allen, N. Henderson, D. Parackal, K. Dunford, M. Mason, M. Rahma, M. Hewison, R. Ryu, H. Corby, N. and Butt, S. *Severe Wind Hazard Assessment for South East Queensland*, Technical Report, Record 2022/45, eCat 147446, Geoscience Australia, pp. 81-89.

As a high-level indicator of the potential impacts of this poleward shift, we consider a scenario where the southern border of Wind Regions C on the east coast shifts southward at the rate observed over the past 30 years.

- Currently, Wind Region C (i.e. the area classified as 'cyclonic') on the east coast extends to 25° South.
- According to the IAG report, on the east coast of Australia, the Latitude of Lifetime Maximum Intensity (LLMI) has shifted 1.8° southward over the period from 1989 to

68 Edwards, M.R. Arthur, C. Wehner, M. Allen, N. Henderson, D. Parackal, K. Dunford, M. Mason, M. Rahman, M. Hewison, R. Ryu, H. Corby, N. and Butt, S., Severe Wind Hazard Assessment for South East Queensland: Technical Report, Record 2022/45, eCat 147446, Geoscience Australia, p. 123.

69 Edwards, M.R. Arthur, C. Wehner, M. Allen, N. Henderson, D. Parackal, K. Dunford, M. Mason, M. Rahman, M. Hewison, R. Ryu, H. Corby, N. and Butt, S., Severe Wind Hazard Assessment for South East Queensland: Technical Report, Record 2022/45, eCat 147446, Geoscience Australia, p. 59.

2020, a rate of 6.4 Km per year.[70] If Wind Region C were to extend south at this rate, a significant number of dwellings currently in Wind Region B1 (transitional) would move into Wind Region C (cyclonic) would increase significantly over time (table 3.13).

- As a high-level indicator of differences in risk, the modelling for the Northern Australia Insurance Inquiry suggested that around **60 per cent** of the average annual losses are likely to be incurred in Northern Australia (Northern Australia is defined as north of the Tropic of Capricorn). By comparison only around **15 per cent** of total dwellings in cyclonic and transitional regions (i.e. Wind Regions B1, B2, C and D) are in Northern Australia. This implies that on average cyclone damage per dwelling is around 7-8 times higher in Northern Australia than in cyclone-affected areas south of the Tropic of Capricorn.

Under the high-level assumption that damage per dwelling is around 7.5 times higher in cyclonic areas (most dwellings in Northern Australia are in cyclonic wind regions), this implies a large increase in the damage risk from cyclones. In general, the increase in risk through this mechanism is relatively modest to 2050. However, the risks would accelerate significantly as the poleward shift would eventually reach the area around Brisbane.

3.13 Potential impact of poleward shift on the number of dwellings in cyclonic regions

Year	Wind Region C (east coast) - southern latitude	Number of dwellings that would move into Wind Region C	Share of dwellings in Wind Region B1	Indicative increase in cyclone damage — Wind Region B1[a]	Indicative increase in total damage costs [b]
	Degrees	No.	Per cent	Per cent	
2020	25.0	0	0.0	0.0	0.0
2030	25.6	50 697	2.2	16.8	7.1
2040	26.2	62 065	2.7	20.5	8.7
2050	26.7	197 940	8.7	65.5	27.7
2060	27.3	414 757	18.3	137.3	58.1
2070	27.9	1280 517	56.5	423.9	179.3
2080	28.5	1561 224	68.9	516.8	218.6
2090	29.0	1624 351	71.7	537.7	227.5
2100	29.6	1638 009	72.3	542.2	229.4

[a] Assumes that damage

Source: CIE estimates.

Future projections

As an indicative estimate of future residential building-related costs of tropical cyclones, we assume:

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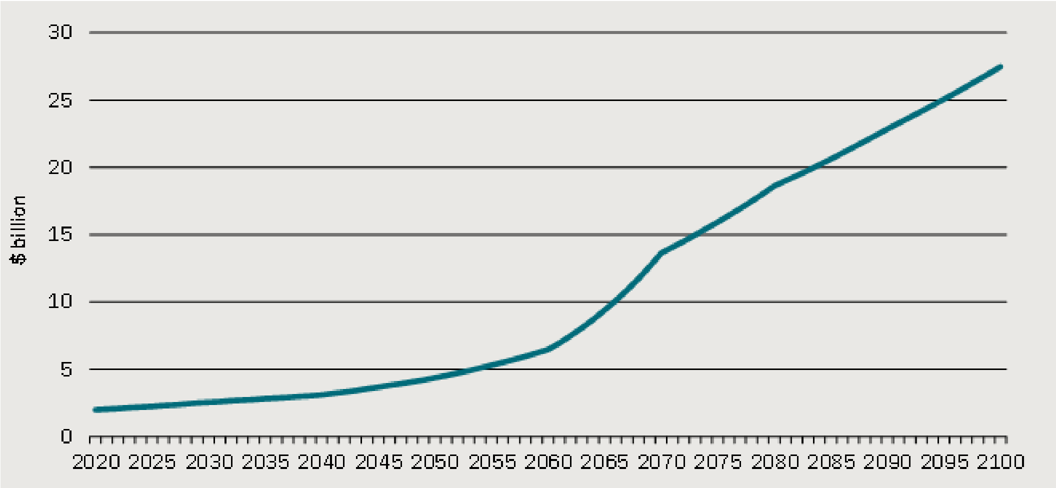
70 Bruyere, C. Buckley, B. Prein, A. Holland, G. Leplastrier, M. Henderson, D. Chan, P. Done, J. and Dyer, A. 2020, *Severe Weather in a changing climate*, 2nd edition, IAG, p. 29.

- a 1.8 per cent annual increase due to future development in affected areas
- an increase in costs due to climate change, as implied by table 3.13. This is an indicative estimate of the impact of the poleward shift in cyclone activity, but does not take into account other climate-related factors that are likely to increase costs from tropical cyclones, such as the increase in the proportion of intense tropical cyclones, increased rainfall (and greater inland penetration), and lower transitional speeds.

Under these high-level assumptions, the annual cost increases steadily to around $4.4 billion by 2050, but accelerates in the second half of the century to around $27.5 billion (in 2022 dollar terms) by 2100, as more densely populated areas become increasingly affected by cyclone activity (chart 3.14).

3.14 Estimated residential building-related costs from tropical cyclones — future projections



Data source: CIE estimates.

Limitations of the NCC

Previous studies, including some commissioned by the Insurance Council of Australia (ICA), have highlighted several limitations of the NCC in relation to cyclone-related damage. In particular, the ICA commissioned James Cook University (JCU) Cyclone Testing Station (CTS) and Risk Frontiers to identify key issues affecting modern housing during tropical cyclone events and to make recommendations that would improve Australia's resilience against tropical cyclones.[71]

Water ingress

The study reviewed the performance of modern (post-2000) residential construction impacted by tropical cyclones, based on industry-wide policy and claims data from several recent events in North Queensland, including Tropical Cyclones Yasi, Marcia

71 Insurance Council of Australia, *Climate Change Impact Series: Tropical Cyclones and Future Risks*, November 2021, p. 4.

and Debbie.[72] These events had a combined total cost of $3.83 billion (normalised to 2017 values). The IAG *Severe Weather in changing climate* report also noted that increased wind-driven rainfall ingress should be expected both inland and along the coast as winds are likely to decay more slowly.[73]

Key findings from the report were as follows.[74]

- Some modern homes (i.e. homes built to existing standards) suffered significant damage, even though wind speed did not exceed the design limits for the areas studied in the cyclone events analysed.
- Water ingress — including through wind-driven rain — was found to be a key driver of damage and common for homes with zero or minimal envelope damage.
  - At least 20 per cent of modern homes affected by a tropical cyclone were found to have some form of water ingress damage regardless of wind speed.
  - Once wind speeds exceed 35 m/s, at least 40 per cent of homes will have water ingress.
  - For properties which experienced close to design wind speeds of 70 m/s within wind region C, over 50 per cent of modern properties filed some form of insurance claim.
  - Non-structural damage can still render properties uninhabitable and the wider community dysfunctional for a long period of time.

The main issue appears to be in circumstances where there is both rain and high wind, the pressure leads to water ingress via seals or pan lengths for:

- windows
- vents
- doors
- flashings and valley gutters.

Building standards require strengthening in Wind Region B

Previous work has also highlighted some weaknesses in NCC standards in Wind Region B (transitional zone). This has largely been based on observations of the damage caused by Tropical Cyclone Seroja, which hit the region around Kalbarri on the Mid-West Coast of Western Australia, an area in Wind Region B2, in 2021.[75]

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72 ibid.

73 Bruyere, C. Buckley, B. Prein, A. Holland, G. Leplastrier, M. Henderson, D. Chan, P. Done, J. and Dyer, A. 2020, *Severe Weather in a changing climate*, 2nd edition, IAG, p. 102.

74 Insurance Council of Australia (2021), op.cit., pp. 5-6.

75 Insurance Council of Australia, Climate Change Impact Series: Tropical Cyclones and Future Risks, November 2021, p. 6.

- Despite not generating wind gusts above the design levels in the building code, Tropical Cyclone Seroja caused devastating damage with latest industry claims totals of $400 million (based on ICA Catastrophe List).[76]
- Damage surveys by CTS and the Western Australian government found that the high degree of damage was attributable to structural failures associated within internal pressures, for which houses in Wind Region B are typically not designed.
- If a house experiences damage to an external opening, such as a window, door or garage door in a tropical cyclone, it experiences a sudden positive internal pressure. Combined with the large uplift pressures on the roof, this overloads the minimal tie down components resulting in roof failures.
- This pattern of damage is generally not seen in Wind Region C for modern housing, where more stringent roof tie downs apply (compared with the requirements in Wind Region B).

Addressing water ingress from wind-driven rain

Some potential options to address water ingress from wind-driven rain and some high-level estimates of the potential impacts are presented below.

Options

It is beyond the scope of this exercise to develop a fully specified standard to address water ingress from wind-driven rain.

A previous article by the JCU team refers to this issue:

> "The pressure developed across the building envelope during windstorms frequently exceed the serviceability test pressures specified in AS 2047 (1999) for window resistance to water ingress. Therefore, if a severe storm event is accompanied by rain, water ingress can be expected. The only means of minimising water ingress is by incorporating adequate seals for all windows, vents, doors, flashings, etc."[77]

Estimated costs

Some indicative estimates of the costs of improved sealing were prepared by quantity surveyors, Rider Levett and Bucknall. The dwelling archetypes are summarised in box 3.15.

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76 Insurance Council of Australia website, https://insurancecouncil.com.au/industry-members/data-hub/, accessed July 2023.

77 Henderson D. and Ginger, J. 2008, 'Role of building codes and construction standards in windstorm disaster mitigation', *The Australian Journal of Emergency Management*, Vol. 23, No. 2, May 2008, p. 45.

3.15 Dwelling assumptions — costings

The costings are based on the following dwelling archetypes.

- The Class 1a archetype was based on a 4-bedroom freestanding house with a total area of 230 m2.
- The Class 2 multi-unit dwelling was based on the average across an apartment complex that includes:
  - 89 x 1 bedroom units
  - 67 x 2 bedroom units
  - 16 x 3 bedroom units
  - 6 x other units.

For Class 1a buildings (separate houses), the costs were estimated at around $8,000 per dwelling (table 3.16).

3.16 Estimated cost of improved sealing — Class 1a

	Unit	Quantity	Rate	Total
		Unit	$	$
Windows	m	101.4	31	3 143
Vents:				
— Replace: Dektite and penetration	No.	- 2.0	210	- 420
— Back tray penetrations	No.	2.0	1 060	2 120
Doors	m	38.6	27	1 042
Flashings	m	77.0	27	2 079
Total				**7 965**

Source: Rider Levett Bucknall.

The average cost per dwelling for the Class 2 complex is estimated at around $3,700 (table 3.17).

3.17 Cost of improved sealing — Class 2

	Unit	Quantity	Rate	Total cost	Total cost per dwelling
			$	$	$
Windows	m	7 251.0	36	261 036	1 466
Vents:					
- Dektite and penetration	No.	- 143.0	240	-34 320	- 193
- Back tray penetrations	No.	143.0	1250	178 750	1 004
Doors	m	2 760.2	31	85 566	481
Flashings	m	5 506.2	31	170 692	959
Total				**661 724**	**3 718**

Source: Rider Levett Bucknall.

Potential benefits

Water ingress from wind-driven rain has been found to be a significant driver of insurance costs in relation to cyclones, even when wind speeds remain below design levels. We estimate the total expected cost in the event of water ingress from wind-driven rain could be around **$42,154** per dwelling (table 3.18), based on the following assumptions.

- The average cost of repairing damage from water ingress is estimated at around $19,769 (in 2018 dollar terms), which is around **$21,769** in 2022 dollars (inflated using the national CPI).
  - Previous analysis of housing claims found that the average cost of repairing damage from the water ingress was $25,000 (in 2018 dollar terms).[78]
  - However, as many policy-holders do not claim where the damage is minor, this could overstate the average cost. As discussed in chapter 2:
    - The Northern Australia Insurance Inquiry found that around **25 per cent** of residents who had some insurance when their most recent event occurred, did not make a claim. [79]
    - The information provided in the report suggests that the average loss not claimed for was around **$2500** (i.e. around 60 per cent was less than $1000 and around 40 per cent between $1000 and $9999).
  - The average cost is based on a weighted average of the cost of claims (75% x $25,000) and the cost of minor damage that did not result in a claim (25% x $2500).
- A previous ICA study notes that non-structural damage can still render properties uninhabitable and the wider community dysfunctional for a long period of time.[80] The proportion of properties that become uninhabitable and the average period these properties are uninhabitable is not clear. For illustrative purposes, we assume:
  - **8.8 per cent** of properties damaged through water ingress (without significant structural damage) become uninhabitable.
    - This assumption is consistent with the assumption that 50 per cent of claims with 'moderate damage' are uninhabitable (see above). Claims with moderate damage were around 17.5 per cent of total claims, based on analysis for Cyclones Yasi and Larry (although the share of properties that become uninhabitable through this mechanism may be lower).
    - Note that this assumption is drawn from cyclone regions, which may not apply in Wind Region B (in general, there will be less damage through water ingress from wind-driven rain in Wind Region B and more significant structural damage).
  - these properties are uninhabitable for a period of 18 months.

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78 James Cook University Cyclone Testing Station, *North Queensland Study into Water Damage from Cyclones*, October 2018,

79 Australian Competition and Consumer Commission, 2020, *Northern Australia Insurance Inquiry*, Final Report, pp. 288-289.

80 Insurance Council of Australia (2021), op.cit., p.5

- Based on these assumptions (see the approach to estimating these impacts set out in chapter 2):
  – the expected mental health impacts are estimated at around **$15,431** per dwelling.
  – the expected loss of housing services is estimated at around **$2778** per dwelling
  – the expected employment impacts are estimated at around **$2176** per dwelling.

The ICA study reports that once wind speeds exceed 35 m/s, at least 40 per cent of homes will have water ingress.[81] This implies that the expected loss once the windspeed exceeds 35 m/s is around **$16,862** (table 3.18). A more comprehensive approach would use different vulnerability curves for different levels of damage to the building envelope (following the approach used in the Geoscience Australia report).

3.18 Expected losses due to water ingress

	Estimated loss in the event of water ingress from wind driven rain	Expected loss where wind exceed 35 m/s[a]
	$	$
Average cost of repairs	21 769	8 708
Expected mental health costs	15 431	6 172
Expected loss of housing services	2 778	1 111
Expected employment impacts	2 176	870
Total cost	**42 154**	**16 862**

[a] Assumes that 40 per cent of dwellings will be affected by water ingress once the windspeed exceeds 35 m/s.
Source: CIE estimates.

The annual benefits of the proposed measures depend on:

- The frequency with which wind speeds are likely to exceed 35 m/s — this will vary depending on a range of factors, including the wind region (see table 3.19 for an estimate of the benefits across different wind regions) and the specific location factors, including topography and shelter.
  – Estimated average return intervals (ARIs) are based on AS/NZS 1170.2:2021 and assume no local wind multipliers to account for upwind terrain category, shielding and topography. Note that AS/NZS 1170.2:2021 may be conservative and these wind speeds may be experienced less frequently for some buildings once shielding and other factors are taken into account. A more comprehensive analysis could consider the impact of shielding and different terrain etc.
  – The expected annual cost is the probability that the wind speed will exceed 35 m/s (i.e. the inverse of the ARI) multiplied by **$16,862**, the expected loss if such an event occurred (see table 3.18 above).
- How effective the proposed measures are at reducing the avoiding the impacts of wind-driven rain — although this is not known, we assume that the measures reduce the impacts of rain by 80 per cent (to reflect the fact that these measures are unlikely to be fully effective).

81 Insurance Council of Australia (2021), op.cit., p.6.

The expected lifetime benefit assumes a 50-year building life and uses a discount rate of 7 per cent.

3.19 Estimated benefits

	Average return interval	Annual exceedance probability	Expected annual cost[a]	Expected avoided cost[b]	Expected lifetime benefit[c]
	Years	Per cent	$		$
Wind region B	13.3	7.5	1 264	1 011	14 927
Wind region C	4.9	20.3	3 421	2 737	40 416
Wind region D	3.8	26.2	4 412	3 529	52 116

[a] Expected annual benefit is based on the annual exceedance probability multiplied by the expected loss in the event that the wind speed exceeds 35 m/s: $20 555 (see table 3.18 above). [b] Assumes the proposed measure is effective in reducing costs by 80 per cent. [c] Based on a 50 year life, using a discount rate of 7 per cent.

Source: CIE estimates.

Rainfall rates and volumes may increase with further climate change, which could significantly increase the costs under the base case, but also reduce the effectiveness of the proposed change.

Building-level impact

Bringing the indicative cost and benefit estimates together suggests that the benefits could significantly outweigh the costs for both houses and multi-dwelling in all relevant wind regions (table 3.20).

3.20 Building level impacts

	House: B	House: C	House: D	Multi-dwelling: B	Multi-dwelling: C	Multi-dwelling: D
	$	$	$	$	$	$
Expected lifetime benefit	14 927	40 416	52 116	14 927	40 416	52 116
Estimate cost	-7 965	-7 965	-7 965	-3 718	-3 718	-3 718
Net benefit/cost	**6 963**	**32 451**	**44 152**	**11 210**	**36 698**	**48 399**
Benefit-cost ratio	**1.9**	**5.1**	**6.5**	**4.0**	**10.9**	**14.0**

Source: CIE estimates.

Aggregate impacts

To estimate the aggregate level impacts, we multiply the lifetime building-level impacts across the average number of new dwellings in each wind region over the period to 2050 (table 3.21). This suggests that the net benefits could be in the order of **$7.8 billion**, using a discount rate of 7 per cent.

3.21 Aggregate impacts

	Benefits	Costs	Net benefit/cost
	$ billion	$ billion	$ billion
Houses			
Wind Region B1	4.40	- 2.35	2.05
Wind Region B2	0.02	- 0.01	0.01
Wind Region C	2.15	- 0.42	1.73
Wind Region D	0.00	0.00	0.00
Total - houses	**6.58**	**- 2.78**	**3.79**
Multi-dwelling			
Wind Region B1	3.98	- 0.99	2.99
Wind Region B2	0.07	- 0.02	0.05
Wind Region C	0.76	- 0.07	0.69
Wind Region D	0.26	- 0.02	0.24
Total – multi-dwelling	**5.07**	**- 1.10**	**3.97**
Total	**11.65**	**- 3.88**	**7.76**

Note: Estimates presented in net present value terms, using a discount rate of 7 per cent.
Source: CIE estimates.

