Where We Build, What We Build

Project Report

1 May 2020

EDGE

Project Delivered for:

Southern and Hills LGA

Project Delivered by:

Mark Siebentritt - Director

Maisie Auld - Senior Consultant

Edge Environment

106 Giles Street, Adelaide, SA 5000, AUSTRALIA

+61 418 603 015 - mark.siebentrittedgeenvironment.com

This project was jointly funded by the Commonwealth and South Australian Governments under the South Australian Disaster Resilience Grant Program, and the Insurance Council of Australia. The views and findings of this project are expressed independently and do not necessarily represent the views of the funding bodies.

Revision	Revision Details	Author	Approved by	Date Approved
V1.0	Draft Report	Maisie Auld, Elizabeth Cuan, Mark Siebentritt	Mark Siebentritt	3 April 2020
V2.0	Final Report	Maisie Auld, Elizabeth Cuan, Mark Siebentritt	Mark Siebentritt	1 May 2020

Executive Summary

It is widely accepted that Australia's housing stock is often poorly sited, designed and constructed to account for local natural hazards like flood, fire and heat. Yet there are few examples of analyses that build the evidence base at a regional scale to validate this assertion in a systematic and quantitative way. It is only by doing this that the business case for a transition to climate ready homes can successfully be made.

The *Where We Build What We Build* project is supporting the Resilient Hills and Coasts (RH&C) region by enabling assessment of the climate risk exposure of homes and encouraging better climate risk mitigation decisions. To achieve this, it combines:

- Where We Build – flood, heat and fire hazard mapping, comparing the data used by the insurance industry and the data available to Councils; and
- What We Build – risk exposure categorisation of region-specific housing archetypes.

The Where We Build What We Build project has demonstrated how to apply a repeatable methodology for assessing the types of homes in a region, identifying climate archetypes, identifying the resilience of homes to climate hazards and undertaking economic analysis to determine the benefit cost of new build or retrofitting homes with a climate-ready home specification.

The project has delivered:

- Climate hazard and resilience maps, which can continue to be used in the future to assess the resilience of homes to natural hazards. This information can also be updated as new hazard mapping information become available.
- Climate ready home specification, which identifies building and construction materials that can be used for improving the climate resilience of new build and retrofit homes.

Key findings of the project are as follows:

- **The building stock in the region varies significantly in terms of its resilience to natural hazards** – The Adelaide Hills and Fleurieu Peninsula has a range of housing types that can be described as mostly belonging to one of 5 archetypes as follows: modern house, contemporary house, brick veneer house, Lightweight 50s house and Victorian house. The resilience of these homes to natural hazards differs because of the materials they are built from.

  The most resilient home type in the region is the "Contemporary" home, which accounts for 30% of all homes in climate hazard areas and has an average year of construction of 2012. Its resilience was the highest or equal highest for flood, bushfire and heat. In contrast, the Victorian house and Lightweight 50s house, which combined account for nearly 20% of homes in climate hazard areas, have the lowest resilience, being built about 50-100 years ago.

  Overall, 70% of the homes in climate hazard hotspots had a resilience rating of less than 3/5.
- **Vulnerable housing leads to higher living costs -** Vulnerable housing leads to higher living costs, based on a range of factors such as:
  - Higher insurance premiums – annual insurance premiums for the Victorian house were found to be nearly double the climate ready house;
  - Higher energy costs – annual energy costs for the Contemporary and Modern house were 30% higher than for the climate ready home
- **There is sufficient information available to know how to build climate ready homes** – Baseline compliance is currently inadequate to ensure climate resilience of homes. The project has developed a climate ready home specification that provides increased resilience against flood, fire and heat compared with traditional houses. This project used two tools – the Building Resilience Knowledge Database and the Building Resilience Rating Tool – to determine the resilience of building materials and to identify materials for use in constructing climate ready homes. Importantly, the climate ready home specification

can be used for new build or retrofit homes and identifies 23 different types of construction and building elements.

- **The changing cost of insurance will influence how we build new homes and retrofit old homes** – Without insurance people are unable to obtain a mortgage, and without access to a home loan, most people will be unable to buy a home. The insurance industry uses hazard maps and information on construction materials and design to judge the probability and size of an insurance claim arising from climate hazards. We can expect insurance premiums to rise in the future, as hazard exposure increases.
- **Poor quality natural hazard data impacts insurance premiums** - In the absence of quality data about natural hazards, insurers assume the worst-case scenario for the likelihood and consequence of natural hazards, and price accordingly. It is estimated that South Australians pay too much for insurance because of uncertainty about natural hazard data. This project found that obtaining hazard data to supporting cost benefit analysis and resilience mapping was difficult, with limited trust about how data will be used. This project has demonstrated the need for a centrally coordinated, jointly resourced hazard mapping framework in South Australia to overcome knowledge gaps. Further, greater clarity is required about the legal conditions that underpin data provision to the insurance industry.
- **The benefits of climate ready homes outweigh the costs for both new builds and retrofits** – Factoring in the broader costs and benefits of living in a house – including construction and maintenance costs, energy savings, insurance premiums, disruptions from exposure to natural hazards – shows results of benefits outweighing the costs. On average, the greatest value is achieved through a staggered retrofit, however, the investment is viable regardless of when the building improvements occur (i.e. new build, immediate retrofit and staggered retrofit).
  - Homeowners can realise benefits valued at up to $76,000 by retrofitting a Lightweight 50s House. This includes upfront, maintenance and operational costs, insurance savings, and reduced disruption.
- **The regional net present value of immediately retrofitting all 2,956 homes in regional hazard hotspots is estimated at over $72 million** - Over a 50-year period, the net present value of immediately retrofitting the region's housing stock to a climate-ready standard is estimated at over $72 million. Over $46 million of this value is in the District Council of Mount Barker area.
- **A climate ready home standard should be developed** - Given market dynamics, it is unlikely that individual insurers will be able to offer a preferential premium for the climate-ready home while still being certain that they will not be undercut, as other insurers may have different commercial imperatives which allow them to price lower. As such a directional approach is required. The insurance industry recommendation is that climate ready houses pursue a standard/rating, endorsed by the insurance industry that certifies that the house meets a standard that can be described as “Climate Ready”. This rating can then be used by insurers to inform their risk ratings and further contribute to the set of risk information that is used for premium pricing.
- **Vulnerable housing results in lower community resilience** - The outcome of vulnerable housing is reduced community resilience, and higher costs for governments, which tend to become the insurer of last resort when houses are under-insured or uninsured.

Contents

1 Introduction

1.1 Context

Australia's housing stock is often poorly sited and designed to account for local climatic factors such as flood, heat and fire. This results in negative outcomes for occupant health and wellbeing and household running costs.

Now, in response to intensifying climate hazards, the insurance and finance sectors are factoring the risk costs of poor siting and design into their pricing and decision-making. In other words, mortgages and insurance are getting more expensive for climate exposed homes – those that are located in high-risk areas and those that have not been designed to mitigate those risks.

This is not widely understood or communicated. Nor are the costs and benefits of delivering new or retrofitted climate resilient homes that go beyond basic compliance.

1.2 The region

The Resilient Hills and Coasts region aims to attract growth and investment by positioning itself as a resilient region – a leader in empowering climate-ready and disaster resilient communities. The region is experiencing significant urban development, particularly in growth hotspots like Mount Barker, Goolwa and Victor Harbor, and this growth is expected to continue. There is an opportunity to encourage building and retrofitting of homes that are climate-ready – that is, are well-suited to a warmer and drier climate and robust against extreme events. By doing so, the region can become more liveable, affordable, and resilient.

1.3 The project

Where We Build What We Build will support the goals of the region by enabling assessment of the climate risk exposure of homes and encouraging better climate risk mitigation decisions. To achieve this, it will combine:

- Where We Build – flood, heat and fire hazard mapping, comparing the data used by the insurance industry and the data available to Councils; and
- What We Build – risk exposure categorisation of region-specific housing archetypes.

Where We Build What We Build provides a framework and knowledge portal that can be used by developers and homeowners, that can be shared with Councils across the State, and that will support action on other climate risk management priorities.

The project is an initiative of Resilient Hills & Coasts (RH&C), in partnership with the Insurance Council of Australia (ICA) and National Disaster Resilience Program. It is being delivered by Seed Consulting Services and Edge Environment. The project scope covers focus areas within Adelaide Hills Council, Alexandrina Council, District Council of Mount Barker, City of Victor Harbor, and District Council of Yankalilla.

1.4 Methodology overview

The project consisted of six main stages. The stages and key findings of each stage were:

1. Climate hazard mapping

An analysis was undertaken to identify existing hazard data gaps across the RH&C region and climate hazard hotspots. Following a project workshop in May 2019, key stakeholders were asked to review natural hazard maps generated using data from the Insurance Council of Australia's (ICA) DataGlobe relevant to their jurisdiction and consider whether they are different from the maps they use for decision-making. Councils were asked to provide additional data, where available, to update the DataGlobe.

Despite some data and flood maps being provided, no new data was identified that could be used to revise the natural hazard maps on the ICA's DataGlobe and therefore only the existing data was used to generate the climate hazard hotspot maps.

Climate hazard hotspots were defined as areas with either:

- high exposure to bushfire, extreme heat and flood; or
- high exposure to bushfire and flood

The focus areas of the analysis were:

- District Council of Mount Barker – Mount Barker & Nairne;
- Alexandrina Council – Strathalbyn, Goolwa, Hindmarsh Island, Middleton & Port Elliot;
- City of Victor Harbor – Victor Harbor;
- District Council of Yankalilla – Yankalilla & Cape Jervis; and
- Adelaide Hills Council – Stirling, Crafers & Aldgate (all rural living).

2. Housing typology study

Housing archetypes that represent at least 80% of the housing stock in the region (a total of five archetypes) were identified and their resilience analysed.

The project team utilised components of the ICA's Resilience Program to assess the resilience of the archetypes. Specifically, assigned resilience values for flood and bushfire were based on the ICA's Building Resilience Knowledge Database and the Building Resilience Rating Tool. Extreme heat is not currently considered by the ICA as it does not lead to physical damage of a home. For the purposes of this study, extreme heat is considered in terms of occupant comfort.

The results of the assessment indicate the resilience of building products used in each archetype to flood, fire and extreme heat, and the cost of replacement of each building product for flood and fire. This data provides an insight into the overall resilience of each archetype to flood, bushfire and extreme heat.

A verification workshop with the ICA was held to validate the flood and bushfire results. Overall, the Contemporary House performs the best with the Victorian House performing the worst in terms of resilience to all three hazards. Resilience to extreme heat provides the greatest differentiation between archetypes followed by bushfire resilience.

3. Resilience mapping

Archetypes and their respective resilience ratings were applied to each of the lots within the climate hazard hotspots. This data provides an insight into the resilience of the region (average overall resilience rating of 2.7), and is summarised as follows:

Archetype	Overall Resilience Rating	# Assigned	% of total
Modern house	3.1	881	30%
Contemporary house	2.7	831	28%
Brick veneer house	2.7	560	19%
Lightweight 50s house	2.5	392	13%
Victorian house	2.4	166	6%
Unclassified	-	126	4%
TOTAL		**2,956**	**100%**

4. Development of climate-ready home specification

After characterising the resilience of the existing housing stock, a recommended building specification for a climate-ready home that has improved resilience to bushfire, flood and extreme heat was developed. Materials were chosen based on their performance in response to bushfire, flood and extreme heat exposure.

In general terms, a climate-ready home would include considerations beyond resilience to extreme weather events (e.g. embodied carbon of materials, dependence on the electricity grid). However, for the purposes of this project and in the context of the Southern and Hills Local Government Area (LGA), a climate-ready home is defined as a detached residential home that is resilient to bushfire, flood and extreme heat. Resilience is defined as a home that has reduced impacts from difficult conditions.

The specification that has been developed identifies those building elements and materials that achieve a high level of resilience when exposed to high bushfire, flood and extreme heat.

5. Economic analysis

An economic analysis was conducted to assess the costs and benefits of converting the housing stock to a climate-ready housing stock, guided by the housing typology study undertaken earlier in the project. The analysis focused on broadening out consideration of costs and benefits from the costs of housing to the costs of living. As such, this analysis presented the cost of materials for new build and retrofitting, the average insurance premiums for the existing housing stock compared with the climate-ready home specification, costs associated with damage or loss of the home following a climate event, and predicted energy savings.

6. Development of knowledge portal and regional communications

An online knowledge portal has been developed to provide guidance information on how to mitigate built environment risks associated with flood, bushfire and extreme heat within the RH&C region. Under this step, the climate -ready home specification and findings have been converted into guidance information targeted at key stakeholder groups. A regional communications process accompanies this phase to ensure that key stakeholders understand how to interpret and apply the guidance provided on the knowledge portal. The process includes final project presentations to the RH&C steering committee, the Southern and Hills LGA Board of Mayors & CEOs and the South Australian climate adaptation practitioners’ networks, plus preparation of factsheets for key target audiences.

2 Climate hazard mapping

This phase of the project consisted of analysing and identifying any existing hazard data gaps across the RH&C region to produce documented understanding of existing hazard mapping, survey data and planning controls across the region.

2.1 Data identification process

A workshop was held on 16 May 2019 to present an overview of the project and to describe the key tasks of identifying natural hazard data and receiving feedback on the draft housing archetypes. This workshop described in particular the availability of natural hazard data from the ICA's DataGlobe and how this will be used for the project to assess the potential risk of natural hazards to housing in the region.

Following the workshop, email correspondence was sent to key contacts from councils in the region and relevant State government agencies requesting feedback on the natural hazard data and the draft housing archetypes. Specifically in relation to the natural hazard data, the email provided a document containing natural hazard maps for townships in the region for comparison against council data along with a link to the ICA DataGlobe. Key stakeholders were asked to review the maps relevant to their jurisdiction and consider whether they are different from the maps they use for decision-making.

The project team was provided with the following feedback in response to the email:

- Alexandrina Council:
  - GIS shapefiles for mapping in the Langhorne Creek area;
  - PDF maps for localised stormwater flooding in Port Elliot;
- District Council of Yankalilla:
  - PDF maps for localised stormwater flooding along the Bungala River in Yankalilla and Normanville;
- Department for Environment and Water:
  - a link to the Flood Awareness maps on Water Connect.

No other councils or agencies were willing or able to share data, with some indicating concern about data quality and others highlighting the implications of sharing the data if it was to be uploaded to the ICA's DataGlobe.

Overall, no new data was provided that could be used to revise the natural hazard maps on the ICA DataGlobe and so only the existing data was used to generate the climate hazard hotspot maps described in Section 3.

It should be noted that Langhorne Creek is outside of the study's focus townships meaning the data cannot be used, though discussions will continue with the ICA to determine if there is a difference between the data sets and if so, what the implications could mean for insurance premiums in this location.

2.2 Climate hazard hotspots

Following the completion of data collection, a mapping exercise was undertaken to identify climate hazard hotspots within the RH&C region.

2.2.1 Method

A climate hazard hotspot is defined as an area with high exposure to bushfire, extreme heat and flood and is within the following focus areas:

- District Council of Mount Barker – Mount Barker & Nairne;
- Alexandrina Council – Strathalbyn, Goolwa, Hindmarsh Island, Middleton & Port Elliot;

- City of Victor Harbor – Victor Harbor;
- District Council of Yankalilla – Yankalilla & Cape Jervis; and
- Adelaide Hills Council – Stirling, Crafers & Aldgate (all rural living).

To identify climate hazard hotspots a number of datasets were compared and combined.

2.2.1.1 Bushfire

The Government of South Australia's bushfire protection areas dataset (Department of Planning, Transport and Infrastructure, 2015) was used to identify those areas with high bushfire exposure. This dataset incorporates fuel load, slope, aspect and weather data to indicate bushfire risk.

The bushfire protection areas dataset excludes urban areas, so a 3 km buffer area was added to the perimeter of each high bushfire exposure area to account for the ability of an ember to travel up to 3 km, allowing bushfire to spread from a high exposure area into an urban area.

Areas identified as high bushfire exposure (including the 3 km buffer zone) are identified in Figure 1. Where only a portion of a property lot was found to be within the high bushfire exposure area, the whole lot was treated as a high bushfire exposure area.