Addressing internal pressure in Wind Region B

Some potential options to address internal pressure in Wind Region B and some high-level estimates of the potential impacts are presented below.

Options

Wind loading standards such AS/NZS 1170.2 and AS 4055 incorporate high internal pressure from large openings for tropical cyclone areas (Wind Regions C and D), but not for non-cyclone areas (including Wind Regions B1 and B2).

The problem arises where there is an opening in the building envelope, the internal pressure can lead to structural damage (including in some cases, the roof blows off).

The main strategies to address this issue appear to be:

- Measures to keep the building sealed, such as:
  - heavier doors/roller doors/door frames
  - stronger glazing/window shutters.
- Designing for internal pressure (e.g. strengthening the roof connections etc.) to minimise damage if an opening does occur.

According to Parackal et. al. (2022), Tropical Cyclone Seroja demonstrated that there is a strong case for requiring the design for higher internal pressure in intermediate wind regions such as Australia's Wind Region B.[82] Openings in the building envelope can occur due to behavioural factors (such as opening garage doors, doors or windows left open), which can be difficult to address through design (the concept of building in redundancy is also relevant here).

One option is to apply the internal pressure requirements that currently apply in Wind Regions C and D to Wind Region B (including B1 and B2). This has already happened in Western Australia (through a WA variation to the NCC), so the proposal is effectively extending this to Queensland, the Northern Territory and northern NSW.

Potential costs

The costs depend on how construction methods would change to achieve compliance with relevant changes to the NCC. The types of retrofit options to achieve greater resilience in existing dwellings are not relevant as they do not reflect contemporary construction methods in the relevant regions. Furthermore, design wind speeds are still lower in Wind Region B, so the design solutions will not be the same as for Wind Region C.

There are no publicly available estimates of the costs of complying with new internal pressure requirements in Wind Region B. As an approximate estimate, engineers from JCU have estimated that the additional costs could be in the order of **$4000 per dwelling** based on:

- a 1-2 per cent increase in the cost of manufactured roof trusses
- a 1-2 per cent increase in the roof structure tie down costs
- negligible increase in labour costs (assuming the builder is coming from Region B or C)
- no increase in wall framing construction (as the wind design speed would not change)
- an increase in the cost of windows and garage door.

These costs would need to be confirmed as part of a more comprehensive analysis.

Potential benefits

The proposed measures would, to some extent, avoid the costs associated with severe damage to the roof, as observed as a result of Tropical Cyclone Seroja.

- In the event of severe roof damage, costs are estimated at around $513,000. This is based on the following.

82 Parackal, K. Boughton, G. Henderson, D. and Falck, D. 2022, 'Minimising damage to houses by designing for high internal pressure', *Frontiers in Built Environment*, 23 November 2022, p. 10.

- The cost of rebuild/repair is assumed to be around $300,000. This is broadly consistent with the reported costs for dwellings with severe damage for Cyclones Yasi and Larry (once inflation is taken into account).[83]
- Assuming the dwelling is uninhabitable for 2 years:
  - Expected mental health costs are estimated at $146,000
  - The value of the loss of the services provided by the dwelling is estimated at around $41,863
  - The employment impacts could be around $24,870 (see above).
- The investigation estimated that more than 10 per cent of contemporary houses in Kalbarri had significant damage to the roof due to internal pressure following damage to doors or windows.[84] This implies that the expected cost in the event of a similar event is around $51,000 for new buildings built to the existing code.

3.22 Expected avoided cost

	Estimated cost	Expected cost: base case[a]	Assumed reduction	Expected avoided cost: proposed changes
	$	$	Per cent	$
Rebuild/repair cost	300 000	30 000	50	15 000
Mental health costs	146 006	14 601	100	14 601
Loss of housing	41 863	4 186	100	4 186
Employment impacts	24 870	2 487	100	2 487
Total	**512 739**	**51 274**		**36 274**

[a] Assumes that in the event of an event similar to Tropical Cyclone Seroja, 10 per cent of dwellings would be affected.

Source: CIE estimates.

Impact of the proposed measures

The impacts of the proposed measures have not been specifically modelled for this project. However, previous modelling provides some indication of the potential benefits from avoiding the type of roof damage observed from Tropical Cyclone Seroja.

Smith and Henderson (2015) modelled the impact of roofing upgrades on older (pre-1980s) houses based on insurance data from Cyclone Yasi.

- The modelling for structural roof upgrades was focused on pre-1960s and 1960-80s housing as follows:[85]
  - strapping at batten/rafter and ridge connections (pre-1960s and 1960-80s),

83 Smith, D.J. and Henderson, D. 2015, *Insurance Claims Data Analysis for Cyclones Yasi and Larry*, Report for Suncorp Group Limited, Cyclone Testing Station, James Cook University, pp. 12-17.

84 Boughton, G. Falck, D. Paracka l, K. Henderson, D. and Bodhinayake, G. 2021, *Tropical Cyclone Seroja: Damage to buildings in the Mid-West Coastal Region of Western Australia*, Cyclone Testing Station, Technical Report No. 66, James Cook University, p. 25.

85 Smith, D.J. Henderson, D.J. Terza, L.M. 2015, *Modelling Cyclone Loss Mitigation Using Claims Analysis*, Cyclone Testing Station, James Cook University.

  - collar ties between rafters (pre-1960s), and
  - vertical tension members between rafters and ceiling joists (1960-80s).
- The simulated roof upgrades were estimated to result in a **47 per cent** reduction in claims.[86]
- Although this study is not directly relevant to the proposed changes under consideration as: it refers to Wind Region C and covers different measures in a retrofit context, it nevertheless provides an indicative estimate of the benefits of preventing the roof from blowing off.

Parackal et. al. (2022) modelled the impact of different strategies to address roof damage in Wind Region B2, including:

- a house designed for low internal pressure (N2)
- a house designed for high internal pressure (C1)
- a house designed for low internal pressure, but with the addition of debris-rated shutters for all windows and doors to minimise the chances of internal pressurisation due to debris impact or windows and doors blowing in under wind pressures (N2 House + window and door protection).

This modelling more closely reflects the potential measures under consideration. A key observation from these modelling results (see chart 3.23) is that the measures to address internal pressure (i.e. the C1 house) completely eliminates the damage state involving significant roof damage from internal pressurisation in the N2 house (i.e. the high cluster of dots with a damage index between 0.6 and 0.9).

3.23 Modelling results

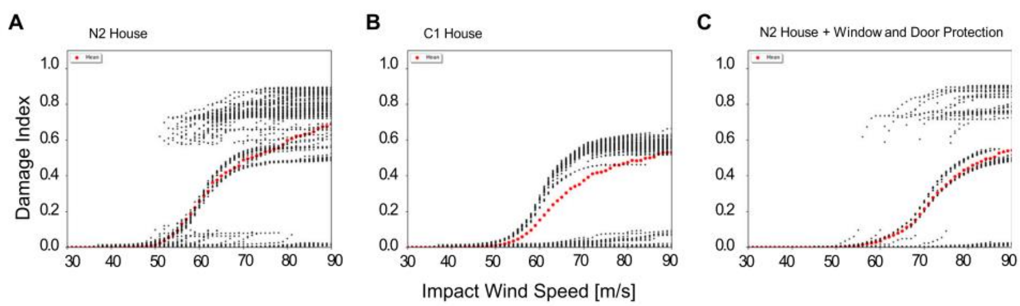

FIGURE 7
Vulnerability functions generated by the VAWS software for the case study house. **(A)** for an N2 wind rated house, **(B)** for a C1 wind rated house and **(C)** for a N2 wind rated house with window and door protection.

Data source: Parackal, K. Boughton, G. Henderson, D. and Flack, D. 2022, "Minimising damage to houses by designing for high internal pressure", *Frontiers in Built Environment*, p. 8.

As part of the severe wind hazard assessment for south-east Queensland (Wind Region B1), cost-benefit analysis was completed for a range of retro-fit options for various legacy

86 ibid.

house designs, as well as some modern code-compliant designs that are common in the study area, including with:[87]

- sheet metal roof and brick veneer walls
- tiled roof and brick veneer walls.

As the modern houses should be designed to comply with the NCC, the only retro-fit options considered was window protection and door upgrade.[88] Houses in Wind Region B1 have not been designed for high internal pressure. Therefore, NCC compliant houses are still exposed to severe damage from a tropical cyclone where large debris causes an opening in the envelope even if windows are protected and the external doors are upgraded. Key points from the analysis are as follows.

For the modern houses, the window protection and door upgrade reduced in the average annual loss (the report expresses the average annual loss as a percentage of full reconstruction costs) significantly.[89] The reductions in the average annual loss implied by the modelling varied depending on the Wind Hazard Category, but generally ranged from around 40 per cent up to more than 80 per cent.

The reported benefit-cost ratios for the retro fit to the modern homes was mostly well above 1, meaning the benefits outweigh the costs.[90] The benefits measured in the report included: avoided building damage loss avoided damage to contents achieved by reduced building damage and/or water ingress; and avoided temporary accommodation cost.[91] Some other costs that we have attempted to measure (including: mental health impacts and employment-related impacts). Our estimates imply that including these costs could add an additional 25 per cent to the benefits, which would make the benefit-cost ratios look even more favourable.

Based on these modelling results, reasonable high-level assumptions on the impacts of the proposed measures to address internal pressure are as follows.

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87 Edwards, M.R. Arthur, C. Wehner, M. Allen, N. Henderson, D. Parackal, K. Dunford, M. Mason, M. Rahman, M. Hewison, R. Ryu, H. Corby, N. and Butt, S., Severe Wind Hazard Assessment for South East Queensland: Technical Report, Record 2022/45, eCat 147446, Geoscience Australia, p. 45.

88 Edwards, M.R. Arthur, C. Wehner, M. Allen, N. Henderson, D. Parackal, K. Dunford, M. Mason, M. Rahman, M. Hewison, R. Ryu, H. Corby, N. and Butt, S., Severe Wind Hazard Assessment for South East Queensland: Technical Report, Record 2022/45, eCat 147446, Geoscience Australia, p. 51.

89 Edwards, M.R. Arthur, C. Wehner, M. Allen, N. Henderson, D. Parackal, K. Dunford, M. Mason, M. Rahman, M. Hewison, R. Ryu, H. Corby, N. and Butt, S., Severe Wind Hazard Assessment for South East Queensland: Technical Report, Record 2022/45, eCat 147446, Geoscience Australia, p. 103.

90 Edwards, M.R. Arthur, C. Wehner, M. Allen, N. Henderson, D. Parackal, K. Dunford, M. Mason, M. Rahman, M. Hewison, R. Ryu, H. Corby, N. and Butt, S., Severe Wind Hazard Assessment for South East Queensland: Technical Report, Record 2022/45, eCat 147446, Geoscience Australia, p. 106.

91 Mason, M. Rahman, M. Hewison, R. Ryu, H. Corby, N. and Butt, S., Severe Wind Hazard Assessment for South East Queensland: Technical Report, Record 2022/45, eCat 147446, Geoscience Australia, p. 104.

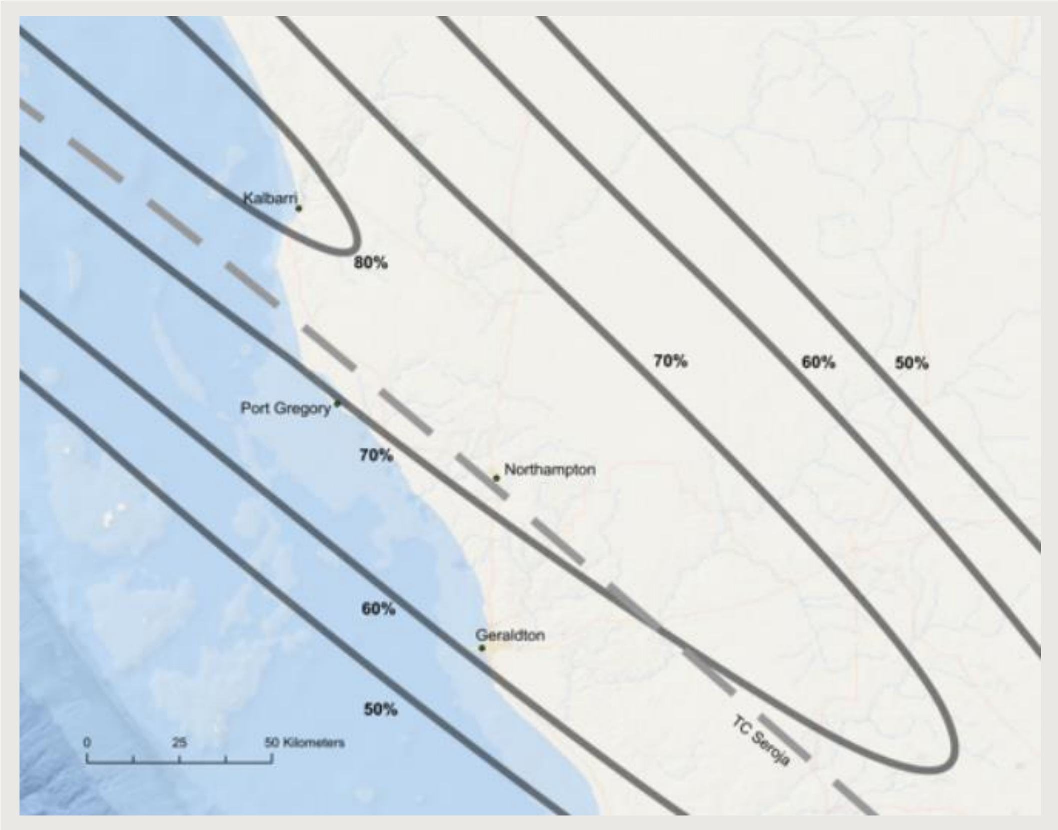
- The proposed measures reduce building damage by around 50 per cent, Even though the proposed measures eliminate the incidence of significant roof damage due to internal pressurisation, there is likely to be some damage through other failures.
- As Parackal et. al. (2022) indicates that the proposed measures eliminate the incidence of significant roof damage due to internal pressurisation (the specific issue under focus), we assume this would eliminate long-term displacement from the dwelling and therefore avoid the associated costs.

Estimated lifetime benefits

The benefits of the proposed changes are estimated at around **$7968** in present value terms (using a discount rate of 7 per cent) over an assumed 50 year life. This is based on an expected annual benefit of **$540** estimated as follows.

- The benefits depend on the frequency of an event similar to Tropical Cyclone Seroja occurring. The average return interval (ARI) for such an event is estimated to occur approximately every **17.9 years**
  - As discussed above, the wind speeds experienced during Tropical Cyclone Seroja were below the design level (set to withstand a 1 in 500 year event). According to the analysis by a team from the CTS at JCU, the peak gust wind speed produced would have been around 80 per cent of the design wind speed for Level 2 buildings in the areas where most of the extensive damage occurred (see chart 3.24 below).
  - The peak gust speed in the areas where most of the extensive damage occurred would therefore have been around 46 m/s (i.e. 80 per cent of the design speed of 57 m/s).
  - The ARI estimate for exceeding a wind speed of 46 m/s within Wind Region B is consistent with AS/NZS 1170.2:2021. Note that AS/NZS 1170.2:2021 may be conservative and these wind speeds may be experienced less frequently for some buildings once shielding and other factors are taken into account.
- This implies an annual exceedance probability (AEP) of around **1.5 per cent**. This is then multiplied by $38 274 (the expected avoided cost should such an event occur — see table 3.22 above).

3.24 Tropical Cyclone Seroja — wind speeds as a percentage of the design wind speed



Data source: Dr G. Boughton, D. Falck, Dr K. Parackal, Dr D. Henderson and G. Bodhinayake, Tropical Cyclone Seroja Damage to buildings in the Mid-West Coastal Region of Western Australia, Cyclone Testing Station, James Cook University, Technical report No. 66, 3 June 2021, p. 16.

Indicative building-level impacts

Estimated building-level impacts are shown in table 3.25. The estimates assume dwellings have a 50-year life and use a discount rate of 7 per cent. Under these assumptions, the benefit-cost ratio is estimated at around 2.

3.25 Estimated building-level impacts

	Estimated impacts
	$
Estimated lifetime benefits	7 968
Estimated costs	-4 000
Net impact	**3 968**
Benefit-cost ratio	**2.0**

Note: Benefits are estimated over the life of the building (assumed to be 50 years), using a discount rate of 7 per cent.
Source: CIE estimates.

Aggregate impacts

As Western Australia has already adopted these measures (as a variation to the NCC), the proposed changes would apply only in Queensland, the Northern Territory and northern NSW.

The estimated aggregate benefits reflect the lifetime benefits of all new houses built from 2024 to 2050. The estimated number of new houses per year was based on the change in the number of houses between the 2016 and 2021 Censuses in each Wind Region and State (see table 3.10 above) and also take into account state-based estimates of the proportion of existing houses that are demolished each year.

The aggregate net benefits are estimated at around $1.1 billion in net present value terms (using a discount rate of 7 per cent). Most of the benefits are estimated to accrue in Wind Region B1 reflecting higher levels of new development in that region.

3.26 Estimated aggregate impacts

	Wind Region B1	Wind Region B2	Total
	$ million	$ million	
Estimated benefits	2 349.7	5.7	2 355.4
Estimated costs	-1 179.5	- 2.8	-1 182.4
Net benefit/cost	**1 170.0**	**2.8**	**1 173.0**

Note: Impacts are presented in net present value terms and reflect the lifetime benefits (assumed to be 50 years) of all new houses built between 2024 and 2050.

Source: CIE estimates.

Key findings

Key findings from our high-level analysis in relation to tropical cyclones are as follows.

- A lack of resilience of residential buildings to tropical cyclones imposes significant costs on the relevant communities.
  - We estimate that these costs could be in the order of $2.0 billion per year.
  - These costs could increase to around $4.4 billion per year by 2050 and $27.5 billion by 2100 due to climate change and additional development in cyclone-prone areas (although the impacts of climate change are not settled).
- Several limitations in the current approach to mitigating risks associated with tropical cyclones through the NCC have been identified.
- The high-level estimates suggest that there may be scope to strengthen aspects of the NCC requirements in relation to tropical cyclones to improve building resilience.
- Furthermore, there is significant cross-over between storm and bushfire resilience measures. Taking into account these cross-overs would provide even more favourable outcomes from cost-benefit analysis.

4 Floods

Current arrangements

NCC's objective and the ABCB Standard

The scope of the NCC does not contain specific construction practice for buildings in flood prone areas, but its objectives of health, safety, amenity, and sustainability reflect performance requirements that buildings should be structurally resistant to the action of liquids, ground water and rainwater ponding.[92] Consistent with the scope of the NCC, the ABCB Standard on Construction of Buildings in Flood Hazard Areas (the ABCB Flood Standard) contains technical construction provisions to ensure that new buildings and structures do not collapse in a hazardous event up to and including the Defined Flood Event (DFE).[93]

The ABCB Flood Standard is designed mainly to cope with the infrequent flooding events in the order of 1 in 100 Annual Exceedance Probability (AEP). The 1 in 100 AEP flood event is also a common reference of flood hazards embedded in State or Territory flood related building and planning provisions.

In general, the ABCB Flood Standard provides minimum design requirements in the following aspects.[94] They are applicable to new Classes 1, 2, 3, 4, 9a health care units and 9c buildings.