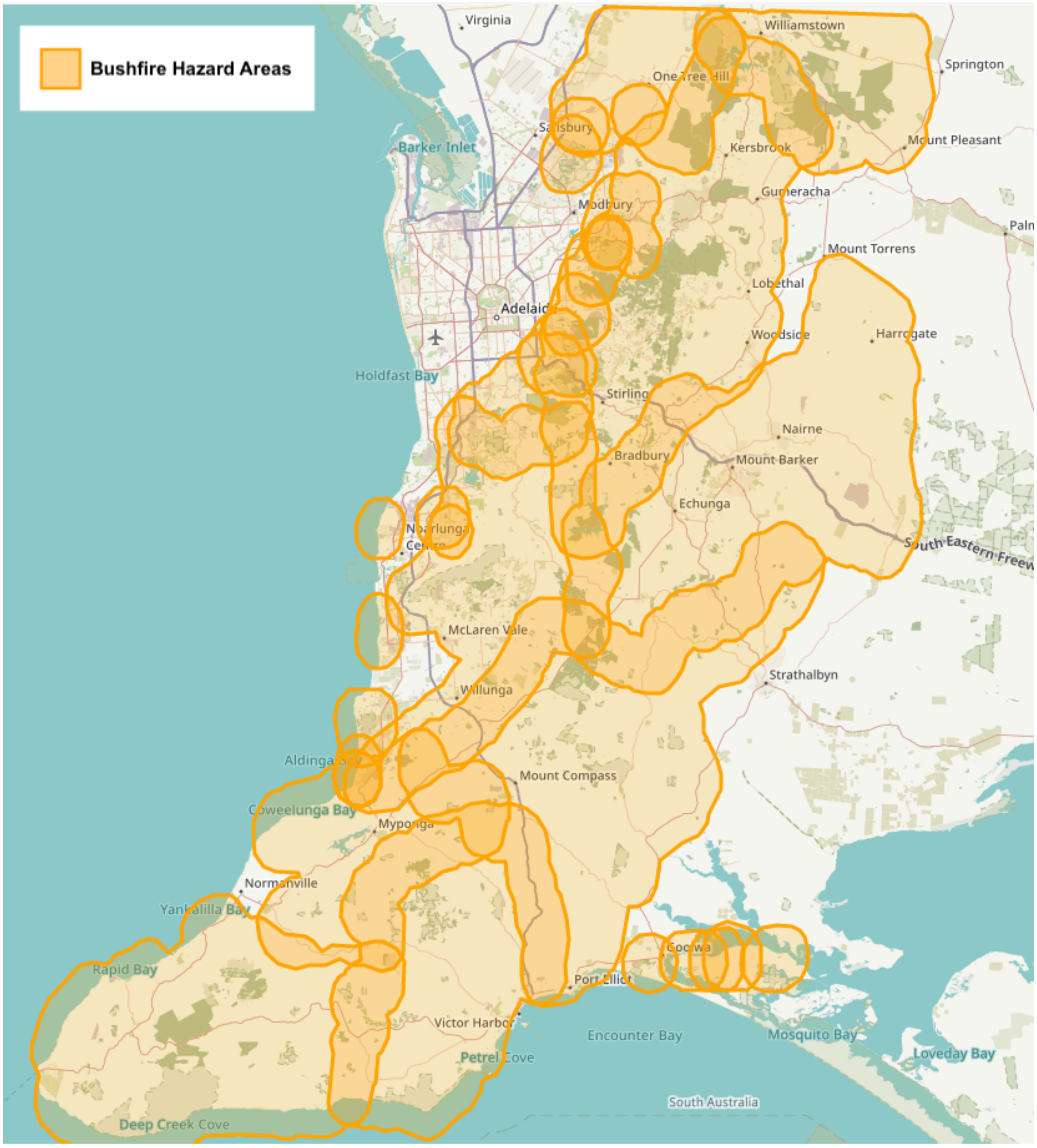

Figure 1 | High bushfire exposure.

2.2.1.2 Flood

The ICA's iLEAD dataset was used to identify areas of possible flood risk. The iLEAD dataset uses local government riverine flood surveys to provide probable flood risk and depth for the 1-in-20-year, 1-in-50-year, and 1-in-100-year ARI floods. Where flood surveys are unavailable, the iLEAD dataset applies topographic information to predict areas that are likely prone to riverine flooding.

Those areas identified by the iLEAD dataset as "Flooding Likely" or having any probable flood risk are considered to have high flood exposure for the purposes of this study (Figure 2).

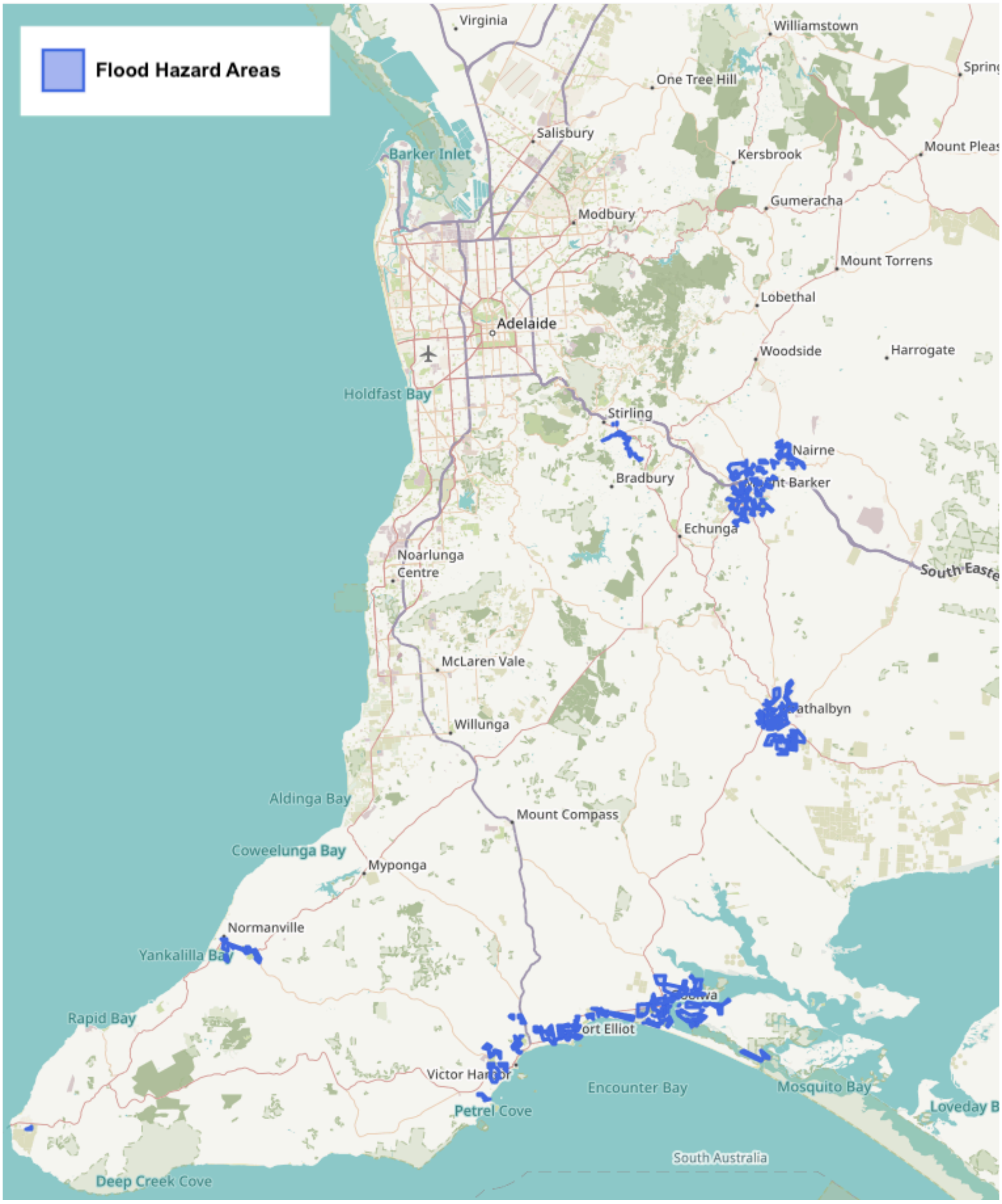

Figure 2 | Flood mapping.

2.2.1.3 Extreme heat

Extreme heat areas were identified using a Land Surface Temperature raster that was collected on 16 February 2019 by the Landsat 8 Operational Land Imager satellite using a Thermal Infrared Sensor.

The Bureau of Meteorology reports 16 February 2019 as a 29˚C day at the Strathalbyn Racecourse. Land surface temperature across the area ranged between 18.8˚C and 40.5˚C (Figure 3). Any areas registering as 32˚C or above are considered to have high extreme heat exposure.

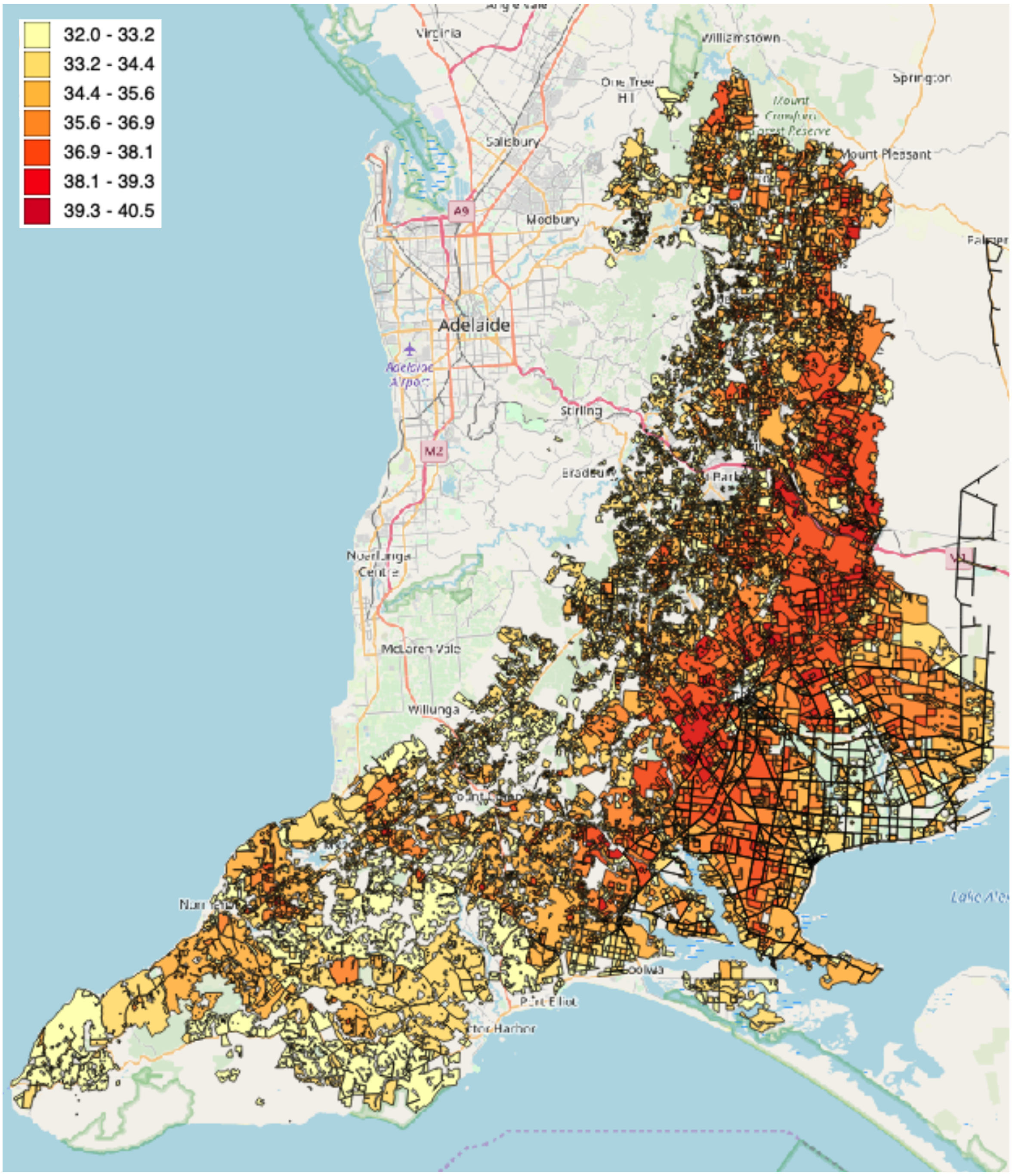

Figure 3 | Land Surface Temperature data captured on 16 February 2019.

2.2.1.4 Study focus areas

Mapping layers containing the identified high exposure areas of extreme heat, bushfire and flood were combined to show areas of overlap (i.e. climate hazard hotspots). The resulting climate hazard hotspot layer was clipped to align to the study focus areas only (Figure 4).

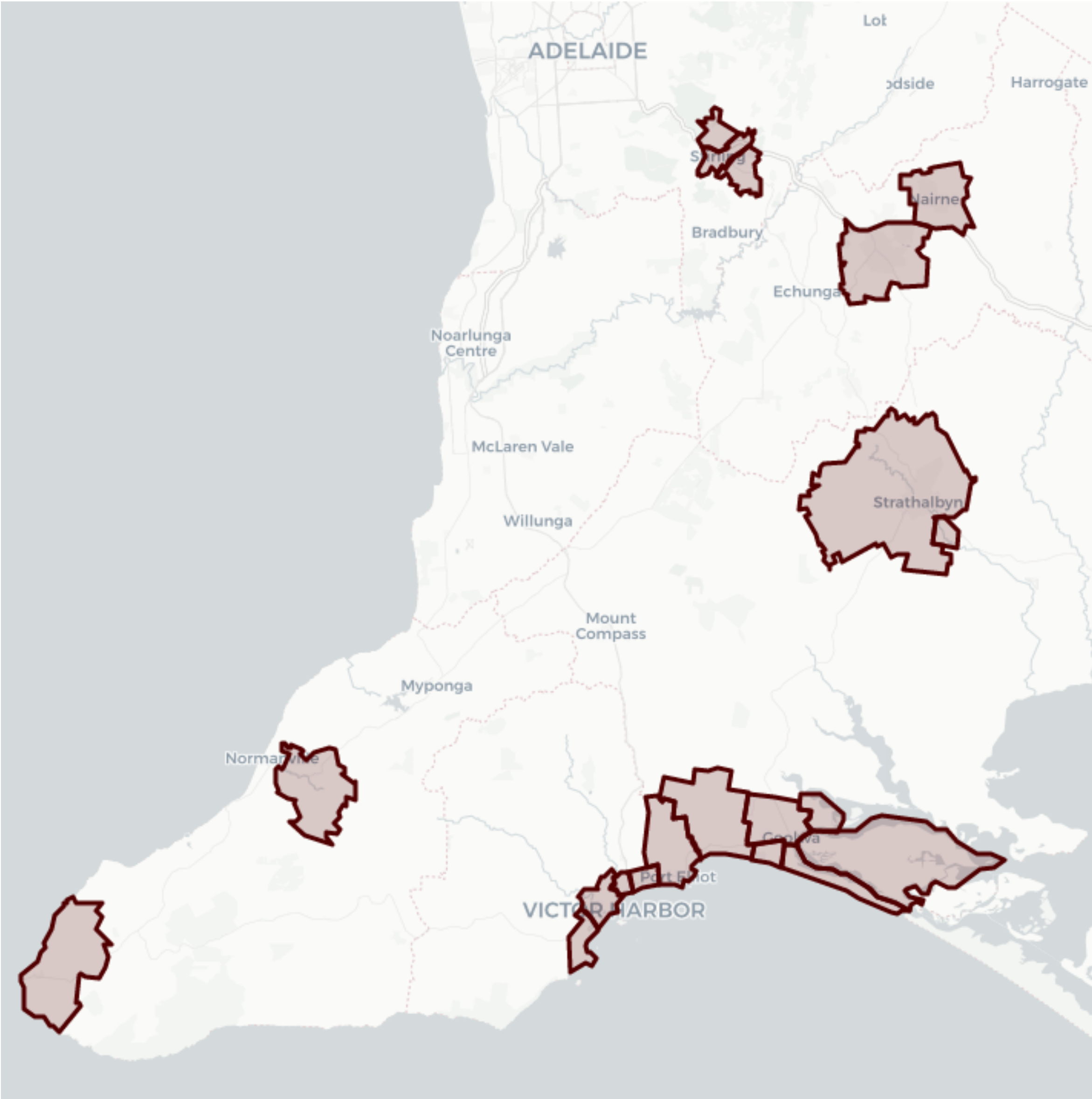

Figure 4 | Study focus areas.

2.2.2 Climate hazard mapping findings

Figure 5 summarises the climate hazard hotspots identified within the study focus area. These hotspots served as the focus for the project.

It was also identified that much of the study focus area experiences high exposure to both bushfire and flood on a single land parcel. From an insurance perspective, bushfire and flood exposure are important considerations when determining residential insurance premiums as these are some of the costliest hazard events in terms of financial loss.