- Flood height — the habitable floor is required to stay above the flood hazard level (FHL), i.e., the Defined Flood Level (DFL) plus the freeboard, and the non-habitable floors should not be more than 1 meter below the DFL.
- Footing system – the Deemed-to-Satisfy (DTS) provisions require the footing system to prevent flotation, collapse, or movement against a flood situation up to flow velocity of 1.5m/s.
- Enclosures below the FHL — the wet flood proofing is required by the DTS provisions for enclosures below the FHL. Floodwater is allowed to enter and leave the enclosures freely.
- Structural attachments — they must be structurally adequate so as not to cause failure of the main structure.

92 Australian Building Codes Board 2012, *Construction of buildings in flood hazard areas handbook,* p.4

93 Australian Building Codes Board 2012, *Construction of buildings in flood hazard areas*, p.1.

94 Australian Building Codes Board 2012, *Construction of buildings in flood hazard areas handbook,* pp.13-18

- Materials — the DTS provisions are applicable for wet flood proofing so that the materials are suitable for use when they are wet.
- Utilities — electrical, plumbing, telecommunication, HVAC services should be designed, constructed, and installed to prevent flood water from entering and accumulating within the system.
- Egress — a means of exiting the building must be available to allow rescue.

The ABCB Flood Standard serves as a risk mitigation instrument for flood hazards associated with new development in the floodplains. Nevertheless, land use planning is still the most effective measure to control flood hazards, as it prevents the problem of being flooded in the first place.[95] It addresses the issue of whether the building should be constructed in part of any flood hazard area; where construction is permissible, it underlies the minimum requirements that buildings must satisfy, often related to floor levels and fill levels.[96]

Locality-based risk management

Flood is a local hazard with parameters such as depth and flow velocity varying significantly within or across flood prone areas. As a result, flood risk management is primarily devolved to local councils (or in some cases in conjunction with water catchment or state government authorities) who are statutorily responsible for managing flood plains and playing a direct risk management role.

For example, land use planning in consideration of flood hazard is subject to local flood risk management. With building and planning regulations, local governments are able to identify the DFE and the related flood level, define the flood hazard areas, and determine the habitable floor height.

The 1 in 100 AEP flood is adopted as the common basis for setting the flood planning level. For instance, many local authorities in NSW require new houses to have their habitable floors at 0.5 metre (i.e., the maximum height of the freeboard specified in the ABCB Flood Standard) above the 1 in 100 AEP flood level.[97] Additional hazards associated with the full range of flood events up to the probably maximum flood (PMF) is often considered in information guidance for local flood plains.[98] Townsville land use planning used to adopt the 1 in 50 AEP flood standard.[99]

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95 Insurance Council of Australia, *Climate Change Impact Series: Flooding and Future Risks*, 2022, p.3

96 Australian Building Codes Board, *Construction of buildings in flood hazard areas handbook,* 2012, p. 13

97 Hawkesbury-Nepean Floodplain Management Steering Committee, *Reducing vulnerability of buildings to flood damage - Guidance on Building in Flood Prone Areas*, 2017, p. 3

98 ibid.

99 A Gissing, 'To build or not build: that is the Townsville question', in *Risk Frontiers*, 15 February 2019

Number of dwellings affected by flood hazards

According to the National Flood Information Database (NFID), at least 230,000 allotments are below the 100-year Average Recurrence Interval (ARI) flood level (i.e., within the 1 in 100 AEP flood zone). Of these allotments, about two thirds have a flood depth of less than 1 metre, and about three quarters have a flood depth less than 1.5 metre.[100]

There are a range of estimates for the number of dwellings affected by flood hazards (table 4.1). Nevertheless, the type of properties quoted to face the flood risks and reference data are unclear.

4.1 Estimates of dwellings and households affected by flood hazards

Estimate	Source
About 7 per cent of Australian households are subject to flood risks.	The 2018 AXCO Insurance Market Report, referred by the N Dufty, A Dyer & M Golnaraghi, *Flood Risk Management in Australia - Building flood resilience in a changing climate*, Zurich, The Geneva Association—International Association for the Study of Insurance Economics, 2020, p.24
Flood risk impacts less than 10 per cent of Australian dwellings.	A Dyer et al., 'Regional sensitivity of Australian flood risk to climate drivers', presented at the 2019 Floodplain Management Australia National Conference, IAG Natural Perils, p. 15.
Over 1 million private properties have some level of flood risk in Australia.	The IAG Fact Sheet - Flooding in Australia 2020, referred by Insurance Council of Australia, *Climate Change Impact Series: Flooding and Future Risks*, 2022, p.4
10 - 20 per cent of properties are often quoted to have flood risks.	Industry stakeholder

Source: as above.

In line with the scope of this high-level analysis, we estimated the number of flood-prone houses or semi-detached, row or terrace houses and townhouses (class 1a dwellings) by applying 10 per cent to the private dwelling stock for a ballpark figure. As of June 2022, 913 167 class 1a dwellings are estimated to have some level of flood risks (table 4.2). Of these dwellings, 835 958 dwellings are occupied, according to the ratio of occupied to unoccupied dwellings in the ABS 2021 Census data.

4.2 Implied number of Class 1a dwellings subject to flood risks, as of 2022 June

Dwelling stock	Houses, semi-detached, row or terrace houses and townhouses
	No. of dwellings
ABS estimated dwelling stock [a]	9 131 674
Implied number of flood prone dwellings	913 167

[100] Note that National Flood Information Database (NFID) does not include data for Melbourne and South Australia by the time of writing.

Australian Building Codes Board, *Construction of buildings in flood hazard areas handbook,* 2012, p.7

Dwelling stock	Houses, semi-detached, row or terrace houses and townhouses
	No. of dwellings
Occupied flood prone dwellings	835 958

[a] It excludes non-private dwellings that provide communal and short-term accommodation. It is a dwelling stock estimate includes both private and public/government owned dwellings for residential use.

Note: Class 1a buildings comprise separate houses and semi-detached, row or terrace house, and townhouses as a permanent and fixed structure intended for long-term residential use in ABS. https://www.abs.gov.au/methodologies/estimated-dwelling-stock-methodology/jun-quarter-2022

Source: CIE calculation based on ABS - estimated dwelling stock June Quarter 2022 and ABS 2021 Census - counting families at place of enumeration.

Size and nature of the problem

This section discusses the size of flood damage to residential buildings including property damage and disruption costs. Property damages are cost related to repair or rebuild damaged buildings in flood events, while disruption costs are related to uninhabitable homes, including mental health cost, loss of housing service (that is providing shelter to residents), and productivity loss. For details, please see chapter 2.

Dyer et al (2019) estimated the property damage measured as annual average loss (AAL) of a residential property which is a combination of annual likelihood of a flood event (i.e., the AEP) and the replacement value (i.e., sum insured). By aggregating AALs for all flood-prone residential property, the national property damages are totalled at $1.8 billion ($2.0 billion in 2022 dollar terms) per year under the current climate conditions.[101]

This estimate of property damages by Dyer et al (2019) may be overstated because the number of flood prone properties were overestimated without adjusting for unoccupied or unbuilt dwellings.

Dyer et al (2019) does not consider disruption costs.

Based on the ICA historical data which reflects the 10-year moving average of historical events since the 1960s, we estimated that the cost of property damages is more than $1 billion per year. Assumption that 15 per cent of damaged homes (insured and uninsured) are uninhabitable, disruption costs are estimated to be around $726 million.

The 2019 Townsville flood represents a recent major flood event. The average claimed loss to repair or rebuild homes was $90 023 in 2022 dollars during this event.[102] With this average loss per claim, it is estimated that total property damage caused by floods in Australia is $1.2 billion per year for both insured and uninsured losses.

101 Dyer, A., B. Buckley, P. Conway and M. Leplastrier 2019, *Regional sensitivity of Australian flood risk to climate drivers*, presentation to the 2019 Floodplain Management Australia National Conference, IAG Natural Perils, p. 13.

102 Insurance Australia Group, *Fact Sheet - Flooding in Australia*, 2020, p.4.

Only 9 per cent of total damaged homes (insured and uninsured) were uninhabitable during the 2019 Townsville floods. Applying this share leads to an estimate of the disruption costs at $368 million per year.

Table 4.3 compares these estimates.

4.3 Estimated size of flood damage, in 2022 dollars

	Estimate by Dyer et al (2019)	Estimates based on ICA historical data	Estimates based on the 2019 Townsville floods data
	$ million	$ million	$ million
Property damages [a]	2 042.4	1 183.2	1 234.5
Disruption-related losses [b]	n/a	267.2	267.4
Total losses	**2 042.4**	**1 450.4**	**1 501.9**

[a] including insured and uninsured residential properties

[b] excluding unoccupied dwellings

Source: Dyer, A. et al. 2019, 'Regional sensitivity of Australian flood risk to climate drivers', presented at the 2019 Floodplain Management Australia National Conference, IAG Natural Perils, p. 13.; ICA Historical Catastrophe Data; Insurance Australia Group , *Fact Sheet - Flooding in Australia*, 2020, p.4; and J Fernyhough, 'Insurers reveal Townsville flood cost, warn region is "unprofitable"', in *Australian Financial Review*, 2019.

The ICA report *Climate Change Impact Series: Flooding and Future Risks* also referred to an average claim of $142 000 for dwellings with a sum insured of $528 000 from aggregated data across insurers.[103] The claim data were largely sourced from the 2019 Townsville event and reflected flood damage for modern developments. The average claim cost will feed into the benefit cost analysis to illustrate how proposed building level modifications mitigate flood damage that occurs despite modern houses meeting current development controls and building standards.

Cost of property damage

Insured losses

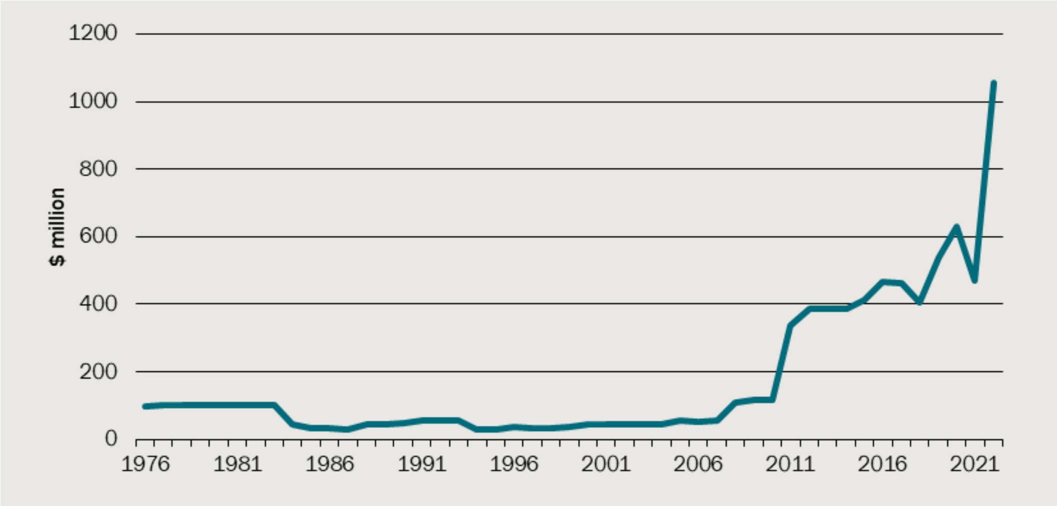
The ICA historical data show that insurance losses of flooding have increased significantly in recent years (chart 4.4). Average insured losses remained at about $110 million per year before increasing sharply from 2011 largely because flood covers were not commonly available prior to the 2010s. In the past decade, flood related insured losses ranged from $300 million to $1 billion in 10-year moving average terms. In 2022, the insured losses skyrocketed to $1 billion, reflecting the 2022 eastern Australian floods in Southeast Queensland.

While the ICA historical data provides a perspective of insurers to understand the size of the problem, it is acknowledged that it may not serve as the best source of information to capture large flood events in earlier years - for example, it misses the triple-dip La Niña

103 Insurance Council of Australia, *Climate Change Impact Series: Flooding and Future Risks*, 2022, p.7

events in 1973-76 and 1998-2001[104] - or reflect the true size of flood damage as a result of low uptake of flood cover before 2010s.

4.4 Flood-related insurance losses — 10 year moving average



Data source: Based on the ICA Historical catastrophe list, inflated to 2022 dollar terms using the national CPI published by the ABS.

Data provided by ICA for a small sample of 3 recent flood events suggests that on average around 75 per cent of total insured losses relate to domestic building and contents claims, which are directly related to a lack of resilience in residential buildings. This implies an annual cost of around $795 million.

Uninsured and under-insured losses

Using the methodology set out in chapter 2, uninsured and under-insured losses are estimated at around $587 million (table 4.5).

4.5 Losses not covered by insurance, in 2022 dollars

	Estimated losses
	$ million
Uninsured losses	198.6
Under-insured losses	190.0
Total	**587.3**

Note: See chapter 2 for the approach used to estimate uninsured and under-insured losses.
Source: CIE estimates.

104 Z Gillett & A Taschetto, *Multi-year La Niña events ARC Centre of Excellence for Climate Extremes Briefing Note 20*, Australian Research Council, 2022, p.2

Disruption-related costs

Based on the 2022 NSW and Queensland floods, we estimate that around 4 per cent of domestic building insurance claims relate to a building that is uninhabitable leading to long-term displacement.

- The NSW Flood Inquiry reported that over **5 000** homes were rendered uninhabitable.[105]
- ICA reports that there were around **130 000** domestic building claims.

This implies around 1 372 uninhabitable dwellings - including 1 098 insured and 274 uninsured dwellings - per year as a result of flood (table 2.8 above). The costs associated with long-term displacement are measured as set out in chapter 2 and summarised in table 4.6.

4.6 Disruption-related costs, in 2022 dollars

State/territory	Uninhabitable buildings	Alternative accommodation	Mental health costs	Income loss	Total [a]
	No. of buildings	$m	$m	$m	$m
National	**1 372**	**57**	**200**	**34**	**267**

[a] adjusted for unoccupied dwellings with the occupancy rate of 0.92 according to table 4.2.

Source: table 2.8 above

Impact of climate change

Climate change is expected to increase overall flood risks of Australian dwellings. There are two main climate drivers acting as risk multipliers on future flood risks in Australia:

- Sea level rise
- Intensified extreme precipitation.

Sea level rise

In Australia sea levels have continued to rise at an average rate of 2mm per year over the past five decades. According to CSIRO and the Bureau of Meteorology, a likely estimate of sea level rise in Australia by 2090 ranges from 45 to 82 mm higher than the 1986-2005 sea levels. Coastal cities such as Brisbane, Darwin, Perth, Adelaide and Sydney can expect an average sea level rise of 60-66 mm by 2090.[106]

The consequences of sea level rise include increased inundation of low-lying coastal areas, costal erosion, loss of beaches and intensified storm surges. Note that flood hazards associated with storm surges or costal wave actions are not considered in the current ABCB Flood Standard or the NCC.

105 NSW Government, 2022 Flood Inquiry Volume Two: Full report, 29 July 2022, p. 299

106 CSIRO & Bureau of Meteorology, *Climate Change in Australia - Technical Report*, 2015; referred by N Dufty, A Dyer & M Golnaraghi, *Flood Risk Management in Australia - Building flood resilience in a changing climate*, Zurich, The Geneva Association—International Association for the Study of Insurance Economics, 2020, p.26.

Intensified extreme precipitation

Observed warming has affected many weather and climate extremes in every region across the globe.[107] In Australia, recent studies on changes to extreme weather conditions note that:[108]

- Despite periods of extreme heat and drought, average daily rainfall increased by 7 per cent per degree of warming based on historical trends in Australian hourly and daily rainfall from the period 1966-1989 to 1990-2013.[109] It implies a general trend of increasing riverine flood risk related to increases in daily and sub-daily rainfall intensity.
- Frequency of intense rainfall increases. Intense precipitation across southern Australia increased by about 14 per cent per degree of warming and 21 per cent for the tropical regions.
- Observed flood severity for smaller, faster response catchments has increased. These catchments have increased flood frequency, flood volumes and peak flow rate, leading to non-linear incremental damage as a result of intensified short-duration rainfall.

Increased future flood risks

There are a few main implications of climate change for future flood risks:

- Changing flood extent. For example, a 0.95 per cent AEP zone can be flooded by a 1-in-100 AEP flood event and thus will be identified as a 1 per cent AEP zone. This implies increasing number of households and dwellings are subject to residual flood risks not targeted by current flood management measures.
- Increased flood depth and flood velocity. For the households and dwellings already located within the 1-in-100 AEP planning zone, they will incur greater damage as a result of increased flood hazards. This constitutes residual risk that may not be considered in current flood management measures.
- Changing the flood planning level (FPL). As a result of changing flood extent, the general FPL defined as 1-in-100 AEP flood line in land use planning would not suffice to delineate areas that are allowed for developments against those are not.

Table 4.7 summarises regional future flood risks based on current stock of residential dwellings under RCP 2.6 (limit warming to 2 ˚C) and RCP 4.5 (limit warming to 3 ˚C) scenarios based on Dyer et al (2019).

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107 IPCC, *Summary for Policymakers. In: Climate Change 2023: Synthesis Report. A Report of the Intergovernmental Panel on Climate Change. Contribution of Working Groups I, II and III to the Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change* , 2023, pp.4-5

108 C Bruyère, C., B. Buckley, A. Prein, G. Holland, M. Leplastrier, D. Henderson, P. Chan, J. Done and A. Dyer 2020, *Severe weather in a changing climate - 2nd edition*, IAG, September 2020, pp.37–48.

109 This is the average intense rainfall rate across cycles of high and low precipitation period, acknowledging that intense rainfall rates vary across regions. For example, intense rainfall rate is about 14 per cent per degree of warming for southern Australia and 21 per cent for the tropics.

4.7 Increased future flood risks (AAL) compared to current climate scenario by 2100

State/territory	RCP 2.6 scenario	RCP 4.5 scenario
	%	%
NSW	20	38
VIC	25	47
QLD	19	35
SA	25	49
WA	41	87
TAS	24	52
NT	23	50
ACT	25	55
National	**21**	**41**

Note: Flood risks are represented by the annual average losses by properties. This table summarise percentage increases in annual average losses as a result of climate change scenarios vis-à-vis current climate scenario, based on an unchanged stock of residential dwellings.

Source: Dyer et al (2019), Table 7, p. 13.

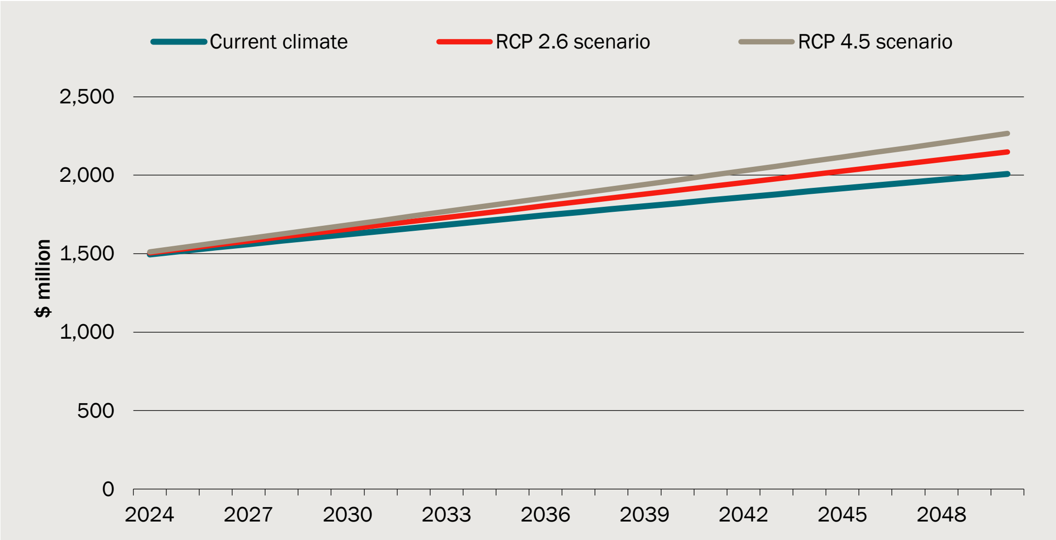
The RCP 2.6 scenario is also known as the low emission scenario where greenhouse gas emissions are significantly reduced to limit the global average temperature rise to 1.8˚C by 2100, compared to pre-industrial levels. This scenario is in line with the Paris Agreement's central aim and commonly pursued by global climate change policies. On average the flood risk will increase by 21 per cent for the whole nation by 2100 under this scenario.