Therefore, climate hazard hotspots were identified as areas with:

- High exposure to bushfire, flood and extreme heat; or
- High exposure to bushfire and flood.

Figure 5 | Climate hazard hotspots within the study focus areas.

3 Housing typology study

The housing typology study was applied to those areas within the RH&C region identified as climate hazard hotspots. The purpose of the study was to identify housing archetypes that represent at least 80% of the housing stock in the target area. Information was gathered from:

- Literature review;
- Development applications;
- Local construction companies;
- Local Government records of development;
- Insurance information;
- Online Google Street View data collection; and
- Stakeholder consultation and expert review.

The outcome of the housing typology study identified five archetypes representative of 80% of the building stocking in the study area:

- Brick veneer house;
- Modern house;
- Lightweight 50s house;
- Victorian house; and
- Contemporary house.

Appendix A presents the finalised archetypes and their characteristics.

3.1 Archetypes

Using Google Street View and the Department of Planning, Transport and Infrastructure's Valuation Cadastre Subset (dataset number 956), the Edge team applied the most representative archetype to each lot within the identified climate hazard hotspots (i.e. areas with either (1) high flood and high bushfire exposure or (2) areas with high flood, high bushfire and extreme heat exposure). Table 1 presents a summary of the outcome of this task for all councils combined, and Table 2 to Table 6 provides .

Unclassified refers to those lots that the project team was unable to classify due to:

- Visibility (e.g. house not visible from the road and archetype unable to be identified through satellite imagery);
- Application to study (e.g. the house differs substantially to the five archetypes); and
- Non-residential land use (e.g. lot classified as commercial land).

Table 1 – Summary of application of region-specific housing archetypes to climate hazard hotspots

Archetype	# Assigned	% of total
Modern house	881	30%
Contemporary house	831	28%
Brick veneer house	560	19%
Lightweight 50s house	392	13%
Victorian house	166	6%
Unclassified	126	4%
TOTAL	**2,956**	**100%**

Table 2 - # Archetypes assigned in Adelaide Hills

Archetype	# assigned	% of total
Brick veneer house	40	37%
Modern house	19	18%
Lightweight 50s house	16	15%
Victorian house	22	21%
Contemporary house	3	3%
Unclassified	7	7%
TOTAL	**107**	**100%**

Table 3 - # Archetypes assigned in Alexandrina

Archetype	# assigned	% of total
Brick veneer house	89	12%
Modern house	123	16%
Lightweight 50s house	160	21%
Victorian house	31	4%
Contemporary house	280	36%
Unclassified	86	11%
TOTAL	**769**	**100%**

Table 4 - # Archetypes assigned in Mount Barker

Archetype	# assigned	% of total
Brick veneer house	402	21%
Modern house	706	38%
Lightweight 50s house	150	8%
Victorian house	78	4%
Contemporary house	517	27%
Unclassified	28	1%
TOTAL	**1881**	**100%**

Table 5 - # Archetypes assigned in Victor Harbor

Archetype	# assigned	% of total
Brick veneer house	3	14%
Modern house	6	29%
Lightweight 50s house	4	19%
Victorian house	2	10%
Contemporary house	6	29%
Unclassified	0	0%
TOTAL	**21**	**100%**

Table 6 - # Archetypes assigned in Yankalilla

Archetype	# assigned	% of total
Brick veneer house	26	15%
Modern house	27	15%
Lightweight 50s house	62	35%
Victorian house	33	19%
Contemporary house	25	14%
Unclassified	5	3%
TOTAL	**178**	**100%**

3.2 Resilience of archetypes

The project team used components of the ICA's Resilience Program to assess the resilience of the archetypes. Specifically, the assigned resilience values for flood and bushfire are based on the ICA's Building Resilience Knowledge Database (BRKD) and the Building Resilience Rating Tool (BRRT). Resilience ratings range from 1 to 5, with 1 being the least resilient to natural hazards and 5 being the most resilient to natural hazards.

Extreme heat is not currently considered by the ICA as it does not lead to physical damage of the home. For the purposes of this study, extreme heat is considered in terms of occupant comfort.

3.2.1 The Building Resilience Knowledge Database

The BRKD is an information database concerning building materials and their resilience to extreme weather events. The BRKD provides a resilience rating (1-5) to a range of building materials to represent their performance in response to a number of climate hazards.

3.2.1.1 Flood

The resilience ratings for freshwater inundation follow a 1 to 5 scale which indicates the flood resilience of a product. Where the element/material has a rating under the US Federal Emergency Management Agency (FEMA) guidelines, this has been used as a representative resilience rating. The FEMA '*Guidelines for Flood Damage-Resistant Materials Requirements for Buildings Located in Special Flood Hazard Areas'* has been developed in accordance with the US National Flood Insurance Program (NFIP) with the objective of protecting buildings that are constructed in special flood hazard areas.

- FEMA ratings 1, 2 and 3 are translated directly to the BRKD scale with 1, 2 and 3 ratings respectively, and are all considered as 'inappropriate' for use in flood-prone areas;
- FEMA ratings 4 and 5 are given a 4 under the BRKD scale. These materials are considered appropriate for use in areas that may be inundated;
- A rating of 5 is assigned to only those materials that require no intervention post-hazard; and
- Materials for which there is no FEMA rating refer to other sources for classification as 'suitable' or 'not suitable' in an inundation scenario. Materials classified as 'suitable' or 'not-suitable' and have been given a 4 or 1 rating in the BRKD, respectively.

3.2.1.2 Bushfire

The resilience ratings for bushfire follow a 1 to 5 scale which indicates the bushfire resilience of a product. However, an additional 0 rating has been applied for combustible materials. These ratings correspond directly to the BAL ratings outlined in the AS3959 standard. In this way, a material rated as 5 has suitable properties to be used in a flame zone (BAL FZ) and a material with a rating of 1 can be used in a BAL 12.5. A material with a rating of 0 is considered unacceptable.

The bushfire resilience ratings and corresponding BAL exposure level are outlined in Table 7.

Table 7 – BAL exposure level and associated resilience rating

BAL rating	BRKD resilience rating
BAL FZ	5
BAL 40	4
BAL 29	3
BAL 19	2
BAL 12.5	1
Combustible	0

3.2.2 The Building Resilience Rating Tool (BRRT)

The BRRT uses the resilience ratings from the BRKD to estimate the resilience of an entire dwelling. The BRRT estimates a dwelling's resilience by calculating a weighted expected cost for damages to the house based on the resilience of construction materials (as per the BRKD), size of each element as part of the overall house and the natural hazard risk profile of the home's specific location.

The BRRT mathematical formulation to determine this uses a significant number of variables. Most of these variables remain constant in the calculation of the overall resilience rating of the archetypes in this study, as they do not affect the overall resilience rating when considering flood and bushfire. The variables that are relevant to this project and change across the identified archetypes include:

- Floor height – 0.2 m or 0.5 m depending on the archetype characteristics;
- Cost of elements (refer to Appendix B);
- Roof shape – hip or gable depending on the archetype characteristics; and
- Roof pitch – 15º to 45º depending on archetype characteristics.

Element size can vary between archetypes (e.g. the roof size of a modern house may be different to that in a Victorian house). However, for the purpose of this study, element sizes have remained constant in proportion to the overall size of the archetype (Table 8).

Table 8 – Assume archetype size

Archetype	Average size (m^2)
Brick Veneer House	160
Modern House	200
Lightweight 50s House	160
Victorian House	160
Contemporary House	214
Climate-ready Home	214

Source: ABS (2010)

More information around the mathematical formulation to obtain the overall archetype's resilience rating can be found in BRRT 17.2 Specification Report_Rev1.

3.2.3 Flood

As identified in the ICA's BRKD and the BRRT, the primary building elements that influence the resilience of a home to flood are:

- Floor height;
- External wall cladding;
- Internal linings;
- Wall insulation;
- Internal wall coverings;
- Ceiling lining; and
- Floor finishes.

Table 9 presents the resilience of these building elements in response to flood by archetype. Floor height has been excluded from Table 9 as the BRKD does not assign a specific resilience value to this element. However, it does contribute to the overall resilience rating of each archetype and therefore has been used to determine the overall resilience ratings presented in section 3.2.4, as per the Building Resilience Rating Tool (BRRT) results (Refer to section 3.2.2).

Table 9 – Resilience of building elements to flood by archetype

	Brick Veneer House		Modern House		Lightweight 50s House		Victorian House		Contemporary House	
External wall cladding	Brick cladding	5	Brick cladding	5	Fibre cement weatherboard	4	Stone cladding	5	Brick cladding	5
Internal linings	Plasterboard	1	Plasterboard	1	Fibre cement sheet	4	Plaster	2	Plasterboard	1
Wall insulation	None	n/a	Glasswool	1	None	n/a	None	n/a	Glasswool	1
Internal wall coverings	Paint	4	Paint	4	Paint	4	Paint	4	Paint	4
Floor finishes	Timber	3	Broadloom carpet	1	Timber	3	Timber	3	Timber	3
Ceiling lining	Plasterboard	1	Plasterboard	1	Fibre cement sheet	4	Plaster	1	Plasterboard	1

The insurance industry also considers replacement cost as an indicator of resilience. Table 10 presents the cost of each building element by archetype. Classification of costs is as follows:

- Low: average cost of <$20 per unit;
- Medium: average cost of $20 - $100 per unit;
- High: average cost of $100 - $400 per unit; and
- Very high: average cost of >$400 per unit.

Table 10 – Cost of building elements by archetype

	Brick Veneer House		Modern House		Lightweight 50s House		Victorian House		Contemporary House	
External wall cladding	Brick cladding	High	Brick cladding	High	Fibre cement weatherboard	Med	Stone cladding	Very High	Brick cladding	High
Internal linings	Plasterboard	Med	Plasterboard	Med	Fibre cement sheet	Med	Plaster	Med	Plasterboard	Med
Wall insulation	None	n/a	Glasswool	Low	None	n/a	None	n/a	Glasswool	Low
Internal wall coverings	Paint	Low	Paint	Low	Paint	Low	Paint	Low	Paint	Low
Floor finishes	Timber	High	Broadloom carpet	Med	Timber	High	Timber	High	Timber	High
Ceiling lining	Plasterboard	Med	Plasterboard	Med	Fibre cement sheet	Med	Plaster	Med	Plasterboard	Med

3.2.4 Overall flood resilience ratings

The resilience of each material in addition to the replacement cost of each building element and the size of each element as part of the overall house are weighted to provide an overall resilience score to each archetype in response to high flood exposure (Table 11). For further detail on the specific algorithms behind the overall resilience ratings and the methodology as defined by the ICA's Resilience Program, refer to https://www.resilient.property/resources.

Table 11 – Flood resilience rating by archetype

Archetype (% of housing stock)	Flood Resilience
Contemporary House (28%)	3.0
Brick Veneer House (19%)	3.0
Modern House (30%)	2.0
Lightweight 50s House (13%)	3.0
Victorian House (6%)	3.0

3.2.5 Bushfire

As identified in the ICA's BRKD and the BRRT, the primary building elements that influence the resilience of a home to bushfire are:

- Roof shape;
- Roof pitch;
- Roof covering;
- Guttering;
- External rafters/beams or soffits openings;

- External wall cladding;
- Window frame;
- Window glazing;
- External door;
- Ground floor structure; and
- Ground floor enclosure.

Table 12 presents the resilience of these building elements in response to bushfire by archetype. Roof shape and roof pitch have been excluded from Table 12 as the Building Resilience Knowledge Database does not assign a specific resilience value to these elements. However, they do contribute to the overall resilience rating of each archetype and therefore have been used to determine the overall bushfire resilience ratings presented in section 3.2.6, as per the Building Resilience Rating Tool (BRRT) results (Refer to section 3.2.2).

Table 12 – Resilience of building elements to bushfire by archetype

	Brick Veneer House		Modern House		Lightweight 50s House		Victorian House		Contemporary House	
Roof covering	Concrete tile	5	Zinc aluminium coated corrugated steel	5	Terracotta tile	5	Zinc aluminium coated corrugated steel	5	Zinc aluminium coated corrugated steel	5
Guttering	Painted steel	5	Painted steel	5	Painted steel	5	Painted steel	5	Painted steel	5
External rafters and beams or soffits openings	None	n/a	Yes	0	None	n/a	Yes	0	Yes	0
External wall cladding	Brick cladding	5	Brick cladding	5	Fibre cement weatherboard	4	Stone cladding	5	Brick cladding	5
Window frame	Aluminium	4	Aluminium	4	Timber	0	Timber	0	Aluminium	4
Window glazing	Standard glass	0	Standard glass	0	Standard glass	0	Standard glass	0	Standard glass	0
External door	Timber door	0	Timber door	0	Timber door	0	Timber door	0	Timber door	0
Ground floor structure	Concrete slab on ground	5	Concrete slab on ground	5	Suspended timber structure	0	Concrete slab on ground	5	Concrete slab on ground	5
Ground floor enclosure	Masonry	5	Masonry	5	Timber	0	Masonry	5	Masonry	5

The insurance industry also considers replacement cost as an indicator of resilience. Table 13 presents the cost of each building element by archetype. Classification of costs is as follows:

- Low: average cost of <$20 per unit;
- Medium: average cost of $20 - $100 per unit;
- High: average cost of $100 - $400 per unit; and
- Very high: average cost of >$400 per unit.

Table 13 – Cost of building elements by archetype

	Brick Veneer House		Modern House		Lightweight 50s House		Victorian House		Contemporary House	
Roof covering	Concrete tile	Med	Zinc aluminium coated corrugated steel	Med	Terracotta tile	Med	Zinc aluminium coated corrugated steel	Med	Zinc aluminium coated corrugated steel	Med
Guttering	Painted steel	Med	Painted steel	Med	Painted steel	Med	Painted steel	Med	Painted steel	Med
External rafters and beams or soffits openings	None	Low	Yes	Med	None	Low	Yes	Med	Yes	Med
External wall cladding	Brick cladding	High	Brick cladding	High	Fibre cement weatherboard	Med	Stone cladding	Very high	Brick cladding	High
Window frame	Aluminium	High	Aluminium	High	Timber	Very High	Timber	Very high	Aluminium	High
Window glazing	Standard glass	High	Standard glass	High	Standard glass	High	Standard glass	High	Standard glass	High
External door	Timber door	Very High	Timber door	Very High	Timber door	Very High	Timber door	Very high	Timber door	Very high
Ground floor structure	Concrete slab on ground	Med	Concrete slab on ground	Med	Suspended timber structure	Med	Concrete slab on ground	Med	Concrete slab on ground	Med
Ground floor enclosure	Masonry	High	Masonry	High	Timber	Med	Masonry	High	Masonry	High

3.2.6 Overall bushfire resilience ratings

The Building Resilience Rating Tool (BRRT) was used to estimate the resilience of each archetype (refer to section 2.4.2). The resilience score of each archetype in response to high bushfire exposure is provided in Table 14.

Table 14 – Bushfire resilience rating by archetype

Archetype (% of housing stock)	Bushfire Resilience
Contemporary House (28%)	3.2
Brick Veneer House (19%)	3.0
Modern House (30%)	3.0
Lightweight 50s House (13%)	2.9
Victorian House (6%)	2.9

From an insurance perspective, bushfire is considered to be binary. Once a house ignites, it typically leads to total loss. However, this is shifting with improved building codes. The insurance industry is now seeing partial loss for some houses built post-2009. However, for the majority of homes, bushfire is still considered to be binary. Incremental differences in the resilience ratings are significant. For example, a Lightweight 50s House is 10% more likely to ignite than the Contemporary House.

For further detail on the specific algorithms behind the overall resilience ratings and the methodology as defined by the ICA's Resilience Program, refer to https://www.resilient.property/resources.

3.2.7 Extreme heat

The resilience rating associated with each archetype in response to flood and bushfire were determined based on existing methodology as defined by the ICA's Resilience Program. To assess the performance of each archetype in response to extreme heat, the Edge team developed a methodology as defined in this section. This section provides the research and evidence applied as the basis for the performance rating, or resilience rating of different materials in response to extreme heat.

3.2.7.1 Characteristics of the climate in the Southern Hills & Coast Region

Location and climate play an important role when defining the performance requirements of a building's envelope. To characterise climatic conditions more easily, the Australian Building Codes Board (ABCB) divides Australia into eight climate zones. According to this division, South Australia has three climate zones: zone 4, zone 5 and zone 6. The Southern Hills & Coasts region is located within Zone 6 - Mild temperate (Figure 6). The hot weather in this zone is characterized by an average high temperature of about 25ºC (during summer) with occasional periods of extreme heat with highs over 35ºC (and sometimes 40ºC).

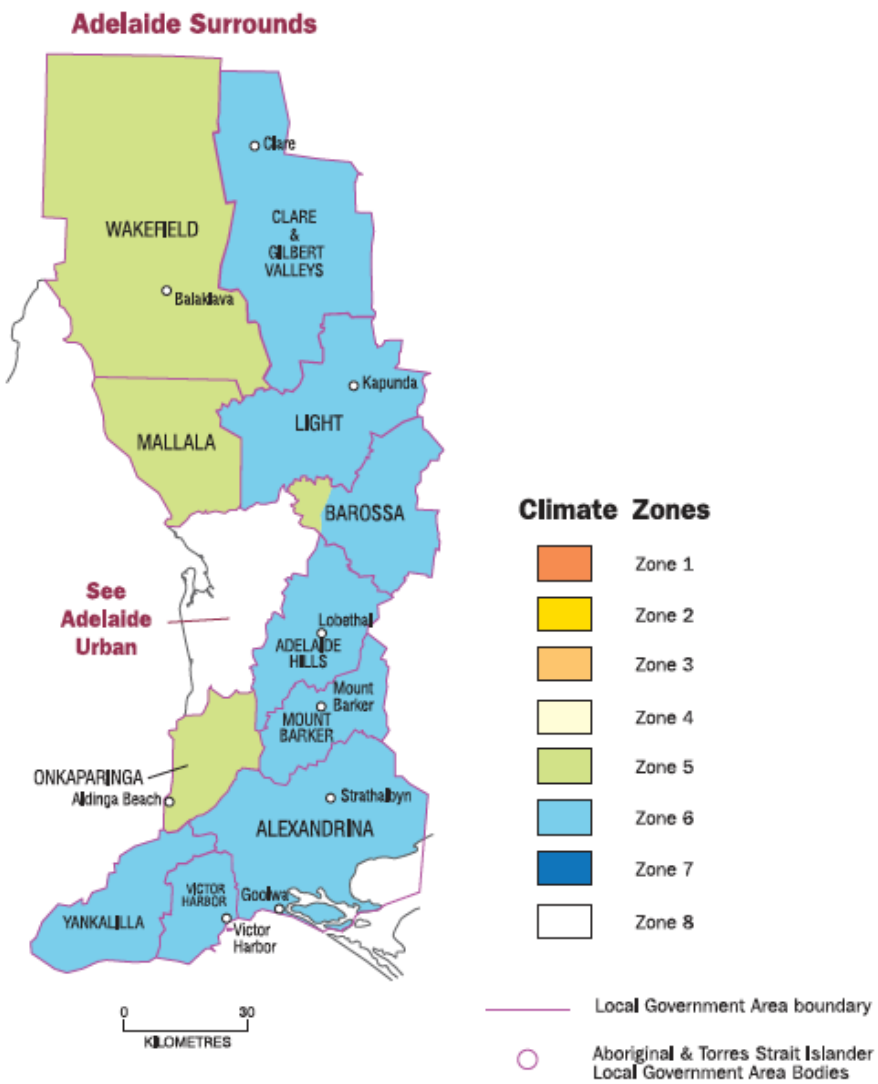

Figure 6 | Climate Zones in Adelaide Surrounds

The National Construction Code (NCC) outlines building envelope requirements for new buildings based on climatic zones. These requirements served as the basis of determining each of the five archetype's characteristics in relation to thermal performance.

The primary building elements that influence the heat resilience of a home are:

Building elements	System
• Window glazing • Window frame	Window system
• Wall cladding • Wall insulation	Wall system
• Roof colour • Roof material • Ceiling insulation	Roof system

A detailed description of the thermal performance of these materials is provided in Appendix B.

Table 15 presents a summary of the resilience of the building systems in response to extreme heat by archetype. It is recognised that the elements addressed in Table 15 are only a subset of building elements that contribute to heat resilience; however, these elements represent the majority of heat flow.

Table 15 - Resilience of building systems to extreme heat by archetype

	Brick Veneer House		Modern House		Lightweight 50s House		Victorian House		Contemporary House	
Roof system R- value	Concrete tiles	4	Zinc aluminum coated corrugated steel	4	Terracotta tiles	2	Zinc aluminum coated corrugated steel	2	Zinc aluminum coated corrugated steel	4
Wall system R- value	Brick cladding (no insulation)	1	Brick cladding (glasswool insulation)	5	Fibre cement weatherboard (no insulation)	1	Stone cladding (no insulation)	1	Brick cladding (glasswool insulation)	5
Window system R- value	Standard glass, aluminium frame	1	Standard glass, aluminium frame	1	Standard glass, timber frame	2	Standard glass, aluminium frame	1	Standard glass, aluminium frame	1

Ceiling insulation is assumed for each archetype based on the building code and the archetype's typical year of construction. Common roof types do not achieve the ideal roof system total R-value without the use of insulation; therefore, the lack of insulation can be related to poor thermal performance.

Each element in a building envelope has a different heat flow impact. The percentages in Figure 7 for summer heat flow inform the weight of each building system on the resilience rating.

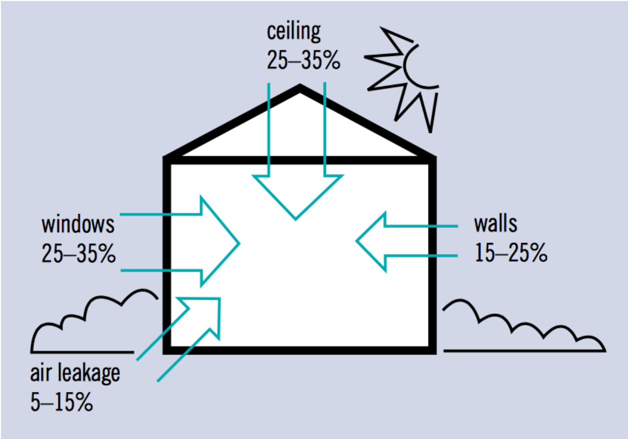

Figure 7 | Heat flow without insulation (SEAV, 2002)

Table 16 provides the overall resilience rating of each archetype to extreme heat, based on R-value, U-value and weighted as per Figure 7.

Table 16 – Extreme heat resilience rating by archetype

Archetype (% of housing stock)	Extreme Heat Resilience
Contemporary House (28%)	3.2
Brick Veneer House (19%)	2.1
Modern House (30%)	3.2
Lightweight 50s House (13%)	1.7
Victorian House (6%)	1.4

As discussed previously, extreme heat is considered from a thermal comfort perspective, rather than an insurance perspective. As such, replacement cost of materials is not considered in the resilience rating.

3.2.8 Results

Table 17 provides a summary of each archetype's resilience to flood, bushfire and extreme heat, as well as each archetype's overall resilience rating.

Table 17 – Overall resilience rating by archetype

Archetype (% of housing stock)	Flood Resilience	Bushfire Resilience	Extreme Heat Resilience	Overall Resilience Rating
Contemporary House (28%)	3.0	3.2	3.2	**3.1**
Brick Veneer House (19%)	3.0	3.0	2.1	**2.7**
Modern House (30%)	2.0	3.0	3.2	**2.7**
Lightweight 50s House (13%)	3.0	2.9	1.7	**2.5**
Victorian House (6%)	3.0	2.9	1.4	**2.4**

The Edge team held a Verification Workshop with the ICA to validate the flood and bushfire results. The results presented in Table 17 align to that expected by the ICA.

Overall, the Contemporary House performs the best with the Victorian House performing the worst in terms of resilience to all three hazards. Resilience to extreme heat provides the greatest differentiation between archetypes followed by bushfire resilience.

It is important to note that from an insurance perspective, bushfire is binary. If a house ignites, it typically leads to total loss. However, the insurance industry is now seeing more incidents of partial loss. This is largely due to improvements in the building code from 2009 onwards. The Contemporary House performs the best in terms of bushfire resilience, as would be expected given this archetype's likely construction to an improved building code in comparison to the other archetypes.

The differentiation in flood resilience is largely based on the floor finishes. Timber is increasingly being repaired rather than replaced following a flood event. In comparison, broadloom carpet typically requires total replacement. As such, the Modern House (the only archetype with carpet instead of timber floor finishes) receives a lower resilience rating.

4 Resilience mapping

Following the completion of hazard mapping and finalisation of the housing typology study, a mapping exercise was undertaken to assign archetypes and resilience values across the housing stock vulnerable to flood, bushfire and extreme heat.

To do this, the archetypes and the results of the resilience rating exercise were applied to each of the lots within the climate hazard hotspots. The number of archetypes assigned within the areas of study and their respective resilience ratings are provided in the Table 18.

The average overall resilience rating in the region is 2.7 (excluding unclassified houses).

Table 18 - Archetypes assigned within climate hazard hotspots

Archetype	Overall Resilience Rating	# Assigned	% of total
Contemporary house	3.1	881	30%
Modern house	2.7	831	28%
Brick veneer house	2.7	560	19%
Lightweight 50s house	2.5	392	13%
Victorian house	2.4	166	6%
Unclassified	-	126	4%
TOTAL		**2,956**	**100%**

5 Development of climate-ready home specification

5.1 Background

Local and state development control plans and national building standards provide guidelines for homeowners and building professionals to ensure residential homes are built to specified standards. The Australian Building Codes Board's mission is to oversee issues relating to health, safety, amenity and sustainability in building. These principles flow down to the local planning and development controls. This guidance is primarily provided to address risk to life and can lead to a built environment vulnerable to multiple climatic hazards, particularly when locations experience high exposure to multiple hazards, as is the case in the RH&C region. There is opportunity to couple this guidance with a standard that promotes greater focus on the interest of the insurance industry to reduce financial loss which will ultimately improve the resilience of the built environment.

There are a number of guidelines and schemes developed to address different hazards and high exposure risks. These, in conjunction with local and state development control plans were reviewed to complement and support existing government planning schemes, development controls and building standards to encourage more resilient residential building practices in areas exposed to multiple climate hazards. Reviewed sources include those specific to the Southern and Hills LGA area and South Australia, as well as Australia more broadly.

The most robust recommendations, no matter the region from which they came (e.g. flood recommendations from Queensland may be adopted due to their robustness), were considered for inclusion in a "climate-ready home specification". The aim of the specification was to identify a housing archetypes that has high resilience to bushfire, flood an heat. In consultation with the ICA, some recommendations were edited to go above and beyond current guidance to ensure resilience in a changing future climate.

A number of resources were consulted in the development of the climate-ready home specification. The References section provides the full list of resources, though the primary resources include:

- A suite of tools and guidance developed by Edge in consultation with the ICA for their Resilience Program (e.g. Beyond Compliance – A Voluntary Standard for Resilient Homes (2017), Building Resilience Knowledge Database, Building Resilience Rating Tool);
- Development Control Plans for the Southern Hills and Coasts Regions, as well as across Australia;
- National Construction Code, Building Code of Australia 2019;
- Australian Standard 3959 Construction of Buildings in Bushfire-prone Areas; and
- Other hazard-specific guidance such as: Queensland Reconstruction Authority's Flood Resilience Building Guidance for Queensland Homes (2019); Government of South Australia's Undertaking development in Bushfire Protection Areas (2012); Insurance Institute for Business & Home Safety's Fortified guidance; Green Cross Australia's Harden Up: Protecting Queensland (2017); Hawkesbury-Nepean Floodplain Management Steering Committee's Reducing Vulnerability of Buildings to Flood Damage: Guidance on Building in Flood Prone Areas (2007); and Western Australia Department of Fire and Emergency Services' The Homeowner's Bushfire Survival Manual (2014).

There are substantial differences in the guidance across different hazards as well as across each specific hazard (e.g. bushfire attack levels). Therefore, the most stringent recommendations applied at a general level were noted and a recommendation that considered these, in addition to bushfire, flood and extreme heat, was developed.

5.2 Approach to defining a Climate-ready home

The addition of new housing in the region presents an opportunity to build climate-ready, resilient housing, more suited to a future climate that is warmer and drier. Not only can these buildings be better designed to cope with changing climatic conditions and frequency of extreme events, but they can also provide improved living conditions for residents and decrease energy use and recover quickly from extreme natural hazard events.

The climate-ready home specification was developed to provide recommendations on elements such as materials, finishes, and fixtures, needed to build new housing or retrofit dwellings located in high bushfire, flood and extreme heat prone areas. Based on findings through the desktop review and hazard mapping, the following conditions were chosen as the most relevant to develop recommendations for resilient homes:

- Single storey dwellings and/or retrofitting of dwellings in riverine flood prone areas1, bushfire prone areas (Bushfire Attack Level 402) and within the climate zone 6 according to the Australian Building Code Board.

These conditions are defined as follows:

- Riverine flood: The covering of normally dry land by water that has escaped or been released from the normal confines of:
    - any lake, or any river, creek or other natural watercourse, whether or not altered or modified; or
    - any reservoir, canal, or dam (Insurance Council of Australia, 2019);
- A Bushfire Attack Level (BAL) is a measurement of a building's potential exposure to ember attack, radiant heat and direct flame contact. There are six BALs as part of the Australian Standard for the construction of buildings in bushfire prone areas. BAL 40 is defined by: increasing levels of ember attack and burning debris ignited by windborne embers together with increasing heat flux with the increased likelihood of exposure to flames (AS3959, 2009); and
- Climate Zone 6: Low diurnal temperature range near coast to high diurnal range inland, four distinct seasons, summer and winter can exceed human comfort range, spring and autumn are ideal for human comfort, mild to cool winters with low humidity, hot to very hot summers, moderate humidity (Australian Bureau of Statistics, 2013).

5.3 Specification

Table 31 in Appendix C provides the recommended building specification for a new build climate-ready home that has improved resilience to bushfire, flood and extreme heat. Table 32 provides recommended materials that are different for a retrofit home. The materials have been chosen based on their performance in response to bushfire, flood and extreme heat exposure. Material cost, applicability and ease of construction have also been considered to minimise up-front and replacement costs.

Beyond those materials recommended in Appendix C, there may be other suitable materials that can achieve a similar resilience rating to the hazards in question. For example, stone cladding achieves a similar resilience to brick cladding in response to flood and bushfire; however, stone cladding is significantly more expensive than brick cladding. For the purposes of this project, the cheapest material of highest resilience is recommended.

Homeowners can choose variant materials so long as the level of resilience remains. However, it is important to understand the link between the cost of building materials and insurance premiums. Premium building materials directly contribute to a higher sum insured. In instances where

[1] This guidance does not address overland flow. Homes exposed to overland flow should ensure all adopted recommendations comply with overland flow requirements.

[2] Not all lots fall within this designation; however, BAL40 building guidance was chosen to be representative of a highly resilient dwelling when exposed to bushfire.

homeowners are focused on minimising insurance premiums, material costs should be considered and minimised, as per the recommended specification.

The ICA recognises the need to develop and build resilient homes, particularly in a future where natural hazard risks will be exacerbated by climate change. From an insurance perspective the cost of covering risks will be predominantly determined by the cost of rebuild/repairing damage. In this way the most effective way of limiting damage is to avoid damage in the first instance, by selecting sites where hazard exposure is minimised. To further limit damage, resilient products should be selected. From an insurance perspective, cost of replacement is a factor in the resilience rating, which is why some materials are selected over others based on their replacement value.

The ICA also acknowledges the need to continually evolve what we build, where we build it and out of what. In this way it recognises that any guidelines need to enable innovation and new, improved products as they become available. As such, the narrative and the intent of particular specifications is important so that users may respond with design and building actions that may enhance resilience. The specification includes a narrative aspect to it and the ICA suggests that continual engagement with the building industry be an aspect of the design and build process (personal communication with ICA, 2019).

Figures 8 to 10 illustrate the recommended systems build-up.