The RCP 4.5 scenario expects a slower decline of greenhouse gas emissions, leading to a global average temperature rise of 2.7˚C by 2100, compared to pre-industrial levels. The flood risk will increase by 41 per cent for whole Australia by 2100 under this scenario.

Future projections

In line with the implied number of class 1a flood-prone dwellings (table 4.2), projected population growth and implied demand for private dwellings, annual total flood damage - property damage and disruption costs - is projected to exceed $2.0 billion under current climate by 2050 (chart 4.8). In consideration of climate risks, annual flood damage will exceed $2.1 billion in the RCP 2.6 scenario and $2.3 billion in the RCP 4.5 scenario.

4.8 Projected annual flood damage, 2024-2050



Note: Property damage and share of uninhabitable homes in total affected dwellings are adjusted to reflect climate risks.

Data source: CIE projection based on ICA data; ABS 2021 Census - counting families and counting dwellings, place of enumeration; Geneva Association 2020; and ABS Estimated dwelling stock June quarter 2022.

Limitations of the NCC

ABCB Flood Standard does not consider flood resilience

The ABCB Flood Standard is designed to reflect the current NCC objectives of health, safety, amenity and sustainability, so it primarily focuses on structural safety and life safety, rather than building resilience.[110]

For example, the ABCB Flood Standard does not contain detailed provisions for non-structural resilient materials or design solutions. In all instances, it calls for designers to use professional judgement for designs intended to comply with the NCC Performance Requirements, but there appears no testing standards or evidence base for professional to make their decisions.

Residual risks in a changing climate

Current Australian building standards and codes are underpinned by analyses of historical rainfall regimes and do not adequately account for current and future conditions.[111]

Larger floods than the defined flood events – typically 1-in-100 AEP flood events – can occur more frequently with unpredictable severity and exceed the design parameters and limitations in the ABCB Flood Standard. A changing climate has an implication that

110 Australian Building Codes Board, *Construction of buildings in flood hazard areas handbook,* 2012, p. 4.

111 Bruyère, C. and et al., *Severe weather in a changing climate - 2nd edition*, IAG, September 2020, p.37.

current building codes and standards have limited scope to reduce impacts from larger floods in current and future climate conditions.

Relation to land use planning

Land use planning appears a more direct, and probably more effective instrument because it intends to minimise risk exposure in the first place. However, it could be complemented by building standards and other instruments to form a comprehensive flood risk management system.

In certain instances, the existing land planning regime may prove insufficient to cope with increasingly frequent and intense weather events. This issue was exemplified by the inundation of the suburb of Idalia in Townsville in 2019. Despite being a new development that was not fully completed, Idalia experienced significant flooding primarily due to inadequate planning decisions. [112]

When faced with such situations where the inevitability of risk exposure arises from inappropriate land planning, enhanced building standards could play a crucial role in ensuring there is a minimisation of damage, disruption, and cost to the communities.

Impacts of illustrative flood resilient measures

This section discusses some illustrative measures to improve building resilience to floods, and their impacts through high level cost-benefit analyses.

Illustrative measures

To illustrate addressing residual risks in consideration of climate change, this analysis examines four property-level measures to be applied to new Class 1a developments for flood resilience:

- 1-meter elevation of ground slab above the defined flood level
- Polished concrete as habitable floor covering
- Single skin wall systems
- Installation of separate circuits to each level and elevation of power points

Estimated costs

Costing for the prosed measures per Class 1a new development is provided by RLB and summarised in table 4.9 below.

112 Commonwealth Government of Australia, 'Chapter 19: Land-use planning and building regulation' in *Royal Commission into National Natural Disaster Arrangements*, 2020, accessed 2 June 2023.

4.9 Costing for proposed measures per new development

Measure	Category	$ per new dwelling
1-meter elevation of ground slab above the defined flood level	Structural	46 006
Polished concrete as habitable floor covering	Non- Structural	33 320
Single skin wall systems	Non- Structural	103 270
Installation of separate circuits to each level and elevation of power points	Non- Structural	Minimal

Note: The benchmark example for class 1a new development is a 4-bedroom free-standing dwelling, with a gross floor area of 230m^2.
Source: RLB.

Potential benefits

Consistent with the localised nature of the flood risk, potential benefits vary on a building-by-building basis. As a result, the effectiveness of building level resilient measures is often poorly tracked and difficult to understand. A few flood resilience studies have reported evidence of reduction in damage and claimed losses for the proposed measures. The cost reduction due to resilient measures ranges from 25 per cent to 50 per cent (table 4.10). There is no evidence for single skin wall systems, so it is assumed to align with the cost reduction from overall resilience measures. A caveat is noted that overseas evidence is difficult to be scaled to Australian conditions, so a sensitivity analysis has been included for the measures with overseas evidence.

4.10 Effectiveness of examined measures in loss reduction

Measure	Country of assessment	Building loss reduction - low	Building loss reduction - high	Disruption-related loss reduction
		%	%	%
1-m floor elevation	By assumption		100	
Polished concrete	UK, scaled to AU	38	55	
Single skin walls	By assumption	25	50	
Accessing to electricity above the ground floor	Germany		36	
All measures	By assumption			100
Overall non-structural measures	**AU**	**25**	**50**	**100**

Note: Overall resilient measures do not consider floor elevation.
Source: Rhelm Consulting & Insurance Australia Group, *National Flood Hazard Mitigation Priorities*, Insurance Australia Group, April 2022, pp.31-32

The average tangible and intangible cost per claim (per building) in a major event is presented in table 4.11. The property damage cost per claim referred to the 2019 Townsville floods which were more severe than the 1 in 100 AEP flood event.[113] The ICA report *Climate Change Impact Series: Flooding and Future Risks* also estimated an

113 A Gissing, 'To build or not build: that is the Townsville question', in *Risk Frontiers*, 15 February 2019, accessed 11 May 2023.

average claim of $142 000 for an average sum average sum insured of $528 000 from aggregated data across insurers[114]. The majority claim data were sourced from the 2019 Townsville event; however, the type of house described as well as damage reported are typical of modern development and flood repairs across the country. This is despite these modern houses meeting contemporary development controls and building and standards, and thus our analysis refers to it inform an expected property damage cost per claim for a new dwelling.

4.11 Average costs per claim in a major flood event, in 2022 dollars

Measure	Current climate [a]	RCP 2.6 scenario [a]	RCP 4.5 scenario [a]
	$	$	$
Property damage	142 000	151 678	159 787
Disruption-related loss	19 292	20 607	21 708
Total loss per claim in an event	**161 292**	**172 285**	**181 495**

[a] by 2050 for an occupied dwelling. We assume that average costs under current climate remain unchanged.

Note: Disruption-related loss per dwelling is an expected loss per affected dwelling. The estimate in current climate is the per dwelling estimate in 2019 Townsville floods (table 4.3). It is derived by the number of displaced homes, multiplied by unitary disruption costs (incl. mental distress, loss of housing service, and income loss), divided by total number of affected properties. Estimates in RCP 2.6 and RCP 4.5 scenarios are adjusted for climate risk based on current climate's estimate.

Source: CIE calculation; Insurance Australia Group, *Fact Sheet - Flooding in Australia*, 2020; ABS CPI series, December quarter 2022

We assume in any given measure, disruption-related costs will be fully averted because they will only occur in case of a building becoming uninhabitable, which will be avoided by all proposed measures. The cost reduction varies with the AEPs. Table 4.12 demonstrates the cost reduction of adopting proposed measures with an AEP of 10 per cent.

4.12 Implied loss reduction per year per building in AEP=10% flood zone, in 2022 dollars

Measure	Current climate [a]	RCP 2.6 scenario [a]	RCP 4.5 scenario [a]
	$	$	$
Floor elevation	16 129	17 228	18 150
Non-structural measures - low	5 479	5 853	6 165
Non-structural measures - high	9 029	9 645	10 160

[a] by 2050 for an occupied dwelling

Source: CIE calculation; Insurance Australia Group, *Fact Sheet - Flooding in Australia*, 2020; ABS CPI series, December quarter 2022

Building-level CBA

Building level cost-benefit analysis (CBA) is conducted by bringing the above-mentioned indicative cost and benefit estimates together. It is assumed a new residential building will be built in 2050 with a building life of 50 years. It serves as a case study illustrating

114 Insurance Council of Australia, *Climate Change Impact Series: Flooding and Future Risks*, 2022, p.7

the potential for cost reduction in properties located within different AEP zones when confronted with a significant flood event comparable to the 2019 Townsville floods.

Whether the measures are economically viable (present value of benefits is higher than present value of costs, or a benefit-cost ratio over 1) is dependent on which flood zone the building is located as it determines annual likelihood of flood event and damage incurred. In general, the measures are more likely to be viable in areas with higher AEP levels.

In all climate scenarios, floor elevation is not economically viable for buildings located outside the flood zones with AEP of 1 per cent (table 4.13). The sensitivity test shows that floor elevation is generally economically viable for buildings located in areas above the AEP of 2.1 per cent. This estimate is in line with a building level analysis in recent literature in the sense that no effectiveness is found for buildings in an infrequent flood zone less than the AEP of 1 per cent. The analysis shows that for a typical established house with a floor level of 0.4 metre, 1.4-m elevation is not economically viable unless it is located within flood zone lower than AEP of 10 per cent, assuming remaining service life of 30 years.[115]

4.13 Benefits and costs associated with floor elevation

	AEP=1%	AEP=2.1%	AEP=5%	AEP=10%
	$	$	$	$
Cost				
	46 006	46 006	46 006	46 006
Benefits				
Current climate [a]	22 259	46 745	111 297	222 595
RCP 2.6 scenario [a]	23 777	49 931	118 883	237 766
RCP 4.5 scenario [a]	25 048	52 600	125 238	250 477
B/C ratio				
Current climate [a]	0.48	1.02	2.42	4.84
RCP 2.6 scenario [a]	0.52	1.09	2.58	5.17
RCP 4.5 scenario [a]	0.54	1.14	2.72	5.44

[a] For a new, occupied dwelling built in 2050 with a 50-year life of building.

Note: Estimates are expressed in the present value with a discount rate of 7%.

Source: CIE calculation; Insurance Australia Group, *Fact Sheet – Flooding in Australia*, 2020; ABS CPI series, December quarter 2022

In all climate scenarios, non-structural measures are not economically viable unless buildings are located within high likelihood areas. The sensitivity test shows that non-structural measures are generally economically viable for buildings above AEP of 11 per cent with the high impact assumption (table 4.14). Again, the estimates are consistent with results of an analysis for large scale resilience program based on the

115 Rhelm Consulting & Insurance Australia Group, *National Flood Hazard Mitigation Priorities*, Insurance Australia Group, April 2022, p.36

retrofit of a single dwelling. It shows that improved performance from resilience measures is viable for properties located outside the 1-in-20 AEP range.[116]

4.14 Benefits and costs associated with non-structural measures

	AEP=5%	AE=10%	AEP=11%	AEP=20%
	$	$	$	$
Cost				
	136 590	136 590	136 590	136 590
Benefits - low				
Current climate [a]	37 808	75 617	83 178	151 233
RCP 2.6 scenario [a]	40 385	80 770	88 847	161 541
RCP 4.5 scenario [a]	42 544	85 088	93 597	170 177
B/C ratio - low				
Current climate [a]	0.28	0.55	0.61	1.11
RCP 2.6 scenario [a]	0.30	0.59	0.65	1.18
RCP 4.5 scenario [a]	0.31	0.62	0.69	1.25
Benefits - high				
Current climate [a]	62 305	124 609	137 070	249 219
RCP 2.6 scenario [a]	66 551	133 102	146 413	266 205
RCP 4.5 scenario [a]	70 109	140 218	154 240	280 436
B/C ratio -high				
Current climate [a]	0.46	0.91	1.00	1.82
RCP 2.6 scenario [a]	0.49	0.97	1.07	1.95
RCP 4.5 scenario [a]	0.51	1.03	1.13	2.05

[a] For a new, occupied development built in 2050 with a 50-year life of building.

Note: Estimates are expressed in the present value with a discount rate is 7%.

Source: CIE calculation; Insurance Australia Group, *Fact Sheet - Flooding in Australia*, 2020; ABS CPI series, December quarter 2022

Break-even analysis

In line with building-level impact analysis above, break-even frequency of flooding for flood resilience measures are summarised in table 4.15. In general, the break-even frequency for the non-structural option is much higher than that for the elevation option.

116 Rhelm Consulting & Insurance Australia Group (2022), op.cit., p.35

4.15 Break-even AEP for flood resilience measures

x	Elevation	Non-structural option	
		Low impact	High impact
	AEP %	AEP %	AEP %
Current climate [a]	2.1	18.1	11.0
RCP 2.6 scenario [a]	2.0	17.0	10.3
RCP 4.5 scenario [a]	1.9	16.1	9.8

[a] For a new, occupied development built in 2050 with a 50-year life of building.

Source: CIE calculation; Insurance Australia Group, *Fact Sheet - Flooding in Australia*, 2020; ABS CPI series, December quarter 2022

Aggregate analysis

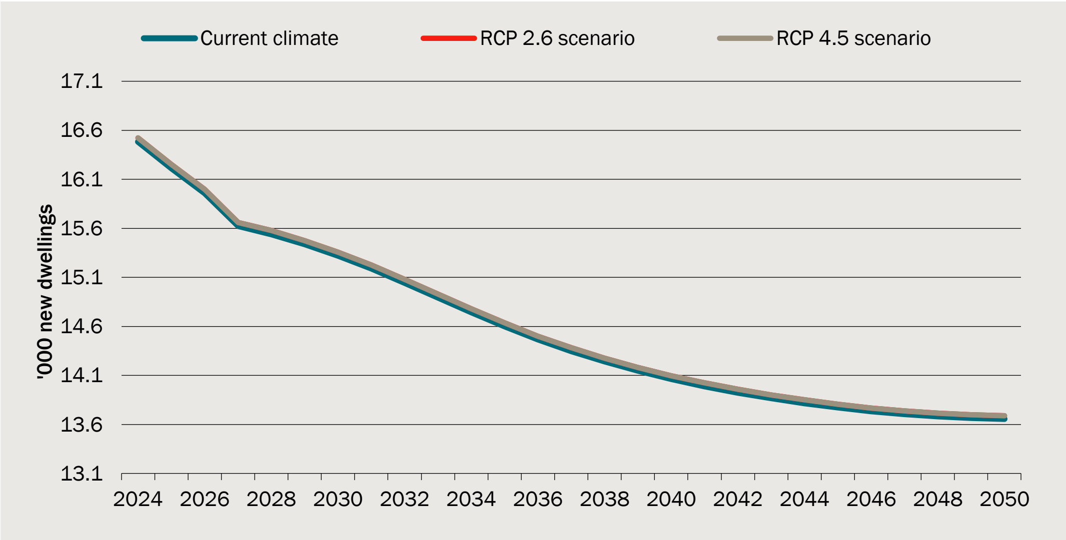
The aggregate analysis is conducted for new Class 1a buildings built from 2024 to 2050 with a building life of 50 years. Similar to the building level analysis, property damage costs are the estimated claim cost of ICA report *Climate Change Impact Series: Flooding and Future Risks*, as per the table 4.11.

Projections of new Class 1a buildings are presented first, followed by the CBA results.

Projections of new dwellings subject to flood risks

In line with population growth and implied demand for private dwellings, the projected number of new Class 1a dwellings declines throughout 2024 to 2050 (chart 4.16).

4.16 Projected number of new Class 1a developments subject to flood risks, 2024-2050



Data source: CIE projection based on ABS 2021 Census - counting families and counting dwellings, place of enumeration; Geneva Association 2020; ABS Estimated dwelling stock June quarter 2022.

Cost benefit analysis

The aggregate impact analysis combines building level impacts with the projected number of Class 1a new developments from 2024 up to 2050, assuming full adoption of all proposed measures from 2024 among new developments with 50-year life of building. Annual aggregate impacts incorporate annual growth of new development and annual growth of claimed costs given climate drivers.

In seeking an aggregate level analysis, we assume full adoption of proposed measures among all new class 1a developments subject to flood risks. Furthermore, we assume low, medium and high occurrence and intensity of flooding events to these flood prone buildings based on the AEP levels:

- Low – AEP of 1 per cent;
- Medium – AEP of 2 per cent; and
- High – AEP of 3 per cent.

Meanwhile, we assume a constant occupancy rate of 91.5 per cent in total flood prone class-1 dwellings and exclude disruption-related costs for unoccupied dwellings.

As non-structural option requires AEP greater than 9.5 per cent to break-even (see RCP 4.5 scenario in the table 4.15 above), it will have net costs under this broad region classification of AEP levels anyway. As a result, the aggregate analysis is focused on the elevation option.

Without more granular level details on new development decisions within and across AEP zones, we assume all new developments are to be built in each of the three AEP regions for the analysis.

Consistent with the building-level analyses above, proposed measures are not economically viable in infrequent flood zones. As shown in table 4.17, the elevation option is too expensive to be recouped for current climate and RCP 2.6 scenarios unless the AEP is at 2 per cent or higher. In addition, it is not economically viable for buildings outside the AEP of 1 per cent under all climate scenarios.

Unlike building level CBA break-even analysis (table 4.15), the elevation option does not break even among dwellings located at the AEP of 2 per cent under current climate and RCP 2.6 scenarios in the aggregate analysis (table 4.17). This is because the aggregate analysis includes unoccupied dwellings which do not reflect the benefit in the form of reduction in disruption related costs as they are not considered for unoccupied dwellings.

4.17 Benefit-cost ratio of aggregate analysis for elevation option

	Low		Medium		High	
	Net benefit	BCR	Net benefit	BCR	Net benefit	BCR
	$m	ratio	$m	ratio	$m	ratio
Current climate	-4 621	0.48	-373	0.96	3 874	1.44
RCP 2.6 scenario	-4 506	0.49	-143	0.98	4 221	1.48
RCP 4.5 scenario	-4 413	0.50	44	1.00	4 500	1.51

Source: CIE calculations.

Limitations

The scope of the analysis remains high-level for riverine flooding, which accounts for over 96 per cent of flood risk in Australia.[117] Other flood risks and damages arising from surface flooding and coastal inundation are not captured in this analysis. Although they are not considered a major source of losses to communities, they are part of the residual risks that may not be addressed by current building codes and land use planning tools in both current and future climate contexts. Future assessments may need to incorporate all different types of flood risk and damage to inform a comprehensive set of risk mitigation measures.