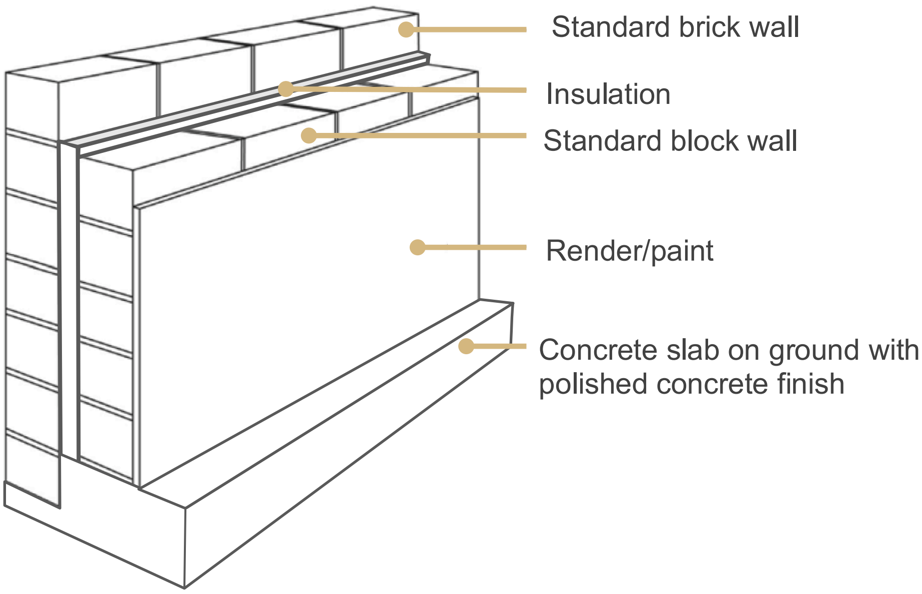

Figure 8 | New climate-ready house wall build-up (Source: Adapted from NCC2019 volume 2)

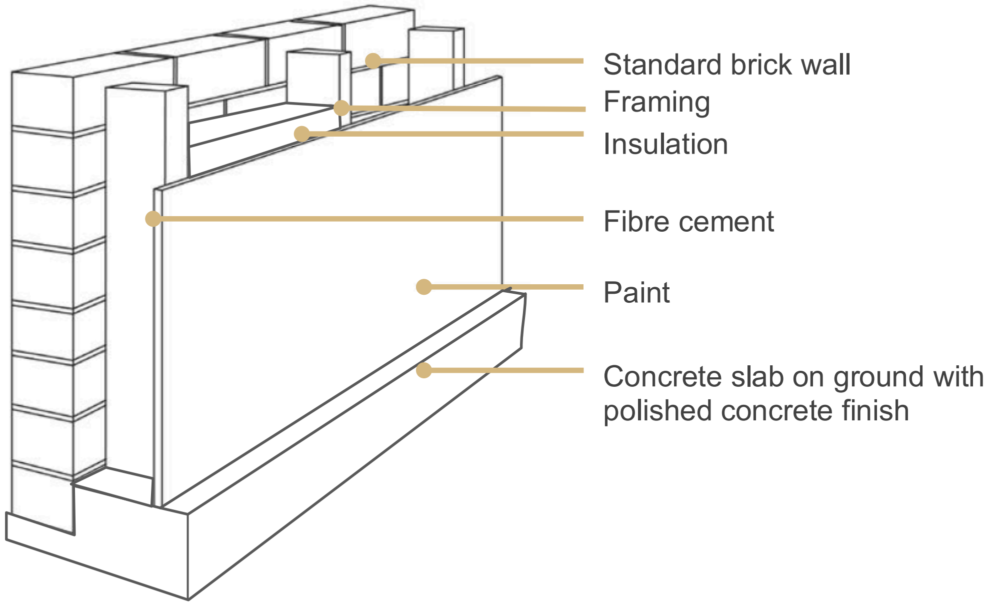

Figure 9 | Retrofit climate-ready wall build (Source: Adapted from NCC2019 volume 2)

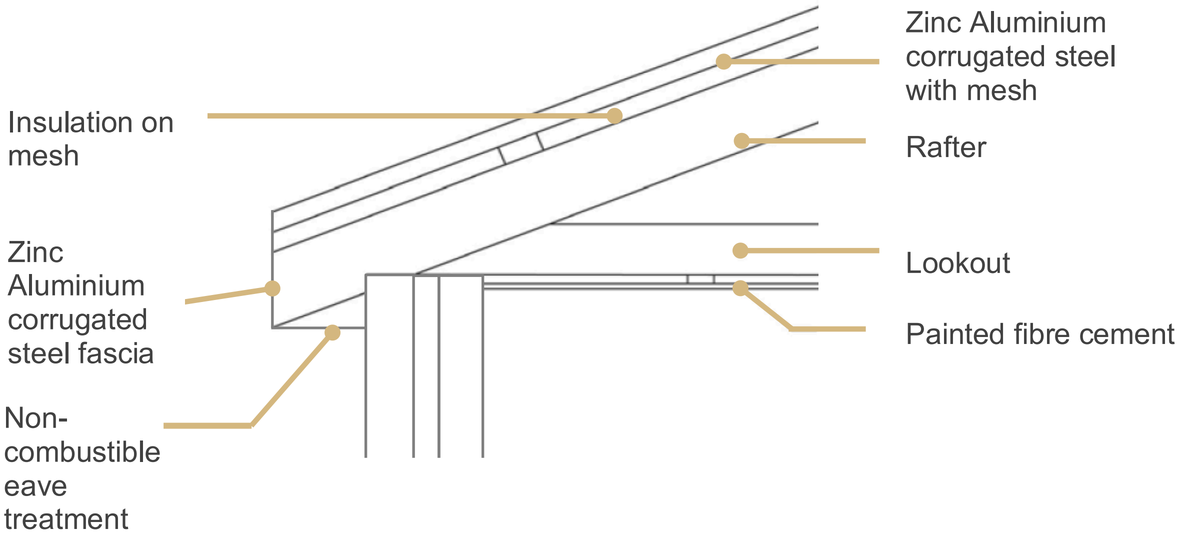

Figure 10 | Climate-ready roof build-up (source: adapted from NCC2019 volume 2)

5.4 Additional considerations

Table 31 and Table 32 provide specific recommendations for elements and materials used in building. Beyond these, additional measures are also recommended to ensure a climate-ready home.

To address extreme heat resilience in a manner that reduces dependency on the electricity grid, the inclusion of passive design is a vital component of a climate-ready home. Passive design is a type of building design that works with the climate, rather than against it, through design that addresses orientation, ventilation and insulation to control and reduce heating and cooling requirements. Passive design considerations are highly dependent on location; however, broad considerations for the RH&C region include:

- Reductions in heat gain through use of adequate windows and glazing (e.g. low U-value glazing and high solar heat gain coefficient);
- Minimisation of heat gain through shading (e.g. increased eave length) and insulation;
- Minimisation of east- and west-facing external wall areas;
- Cross-ventilation;
- Passive solar heating;
- Roof space thermal buffer zones;
- Proper sealing of any gaps or air leaks;
- Use of ceiling fans in living spaces; and
- Earth-coupled slabs.

Use of passive design can easily reduce household heating and cooling energy use by 20% (Department of the Environment and Energy, 2017). For further guidance on passive design, refer to YourHome. Solar with battery storage is also highly encouraged. If installing solar, homeowners should consider a kill switch to ensure panels can be disengaged in a bushfire scenario.

5.5 Resilience rating

Further to Table 17, Table 19 provides the resilience rating of each archetype in comparison to the climate-ready home resilience rating. Overall, the climate-ready home achieves a resilience rating of 3.9, which is a 61% improvement compared to the worst performing archetype (Victorian House) and a 25% improvement against the best performing archetype (Contemporary House).

Table 19 – Resilience rating of climate-ready home compared to archetypes

Archetype (% of housing stock)	Flood Resilience	Bushfire Resilience	Extreme Heat Resilience	Overall Resilience Rating
Contemporary House (28%)	3.0	3.2	3.2	**3.1**
Brick Veneer House (19%)	3.0	3.0	2.1	**2.7**
Modern House (30%)	2.0	3.0	3.2	**2.7**
Lightweight 50s House (13%)	3.0	2.9	1.7	**2.5**
Victorian House (6%)	3.0	2.9	1.4	**2.4**
Climate-ready home	3.2	3.5	5.0	**3.9**

The resilience rating is a function of the exposure and vulnerability of a house. Each archetype, including the climate-ready home, has been assessed under a high exposure scenario (to bushfire, flood and extreme heat). A resilience rating of 5.0 is not achievable in a high exposure area for flood and fire, as there will always be some level of inherent risk to the house that cannot be mitigated. It is possible to *reduce* the vulnerability through improvements in resilience, but the vulnerability cannot be *eliminated*.

The resilience rating is indicative of the resilience of a home in response to flood, bushfire and extreme heat and should be considered alongside the results of the economic assessment. The resilience ratings are based on replacement and damage costs of the materials in each archetype. The economic analysis goes beyond these to also consider additional measures such as insurance premiums and cost of disruption. As such, the magnitude of incremental change across the resilience ratings does is not equivalent to changes in net present value as determined in the economic analysis (Section 6).

6 Economic analysis

An economic analysis was conducted to assess the costs and benefits of converting the housing stock to a climate-ready housing stock. Detailing the costs and benefits associated with transitioning the housing stock to be climate-ready enables councils, homeowners, developers and insurers the ability to accurately inform the decision-making process regarding mitigation strategies and insurance affordability.

The analysis has been undertaken from the perspective of the homeowner. Therefore, the overall cost to society, which is largely covered by the insurance industry, is not included in this assessment.

6.1 Methodology

The climate ready home specification was costed and compared to a typical new build home in the Southern and Hills LGA area. The specification was then modelled over the lifetime of a home to determine likely running costs including insurance costs and any related energy savings. These costs were benchmarked against the typical new build home (i.e. the contemporary archetype) to demonstrate the economic benefit of investing in a climate-ready home.

New build homes make up a growing proportion of the housing stock; however, there will always be a residual of old stock. It is assumed that the residual old stock will either be adapted through retrofit over time or redeveloped. The current housing stock has been characterised as part of this project, with at least 80% of homes belonging to one of the following archetypes:

- Modern House;
- Contemporary House;
- Brick Veneer House;
- Lightweight 50s House; and
- Victorian House.

Refer to Appendix A for detailed archetype descriptions.

The cost to retrofit each of the five housing archetypes to align to the climate-ready home specification was also assessed. The costs and benefits associated with retrofits were modelled over a 50-year period, accounting for the average age of each archetype and the remaining life of materials that make-up any one archetype. Energy use and insurance costs were also included.

Explanation for each of these assumptions is provided in subsequent sections of this report. Costs that do not change across the archetypes were excluded from the analysis (e.g. water use, appliances, home contents).

Table 41 in Appendix E provides a list of the assumptions applied in the economic analysis. Explanation for each of these assumptions is provided in subsequent sections of this report.

Assumptions regarding the following inputs for the economic modelling are provided in Appendix E:

- Cost of materials;
- Building and materials lifespan;
- Insurance premiums;
- Disruption; and
- Energy savings.

6.2 Results

Using cost-benefit analysis, multiple scenarios were assessed to understand the costs and benefits associated with building and/or retrofitting to the climate-ready specification, including:

- New build scenario comparing the Contemporary House to the Climate-ready Home (Scenario A);
- Retrofit scenarios separately comparing each of the five archetypes to the Climate-ready Home, assuming immediate retrofit (Scenario B.1-B.5); and
- Retrofit scenarios separately comparing each of the five archetypes to the Climate-ready Home, assuming staggered retrofit (i.e. retrofit only when each building element requires replacement at end of life) (Scenario C.1-C.5).

The analysis considers the following parameters:

- Assumed age of each archetype based on typical year of construction;
- Cost of building elements/materials;
- Insurance premium cost, including expected increase over time;
- Average excess;
- Average underinsurance;
- Proxy for the cost of disruption to the homeowner (beyond direct costs) following a climate hazard incident such as bushfire or flood; and

Reference service life of materials.

Table 20 presents the results of the economic analysis.

Table 20 – Economic analysis results

Scenario	Present value of costs	Present value of benefits	Net present value	Benefit-cost ratio
A - New Build (Climate-ready compared to Contemporary)	$22,914.01	$59,398.85	$36,484.84	2.59
B.1 - Immediate retrofit - Contemporary House	$58,854.66	$59,819.54	$964.88	1.02
B.2 - Immediate retrofit - Brick Veneer House	$24,777.54	$74,151.81	$49,374.27	2.99
B.3 - Immediate retrofit - Modern House	$51,826.73	$74,605.14	$22,778.41	1.44
B.4 - Immediate retrofit - Lightweight 50s House	$32,700.51	$67,532.08	$34,831.57	2.07
B.5 - Immediate retrofit - Victorian House	$27,675.01	$91,715.85	$64,040.84	3.31
C.1 - Staggered retrofit - Contemporary House	$1,578.41	$27,033.25	$25,454.84	17.13
C.2 - Staggered retrofit - Brick Veneer House	$36,282.85	$70,627.07	$34,344.22	1.95
C.3 - Staggered retrofit - Modern House	$7,227.96	$33,127.26	$25,899.31	4.58
C.4 - Staggered retrofit - Lightweight 50s House	-$44,562.42	$31,444.23	$76,006.65	n/a*
C.5 - Staggered retrofit - Victorian House	$586.36	$54,715.70	$54,129.34	93.31

*A BCR is unable to be calculated in the instance of negative costs (i.e. cost savings).

The following definitions can be used to assist in the interpretation of the results:

- **Present value of costs**: the sum of the cost difference between the base case (archetype) and upgrade case (climate-ready home) over the 50-year analysis period discounted at a rate of 7% to account for the time value of money (i.e. a dollar today is worth more than a dollar tomorrow). Costs include capital and operational expenditure.
- **Present value of benefits**: the sum of the benefits (cost savings) associated with the base case (archetype) compared to the upgrade case (climate-ready home) over the 50-year analysis period discounted at a rate of 7% to account for the time value of money (i.e. a dollar today is worth more than a dollar tomorrow). Benefits include savings associated energy use, insurance premiums, excess, underinsurance and disruption.
- **Net present value** (NPV): the difference between the present value of benefits and the present value of costs. A positive NPV signals a viable investment. The net present value is representative of the value to homeowners of retrofitting to the climate-ready home specification. In other words, homeowners will realise this value through savings and / or benefits related to upfront and maintenance costs, energy costs, insurance and reduced disruption.
- **Benefit-cost ratio** (BCR): the BCR is an indicator used to demonstrate the relationship between the benefits and costs associated with a scenario and is the ratio of the benefits compared to the costs. A BCR greater than one signifies a viable investment (i.e. the benefits outweigh the costs). A BCR below one means the costs outweigh the benefits.

The results indicate that investment in improving the resilience of a home in a high bushfire, flood and extreme heat area is viable under all scenarios. On average, the greatest value is achieved through a staggered retrofit; however, the investment is viable regardless of when the building improvements occur (i.e. new build, immediate retrofit and staggered retrofit).

In an immediate retrofit scenario, the costs and benefits associated with the Contemporary House are relatively similar. The Contemporary House is the most recent archetype and is therefore built to an improved standard compared with the other archetypes. The primary differences between the current building code and the climate ready home include: 1.8mm mesh requirement for doors, windows, roof and all gaps/vents; internal wall linings; insulation; window type; flooring and floor height at the 2050 100 Year ARI level + 0.5m. While there are still improvements in terms of building resilience that can be made, the results show that, at least from an immediate retrofit perspective, the financial benefits only slightly outweigh the costs. In instances of constrained capital, it is recommended to undertake a staggered retrofit approach for the Contemporary House as the benefits are significantly greater for this archetype when the retrofit is undertaken over time.

Furthermore, the results presented in Table 20 are based on current expected insurance premium increases over time. Should insurance premium trends shift from the assumptions upon which this analysis is based (i.e. quadruple of premiums over 20-year period), it is recommended to re-assess these results.

Finally, the economic analysis does not account for the environment and social impact associated with resource use. There is an externality cost to society in terms of resource use associated with the replacement of damaged materials and rebuilding of homes. Minimising material use (i.e. by improving the resilience of homes) provides a benefit to society that is not captured by the scope of this project. Furthermore, much of the repair and rebuild cost following a hazard event is covered by the insurance industry. Therefore, the true cost of an event is not felt by the homeowner and therefore not incorporated in the economic analysis (which has been conducted from the perspective of the homeowner).

It is recommended that subsequent research examine the costs and benefits of an improved housing stock to incorporate these externalities and the costs outlaid by the insurance industry.

From a council-wide perspective, Table 21 presents the value to the community over a 50-year period of retrofitting the housing stock to align to the climate-ready home specification. The value in the column labelled “Net present value” is representative of the value to the community in terms of reduced disruption, decreased insurance costs, energy savings and replacement / maintenance costs over the 50-year assessment period.

Table 21 – Value to community of immediate retrofit over 50-year period

Adelaide Hills			
Archetype	**# of archetypes identified in high exposure area**	**% of total**	**Net present value**
Brick veneer house	40	37%	$1,974,970.80
Modern house	19	18%	$432,789.79
Lightweight 50s house	16	15%	$557,305.12
Victorian house	22	21%	$1,408,898.48
Contemporary house	3	3%	$2,894.64
TOTAL	**107**	**100%**	**$4,376,858.83**
Alexandrina			
Archetype	**# of archetypes identified in high exposure area**	**% of total**	**Net present value**
Brick veneer house	89	12%	$4,394,310.03
Modern house	123	16%	$2,801,744.43
Lightweight 50s house	160	21%	$5,573,051.20
Victorian house	31	4%	$1,985,266.04
Contemporary house	280	36%	$270,166.40
TOTAL	**769**	**100%**	**$15,024,538.10**
Mount Barker			
Archetype	**# of archetypes identified in high exposure area**	**% of total**	**Net present value**
Brick veneer house	402	21%	$19,848,456.54
Modern house	706	38%	$16,081,557.46
Lightweight 50s house	150	8%	$5,224,735.50
Victorian house	78	4%	$4,995,185.52
Contemporary house	517	27%	$498,842.96
TOTAL	**1,881**	**100%**	**$46,648,777.98**
Victor Harbor			
Archetype	**# of archetypes identified in high exposure area**	**% of total**	**Net present value**
Brick veneer house	3	14%	$148,122.81
Modern house	6	29%	$136,670.46
Lightweight 50s house	4	19%	$139,326.28
Victorian house	2	10%	$128,081.68
Contemporary house	6	29%	$5,789.28
TOTAL	**21**	**100%**	**$557,990.51**
Yankalilla			
Archetype	**# of archetypes identified in high exposure area**	**% of total**	**Net present value**
Brick veneer house	26	15%	$1,283,731.02
Modern house	27	15%	$615,017.07
Lightweight 50s house	62	35%	$2,159,557.34
Victorian house	33	19%	$2,113,347.72
Contemporary house	25	14%	$24,122.00
TOTAL	**178**	**100%**	**$6,195,775.15**

7 Insurance considerations

7.1 Context

The insurance industry globally is adapting its business to an era of climate change; increased frequency and intensity of natural hazard events is leading to unsustainable losses and a global increase in the cost of reinsurance. This is especially true in Australia, which accounts for 2% of the global reinsurance market, but is responsible for 8% of the losses (MunichRE, 2017). As a consequence, Australians are experiencing increasing insurance premiums which is a trend that is likely to continue.

Australians have historically relied on insurance to manage and cover our residual risks (i.e. the threat that remains after all efforts to identify and eliminate risk have been made). Australia is the second highest consumer of insurance globally with 48% of all assets insured, second only to the United States of America. In summary, insurance is being used widely to manage the residual risk on a continent that boasts the full gamut of extreme weather events from bushfires and extreme heat to floods and cyclones. With an ongoing trend of increased losses, and commensurate increases in insurance premium costs, insurance is becoming less affordable, and therefore there is a risk that fewer people will cover their assets against the risks of natural hazards, leading to an increasingly vulnerable built environment and vulnerable community.

The insurance industry considers this not only a material risk to business, but also a material risk to the communities they have been servicing for decades. There is a global call from insurers to collaborate with governments on initiatives that build resilience in the face of climate change and intervene in a market where there is a risk of insurance unaffordability leading to increased vulnerability.

Insurers set premiums based on the probability and size of a claim being lodged. If the probability is high, then premiums are likely to be correspondingly high. To set premiums, insurers rely upon hazard and building information from a variety of sources. If the information the insurer relies upon is not the best available, then the premiums that the insurers calculate may not precisely reflect the risk. Properly aligned, insurance premiums for constituents should generally reflect a local council's understanding of hazards, development controls and mitigation works.

Where and what we build are of interest to multiple stakeholders within the region, including community, business and government – and both the insurance industry and councils have a mutual interest in progressing adaptation and mitigation in a coordinated manner.

7.2 Results

The results from this project indicate that a "Climate-ready Home" attracts a lower premium, 8.5% lower than that of the contemporary home (and up to 47% lower when compared to the Victorian archetype). The 8.5% (as a minimum) is proportionate with insurance industry premium reduction expectations.

By way of demonstrating the proportionate expectation, the Queensland Government's Household Resilience Program offers an example of similar premium price reductions achieved by investment in strengthening a home to Natural Hazards (Queensland Gov, 2020). The program offers eligible homeowners grants of up to 75% of the cost of improvements to improve their homes resilience to cyclones. The program has been running since late 2018 and to date the Insurance Council can report average premium reductions of 9.9% for houses that have been retrofitted through the program (with a maximum premium reduction of 25%) (personal communication with ICA, 2020).

7.3 The costs of providing insurance

In project discussions we have discussed "commercial noise". To be more articulate, this refers to "the costs of providing insurance" and "how insurers set premiums". There are many factors that determine the difference in premium prices that insurers are able to offer in a particular region. The best description of this is from the ACCC report from the Northern Australia Insurance Enquiry.

In a response to property owner anxiety over rising insurance costs in Northern Australia the ACCC conducted a study as to why the cost of insurance was increasing. In an excerpt from the report:

"Over the past decade, insurers' methodologies for pricing insurance have become much more sophisticated and combined with access to better data, we have seen a shift towards more address based risk assessment and pricing. In northern Australia, insurers have also incurred some heavy losses due to high claims and increasing costs. As a result, insurance premiums are increasing, especially for those in high risk areas. We have observed an unusual competitive dynamic, with insurers in northern Australia not necessarily motivated to compete on price for market share. Instead we have seen them increasing prices to manage their exposure in a region they perceive to be risky or volatile. This is exacerbating affordability concerns. Consumers told us insurance is confusing, that products lack comparability, and that pricing is not transparent. This can leave consumers feeling disempowered, not unlike what we have seen in other critical markets such as energy, telecommunications and financial services"

Insurance is becoming more sophisticated with the evolution of tools and technologies that are enabling insurance underwriters a better appreciation of risk. Generally, the insurance industry is in transition in the way it prices, from a history of pooling risk, to pricing risk at a property level. Some key dynamics which help understand the soft financial signal/economic incentive realised in this project and should be considered in alongside the results include:

1. **Unusual market dynamics** - The structure of insurance markets is complex. Insurers rely on both direct sales to customers and the use of intermediaries such as brokers to distribute their products. In some high-risk areas insurers will not actively try to win market share. Instead they implement commercial strategies to manage their exposure to customers they see as high risk. For example, they may be increasing premiums so as to lose customers or no longer selling, or renewing policies.

2. **Insurer profitability** – Heavy losses and high and rising costs (reinsurance) play a big part in rising costs. In this way the cost of covering risks increases due to the history of loss. We can expect this dynamic to result in increasing costs in the Southern Hills region as a result of the catastrophic 2019/20 bushfire season, likely for a decade to come.

The costs insurers incur in supplying insurance products can be divided into the following categories. The proportions measured are from Northern Australia, and it is likely that there will be some difference, but they are likely similar and therefore indicative of the situation in South Australia.

- **Claims costs – 55%** - This includes costs such as the claims incurred and the cost of handling and assessing claims. These costs tend to vary with the number of policies written and the relative risk of to the property insured. 'Gross claims expense' is a commonly used measure of claims costs. It includes all costs incurred in responding to claims, without considering reinsurance and non-reinsurance recoveries. The difference between 'gross claims expense' and 'net claims expense' is the amount of reinsurance and non-reinsurance recoveries. Across all home, contents and strata insurance products, net claims expense averaged around 55% of insurer costs in northern Australia in 2017–18. This figure has been calculated using net rather than gross claims expenses.
- **Reinsurance costs – 31%** - This includes the cost of premiums paid to reinsurers. These costs tend to vary with the type of reinsurance purchased, the number of policies written, the sum insured of the policies written and the relative risk of the properties insured. Across all home, contents and strata insurance products, this cost category averaged around 31% of insurer costs in northern Australia in 2017–18.
- **Underwriting costs – 7%** - This includes levies, charges, and acquisition costs which are incurred in obtaining and recording insurance contracts. They include selling and underwriting costs such as advertising and risk assessment, the administrative costs of recording policy information and premium collection costs. This is determined in accordance with AASB 1023. Underwriting costs tend to vary with the number of policies written. Across all home, contents and strata insurance products, this cost category averaged around 7% of insurer costs in northern Australia in 2017–18.
- **Commission costs - 7%** - This includes the costs of commission or brokerage paid to an intermediary for obtaining business for the insurer. These costs tend to vary with the

number of policies written and in proportion to gross written premium. Across all home, contents and strata insurance products, this cost averaged around 7% in Northern Australia in 2017-18.

7.4 How insurers set premiums

Insurers set premiums using a three staged approach:

1. Technical Premium – Insurers set a technical premium which reflects their estimate of the cost of providing insurance with a profit margin added. This includes the price of covering the risks;
2. Adjustment – Insurers adjust their technical premium for a range of reasons such as managing their risk exposure or competitive market positioning. Unlike the technical premium these adjustments are not directly related to the individual risk of the property; and
3. Discounts, surcharges, duties and taxes – Stamp duty is levied on insurance premiums as a percentage, so as premiums grow significantly, so too does the dollar value of stamp duty.

Understanding the costs and how insurers set premiums enables an improved appreciation of the economic incentive for the climate ready home in this project. Also, it provides evidence for a future where the economic signal is likely to increase as address level pricing is more pervasive and the claims and reinsurance costs are incorporated into future pricing in the Southern and Hills region.

It should be noted that it is unlikely that individual insurers will be able to offer a preferential premium for the climate-ready home and be certain that they will not be undercut, as other insurers may have different commercial imperatives which allow them to price lower.

A directional approach is required. A certification or an endorsement of a home that provides answers to questions like:

- Is it likely that this house be insurable given the likely exposures in a climate changed future; and
- Is it likely that this house attracts a reasonable premium in a climate changed future?

The insurance industry recommendation is that Climate Ready Houses pursue a standard/rating, endorsed by the insurance industry that certifies that the house meets a standard that can be described as Climate Ready. This rating can then be used by insurers to inform their risk ratings and further contribute to the set of risk information that is used for premium pricing.

8 Development of a knowledge portal and regional communications

A key deliverable for the project is a knowledge Portal and Regional Communications. The project partners agreed that the knowledge portal should be delivered as a web page accessible on each council's website. This page provides the following information:

- Project overview;
- Final report (i.e. this report);
- Fact sheets relating to key project findings and outputs; and
- Access to the online mapping tool.

The online mapping tool has been developed to present the results of the climate hazard and resilience mapping. The tool can be accessed at edge.endevgeo.com (password "wwbwwb"). Figure 11 provides a screenshot of the information available through the resilience mapping online portal.

Figure 11 | Example of the resilience mapping from the online portal

A regional communications process accompanied the completion of the project to ensure that key stakeholders understand how to interpret and apply the guidance provided on the knowledge portal. The process included project presentations to the RH&C steering committee, the Southern and Hills LGA Board of Mayors & CEOs and the South Australian climate adaptation practitioners' network:

9 Key findings

It is widely accepted that Australia's housing stock is often poorly sited, designed and constructed to account for local natural hazards like flood, fire and heat. Yet there are few examples of analyses that build the evidence base at a regional scale to validate this assertion in a systematic and quantitative way. It is only by doing this that the business case for a transition to climate ready homes can successfully be made.

The Where We Build What We Build project has demonstrated how to apply a repeatable methodology for assessing the types of homes in a region, identifying climate archetypes, identifying the resilience of homes to climate hazards and undertaking economic analysis to determine the benefit cost of new build or retrofitting homes with a climate-ready home specification.

The project has delivered:

- Climate hazard and resilience maps, which can continue to be used in the future to assess the resilience of homes to natural hazards. This information can also be updated as new hazard mapping information become available.
- Climate ready home specification, which identifies building and construction materials that can be used for improving the climate resilience of new build and retrofit homes.

Key findings of the project are as follows:

- **The building stock in the region varies significantly in terms of its resilience to natural hazards** – The Adelaide Hills and Fleurieu Peninsula has a range of housing types that can be described as mostly belonging to one of 5 archetypes as follows: modern house, contemporary house, brick veneer house, Lightweight 50s house and Victorian house. The resilience of these homes to natural hazards differs because of the materials they are built from.

  The most resilient home type in the region is the "Contemporary" home, which accounts for 30% of all homes in climate hazard areas and has an average year of construction of 2012. Its resilience was the highest or equal highest for flood, bushfire and heat. In contrast, the Victorian house and Lightweight 50s house, which combined account for nearly 20% of homes in climate hazard areas, have the lowest resilience, being built about 50-100 years ago.

  Overall, 70% of the homes in climate hazard hotspots had a resilience rating of less than 3/5.
- **Vulnerable housing leads to higher living costs -** Vulnerable housing leads to higher living costs, based on a range of factors such as:
  - Higher insurance premiums – annual insurance premiums for the Victorian house were found to be nearly double the climate ready house;
  - Higher energy costs – annual energy costs for the Contemporary and Modern house were 30% higher than for the climate ready home
- **There is sufficient information available to know how to build climate ready homes** – Baseline compliance is currently inadequate to ensure climate resilience of homes. The project has developed a climate ready home specification that provides increased resilience against flood, fire and heat compared with traditional houses. This project used two tools – the Building Resilience Knowledge Database and the Building Resilience Rating Tool – to determine the resilience of building materials and to identify materials for use in constructing climate ready homes. Importantly, the climate ready home specification can be used for new build or retrofit homes and identifies 23 different types of construction and building elements.
- **The changing cost of insurance will influence how we build new homes and retrofit old homes** – Without insurance people are unable to obtain a mortgage, and without access to a home loan, most people will be unable to buy a home. The insurance industry uses hazard maps and information on construction materials and design to judge the

probability and size of an insurance claim arising from climate hazards. We can expect insurance premiums to rise in the future, as hazard exposure increases.

- **Poor quality natural hazard data impacts insurance premiums** - In the absence of quality data about natural hazards, insurers assume the worst-case scenario for the likelihood and consequence of natural hazards, and price accordingly. It is estimated that South Australians pay too much for insurance because of uncertainty about natural hazard data. This project found that obtaining hazard data to supporting cost benefit analysis and resilience mapping was difficult, with limited trust about how data will be used. This project has demonstrated the need for a centrally coordinated, jointly resourced hazard mapping framework in South Australia to overcome knowledge gaps. Further, greater clarity is required about the legal conditions that underpin data provision to the insurance industry.
- **The benefits of climate ready homes outweigh the costs for both new builds and retrofits** – Factoring in the broader costs and benefits of living in a house – including construction and maintenance costs, energy savings, insurance premiums, disruptions from exposure to natural hazards – shows results of benefits outweighing the costs. On average, the greatest value is achieved through a staggered retrofit, however, the investment is viable regardless of when the building improvements occur (i.e. new build, immediate retrofit and staggered retrofit).
    - Homeowners can realise benefits valued at up to $76,000 by retrofitting a Lightweight 50s House. This includes upfront, maintenance and operational costs, insurance savings, and reduced disruption.
- **The regional net present value of immediately retrofitting all 2,956 homes in regional hazard hotspots is estimated at over $72 million** - Over a 50-year period, the net present value of immediately retrofitting the region's housing stock to a climate-ready standard is estimated at over $72 million. Over $46 million of this value is in the District Council of Mount Barker area.
- **A climate ready home standard should be developed** - Given market dynamics, it is unlikely that individual insurers will be able to offer a preferential premium for the climate-ready home while still being certain that they will not be undercut, as other insurers may have different commercial imperatives which allow them to price lower. As such a directional approach is required. The insurance industry recommendation is that climate ready houses pursue a standard/rating, endorsed by the insurance industry that certifies that the house meets a standard that can be described as “Climate Ready”. This rating can then be used by insurers to inform their risk ratings and further contribute to the set of risk information that is used for premium pricing.
- **Vulnerable housing results in lower community resilience** - The outcome of vulnerable housing is reduced community resilience, and higher costs for governments, which tend to become the insurer of last resort when houses are under-insured or uninsured.

References

Australian Bureau of Statistics [ABS] (2010). Houses in South Australia. Retrieved from: https://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/1345.4Feature%20Article1Jan%202010

Australian Building Codes Board (2006). Guideline Document - Durability in Buildings.

Australian Building Codes Board (2019). National Construction Code Volume Two.