The analysis is highly sensitive to data availability of insurance claim details and property flood risk profile, given the localised nature of flood risks and associated measures to be effective. Future flood damage and risk assessments should consider more granular data for:

- Flood risk,
- Claimed costs,
- Construction costs,
- Flood risk mapping as flood risk is split disproportionately within or across floodplains,
- Land use mapping to adjust for presence of non-domestic land use, empty land parcels and combined land parcels, and
- Spatial planning for new developments, including potential downstream and upstream impacts, in higher flood risk areas vis-à-vis lower risk areas.

Note that this analysis is focused on dwelling-level modifications rather than alternative risk mitigation measures such as levees, retention basins, and relocation schemes. These alternative measures are likely to offer high level of protection for flood prone communities and be incorporated into the land use planning regimes.

Key findings

- Floods impose significant costs on the community and a significant share of these costs is related to the resilience (or lack of resilience) of residential buildings. We estimate that these costs could be in the order of $1.5 billion per year.
- Floor elevation appears the more favourable option than non-structural options due to relatively cheaper cost and higher effectiveness.
- The results are highly dependent on the frequency and intensity of flood events, for example,
  – The elevation option becomes economically viable when AEP is greater than 2.1 per cent under the current climate scenario or 1.9 per cent under the RCP 4.5 scenario.

117 A Dyer et al., ‘Regional sensitivity of Australian flood risk to climate drivers’, presented at the 2019 Floodplain Management Australia National Conference, IAG Natural Perils, p. 13.

  - Non-structural options would require the AEP being greater than 9.8 per cent if they can make a high impact (reduction of loss by 50 per cent) or greater than 16.1 per cent if they make a low impact (reduction of loss by 25 per cent) under the RCP 4.5 scenario.
- Flood risk mitigation requires a combination of effective land use planning regimes and robust building standards. Land use planning plays a vital role in minimising risk exposure by addressing flood hazards at their root. However, there are instances where existing land use planning frameworks fail to adequately address the natural hazard risks faced by built environment and communities.[118] This inadequacy underscores the significance of risk-resilient building standards in mitigating costs associated with extreme weather events.
  - In such circumstances, the implementation of building standards becomes crucial to reducing vulnerability to property damage and minimising disruption to affected households and communities, such as early return to homes and early restoration of community facilities and services. As we face the prospect of future extreme weather events that are potentially more intense and frequent, the role of building standards becomes more important in effectively addressing the strain placed on built environments.

118 Commonwealth Government of Australia, 'Chapter 19: Land-use planning and building regulation' in *Royal Commission into National Natural Disaster Arrangements*, 2020, accessed 2 June 2023.

5 Bushfires

Current arrangements

The NCC requires that houses[119] (i.e. Class 1a buildings) located in a designated 'bushfire prone area' (BPA) is to provide resistance to bushfires in order to reduce the danger to life and reduce the risk of the loss of the building. The same performance requirement also applies to non-habitable (Class 10a buildings) buildings, such as sheds, carports and garages.

Houses are 'deemed-to-satisfy' the performance requirements if constructed in accordance with Australian Standard AS3959 — *Construction of building in bushfire prone areas*; or NASH Standard — *Steel Framed Construction in Bushfire Areas*. Alternatively, the NCC also allows the performance requirement to be met through a Performance Solution.

The specific deemed-to-satisfy requirements depend on the Bushfire Attack Level (BAL). The BAL is based on a range of factors, including:[120]

- the slope of the site
- the distance from classified vegetation
- classified vegetation type
- the effective slope under vegetation
- the Forest Fire Danger Index (FFDI) in the relevant area.

Table 5.1 summarises the predicted bushfire attack and level of exposure for different BALs.

5.1 BAL categories

BAL	Heat flux threshold (Kw/m2)	Predicted bushfire attack and level of exposure
BAL-LOW		
BAL 12.5	<=12.5	Significant ember attack, burning debris and radiant heat up to a level of 12.5 kW/m2
BAL-19	12.5 – 19	Increasing levels of ember attack, burning debris and radiant heat up to a level of 19 kW/m2
BAL-29	19 – 29	Increasing levels of ember attack, burning debris and radiant heat up to a level of 29 kW/m2

119 Including associated decks.

120 https://best-practices-assessment-tool.herokuapp.com/calculator, accessed 11 May 2023.

BAL	Heat flux threshold (Kw/m2)	Predicted bushfire attack and level of exposure
BAL-40	29 — 40	Increasing levels of ember attack, burning debris and radiant heat up to a level of 40 kW/m2. Flames from the bushfire front may intermittently contact the house.
BAL-FZ	>=40	Increasing levels of ember attack, burning debris and radiant heat in excess of 40 kW/m2. Flames from the bushfire front are likely to engulf part or all of the house

Source: CSIRO website, https://research.csiro.au/bushfire/assessing-bushfire-hazards/bal-assessment/, accessed 11 May 2023.

The BAL measures the radiant heat potential of the bushfire flame front. Radiant heat is one aspect of a bushfire attack mechanism, but it is not the predominant cause of building loss. The BAL does not measure other relevant factors that can lead to building lose, including ember load/exposure and risk from neighbouring property fire spread.

The 2020 Royal Commission into National Natural Disaster Arrangements identified that land-use planning and building regulations can influence the risk of exposure to natural hazards.[121] Strategic planning for bushfire involves a series of steps that aim to identify, evaluate, and address the potential bushfire hazard and risk in order to plan for future land use, development, and settlement growth.

Bushfire mapping is undertaken by different authorities across each state in Australia with the common goal of enabling hazard data to be used in the planning and building systems.

An area is determined to be bushfire prone based on various factors including the type of vegetation, topography of the land, and history of bushfires in the area, more stringent building and planning controls apply to developments in such areas.

Size and nature of the problem

There are various ways that bushfires can damage buildings. This includes:

- Direct ways, including:
  - ember attack
  - radiant heat attack
  - flame front contact
  - surface fire attack.
- Indirect ways, including:
  - debris accumulation
  - consequential fire
  - wind attack
  - tree strike.

121 Bushfire protection | YourHome

While these actions usually work together to damage the house, research indicates that buildings are most commonly ignited by embers and burning objects around the house.[122]

Ember attacks can occur for some time before the fire front arrives, during its passage and for several hours after. The long duration of ember attacks helps to explain why burning debris is a major cause of the ignition of buildings. If these small ignitions are not extinguished (such as when no one is present), they can grow to involve the whole building.[123] People who are well prepared and who return to their houses after the passage of the fire front can, in many cases, successfully defend them.

Research has found that burning debris can ignite buildings in a number of ways. In particular, burning debris can:[124]

- pile up against combustible materials used at or near ground level such as stumps, posts, subfloor enclosures, building facades and steps
- accumulate on combustible materials used for decks, verandahs, windowsills and pergolas
- lodge in gaps in and around combustible materials used for exterior wall cladding, and window and doorframes
- gain entry to the interior of a building through gaps in the structure and once inside the building, ignite furniture, fittings and other contents.

Number of dwellings in bushfire prone areas

One indicator of the level of bushfire risk is the number of houses in bushfire prone areas. Our approach to estimating the number of dwellings on bushfire prone land is as follows (see appendix A for further details).

- Some states — including NSW, Victoria and Queensland — make statewide maps of bushfire prone land (and the data underpinning these maps) publicly available. We overlay these maps with Census data to estimate the number of houses on bushfire prone land in those states.
- To obtain an indicative estimate of the number of houses on bushfire prone land in other states and territories, we applied the average share across NSW, Victoria and Queensland.

Based on this approach, we estimate there could be around 1.4 million Class 1a buildings in bushfire prone areas across Australia, around 15 per cent of the total (table 5.2). Note that this could somewhat overstate the number of dwellings at risk of bushfires as

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122 Queensland Construction Authority 2020, *Bushfire Resilient Building Guidance for Queensland Homes*, https://www.qra.qld.gov.au/resilient-homes/bushfire-building-guidance-queensland-homes, p.13.

123 Leonard, J. E. and Bowditch, P.A. 2003, *Findings of Studies of Houses Damaged by Bushfire in Australia*, CSIRO.

124 ibid.

bushfire mapping is updated infrequently and bushfire risk for some dwellings decreases over time due to devegetation to support further development.

5.2 Number of Class 1a dwellings in bushfire prone areas — 2021

	Class 1a dwellings in bushfire prone areas	Total Class 1a dwellings	Share of total
	No.	No.	Per cent
NSW	386 501	2 536 847	15.2
Victoria	360 900	2 395 006	15.1
Queensland	295 649	1 835 739	16.1
South Australia	113 820	738 493	15.4
Western Australia	159 930	1 037 672	15.4
Tasmania	37 116	240 821	15.4
Northern Territory	10 721	69 564	15.4
ACT	22 587	146 551	15.4
Total	**1 387 225**	**9 000 693**	**15.4**

Note: The average share of houses in bushfire prone areas across Queensland, Victoria and New South Wales(15.4 per cent) has been applied to South Australia, Tasmania, Western Australia, Australian Capital Territory and Northern Territory.

Source: CIE analysis.

Residential building-related costs of bushfires

We estimate that residential building-related costs of bushfires could be around $487 million per year (table 5.3). Details are provided below.

5.3 Estimated annual residential building-related costs of bushfires

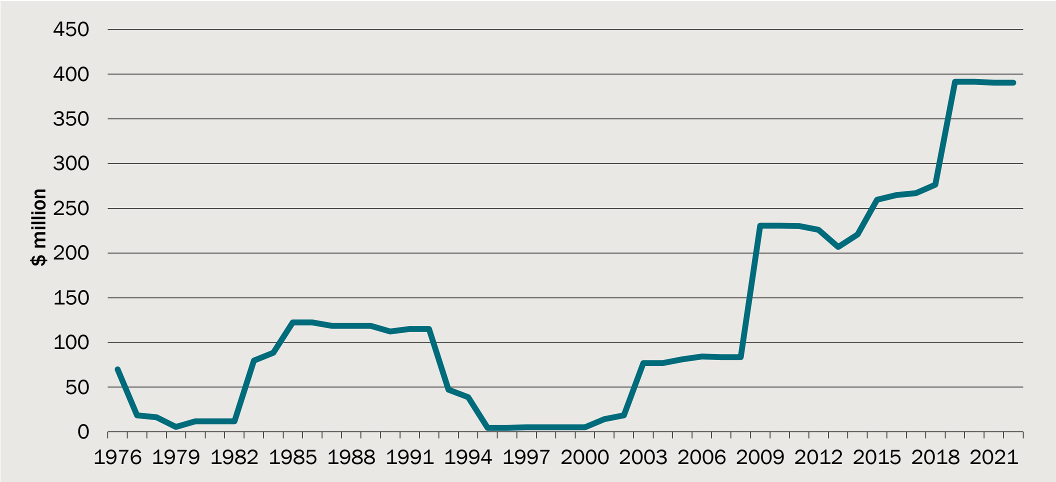
	Estimated cost
	$ million
Insured losses	247.58
Uninsured losses	61.90
Under-insured losses	60.11
Mental health impacts	80.47
Loss of housing	23.07
Employment impacts	13.71
Total	**486.84**

Source: CIE estimates.

Insured losses

Insured losses from bushfires have increased significantly in real terms (i.e. adjusted for inflation) in recent decades. Averaged over 10 years, the annual cost has reached around $400 million (chart 5.4).

5.4 Insured losses — bushfires (10 year moving average)



Data source: Based on the ICA Historical catastrophe list, inflated to 2022 dollar terms using the national CPI published by the ABS.

Data provided by ICA suggests that 60-65 per cent of total insurance losses from bushfires relates to residential buildings and contents (based on the 2019-20 bushfires and the Perth Hills bushfire). Applying an estimate of 62 per cent implies that average insured losses relating to residential buildings and contents is around $245 million per year.

Long-term displacement

Compared with other types of disasters, a higher proportion of houses impacted by bushfires tend to become uninhabitable and therefore lead to long-term displacement for residents. For example, in the 2019-20 Black Summer bushfires, publicly available data implies that around **32 per cent** of insurance claims related to houses that were destroyed.

- There were reportedly 3113 houses lost during the 2019-20 bushfire season.[125]
- ICA reports that there were 9665 domestic building claims.[126]

This implies around 551 uninhabitable dwellings per year as a result of bushfires (table 2.8 above). The costs associated with long-term displacement are measured as set out in chapter 2.

New development in bushfire prone areas

New development in bushfire-prone areas will increase exposure to bushfire-related risks. A comparison between 2016 and 2021 Census data shows that (table 5.5):

- The number of dwellings in designated bushfire-prone areas has grown significantly faster than the stock of Class 1a dwellings more generally (at least in NSW, Victoria

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125 Filkov, A.I. Ngo, T. Matthews, S. Telfer, S. and Penman, T.D. 2020, Impact of Australia's catastrophic 2019/20 bushfire season on communities and environment. Retrospective analysis and current trends, *Journal of Safety Science and Resilience*, p. 49.

126 Insurance Council of Australia website, https://insurancecouncil.com.au/industry-members/data-hub/.

and Queensland). That said, as noted above, this is likely to over-estimate the number of new dwellings at risk from bushfires due to de-vegetation to support new development.

- This has resulted in an increase in the proportion of all Class 1a dwellings that are in bushfire prone areas.

5.5 Change in Class 1 dwellings in bushfire prone area – 2016 to 2021

	Average annual growth rate (2016-2021)		Share of total Class 1a dwellings in BPA	
	Class 1a dwellings in BPA	Total Class 1a dwelling stock	2016	2021
	per cent	per cent	per cent	per cent
New South Wales	2.7	1.5	14.8	16.1
Victoria	2.5	1.9	14.8	16.1
Queensland	3.5	1.8	14.8	16.1
Total selected states	**2.9**	**1.7**	**14.7**	**15.4**

Note: An average of the increase in the share of BPA buildings across Queensland, Victoria and New South Wales has been applied to South Australia, Tasmania, Western Australia, Australian Capital Territory and Northern Territory equal to 0.7 per cent over 5 years i.e. 0.138 per cent each year.

Source: CIE analysis.

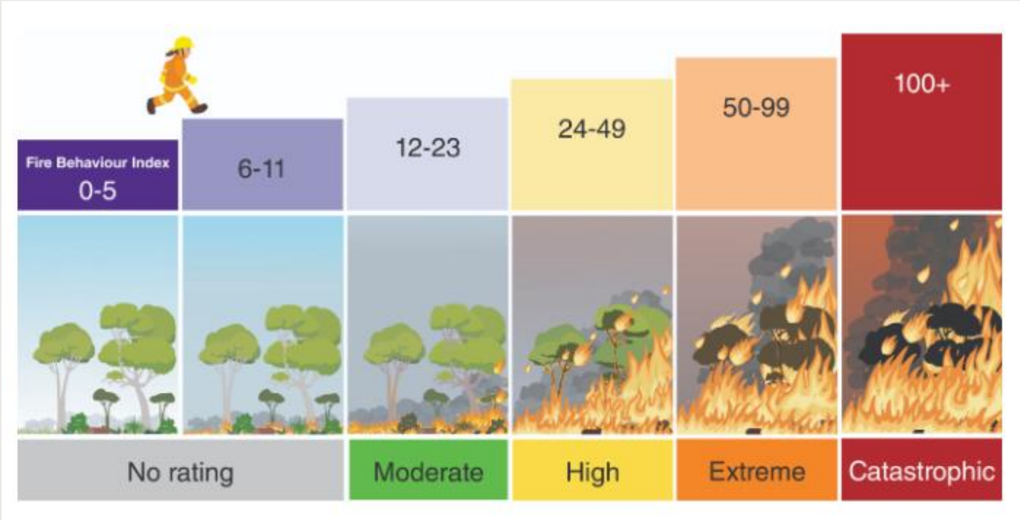
Impact of climate change on bushfires

The Forest Fire Danger Index (FFDI), which is determined by the states and territories, not the NCC, combines a measure of dryness with air temperature, wind speed and humidity. The FFDI is sometimes expressed as an annual cumulative figure which is obtained by adding the daily FDI values over a year for a location.[127]

The FFDI is an input into BAL calculations. Until recently, it was also used as the basis for Fire Danger Ratings. However, from September 2022 the Australian Fire Danger Ratings System now uses the Fire Behaviour Index (chart 5.6).

127 CSIRO website, https://research.csiro.au/bushfire/assessing-bushfire-hazards/hazard-identification/fire-danger-index/#:~:text=The%20Forest%20Fire%20Danger%20Index%20(developed%20by%20CSIRO%20scientist%2C%20A.%20G.,called%20the%20annual%20accumulated%20FDI., accessed 11 May 2023.

5.6 Fire Danger Ratings



Data source: AFAC website, https://www.afac.com.au/initiative/afdrs/afdrs-faqs, accessed 30 August 2023.

Climate modelling suggests that bushfire conditions are likely to worsen with climate change. For example, the Australian Government *Climate Change in Australia* website publishes projections prepared by CSIRO and the Bureau of Meteorology (BOM) of the average annual cumulative FFDI (CFFDI) and average days per year of very high, extreme and catastrophic fire danger:

- in various future period (2030, 2050, 2070 and 2090) compared with the average over the 1986 to 2005 period;
- at 39 different locations
- using 3 different climate models (CESM1-CAM5, GFDL-ESMWM and MIROC5)
- under RCP4.5 and RCP8.5 emissions scenarios (see box 5.7 for a summary of the representative concentration pathways — RCPs — typically used in climate modelling).

5.7 Representative concentration pathways[128]

Representative Concentration Pathways (RCPs) are prescribed pathways for greenhouse gas and aerosol concentrations, together with land use change, that are consistent with a set of broad climate outcomes used by climate modellers. These scenarios span the range of plausible global warming scenarios as follows.

- RCP8.5 —this represents a future with little curbing of emissions, with a CO_2 concentration continuing to rapidly rise, reaching 940 ppm by 2100.

128 Climate Change in Australia website, https://www.climatechangeinaustralia.gov.au/en/changing-climate/future-climate-scenarios/greenhouse-gas-scenarios/, accessed 5 June 2023.

- RCP6.0 — lower emissions, achieved by application of some mitigation strategies and technologies. CO_2 concentration rising less rapidly (than RCP8.5), but still reaching 660 ppm by 2100 and total radiative forcing stabilising shortly after 2100.
- RCP4.5 — CO_2 concentrations are slightly above those of RCP6.0 until after mid-century, but emissions peak earlier (around 2040), and the CO_2 concentration reaches 540 ppm by 2100.
- RCP2.6 — the most ambitious mitigation scenario, with emissions peaking early in the century (around 2020), then rapidly declining. Such a pathway would require early participation from all emitters, including developing countries, as well as the application of technologies for actively removing carbon dioxide from the atmosphere. The CO_2 concentration reaches 440 ppm by 2040 then slowly declines to 420 ppm by 2100).

Table 5.8 summarises modelled changes in the cumulative FFDI (CFFDI) between 1995 and 2050 under the RCP4.5 emissions scenario. The summary numbers are based on the average across the 3 climate change models and averages across the modelled locations in each state.

5.8 Modelled changes in the CFFDI

	Average 1986-2005	2050	Change	Average annual change
	Index	Index	Per cent	Per cent
NSW	2 925	3 336	14.0	0.2
VIC	3 297	3 642	10.5	0.2
QLD	3 597	4 070	13.2	0.2
WA	4 335	5 079	17.2	0.3
SA	4 438	5 058	14.0	0.2
TAS	1 415	1 465	3.6	0.1
ACT	2 635	2 993	13.6	0.2
NT	6 996	7 892	12.8	0.2

Source: Climate Change in Australia website, https://www.climatechangeinaustralia.gov.au/en/obtain-data/download-datasets/#FFDI, accessed 11 May 2023.