Australian Building Codes Board (ABCB). Northern Australia: Guidance material for climate responsive designs. www.abcb.gov.au

Australian Building Codes Board [ABCB] (2018). JV3-Energy Efficiency. Retrieved from Australian Building Codes Board: https://www.abcb.gov.au/Resources/Publications/Education-Training/JV3-Energy-Efficiency

Australian Building Codes Board [ABCB]. (2018). Climate Zone Map: Australia Wide. Retrieved from Australian Building Codes Board: https://www.abcb.gov.au/Resources/Tools-Calculators/Climate-Zone-Map-Australia-Wide

Australian Bureau of Statistics. (2013). Canberra, Retrieved from https://www.abs.gov.au/ausstats/abs@.nsf/Lookup/by%20Subject/4671.0~2012~Main%20Features~Climate%20zone~17

ACCC Northern Australia Insurance Inquiry: https://www.accc.gov.au/system/files/Northern%20Australia%20Insurance%20Inquiry%20-%20First%20interim%20report%202018.PDF

Australian Fenestration Rating Council (AFRC).(2014). Release of default glazing data files. Retrieved from AFRC: http://www.afrc.org.au/announcements/release-of-default-glazing-data-files.

Architectural Institute of B.C. [AIBC]. (2000). Building Envelope Educational Program Module I- Building Science & the Building Envelope.

Australian National Audit Office [ANAO] (2010). Home Insulation Program. Retrieved from ANAO: https://www.anao.gov.au/work/performance-audit/home-insulation-program

Australian Window Association. *A Guide to Windows and Doors in Bushfire Prone Areas*. Retrieved from https://www.qbcc.qld.gov.au/sites/default/files/A%20Guide%20to%20Windows%20and%20Doors%20in%20Bushfire%20Areas.pdf

Bannister, P., Robinson, D., Reedman, L., Harrington, P., Moffitt, S., Zhang, H., Cooper, P., Ma, Z., Ledo, L., Green, L. (2018). Building Code Energy Performance Trajectory project – Interim Technical Report for the Cooperative Research Centre for Low Carbon Living.

Building Code of Australia. (1990). Building Code of Australia Housing Extract.

Canstar Blue (2019). Average Electricity Costs per kWh. Retrieved from: https://www.canstarblue.com.au/electricity/electricity-costs-kwh/

Cement Concrete & Aggregates Australia. (2009). Building in Bushfire-prone Areas.

CSIRO (2019). Climate Change in Australia. Retrieved from https://www.climatechangeinaustralia.gov.au/en/

CSIRO. (2019). Construction - Australian Housing Data. Retrieved from CSIRO: https://ahd.csiro.au/dashboards/construction/

Department of the Environment and Energy (2017). Your Home: Australia’s guide to environmentally sustainable homes. Retrieved from: https://www.yourhome.gov.au/

Department of Fire & Emergency Services. (2014). The Homeowner’s Bushfire Survival Manual. Government of Western Australia. Perth, Australia: Author.

Department of Industry, Innovation and Science [DOIIS]. (2013). *Your Home: Australia’s guide to environmentally sustainable homes*. Retrieved from http://www.yourhome.gov.au

Department of Planning and Environment. (2018). Default window data. Retrieved from https://www.basix.nsw.gov.au/iframe/thermal-help/diy-method/windows/frame-and-glass-types/default-window-data.html

Department of Panning & Environment (2019). Roof colour and solar absorptance. Retrieved from https://www.basix.nsw.gov.au/iframe/basix-help-notes/thermal/diy-method/walls/insulated-concrete-form.html?id=180

Department of Planning, Transport and Infrastructure. (2015, Mar 4). Bushfire Protection Areas. Retrieved from Location SA: https://location.sa.gov.au/lms/Reports/ReportMetadata.aspx?p_no=679&pu=y

Energy Efficient Strategies. (2008). *Energy Use in The Australian Residential Sector 1986 - 2020*. Canberra: Department of the Environment, Water, Heritage and the Arts.

Energy Efficient Strategies. (2008). *Energy Savings from Improvements to the Thermal Performance of South Australian Dwellings*. Adelaide: Department of Transport Energy and Infrastructure.

Forest & Wood Products Australia (2011). A Comparative Life Cycle Assessment of Alternative Constructions of a Typical Australian House Design. Retrieved from: https://www.fwpa.com.au/images/marketaccess/PNA147-0809_Research_Report_Comparative-LCA_0.pdf

Government of South Australia. (2019). Development plans. Retrieved from https://www.sa.gov.au/topics/planning-and-property/development-plans/greater-metropolitan-adelaide-development-plans

Government of South Australia (2019). Energy efficiency requirements for new homes. Retrieved from: https://www.sa.gov.au/topics/energy-and-environment/energy-efficient-home-design/Six-star-energy-efficiency-requirements

Green Cross Australia (2017). *Harden Up: Protecting Queensland*. Retrieved from http://hardenup.org/.

Gupta, R., Kapsali, M., & Howard, A. (2018). Evaluating the influence of building fabric, services and occupant related factors on the actual performance of low energy social housing dwellings in UK. *Energy & Buildings*, *174*, 548–562. https://doi.org/10.1016/j.enbuild.2018.06.057

Hawkesbury-Nepean Floodplain Management Steering Committee (2006). *Reducing Vulnerability of Buildings to Flood Damage: Guidance on Building in Flood Prone Areas*.

Insurance Council of Australia (2017). *Building Resilience Knowledge Database*. Retrieved from http://www.buildingresilience.org.au/brkd.

Insurance Council of Australia (2019). *Flood* Insurance. Retrieved from: http://understandinsurance.com.au/types-of-insurance/flood-insurance

Institute for Catastrophic Loss Reduction. *Hurricanes: Protect yourself and your home*. Retrieved from http://iclr.org/images/hurricane_flyer.pdf.

Insurance Institute for Business & Home Safety *(2017). Fortified Home. Retrieved from https://disastersafety.org/fortified/fortified-home/*

Mackay Regional Council (2017). *Mackay Regional Planning Scheme 2017*

Minimum Energy Performance Standards (MEPS). Energy Rating. www.energyrating.gov.au

MunichRE (2017). *Topics GEO – Annual review 2017*.

Nationwide House Energy Rating Scheme (NatHERS). www.nathers.gov.au

Omar, F., Bushby, S., & Williams, R. (2017). A self-learning algorithm for estimating solar heat gain and temperature changes in a single-Family residence.(Report). *Energy & Buildings*, *150*, 100–110. https://doi.org/10.1016/j.enbuild.2017.06.001

Osmond, P., & Sharifi, E. (2017). Guide to Urban Cooling Strategies. Retrieved from http://www.lowcarbonlivingcrc.com.au/sites/all/files/publications_file_attachments/rp2024_guide_to_urban_cooling_strategies_2017_web.pdf

Personal communication with Bushfire Building Council of Australia [BBCA] (2019)

Persse, J., & Rose, D. (1981). House styles in Adelaide: a pictorial history. Adelaide: Australian Institute of Valuers: Real Estate Institute of South Australia.

Pittwater Council (2015). *Pittwater 21 Development Control Plan – Hazard Controls*

QGIS Open Source Project. (2017, Sep 5). Raster Geoalgorithms - Zonal Statistics. Retrieved from QGIS 2.18 Documentation: https://docs.qgis.org/2.18/en/docs/user_manual/processing_algs/qgis/raster_tools.html?highlight=zonal#zonal-statistics

Qin, Y., He, Y., Wu, B., Ma, S., & Zhang, X. (2017). Regulating top albedo and bottom emissivity of concrete roof tiles for reducing building heat gains. *Energy & Buildings*, *156*, 218–224. https://doi.org/10.1016/j.enbuild.2017.09.090

Queensland Household Resilience Program: https://www.qld.gov.au/housing/buying-owning-home/financial-help-concessions/household-resilience-program

Queensland Reconstruction Authority (2019). Flood Resilience Building Guidance for Queensland Homes. Retrieved from https://www.qra.qld.gov.au/sites/default/files/2019-04/flood_resilient_building_guidance_for_queensland_homes_-_april_2019.pdf

Rawlinsons Construction Cost Consultants and Quantity Surveyors. (2016). *Rawlinsons Australian construction handbook 2016*.

Shi, Z., & Zhang, X. (2011). Analyzing the effect of the longwave emissivity and solar reflectance of building envelopes on energy-saving in buildings in various climates. *Solar Energy*, *85*(1), 28-37.

Standards Australia. (2009). Australian Standard AS 3959-2009: Construction of buildings in bushfire-prone areas. Sydney, Australia: Author.

Suehrcke, H., Peterson, E., & Selby, N. (2008). Effect of roof solar reflectance on the building heat gain in a hot climate. *Energy & Buildings*, *40*(12), 2224–2235. https://doi.org/10.1016/j.enbuild.2008.06.015

Sustainability Victoria (2016). Cavity Wall Insulation Retrofit Trial.

Sustainability Victoria (2019). Window frames. Retrieved from https://www.sustainability.vic.gov.au/You-and-your-home/Building-and-renovating/Windows/Window-frames

Sustainable Buildings Research Centre. (2016). *NSW Housing Typology Development Project*. Wollongong: State of NSW and the Office of Environment and Heritage

Sustainable Energy Authority Victoria [SEAV] (2002). Energy Smart Housing Manual. http://www.aprbuildingservices.com.au/Files_ESHM/ESHousingManualCh07.pdf

Sustainability Victoria. (2014). *Renovation tips for specific house types*. Retrieved from http://www.sustainability.vic.gov.au/services-and-advice/households/energy-efficiency/smarterrenovations/renovation-tips-for-specific-house-types

The Australian Asbestos Network. (2019). Building Materials. Retrieved from https://www.australianasbestosnetwork.org.au/asbestos-history/asbestos-home-3/building-materials/

U.S. Department of Energy. (2019a). Air Sealing your home. Retrieved form https://www.energy.gov/energysaver/weatherize/air-sealing-your-home

U.S. Department of Energy. (2019b). Cool roofs. Retrieved from https://www.energy.gov/energysaver/design/energy-efficient-home-design/cool-roofs

U.S. Department of Energy. (2019c). Detecting Air Leaks. Retrieved from https://www.energy.gov/energysaver/weatherize/air-sealing-your-home/detecting-air-leaks

Wagga Wagga City Council (2010). *Wagga Wagga Development Control Plan 2010 as amended – Section 4 – Environmental Hazards and Management*; and

Wollongong City Council. (2009). Wollongong Development Control Plan- Chapter 13 Floodplain Management

Woollahra. (2015). Woollahra Development Control Plan - Chapter E2 Stormwater and Flood Risk Management

Appendix A – Housing archetype descriptions

Brick Veneer House - Building characteristics:	
Ground floor structure type	Concrete slab on ground
External wall cladding	Brick cladding
Roof covering	Concrete tiles
Building condition	5
Floor height	0.2
Year of construction	1960 - 1980
Roof shape	Hip
Roof colour	Dark
Roof pitch	15 to 20
Roof structure	Trussed roof framing timber
Roof insulation	Glasswool
Ceiling lining	Plasterboard
Guttering	Painted steel
External rafters and beams or soffits openings	No
Internal linings	Plasterboard
Wall insulation	None
Internal wall coverings	Paint
Window frame	Aluminium
Window glazing	Standard glass
Window bushfire shutters	None
External door	Timber door
Door bushfire shutters	None
Floor finishes	Timber feature flooring
Ground floor enclosure	Masonry
External stairs	None
Decks, patios and verandahs	Concrete

Modern house - Building characteristics:	
Ground floor structure type	Concrete slab on ground
External wall cladding	Brick cladding
Roof covering	Zinc aluminium coated corrugated steel
Building condition	10
Floor height	0.2
Year of construction	1980 - 2005
Roof shape	Gable
Roof colour	Dark
Roof pitch	21 to 45
Roof structure	Trussed roof framing timber
Roof insulation	Glasswool
Ceiling lining	Plasterboard
Guttering	Painted steel
External rafters and beams or soffits openings	Yes
Internal linings	Plasterboard
Wall insulation	Glasswool
Internal wall coverings	Paint
Window frame	Aluminium
Window glazing	Standard glass
Window bushfire shutters	None
External door	Timber door
Door bushfire shutters	None
Floor finishes	Broadloom carpet
Ground floor enclosure	Masonry
External stairs	None
Decks, patios and verandahs	Stone

Lightweight 50s House - Building characteristics:	
Ground floor structure type	Suspended timber structure
External wall cladding	Fibre cement weatherboard
Roof covering	Terracotta tiles
Building condition	5
Floor height	0.5
Year of construction	1945 - 1960
Roof shape	Hip
Roof pitch	21 to 45
Roof structure	Trussed roof framing timber
Roof colour	Dark
Roof insulation	Glasswool
Ceiling lining	Fibre cement sheet
Guttering	Painted steel
External rafters/beams or soffits openings	No
Internal linings	Fibre cement sheet
Wall insulation	None
Internal wall coverings	Paint
Window frame	Timber
Window glazing	Standard glass
Window bushfire shutters	None
External door	Timber door
Door bushfire shutters	None
Floor finishes	Timber feature flooring
Ground floor enclosure	Timber
External stairs	Timber
Decks, patios and verandahs	Timber

Victorian House - Building characteristics:	
Ground floor structure type	Concrete slab on ground
External wall cladding	Stone cladding
Roof covering	Zinc aluminium coated corrugated steel
Building condition	5
Floor height	0.2
Year of construction	1845 – 1954
Roof shape	Hip
Roof colour	Dark
Roof pitch	21 to 45
Roof structure	Trussed roof framing timber
Roof insulation	Glasswool
Ceiling lining	Plaster
Guttering	Painted steel
External rafters and beams or soffits openings	Yes
Internal linings	Plaster
Wall insulation	None
Internal wall coverings	Paint
Window frame	Timber
Window glazing	Standard glass
Window bushfire shutters	None
External door	Timber door
Door bushfire shutters	None
Floor finishes	Timber feature flooring
Ground floor enclosure	Masonry
External stairs	None
Decks, patios and verandahs	Concrete

Contemporary House - Building characteristics:	
Ground floor structure type	Concrete slab on ground
External wall cladding	Brick cladding
Roof covering	Zinc aluminium coated corrugated steel
Building condition	10
Floor height	0.2
Year of construction	2005 - onwards
Roof shape	Hip
Roof pitch	21 to 45
Roof structure	Trussed roof framing timber
Roof insulation	Glasswool
Ceiling lining	Plasterboard
Guttering	Painted steel
External rafters and beams or soffits openings	Yes
Internal linings	Plasterboard
Wall insulation	Glasswool
Internal wall coverings	Paint
Window frame	Aluminium
Window glazing	Standard glass
Window bushfire shutters	None
External door	Timber door
Door bushfire shutters	None
Floor finishes	Timber feature flooring
Ground floor enclosure	Masonry
External stairs	None
Decks, patios and verandahs	Tiles

Climate Ready Home - Building characteristics:	
Ground floor structure type	Concrete slab on ground
External wall cladding	Brick cladding
Roof covering	Zinc aluminum coated corrugated steel
Building condition	10
Floor height	2050 100 Year ARI level + 0.5m
Year of construction	Present
Roof shape	Simple to prevent debris accumulation
Roof colour	Light
Roof pitch	lower than 20º
Roof structure	Trussed roof framing timber (minimum requirement though steel is preferred)
Roof insulation	Closed cell rigid insulation
Ceiling lining	Fibre cement sheet (likely not applicable to the majority of houses as it is above the flood height)
Guttering	Aluminium guttering, sumps and downpipes with bushfire-compliant ember guard
External rafters and beams or soffits openings	Non-combustible material
Internal linings	Concrete block
Wall insulation	Closed cell rigid insulation
Internal wall coverings	Paint
Window frame	Aluminium with thermal break
Window glazing	Double pane window with 6mm exterior toughened glass and
Window bushfire shutters	BAL 40 bushfire shutters are best practice, bushfire-compliant mesh is minimum requirement
External door	Solid timber door with bushfire-compliant mesh
Door bushfire shutters	All external doors, and other openings should be covered with 1.8mm steel-wire mesh screens or bushfire shutter to prevent ember entry. Place weather stripping or silicone around doors if any gaps remain.
Floor finishes	Polished concrete
Ground floor enclosure	Bushfire-compliant mesh or masonry, if applicable
External stairs	Non-combustible materials
Decks, patios and verandahs	Non-combustible materials

Appendix B – Thermal Resilient of Building Materials

Window glazing and frame

Window glazing can have the greatest impact on a building's thermal performance (ABCB, 2018). This depends on various factors like shading and location but can be similar to that of the roof which is usually the most exposed element to sunlight in a house. In terms of a window's thermal performance, the ABCB considers the window frame as being part of the "glazing" of a building; therefore, these characteristics are evaluated together.

The two principal characteristics that define a window's thermal performance are U-value and the Solar Heat Gain Coefficient (SHGC). These characteristics vary depending on glazing type, glazing coatings and the material of the window frame. U-value measures the rate of heat transfer of the system (conducted heat); therefore, a greater value represents faster heat transfer (lower insulation). The SHGC measures how readily heat from direct sunlight flows through a window system. Direct sunlight on a window is heavily impacted by orientation, shading devices, and other external factors that are outside of the scope of this study. Therefore, SHGC is presented to inform about windows thermal performance but is not used for the resilience rating in this study.