Bollinger (2021) found that climate impact is a significant factor driving house loss from bushfires and that this will get significantly worse towards the end of the century, under both RCP 4.5 and RCP 8.5 scenarios (table 5.9).[129]

129 Bollinger, T.N. 2021, Extreme Value Analysis for Bushfire House Losses in Australia, Masters Thesis, Faculty of Science, University of Bern, Oeschger Centre for Climate Change Research, p. 6.

5.9 Estimated house losses from bushfire

Return period	Probability	Current	RCP 4.5		RCP 8.5	
			2030	2090	2030	2090
		No.	No.	No.	No.	No.
10	0.100	220	361	671	363	1 252
25	0.040	859	1 089	1 659	1 091	2 735
50	0.020	1 532	1 855	2 699	1 857	4 295
100	0.010	2 433	2 880	4 091	2 882	6 384

Source: Bollinger, T.N. 2021, Extreme Value Analysis for Bushfire House Losses in Australia, Masters Thesis, Faculty of Science, University of Bern, Oeschger Centre for Climate Change Research, p. 6.

Earlier work (for example, McAneney et. al. 2009) had argued that climate change had not had a significant influence on the scale of property damage.[130] However, as shown above, there has been a significant increase in insured losses relating to bushfires (see chart 5.4 above) since that paper was published.

Changes to emergency advice

Prior to February 2009, Australian fire authorities advised residents to prepare to stay and defend their homes in the event of a bushfire; or to leave well before a fire threatened their property. This became known as the 'stay or go' policy.[131]

This advice was based on the observation over many years that many people who died in bushfires across Australia were caught by fires on the road, whether in their cars or on foot. Fire authorities therefore concluded that staying to defend a well-prepared home, or leaving for a safe place well before a fire threat appeared, were the two best survival options for a bushfire.[132]

However, during the 2009 Black Saturday bushfires, 113 people died in or near homes (this was 65 per cent of the 173 people who died in total).[133] This led to the Australian Fire and Emergency Services Authorities Council (AFAC) revising some aspects of the advice to give more weight to the 'leave early' option.[134]

130 McAneney, J. Chen, K. and Pitman, A. 2009, "100-years of Australian bushfire property losses: Is the risk significant and is it increasing?", *Journal of Environmental Management*, **90**(8), June 2009, pp. 2819-2822.

131 McLennan, J., G. Elliot, L. Wright 2014, 'Bushfire survival preparations by householders in at-risk areas of south-eastern Australia', *Australian Journal of Emergency Management*, **29**(2), April 2014, https://knowledge.aidr.org.au/resources/ajem-apr-2014-bushfire-survival-preparations-by-householders-in-at-risk-areas-of-south-eastern-australia/, accessed 11 May 2023.

132 Bushfire CRC website, https://www.bushfirecrc.com/projects/c6/evaluation-stay-or-go-policy, accessed 11 May 2023.

133 2009 Victorian Bushfires Royal Commission, *A New Bushfire Safety Policy — Replacing the Stay or Go Policy, Submissions of Counsel Assisting*, p.4.

134 McLennan, Elliot and Wright (2014), ob.cit.

The number of residents of bushfire prone areas intending to leave early has increased since the Black Saturday bushfires. According to Strahan and Gilbert (2021), comparison of pre-Black Saturday research with six subsequent studies shows an increase in those intending to leave early from 24 per cent in 2009 to 41 per cent (unweighted mean of 6 studies 2011-2014).[135]

The advice rightly focus on the preservation of human life and avoiding the types of tragic outcomes that occurred during the Black Saturday bushfires. However, these developments will also means that fewer residents will be present to defend their property from ember attack.

Ember attacks account for a high proportion of homes destroyed by bushfires. Burning debris (embers) such as leaves, twigs and bark that travel from the main fire body to the building and surrounding elements before, during and after the fire front has passed. These embers are often the source of ignition for many houses that are destroyed.[136]

Although embers can travel long distances, short distance embers tend to have greater impact. A CSIRO report estimates that short distance ember attacks are responsible for over **90 per cent** of ignitions leading to building loss in an urban environment.[137]

Occupants can play an important role in protecting homes from ember attack. When actively defending the property, occupants can extinguish these small fires ignited by embers around the house before they grow to involve the whole building. Blanchi et. al. (2015) reports several studies show that active defence by residents, brigade members or both results in a three to seven times greater chance of the house surviving the fire.[138] This suggests that an increase in the proportion of homes that are undefended could lead to greater property losses.

This information suggests that the increase in the number of undefended dwellings as a result of the change in the advice to households could increase the damage caused by bushfires by around **41 per cent**. This estimate is based on the following assumptions.

- The proportion of bushfire damage caused by ember attacks is around **90 per cent**.[139]
- The proportion of unoccupied homes during a bushfire event increases by around **15 percentage points** (broadly consistent with see findings of Strahan and Gilbert, 2021).[140]

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135 Strahan, K.W. and J. Gilbert 2021, "Protective Decision-Making in Bushfire Part 2: A Rapid Systematic Review of the 'Leave Early' Literature", *Fire*, **4**(3), p. 11.

136 Blanchi, R., J. Whittaker, K. Haynes, J. Leonard, K. Opie, M. Holland and S. Dreyfuss 2015, *Sheltering practices during bushfire*, Report to Emergency Management Victoria, Natural Disaster Resilience Grants Scheme, CSIRO, November 2015, p.13.

137 Leonard, J. and White, N. 2014, *Description of bushfire performance of buildings and its verification*, CSIRO Research Report, Document Number: EP145702, p. 4.

138 ibid.

139 See Leonard, J. and White, N. 2014, *Description of bushfire performance of buildings and its verification*, CSIRO Research Report, Document Number: EP145702, p. 4.

140 Strahan, K.W. and J. Gilbert 2021, "Protective Decision-Making in Bushfire Part 2: A Rapid Systematic Review of the 'Leave Early' Literature", *Fire*, **4**(3), p. 11.

- The increase in property damage for unoccupied homes increases by a **factor of 3** (i.e. 300 per cent). This is the lower end of the range suggested by Blanchi et. al. (2015), which is reasonable because the change is likely to affect the proportion of dwellings actively defended by residents, but not brigade members.

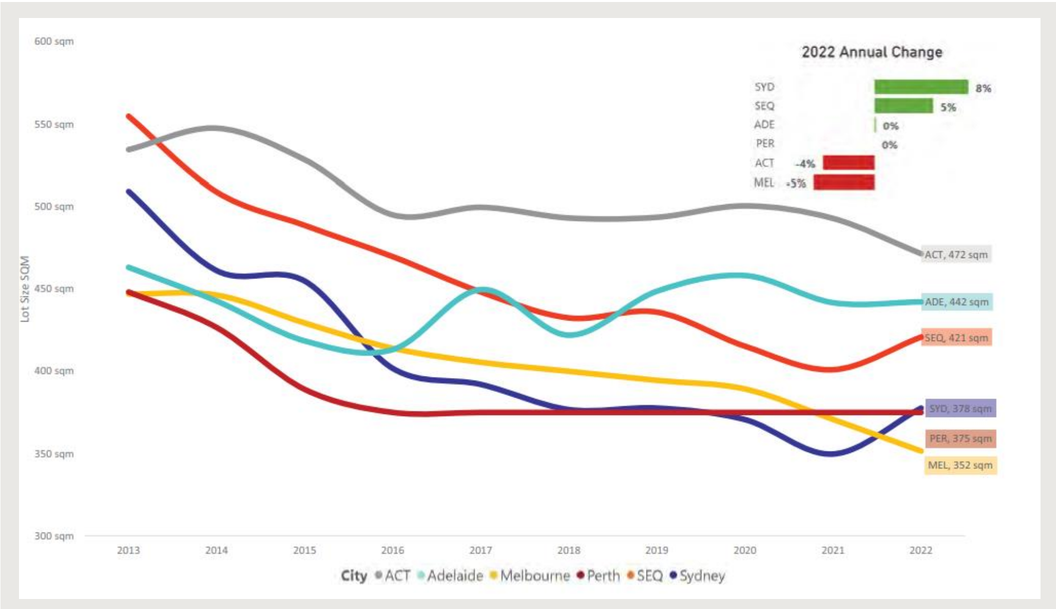
We assume that these behavioural changes have not yet been reflected in the data. However, as the change in advice occurred more than 10 years ago, it is possible that these changes are already at least partly reflected in the data.

Other factors that could also increase property damage major bushfire events include the availability of fire fighting resources in large events and lengthening bushfire seasons, both in Australia and overseas (including places that we currently share fire fighting equipment).

Smaller greenfield lot sizes

Another potentially important development has been the declining greenfield lot sizes over the past decade (chart 5.10). This means that houses will be closer together; increasing the risk of house-to-house ignition, which various studies have identified as a key cause of property loss.[141] Smaller lot sizes may also mean that houses are closer to other structures that can be a source of ignition, such as fences and sheds.

5.10 Median lot size



Data source: UDIA, State of the Land 2023, National Residential Greenfield and Apartment Market Study, Released March 2023, p. 10.

141 See for example, Leonard, J. Opie, K. Blanchi, R. Newnham, G. and Holland, M. *Wye River/Separation Creek: Post-bushfire building survey*, CSIRO Land and Water, Report EP16924, Report to the Victorian Country Fire Authority, April 2016, p. 25.

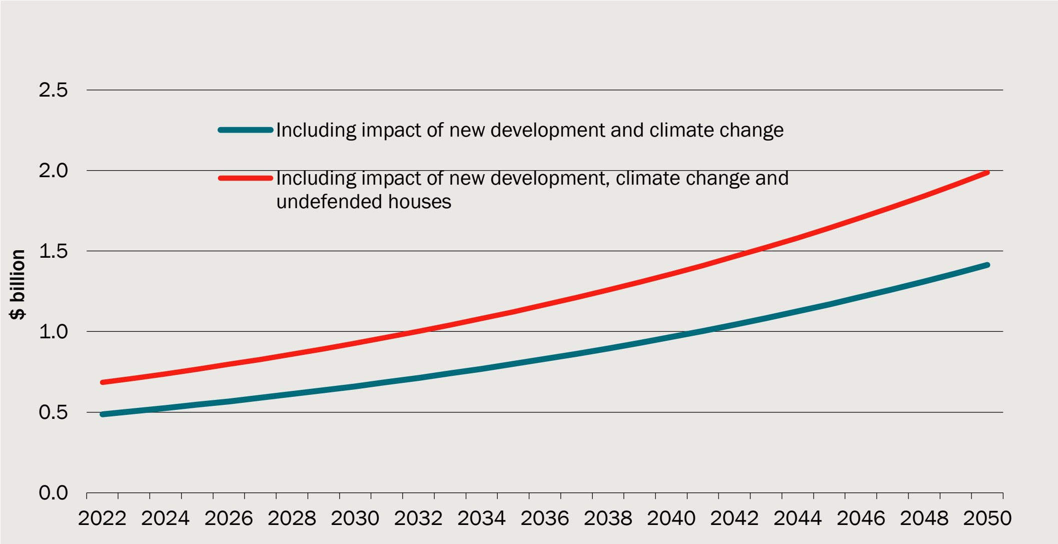
Future projections

To provide an indicative projection of future costs from bushfires (related to residential buildings) taking into account likely future developments as set out above, we assume:

- Costs will increase by 2.85 per cent per year due to new development
- Costs will increase by around 100 per cent by 2090 as a result of climate change (consistent with the estimates set out in Bollinger, 2021), which equates to around 1 per cent per year.
- Costs will be around 41 per cent higher as a result of more dwellings being left undefended as more residents choose to leave early.

Under these assumptions, the annual cost of bushfires would reach around $2 billion by 2050 (chart 5.11).

5.11 Residential building-related costs from bushfires — future projections



Data source: CIE estimates.

Limitations of current building standards

Several weaknesses in current building regulation have been identified. A submission from the Bushfire Building Council of Australia Ltd (BBCA) to the Senate Finance and Public Administration References Committee argued that buildings that have been built to bushfire construction standards may not be resilient because the current deemed-to-satisfy building standard does not, or cannot, address all factors contributing to property loss, such as: house-to-house ignition, maintenance, compliance, landscaping and storage of combustible materials.[142]

142 Cotter, K. 2021, *Lessons to be learned in relation to the Australian bushfire season 2019-20*, Submission to the Senate Finance and Public Administration References Committee, Bushfire Building Council of Australia Ltd, 3 May 2021, p. 9.

The submission noted that many factors that are leading causes of property loss in the Wye River and Separation Creek bushfire are not addressed by the current standard, or are only required for properties at very high bushfire risk areas (BAL-40 and BAL-FZ). A CSIRO study found that the main causes of property losses in these fires were:[143]

- house to house ignition (not dealt with by the building standard)
- retaining walls (not dealt with by the building standard)
- timber decking (permitted for BAL29 and below)
- timber stairways (permitted for BAL29 and below)
- vehicles (not dealt with by the building standard)
- stored equipment (not dealt with by the building standard)
- plastic water tanks (not dealt with by the building standard)
- firewood (not dealt with by the building standard).

More specifically, the Royal Commission into National Natural Disaster Arrangements (2020) found that in some places the fire danger information used to calculate the Bushfire Attack Levels (BALs) for the purposes of AS 3959 is out of date and does not accurately quantify expected risk.

- In the latest (2018) version of AS 3959 BAL the FFDI values used are from 2009 rather than more contemporary values or a future-looking FFDI for the life of a structure.[144]
- In some cases, a single fire danger index is applied across a broad area, regardless of differences in vegetation and topography. For example, Queensland has an FFDI of 40 for the whole state; however, evidence presented to the Royal Commission suggested it should be between 80 and 130.[145]

Other potential weaknesses are that current requirements do not adequately address ember attacks and subsequent fire spread (including structure to structure fire, ember ignition of adjacent heavy fuels leading to subsequent ignition of the home, etc.).

- Ember attacks are the main source of ignition for homes that are lost to bushfires. As noted above, it has been estimated at around 90 per cent.
- Embers can travel several kilometres ahead of the fire front. However, the most intense ember attack occurs within 150 metres of the fire.[146]
  - This suggests that within the area at risk of intense ember attack it may not be appropriate to have different levels of protection from ember attack in the same way that there are different levels of protection from radiant heat, based on distance from vegetation.

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143 Referred to in: Cotter, K. *Lessons to be learned in relation to the Australian bushfire season 2019-20*, Submission to the Senate Finance and Public Administration References Committee, Bushfire Building Council of Australia Ltd, 3 May 2021, p. 9.

144 Royal Commission into National Natural Disaster Arrangements 2020, *Report*, p. 412.

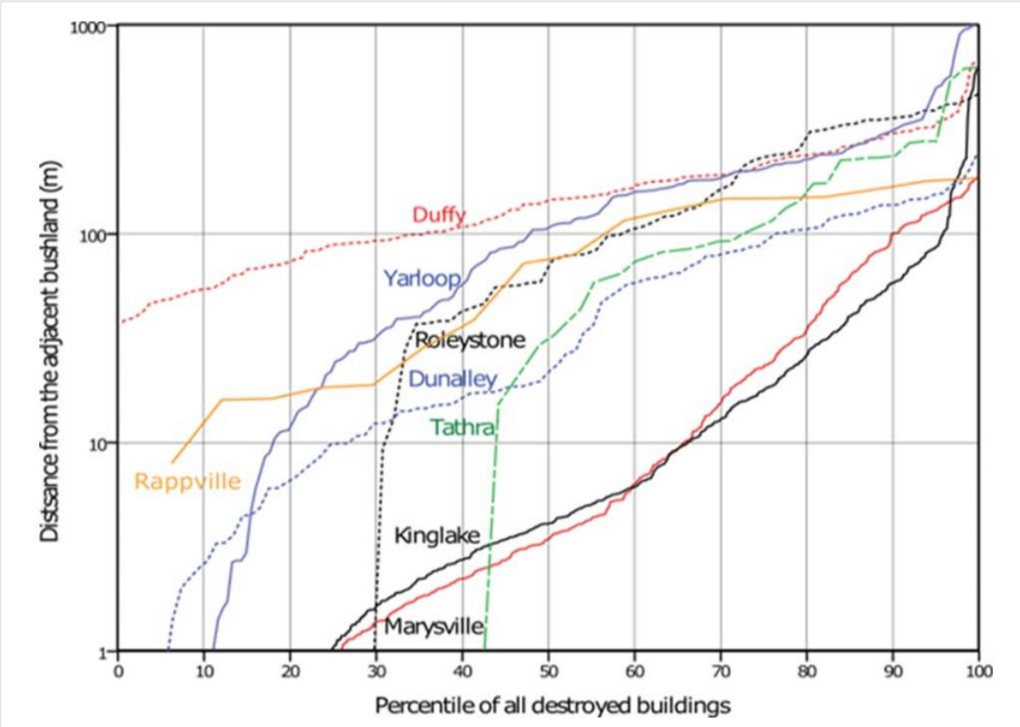
145 Royal Commission into National Natural Disaster Arrangements (2020), op.cit., p. 413.

146 Victorian Government, *Bushfire Management Overlay Mapping Methodology and Criteria*, Planning Advisory Note 46, August 2013, p. 2.

– There are no specific bushfire protections required for dwellings more than 100 metres from vegetation, even if in a designated bushfire-prone area and therefore at risk of ember attack.

The current requirements appear to have been based on the observation from several studies that a high proportion of house loss occurs within 100 metres of the fire. For example, a study of NSW house losses by Douglas et al (2009) reported that more than 90 per cent of cumulative losses of buildings occur within 100 metres of the interface.[147] However, this can vary significantly across different events (see chart 5.12). Based on the recent sample of fires reported in the chart, the proportion of building losses that occur within 100 metres of vegetation ranges between around 35 per cent (the Duffy fires in the ACT) and around 95 per cent (for the Kinglake fire in Victoria).

5.12 Relationship between destroyed buildings and distance from bushland



Data source: Risk Frontiers, https://riskfrontiers.com/insights/northern-nsw-bushfire-impact-research/#:~:text=There%20was%20minimal%20variation%20in,remained%20after%20debris%20was%20removed., accessed 15 May 2023.

If property damage outside the 100 metre range is higher than previously estimated (as suggested by chart 5.12) at (say) 20 per cent, this would imply an annual cost of close to $100 million per year on average, increasing to around $400 million per year by 2050. This is a significant cost incurred in dwellings with no current requirement for any bushfire protection.

147 Douglas, G., S. Midgley, Z. Tan and L. Short 2008, "Bushfire Damage Survey — A NSW Perspective", *Proceedings of the Royal Society of Queensland*, **115**, pp.161-169, Brisbane.

This issue was identified by the 2009 Victorian Bushfires Royal Commission. The Commission concluded that construction standards for bushfire-prone areas do not adequately cover all the important components of bushfire risk. It recommended improving standards and clarifying objectives to redress these deficiencies.[148]

In particular, the Royal Commission recommended reducing the risk of ignition from ember attack be included in the objectives of the BCA and the standard.[149] Furthermore, the Commission supported a review of the 100 metre margin and suggested a 140 metre buffer may be a more conservative choice, but did not make a formal recommendation.[150]

The Victorian Government subsequently introduced a variation to the NCC that provides a BAL-12.5 in all bushfire prone areas irrespective of distance from the interface.

Options

Specific design strategies

Design strategies which can be adopted to achieve a bushfire resilient design include:

- Siting or positioning buildings to minimise exposure to hazards which cannot be readily addressed by building design
- Landscaping around the house by way of resilient plantings
- Design and construction methods

While these strategies are complimentary, the focus for the purposes of this analysis is on design and construction strategies for new builds that protect the house against ember attacks. Table 5.13 addresses the most common elements in a building susceptible to embers and suggests design and construction solutions across both internal and external elements of the building vulnerable to such ignition. Some solutions have levels of protection (with level 4 being the highest level of protection). Lower levels of protection from ember attack would result in higher likelihood of ignition (and would not therefore be consistent with best practice).

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148 2009 Victorian Bushfires Royal Commission, *Final Report, Summary*, July 2010, p.15.

149 2009 Victorian Bushfires Royal Commission (2010), op.cit., p. 33.

150 2009 Victorian Bushfires Royal Commission, *Final Report, Volume II: Fire Preparation, Response and Recovery*, July 2010, p. 223.

5.13 Building elements vulnerable to ember attacks along with associated resilient measures

Vulnerability	Best practice measures
Wall system – Cladding, frames and cavity	
▪ Embers can ignite exposed surfaces made of combustible materials such as wall cladding either by direct attachment or by accumulating against cladding. ▪ Re-entrant corners – reduce the use of wall junctions with other building elements which create re-entrant corners where embers can accumulate ▪ Ember entry into wall cavities ▪ Addressing gaps smaller than 2mm (such as gaps in the wall sheeting in this case)	▪ Non-combustible insulation ▪ **Solid wall** (no cladding or combustible cladding) ▪ **Steel frame** – *Thick non-combustible cladding* Level 3 – Non-combustible 30-minute fire rated system or cladding system such as brick veneer, 50mm aerated concrete Level 4 - Non-combustible 60-minute fire rated system or higher cladding system such as brick veneer – *Thin non-combustible cladding* Level 2 - Steel, cement sheet, fibre cement sheet. Sealing and covering all joints larger than 2mm in the external surface material Level 3 - In additional to level 2 cladding, add an appropriate non-combustible fire barrier under the cladding such as plasterboard ▪ **Timber frame** – same as steel frame cladding categories. In addition to that: – Any gaps <2mm need to be protected using metal mesh (for level 2) – use flame resistant sarking to resist ember penetration (for level 2) – using steel hat section between fire barrier and cladding (for level 3 – thin non-combustible cladding)
Gutters and gutter guards	
▪ Ember attack can ignite combustible eaves, fascia and debris matter that has accumulated in gutters, along ridge lines, in roof valleys, against roof penetrations and inside the roof cavity.	▪ Using non-combustible gutters and gutter guards ▪ Avoid adjacent combustible elements such as fascias, roof framing and battens ▪ Avoid using gutters (this may not be feasible where water supply is collected via gutters).
Roof system (roof frame, roof covering, fascias, barge boards, eave linings and ridges)	
▪ Roof system can ignite, collapse, displace and breach. ▪ Ember accumulation and entry into roof cavity. ▪ Exposed surfaces made of combustible materials (roofs frames in this case) ▪ Ember and potential flame entry into the roof cavity is often difficult to spot and is almost certain to result in total house destruction if the roof contains combustible framing or other combustible elements.	▪ Roof frame: Non-combustible (e.g. steel rather than timber) ▪ Roof covering: – Steel – Tile ▪ Use non-combustible fascias and eaves (level depends on roof frame and covering) – Level 1 – seal ridges and eaves with non-combustible insulation or flashings – Level 2 – in addition to above, fully wrap framing trusses with flame resisting sarking and use steel roofing battens under roof sheets. – Level 3 - Refer to AS3959 BAL FZ roof design solutions. In addition, consider using non-combustible fascia and eave finishes. – Level 4 - Use a 60-minute fire rated roof design that also has non-combustible external finishes and insulation

Vulnerability	Best practice measures
Windows and glazing systems	
▪ Safeguard window systems from ignition, breakage, and collapse ▪ Gaps smaller than 2mm (window gaps in this case) ▪ re-entrant corners (windowsills and wall to floor joints in this case) – preventing embers from accumulating and gaining entry through windowsills. ▪ combustible window components such as frames and seals ▪ cracked or shattered glazing when exposed to radiant heat or flame providing point of entry for ember attack	**Glazing** ▪ Level 2 – toughened glass ▪ Level 3 or 4 – fire rated window ▪ Level 4 – use bushfire shutters as alternative **Frame** ▪ Level 1 – class 1 durability timber acceptable, though non-combustible is preferred. ▪ Level 4 – window frames, sills, reveal should be constructed using non-combustible materials **Openable section windows** ▪ Level 1 to 4 – Install external mesh on all openable windows to protect against ember entry with aperture no larger than 2mm. ▪ Windows extending to floor need toughened safety glass or glass blocks for all glazing within 400mm of ground and screen
Doors, framing and threshold	
Doors, framing and threshold ▪ Preventing combustible part of door to ignite during ember attack and gaining entry through door threshold sill. ▪ Gaps smaller than 2mm (doors gaps in this case) ▪ Re-entrant corners (corner of doorframes in this case)	▪ All doors should be tight fitting, with gaps smaller than 2mm. ▪ If this is not possible, install fire rated weather strips and draft stoppers and seals to ensure there are no gaps greater than 2mm.
Door protection ▪ Preventing combustible part of door to ignite during ember attack and gaining entry through door threshold sill. ▪ Gaps smaller than 2mm (door gaps in this case) ▪ Re-entrant corners (corners of doorframes in this case)	▪ Screens – install a non-combustible screened security door which is self-closing (with apertures no larger than 2mm) ▪ Glass sliding doors – as for windows for the equivalent level ▪ Non-combustible doors: – Level 1 – non-combustible, the use of class 1 durability timber solid core doors is acceptable. – Level 2 – should be constructed using non-combustible materials. – Level 3 – non-combustible fire rated 30mins – Level 4 – non-combustible fire rated 60 mins
Vents and other perforations	
Vents	
▪ Avoiding gaps larger than 2mm (such as vents and weepholes) ▪ Prevents ember entry through vents and perforations in the building envelope	Vents and weepholes etc. should be screened. The screens should: ▪ have the maximum aperture of 2mm ▪ be made of: – Stainless steel or galvanised steel frames and mesh (galvanised steel requires more frequent replacement, this is the best option)

<table>
<tr><th>Vulnerability</th><th colspan="4">Best practice measures</th></tr>
<tr><td></td><td colspan="4">– Bronze mesh as a reasonable alternative to steel mesh
– Aluminium mesh</td></tr>
<tr><td colspan="5">Perforations</td></tr>
<tr><td>▪ Roof, wall, or floor cavities
▪ Avoiding gaps larger than 2mm</td><td colspan="4">▪ Metal flashings around penetrations, tightly fitted, gaps sealed with fire-rated sealant, openings screened with metal mesh (aperture less than 2 mm)
▪ Similarly, any perforation of internal lining (for instance internal light, pipes and extraction) to be sealed with non-combustible material to avoid any gaps larger than 2mm
▪ Any small gaps should be sealed with:
– Fire rated sealants and steel flashings
– No polymer joining strips to be used unless fire rated (no PVC)</td></tr>
<tr><td colspan="5">Decks, verandahs, and stairs</td></tr>
<tr><td>▪ Resisting ignition from ember attack
▪ Protecting deck and supporting posts and columns from burning, collapse and displacement.</td><td colspan="4">▪ Level 1 – Use non-combustible material for the deck, supporting posts and bearers. If the deck is not used as an exit path, then consider using class 1 timber decking slates as an alternative.
▪ Level 4 - Use non-combustible materials for the deck, supporting posts and bearers
▪ Separate direct attachments to the house that are combustible (for instance, carport, pergolas and patio areas)</td></tr>
<tr><td colspan="5">Floor system</td></tr>
<tr><td rowspan="4">▪ Preventing embers from igniting underfloor spaces, underfloor enclosures and combustible supporting posts
▪ Protecting floors and subfloors from burning, collapse, displacement, and breach.</td><td>Floor type</td><td>Associated substrate</td><td>Associated posts & walls</td><td>Enclosure</td></tr>
<tr><td>On ground</td><td>Concrete slab (Level 4)</td><td>Not applicable</td><td>Not applicable</td></tr>
<tr><td>Raised and fully enclosed subfloor (should not be timber if termites and issue)</td><td>Any material</td><td>Non-combustible or fire protected perimeter posts and framing supporting cladding</td><td>Non-combustible enclosure
▪ 30min fire rated system – level 3
▪ 60min fire rated system – level 4</td></tr>
<tr><td>Raised floor</td><td>Non-combustible substrate (concrete, aerated concrete panels, cement sheet) assuming an elevated ground slab as fill as formwork with perimeter brick wall and piers (to align with flood methodology)</td><td>Non-combustible supporting posts and wall
▪ Level 2 – steel post (exposed)
▪ Level 3 – concrete or steel post fire protected</td><td>If enclosing, make sure to fully enclose the underfloor area, using non-combustible materials</td></tr>
<tr><td>Other options</td><td colspan="4">Some other options may be costed separately unless they are included in the above measures:
▪ Non-combustible barriers such as fences and earthworks
▪ Protection system such as shutters, external spray systems or internal sprinkler systems
▪ Flame retardant seals for garage, shed (outbuildings) or industrial doors such as nylon flame retardant material</td></tr>
</table>

Vulnerability	Best practice measures
	▪ Gutter mesh to help prevent the threat of internal fires by preventing the build up of leaves

Source: Bushfire Resilient Building Guidance for Queensland Homes | Queensland Reconstruction Authority (qra.qld.gov.au)

Recommended ember protection measures for home more than 100 metres from bushland could include:

- Ember mesh screens for vents and weepholes
- Non-combustible pathway around home
- Non-combustible heavy landscaping (such as retaining walls) within 2-3 metres of the homes
- Non-combustible fencing if adjacent to windows or combustible cladding
- Window protection such as shutters only where adjacent heavy fuels (immovable) would crack windows if ignited, such as neighbouring property within 6 metres
- Tight-fitting metal flashings, sealant, for all building penetrations
- Non-combustible cladding (such as steel, fibre cement, masonry) 40 cm from ground. Bushfire resistant cladding above 40 cm which may include some timber species (note that this only applies to homes only at risk of ember attack, not homes at risk of bushfire flame radiation or located close to other structures, such as neighbouring homes or outbuildings).
- No gaps greater than 2 mm anywhere, including cladding, roof, services/penetrations, around window and door frames, around doors.

Specific changes to building requirements

It is beyond the scope of the report to propose specific changes to the NCC and/or the associated standards. However, a future review could consider:

- lifting ember protection measures for BAL-LOW to BAL-29
- additional measure to protect from ember attack across all BAL levels, including how to incorporate cost-effective measures that are currently outside the scope of building regulation into the regulatory approach.

Impacts

Various studies have noted that it is not currently possible to accurately assess the effectiveness of enhanced bushfire protection measures in reducing estimated annual damage costs'.[151] For example, Price et. al. (2021) notes that the current standard is not based on empirical evidence.[152]

151 See for example, Royal Commission into National Natural Disaster Arrangements 2020, *Report*, p. 412.

152 Price, O.F., J. Whittaker, P. Gibbons and R. Bradstock 2021, "Comprehensive Examination of the Determinants of Damage to Houses in Two Wildfires in Eastern Australia in 2013", *Fire*, p. 3.

The best evidence on the effectiveness of ehanced bushfire protection measures is based on post-disaster surveys and other research. For example, analysis from the Wye River and Separation Creek bushfire provides some evidence that houses built to comply with the bushfire standard here is some (limited) evidence that the AS3959-2009 were less likely to be destroyed, although compliance with the standard was not fully effective in protecting houses from bushfire (although the sample size is too small to draw definitive conclusions). In particular:

- One-third of houses in the fire zone that were built to a version of the standard were destroyed (table 5.14).
- In comparison, around 80 per cent of all buildings in the fire zone were lost to fire.[153]

5.14 Houses destroyed in the Wye River/Separation Creek bushfires

	Destroyed houses	Surviving houses	Share destroyed
	No.	No.	Per cent
AS3959-2009	4	3	57.1
Prior to AS3959-2009	3	11	21.4
Total	**7**	**14**	**33.3**

Source: Leonard, J. Opie, K. Blanchi, R. Newnham, G. and Holland, M. Wye River/Separation Creek Post-bushfire building survey findings, CSIRO Land and Water, Report EP 16924, Report to the Victorian Country Fire Authority, April 2016, p. 30.

Information on the effectiveness of specific measures is a key input into a CBA and the absence of such information means a robust CBA is not possible. Nevertheless, it may be possible to identify the types of measures that could potentially pay-off.

Potential benefits

The costs in the event of the loss of a single dwelling to bushfire could be in the order of $563 000 (table 5.15).

- The rebuild cost is estimated at around $350 00 (based on estimates of the average costs of building a new house in Australia in 2021/22 provided by Master Builders Australia).
- The other costs are estimated based on the approach outlined in chapter 2.

5.15 Potential costs of house loss

	Estimated cost
	$'000
Rebuild cost	350
Mental health	142
Loss of housing services	78

153 Leonard, J., K. Opie, R. Blanchi, G. Newnham and M. Holland 2016, *Wye River/Separation Creek Post-bushfire building survey findings*, CSIRO Land and Water, Report EP 16924, Report to the Victorian Country Fire Authority, April 2016, p. 29.

	Estimated cost
	$'000
Employment	25
Total costs	**563**

Source: MBA CIE.

Probability of house loss

Venn and Quiggin (2017) estimate the average annual probability of house loss from bushfire at around 1 in 1800 (this estimate specifically refers to dwellings within 100 metres of bushland).[154] This compares to an earlier estimate of 1 in 65,000 based on the PerilAUS database (which covers the period from 1900s).[155]

To provide indicative estimates of the range of potential benefits we use the following assumptions on annual probability of house loss.

- 1 in 1800 (based on Venn and Quiggin 2017).
- To test the impacts of some of the potential factors driving property losses outlined above, we also adjust the above estimates as follows.
  - To account for the impacts of climate change, we scale the probability up by 30 per cent, which is broadly in line with Bollinger's (2021) estimate of the impacts of climate change on house loss by 2030.
  - To account for the impacts of a greater proportion of empty dwellings (due to greater emphasis on leaving early) by 41 per cent (see above).

A more comprehensive analysis would need to take into account important drivers of benefits, such as: the effectiveness of the various measures under consideration in preventing house loss from ember attacks for houses on bushfire prone land that are more than 100 metres from vegetation; and avoided property damage that does not result in complete loss of the house.

Although this analysis has many caveats, it is intended as an indication of the broad orders of magnitude of the potential benefits. The high-level analysis suggests that the lifetime benefits could be in a range between $4600 and $8400 per dwelling (although it may be somewhat lower once the effectiveness of the various measures are taken into account), as summarised in table 5.16.

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154 Venn, TJ and J. Quiggin 2017, "Early evacuation is the best bushfire risk mitigation strategy for south-eastern Australia", *Australian Journal of Agricultural and Resource Economics*, **61**(3), pp.481-497.

155 McAneney, J., K. Chen and A. Pitman 2009, "100-years of Australian bushfire property losses: Is the risk significant and is it increasing?", *Journal of Environmental Management*, **90**(8), pp.2819-2822.

5.16 Indicative benefits

	Annual probability	Expected annual loss[a]	Expected lifetime benefits
	Per cent	$ per dwelling	$ per dwelling
1 in 1800 (Venn and Quiggin 2017)	0.056	313	4 617
Adjusted Venn and Quiggin 2017)	0.101	571	8 432

[a] Annual probability multiplied by $563 000 (see table 5.15 above). [b] Based on 50 year life, using a discount rate of 7 per cent.
Source: CIE estimates.

Costs of measures to reduce vulnerability to bushfires

The costs would depend on the specific measures chosen (table 5.17). It is beyond the scope of this exercise to determine the specific measures that can be applied to reduce vulnerability to ember attack for houses in bushfire prone areas, but more than 100 metres from vegetation.

5.17 Estimated costs

Measure	Estimated cost
	$
Cladding	
Solid walls	36 110
Thick non-combustible cladding	15 023
Thin non-combustible cladding	19 624
Gutters and gutter guards	
Non-combustible gutters	0
Non-combustible gutter guards	1 309
Total — gutters and gutter guards	**1 309**
Roof system	
Non-combustible roof-framing and/or trusses	3 920
Non-combustible roof-fixing battens	546
Non-combustible fascias, barges and eaves	38 481
Windows	
Glazing	62 160
Frame	404
Openable section windows	22 586
Total — windows	**85 150**
Non-combustible doors	
Seals	168
Non-combustible doors	453
Door protection	3 933
Total — non-combustible doors	**4 554**

Measure	Estimated cost
	$
Vents and other perforations	
Vents	640
Penetrations	676
Total — vents and other perforations	**1 316**
Decks, verandahs and stairs	
Non-combustible materials	3 300
On-ground	0
Raised and fully-enclosed subfloor	14 104
Raised floor	5 501
Other	
Non-combustible fences	700
Garage door seals	923

Source: RLB, CIE.

The cost of several of these measures appear to be significantly higher than the potential benefits estimated above, implying that imposing these measures on houses more than 100 metres from vegetation is unlikely to pay-off. Measures that could be too costly include:

- non-combustible wall cladding
- non-combustible fascias, barges and eaves
- glazing
- raised and fully enclosed subfloors.

Several of these measures relate more to protection from the bushfire flame front and are less relevant to houses more than 100 metres away from vegetation.

The cost of several measures (or combinations of measures) that provide additional protection from ember attack is relatively low and likely to be within the 'budget' implied by the estimated benefits. However, the outcome of a full cost-benefit analysis would depend on the effectiveness of these measures in protecting dwellings from ember attack, which is currently not known.

Key findings

Key findings from our high-level analysis in relation to bushfires are as follows.

- Bushfires impose significant costs on the community and a significant share of these costs relate to the resilience (or lack of resilience) of residential buildings. We estimate the residential building-related costs from bushfires could currently be around $487 million per year on average.
- These costs are expected to increase significantly due to a range of factors including:

  - New development in bushfire prone areas (we estimate that an increasing share of the dwelling stock is in bushfire prone areas).
  - Climate change
  - A decreasing share of residents that intend to stay and defend their properties, which partly reflects a change in the advice from fire authorities. Although this will save lives, a consequence will be an increase in property damage.
- As a result of these factors, we estimate these costs could increase to:
  - around $2.2 billion per year by 2050 under a RCP4.5 emissions scenario
  - around $2.8 billion per year by 2050 under a RCP8.5 emissions scenario.
- Several weaknesses have been identified in current arrangements relating to bushfire protection, including the following:
  - Buildings that have been built to bushfire construction standards may not be resilient because the current deemed-to-satisfy building standard does not, or cannot, address all factors contributing to property loss, such as: house-to-house ignition, maintenance, compliance, landscaping and storage of combustible materials.[156]
  - Although ember attack is the main source of ignition for houses lost to bushfires, there is no requirement for houses more than 100 metres from vegetation to include any bushfire protection measures, even if on bushfire prone land.
- Some building-related measures to improve bushfire protection are relatively costly (including: non-combustible wall cladding; non-combustible fascias, barges and eaves; fire-resistant glazing; and raised and fully enclosed subfloors). However, some of these measures are more relevant to radiant heat protection.
- The cost of several measures (or combinations of measures) that provide additional protection from ember attack is relatively low and likely to be within the 'budget' implied by the estimated benefits. However, the outcome of a full cost-benefit analysis would depend on the effectiveness of these measures in protecting dwellings from ember attack, which is currently not known
- Other measures that can be taken to reduce fire risk — some of which may be relatively cost effective — are currently outside the scope of the NCC. These include:[157]
  - separation distances between buildings to limit structure-to-structure spread (the NCC already states that a building should not pose a fire risk to another building)
  - non-combustible fencing
  - the materials used and location of retaining walls proximal to buildings
  - fire-resistant water tanks
  - storage of combustible materials (including firewood and gas cylinders)

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156 Cotter, K. 2021, *Lessons to be learned in relation to the Australian bushfire season 2019-20*, Submission to the Senate Finance and Public Administration References Committee, Bushfire Building Council of Australia Ltd, 3 May 2021, p. 9.

157 See for example: Leonard, J. Opie, K. Blanchi, R. Newnham, G. and Holland, M. *Wye River/Separation Creek Post-bushfire building survey findings*, CSIRO Land and Water, Report EP 16924, Report to the Victorian Country Fire Authority, April 2016, p. 29

- As these options may be complementary to or a substitute for building-related measures, a comprehensive future ABCB RIS could consider:
  – how these approaches to bushfire mitigation could be integrated into the NCC's regulatory approach (including how relatively expensive construction-related measures could be traded off against potentially cheaper and more effective alternatives); or
  – these type of approaches (which could be applied through land use planning regulation) as alternative options to strengthening building-related measures (as required by the RIS process) — although a rigorous evidence-based assessment process is generally applied to changes to building standards, this is less true of changes to planning regulation.

A Estimating the number of dwellings on bushfire prone land

This appendix details the procedure of estimating the number of dwellings on bushfire prone areas, which are used in estimating the size of the problem in chapter 5.

Approach

Some states — including NSW, Victoria and Queensland — make the data underpinning maps of bushfire prone land publicly available. To estimate the number of separate houses in bushfire prone areas we:

- identified the ABS mesh block within designated bushfire prone land in, NSW, Victoria and Queensland (which together account for around 75 per cent of all houses in Australia);
- used 2021(and 2016) Census data to identify the number of separate houses in each of the relevant mesh blocks.

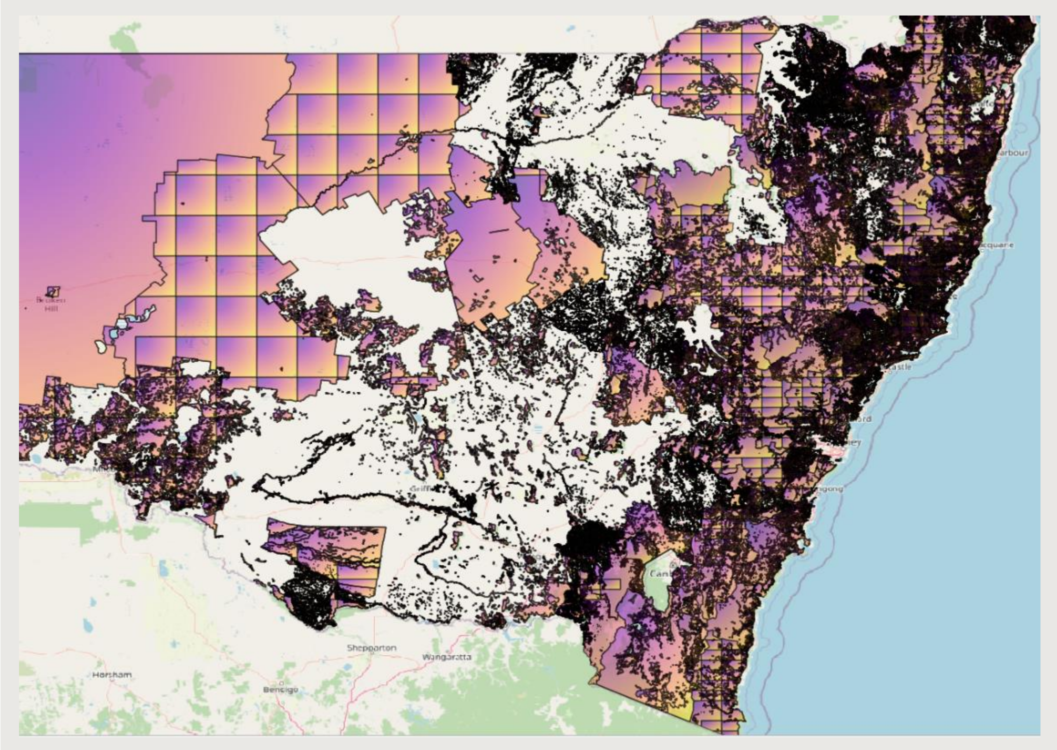
Number of dwellings in bushfire prone areas

Maps of bushfire prone land and details of the number of dwellings on bushfire prone land in 2016 and 2021 are provided below for NSW, Victoria and Queensland.

New South Wales

A map of bushfire prone areas in NSW is shown in chart A.1.

A.1 NSW bushfire prone area



Data source: CIE analysis; https://portal.spatial.nsw.gov.au/portal/home/item.html?id=3de03ae1965840cfa5dcd9e4018745a7

Table A.2 compares the estimated number of Class 1a dwellings in bushfire prone areas in 2016 and 2021 across different regions of NSW. As described above, the analysis was completed at the mesh block level (i.e. the smallest geographical classification) to achieve the greatest accuracy possible and then aggregated up to the Statistical Area Level 4 (SA4 — the largest sub-state regions in the main structure of the ASGS[158]) and state level.

A.2 Number of Class 1 dwellings in bushfire prone areas in NSW

	2016	2021	Overall growth	Annual growth
	number	number	%	%pa
Sydney – Ryde	4 258	4 386	3.0	0.59
Sydney – Paramatta	2 093	2 133	1.9	0.38
Sydney – Sutherland	12 080	12 234	1.3	0.25
Sydney – South West	7 767	10 519	35.4	6.25
Sydney – Outer West and Blue Mountains	31 064	33 959	9.3	1.80
Sydney – Outer South West	11 439	14 933	30.5	5.48
Sydney – Northern Beaches	11 884	12 339	3.8	0.75
Sydney – North Sydney and Hornsby	20 946	21 034	0.4	0.08
Sydney – Inner South West	2 962	2 942	-0.7	-0.14

158 ABS website, https://www.abs.gov.au/statistics/standards/australian-statistical-geography-standard-asgs-edition-3/jul2021-jun2026/main-structure-and-greater-capital-city-statistical-areas/statistical-area-level-4, accessed 5 June 2023.

	2016	2021	Overall growth	Annual growth
	number	number	%	%pa
Capital Region	22 287	24 811	11.3	2.17
Central Coast	38 299	43 429	13.4	2.55
Central West	4 408	4 751	7.8	1.51
Coffs Harbour – Grafton	14 177	15 868	11.9	2.28
Far West and Orana	3 523	3 476	-1.3	-0.27
Hunter Valley excluding Newcastle	21 996	27 024	22.9	4.20
Illawarra	13 699	15 184	10.8	2.08
Mid North Coast	27 315	31 900	16.8	3.15
Murray	5 025	6 012	19.6	3.65
New England and North West	6 166	6 837	10.9	2.09
Newcastle and Lake Macquarie	32 120	37 076	15.4	2.91
Richmond – Tweed	20 554	23 355	13.6	2.59
Riverina	3 942	4 127	4.7	0.92
Southern Highlands and Shoalhaven	20 869	23 359	11.9	2.28
Sydney – Baulkham Hills and Hawkesbury	9 855	14 985	52.1	8.74
Sydney - Blacktown	3 059	4 813	57.3	9.49
Total	**351 787**	**401 486**	**14.1**	**2.68**

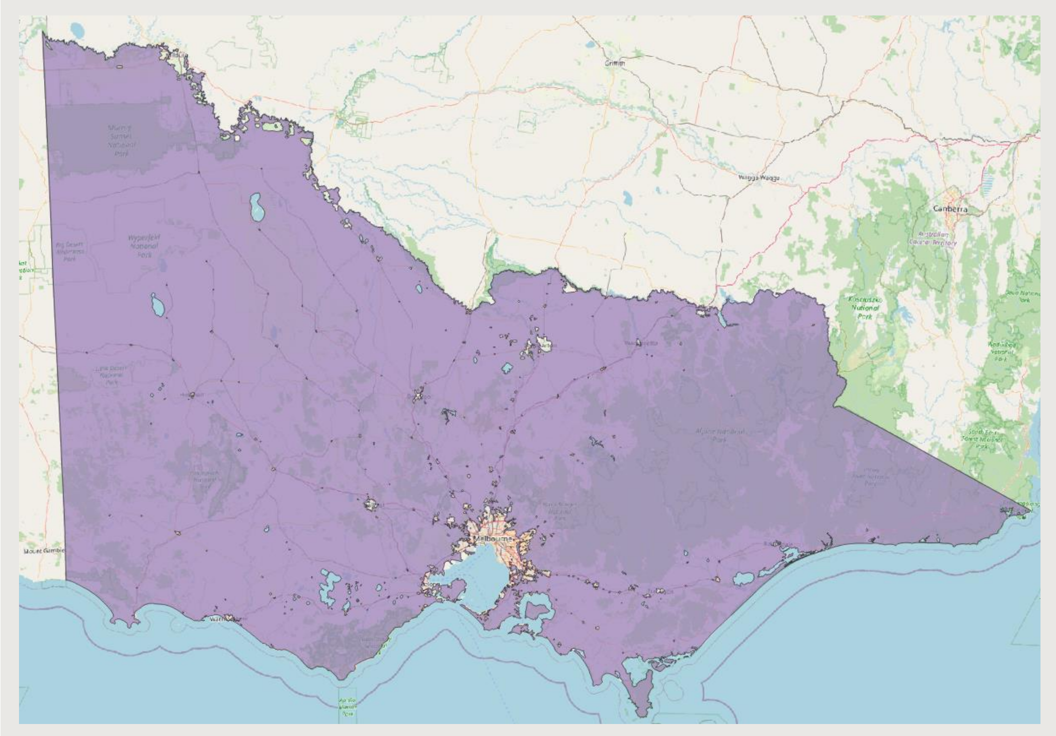
Note: Analysis was done at the mesh block level to ensure accuracy. Class 1 includes separate house and semi-detached, row or terrace house, townhouse etc. with one storey or more storeys. It has been assumed that dwellings are evenly distributed throughout the meshblock. Therefore, if x% of the meshblock is in a bushfire-prone area, the same proportion has been applied to class 1 residences there to determine how many dwellings there are in a bushfire-prone area.

Source: CIE analysis

Victoria

A map of bushfire prone areas in Victoria is shown in chart A.3.

A.3 Victoria designated bush fire prone area



Data source: CIE analysis; https://discover.data.vic.gov.au/dataset/designated-bushfire-prone-area-bpa1

Table A.4 compares the estimated number of Class 1a dwellings in bushfire prone areas in 2016 and 2021 across different regions of Victoria. As above, the analysis was completed at the mesh block level and then aggregated up to SA4 and state level.

A.4 Estimated number of Class 1 dwellings in bushfire prone areas in Victoria

	2016	2021	Overall growth	Annual growth
	number	number	%	%pa
Ballarat	20 994	24 174	15.1	2.86
Bendigo	30 911	35 545	15.0	2.83
Geelong	20 004	24 490	22.4	4.13
Hume	23 593	26 805	13.6	2.59
Latrobe – Gippsland	39 724	45 130	13.6	2.58
Melbourne – Inner East	1 424	1 480	3.9	0.77
Melbourne – Inner South	709	695	-2.0	-0.40
Melbourne – North East	18 637	22 002	18.1	3.38
Melbourne – North West	7 999	10 940	36.8	6.46
Melbourne – Outer East	44 684	46 633	4.4	0.86
Melbourne – South East	19 211	22 806	18.7	3.49
Melbourne - West	5 686	9 653	69.8	11.17
Mornington Peninsula	48 684	51 036	4.8	0.95
North West	11 883	12 823	7.9	1.53

	2016	2021	Overall growth	Annual growth
	number	number	%	%pa
Shepparton	11 091	12 240	10.4	1.99
Warrnambool and South West	12 992	14 448	11.2	2.15
Total	**318 226**	**360 900**	**13.4**	**2.55**

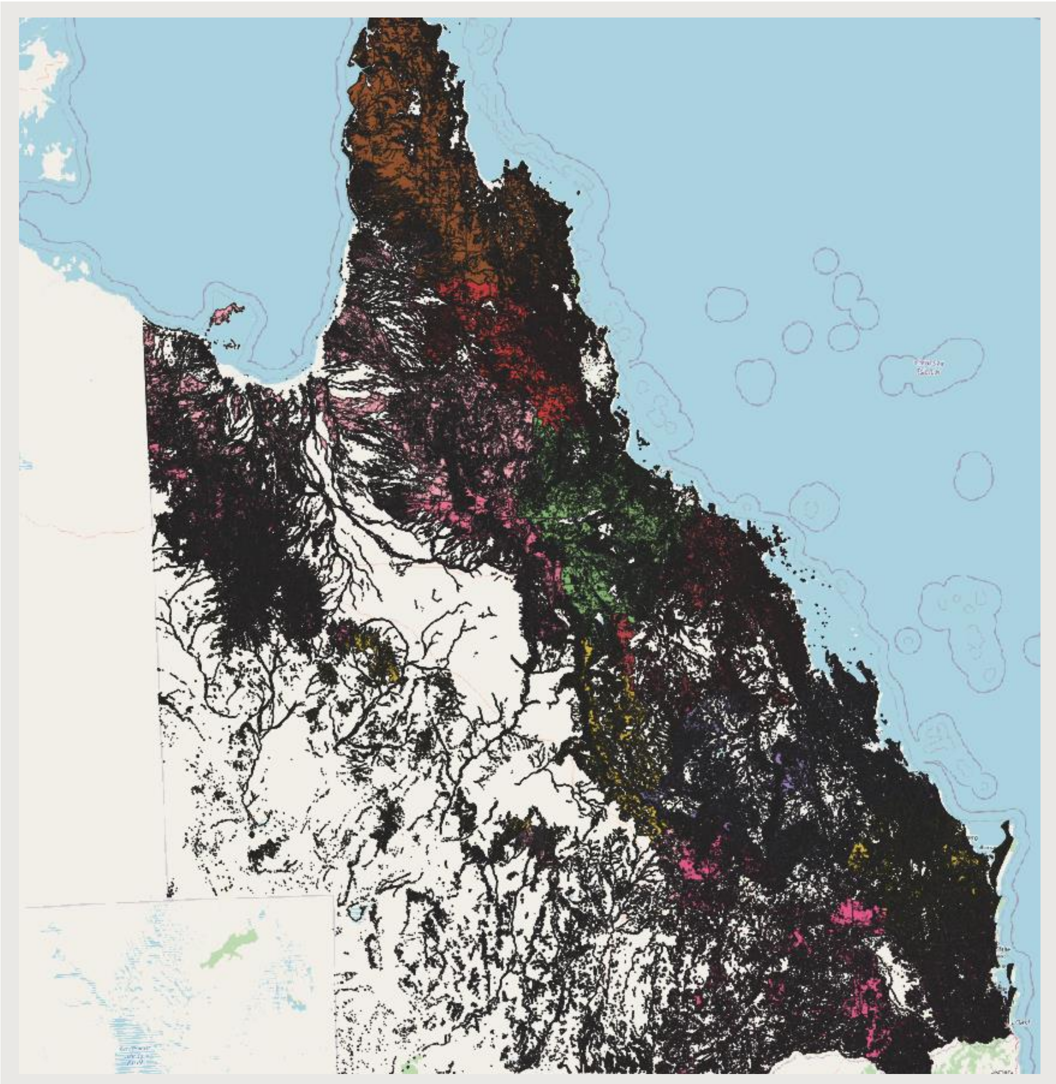
Note: Analysis was done at the mesh block level to ensure accuracy. Class 1 includes separate house and semi-detached, row or terrace house, townhouse etc. with one storey or more storeys. It has been assumed that dwellings are evenly distributed throughout the meshblock. Therefore, if x% of the meshblock is in a bushfire-prone area, the same proportion has been applied to class 1 residences there to determine how many dwellings there are in a bushfire-prone area.

Source: CIE analysis

Queensland

A map of bushfire prone areas in Queensland is shown in chart A.5.

A.5 Queensland bushfire prone area



Data source: CIE analysis; https://www.data.qld.gov.au/dataset/bushfire-prone-area-queensland-series

Table A.6 compares the estimated number of Class 1a dwellings in bushfire prone areas in 2016 and 2021 across different regions of Queensland. As above, the analysis was completed at the mesh block level and then aggregated up to SA4 and state level.

A.6 Number of Class 1 dwellings in bushfire prone areas in Queensland

	2016	2021	Overall growth	Annual growth
	number	number	%	%pa
Cairns	14 181	15 697	10.7	2.05
Queensland – Outback	5 058	5 463	8.0	1.55
Logan – Beaudesert	21 953	29 554	34.6	6.13
Brisbane – East	13 446	14 888	10.7	2.06
Brisbane – North	5 297	6 062	14.4	2.73
Brisbane – South	8 872	10 989	23.9	4.37
Brisbane – West	7 893	8 778	11.2	2.15
Brisbane – Inner city	1 859	1 923	3.4	0.68
Gold Coast	27 153	33 339	22.8	4.19
Ipswich	18 966	27 138	43.1	7.43
Moreton Bay – North	10 966	13 797	25.8	4.70
Moreton Bay – South	10 034	11 707	16.7	3.13
Sunshine Coast	32 537	37 593	15.5	2.93
Toowoomba	5 961	6 996	17.4	3.25
Wide Bay	20 823	23 836	14.5	2.74
Darling Downs – Maranoa	5 299	5 568	5.1	1.00
Townsville	10 820	12 079	11.6	2.23
Mackay – Isaac – Whitsunday	10 266	11 287	9.9	1.91
Central Queensland	17 278	18 954	9.7	1.87
Total	**248 662**	**295 648**	**18.9**	**3.52**

Note: Analysis was done at the mesh block level to ensure accuracy. Class 1 includes separate house and semi-detached, row or terrace house, townhouse etc. with one storey or more storeys. It has been assumed that dwellings are evenly distributed throughout the meshblock. Therefore, if x% of the meshblock is in a bushfire-prone area, the same proportion has been applied to Class 1 residences there to determine how many dwellings there are in a bushfire-prone area.

Source: CIE analysis

Share of dwellings in bushfire prone areas

In addition to the increase in number, these dwellings in bushfire prone areas also account for a higher share in total number of dwellings in 2021 than in 2016. In Queensland, the share increased from 14.8 per cent in 2016 to 16.1 per cent in 2021, or 1.3 percentage points increase over five years (table A.7). For NSW and Victoria, the increase was 0.3 percentage points and 0.7 percentage points, respectively, over five years. For other states and territories, we assume an average of 0.7 percentage points increase over the same period.

A.7 Share of Class 1 dwellings in bushfire prone area of all dwellings

	2016	2021	Change over 5 years
	per cent	per cent	Percentage point
New South Wales	14.9	15.2	0.3
Victoria	14.6	15.1	0.5
Queensland	14.8	16.1	1.3
Average for selected states	**14.7**	**15.4**	**0.7**

Note: An average of the increase in the share of BPA buildings across Queensland, Victoria and New South Wales has been applied to South Australia, Tasmania, Western Australia, Australian Capital Territory and Northern Territory equal to 0.7 per cent over 5 years i.e. 0.138 per cent each year.

Source: CIE analysis.

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