The Australian Fenestration Rating Council (AFRC) has identified 88 "default" windows with corresponding performance data. The "default" windows are intended to provide representative performance values over a wide range of currently available frame and glass combinations.

Table 22 provides descriptions for four common fixed/sliding windows and their associated thermal performance.

Table 22 - Thermal performance of four common windows (Department of Planning and Environment, 2018)

Indicative window type	U- value*	SHGC*	Associated window thermal performance
Aluminium window frame – single glazed with 3mm clear glass	6.7	0.70	Fastest heat transfer and high solar heat transmitted
Timber or uPVC window frame – single glazed with 3mm clear glass	5.4	0.63	Moderate heat transfer and moderate solar heat transmitted
Aluminium window frame – double glazed with 3mm clear glass/6mm air gap/3mm clear glass	4.8	0.59	Moderate heat transfer and moderate solar heat transmitted
Timber or uPVC window frame — double glazed with 3mm clear glass/6mm air gap/3mm clear glass	3.0	0.56	Slowest heat transfer and low solar heat transmission

*average values

Wall system

The thermal performance of walls will vary depending on the composition of the wall and the specific characteristics and thickness of the materials used. This includes and is not limited to the wall cladding, insulation and wall structure. Therefore, the thermal performance of the wall should be evaluated as a system. The thermal performance of a wall system is often referred to as "total R-value". This value considers the heat flow direction and is the inverse of thermal conductivity.

Table 23 provides the overall thermal performance of common wall systems without insulation and Table 24 provides the thermal performance of common insulation materials.

Materials commonly used for wall thermal insulation are rated based on their thermal conductivity. The lower the thermal conductivity of a material, the better it acts as a thermal insulator.

Table 23 - R-value for typical wall construction without added insulation (NCC, 2019)

Description (composition exterior to interior)	Total R- value (m2K/W)
Weatherboard (weatherboards, framing and plasterboard)	0.48
Fibre-cement sheet (fibre-cement sheet, framing, plasterboard)	0.42
Clay masonry veneer (external masonry, framing, plasterboard)	0.56
Cavity clay masonry (external masonry, air gap, internal masonry, plasterboard or render)	0.69

Table 24 - Thermal characteristics of common Insulation materials (AIBC, 2000)

Wall insulation material	Conductivity (W/(mK))
Fibreglass batts 89 – 140mm	0.041
Expanded polystyrene (beadboard)	0.036 – 0.039
Cellulose fibre 100mm	0.038
Extruded expanded polystyrene	0.029
Mineral (rock) wool 100mm	0.023 – 0.026
Polyurethane	0.023 – 0.026

Conductivity and thickness of an insulation material are used to obtain the insulation R-value so that the total system R-value can be determined.

Roof colour

The solar absorptance of a building's roof is linked to how much heat is gained by absorption of solar radiation (Shi and Zhang, 2011). When focusing on extreme heat, a low value of solar absorptance is recommended to avoid the absorption of heat. A roof's colour influences its solar absorptance (Department of Planning and Environment, 2019) and has a significant effect on cooling costs (Suehrcke, Peterson & Selby, 2008). Table 25 categorises the level of solar absorptance associated with roof colour.

Table 25 - Roof colour and solar absorptance (Department of Planning, 2019) (NCC, 2019)

Roof colour	Solar absorptance	Associated colours	Associated roof colour performance
Light	<0.475	• Light cream • Off white • Light grey	Lowest heat gain
Medium	0.475-0.7	• Galvanised steel • Zinc aluminium • Yellow • Buff	Medium heat gain
Dark	>0.7	• Red • Green • Slate (dark grey)	Greatest heat gain

Roof system

Similar to walls, the thermal performance of a roof will vary depending on its overall composition and thickness of materials used. Therefore, the thermal performance of a roof is evaluated in terms of the system's overall thermal performance (R-value). The ideal R-value (4.6 for climate zone 6 (NCC, 2019)) for a dwelling is defined according to the climate conditions of its surroundings and considers colour (solar absorptance).

Table 26 provides the R-value of common roof systems without insulation (upwards direction of heat flow due to climate zone). Refer to Table 24 for the R- value of common insulation materials applicable to both ceilings and walls.

Table 26 - R-value for typical roof construction without added insulation (NCC, 2019)

Roof system description	Total R- value of roof system without insulation (m2K/W)
Unventilated tiled pitched roof with flat ceiling with an upwards direction of heat flow	0.41
Ventilated tiled pitched roof with flat ceiling with an upwards direction of heat flow	0.23
Unventilated metal pitched roof with flat ceiling and an upwards direction of heat flow	0.39
Ventilated metal pitched roof with flat ceiling and an upwards direction of heat flow	0.72

Table 27 provides the minimum total R-values for roof systems in climate zone 6 considering colour (upper surface solar absorptance). Therefore, when a roof colour is lighter (lower surface solar absorptance), the required minimum total R-value (insulation) of the roof system is lower.

Table 27 - Roof upper surface solar absorptance and roof systems minimum total R- value for climate zone 6 (NCC, 2019)

Roof upper surface solar absorptance value	Minimum Total R- value of roof system (m2K/W)
≤ 0.4	4.6
>0.4 but ≤0.6	5.1
>0.6	5.1

Other considerations

The following attributes are likely linked to a building's performance in an extreme heat environment; however, for the purposes of this study, these have been excluded.

Proximity to vegetation

Trees are an important consideration in terms of the shading they can provide to houses and the effect they have on a home's thermal performance. The effect of vegetation on heat is linked to vegetation height, location and canopy density. These factors vary greatly across lots. For this reason, there is a precedent for excluding trees from hazard modelling (e.g. proximity to vegetation has been excluded from the United States HAZUS software) and were therefore excluded in this study.

Air infiltration values

Air infiltration values influence a building's thermal performance (U.S. Department of Energy, 2019). However, infiltration values for housing are difficult to obtain and are highly dependent on construction quality, cracks and gaps from electrical outlets, switch plates, window frames, TV cables, phone lines and other factors (U.S. Department of Energy, 2018) that go beyond the scope of this study. As such, infiltration values are not considered in this study.

External doors

External doors are a specific feature that may affect the degree of infiltration in a house and therefore the home's thermal performance. However, the ability to discriminate between types of doors and the associated degree of infiltration is required for this attribute to be considered in the overall thermal performance of a building (ABCB, 2018). For this reason, there is a precedent for omitting external doors from thermal performance modelling when the degree of infiltration is unknown (ABCB, 2018). As such, external doors are not considered in this study.

Floor insulation

Floor insulation was also found to be a factor affecting the thermal performance of a building; however, estimating heat losses or gains through floors is extremely difficult without substantial data collection (ABCB, 2018). As such, there is precedent for excluding floor insulation (e.g. floor insulation is excluded in the modelling of the reference building and proposed building models to evaluate energy efficiency for the ABCB). Floor insulation is not considered in this study.

Extreme heat resilience rating

A building's performance during an extreme heat event is related to the thermal performance of the building's envelope. The thermal performance refers to the energy efficiency of the building's envelope to maintain comfortable temperatures indoors whilst using the least amount of mechanical energy. This is directly related to a building's insulation and considers the building's performance throughout the year.

The NCC sets the minimum R-values that each component of a building should comply with to achieve energy efficiency. The R-values stated in the NCC from 1990, 2010, 2016 and 2019 for commonly used wall and roof systems in Australia where used to inform the R-values of the archetypes based on the assumed year of construction for each archetype.

The applied resilience ratings of each archetype are based on:

- Roof system R-value
- Wall system R-value
- Window system (glazing and frame) U-value.

A resilience rating (1 being the least resilient, 5 being the most resilient) was assigned following linear distribution based on the archetype's associated R-values and U-values (Table 28).

Table 28 - Archetype's R- values of roof systems and associated resilience ratings

Archetype	Roof system description	Total roof system R-value (m2K/W)	Rating
Brick Veneer House	tiled roof with insulation	4.1	4
Modern House	metal roof with insulation	4.1	4
Lightweight 50s House	terracotta roof with insulation	2.2	2
Victorian House	metal roof with insulation	2.2	2
Contemporary House	metal roof with insulation	4.6	4

Different insulation thicknesses (R- values) where assumed based on the year the houses were built using the NCCs of 1990, 2010, 2016 and 2018. However, since the Victorian and Contemporary houses were built before the first NCC was released, it is assumed that the total system R- value of both of these archetypes comply with the R-values suggested by the NCC from 1990. This takes into account that in 2009 there was a home insulation program that gave stimulus to home owners to insulate their roof to make their homes more energy efficient (ANAO, 2010). However, implementation was not ideal, therefore conservative R-values were chosen for these archetypes.

Table 29 - Archetypes' R- values of wall systems and associated resilience ratings

Archetype	Wall system description	R-value (m2K/W)	Rating
Brick Veneer House	Cavity clay masonry (no insulation) (NCC, 2010 & 2016)	0.69	1
Modern House	brick veneer with insulation (NCC, 2016 & 2019 compliant)	2.8	5
Lightweight 50s House	weatherboards, framing and plasterboard (no insulation) (NCC 2010, 2016)	0.48	1
Victorian House	Cavity clay masonry (no insulation) (NCC 2010, 2016)	0.69	1
Contemporary House	brick veneer with insulation (NCC, 2016 & 2019)	2.8	5

A window's thermal performance is evaluated in terms of U-value, where lower U-value provides greater resistance to heat flow (greater insulation). The window system U-value includes the effect of the frame, glass, seals and any spacers and therefore varies greatly. The U-values used to rate the current archetypes performance were obtained from the Windows Energy Rating Scheme.

Table 30 provides the U-values and associated resilience ratings for the window systems of the archetypes.

Table 30 - Archetypes U-values of window systems and associated resilience ratings

Archetype	Window system description	U-value	Rating
Brick Veneer House	Single clear glass, aluminium frame	6.9	1
Modern House	Single clear glass, aluminium frame	6.9	1
Lightweight 50s House	Single clear glass, timber frame	5.5	2
Victorian House	Single clear glass, aluminium frame	6.9	1
Contemporary House	Single clear glass, aluminium frame	6.9	1

Appendix C - Climate-ready home specifications for new buildings

Table 31 provides the recommended building specification for a climate-ready home that has improved resilience to bushfire, flood and extreme heat. These materials have been chosen based on their performance in response to bushfire, flood and extreme heat exposure. Material cost, applicability and ease of construction have also been considered to minimise up-front and replacement costs.

Extreme heat is not included in the BRKD and therefore the resilience ratings of the materials recommended to improve extreme heat resilience are based on their associated R- and U-values.

Resilience ratings are not determined for all recommendations. Specifically, resilience ratings only apply to recommended building materials (e.g. brick as external wall cladding) and not broader recommendations (e.g. proximity to vegetation). However, the lack of a resilience rating does not denote the robustness of the recommendations. All recommendations in the specification should be considered to ensure optimum resilience.

Building elements not mentioned in the specification are to be determined in consultation with the appropriate professional and should consider exposure to bushfire, flood and extreme heat if relevant. Exclusion from this specification signals minimal relevance to these hazards in comparison to those elements that are specified.

Specific regulations may apply to different areas (e.g. development control plans). Applicable regulations should take priority and are independent from these recommendations. However, in any instance, it is recommended to consider solutions that address any required regulations while also maximising resilience.

Table 31 - Climate-ready home specifications for new buildings

Element	Recommended material	Extreme heat resilience rating	Bushfire resilience rating	Flood resilience rating	Comments and intent
Ground floor structure type	Concrete slab on ground	5	5	N/A	Concrete slab on ground is on balance the most resilient ground floor structure to both flood and bushfire. With best practice passive design, a concrete slab on ground can achieve good thermal comfort and protection from extreme heat. It is important to consider passive design, particularly the appropriate shading of thermal mass in the summer to avoid maladaptation outcomes such as overheating in the summer (see section 5.4). Variants: suspended concrete slab + mesh/masonry ground floor enclosure (though concrete slab on ground is preferred in climate zone 6 for passive design). Sloping blocks can also consider lightweight construction (e.g. steel sub floor with a non-combustible flooring type, such as Autoclaved Aerated Concrete or compressed fibre cement sheet). The ground flood structure must be designed so as not to impede the flow of floodwaters, increase flood affectation elsewhere and entrap debris. References: Government of South Australia (2016). *Development Plan Gawler (CT);* Government of South Australia (2012). *Minister's Code Undertaking development in Bushfire Protection Areas- amended October 2012*; Lake Macquarie City Council (2014). *Lake Macquarie Development Control Plan 2014 – Revision 14: Part 3 – Development within Residential Zones*; Lismore City Council (2012). *Lismore Development Control Plan – Part A: Flood Prone Lands*; Mackay Regional Council (2017). *Mackay Regional Planning Scheme 2017;* Personal communication with Bushfire Building Council of Australia [BBCA] (2019); Pittwater Council (2015). *Pittwater 21 Development Control Plan – Hazard Controls*; Wagga Wagga City Council (2010). *Wagga Wagga Development Control Plan 2010 as amended – Section 4 – Environmental Hazards and Management*; and Wollongong City Council (2009). *Wollongong Development Control Plan 2009 – Chapter E13: Floodplain Management*.

Element	Recommended material	Extreme heat resilience rating	Bushfire resilience rating	Flood resilience rating	Comments and intent
External wall cladding	Standard brick wall	5*	5	5	The intent is a hard, impermeable surface that is non-combustible. Variants: concrete block, stone, concrete in situ Size of external vents, weepholes and gaps should not exceed 1.8mm; bigger ones should be fitted with a mesh with a maximum aperture of 1.8mm, made of corrosion-resistant materials such as steel. Gaps in cladding, window frames and door frames should be sealed with silicone. References: Green Cross Australia (2017). *Harden Up: Protecting Queensland*. Retrieved from http://hardenup.org/; Government of South Australia (2012). *Minister's Code: Undertaking development in Bushfire Protection Areas*; Government of South Australia Department of Planning, Transport and Infrastructure (2014). *Port Lincoln Council Development Plan;* Government of South Australia Department of Planning, Transport and Infrastructure (2015). *Barunga West Council Development Plan;* Government of South Australia Department of Planning, Transport and Infrastructure (2015). *Kangaroo Island Council Development Plan;* Government of South Australia Department of Planning, Transport and Infrastructure (2016). *Adelaide Hills Council Development Plan;* Government of South Australia Department of Planning, Transport and Infrastructure (2017). *Adelaide (City) Development Plan;* Government of South Australia Department of Planning, Transport and Infrastructure (2017). *Victor Harbor Council Development Plan;* Insurance Institute for Business & Home Safety (2017). *Fortified Home*. Retrieved from https://disastersafety.org/fortified/fortified-home/; Personal communication with Bushfire Building Council of Australia [BBCA] (2019); Standards Australia. (2009). Australian Standard AS 3959-2009: Construction of buildings in bushfire-prone areas. Sydney, Australia: Author; and Victoria State Government (2014). *Victoria Planning Provisions 52.47 Planning for Bushfire*.

Element	Recommended material	Extreme heat resilience rating	Bushfire resilience rating	Flood resilience rating	Comments and intent
Roof covering	Timber framed roof with zinc aluminium corrugated steel	5*	5	N/A	Roofs must have a non-combustible covering over the entirety of the roof. Metal roofing has been proven to offer least opportunity for ember penetration and is easiest and least costly to replace. The roof and wall junction should be sealed. Corrugated roofs require fitting with ember guards. Any mechanical equipment on the roof (e.g. solar panels, evaporative coolers) should be fitted with mesh with a maximum aperture of 1.8mm, made of corrosion-resistant materials such as steel. A roof pitch lower than 20º is recommended to reduce material use and cost, while still maintaining a pitch high enough so that fuel (such as leaf litter and twigs) does not collect and that embers will roll off. In addition, a simple roof line is preferred to minimise collection of litter for ember ignition. A steel frame is less likely to ignite in a bushfire scenario. References: Department of Fire & Emergency Services. (2014). *The Homeowner's Bushfire Survival Manual*. Government of Western Australia. Perth, Australia; Insurance Institute for Business & Home Safety (2017). *Fortified Home*. Retrieved from https://disastersafety.org/fortified/fortified-home; and Personal communication with Bushfire Building Council of Australia [BBCA] (2019).
Proximity to vegetation/defendable space	N/A	N/A	N/A	N/A	To minimise bushfire risk, all new dwellings should be sited in areas with low bushfire hazard, set back 20 meters from flammable or combustible vegetation and provide a Building Protection Zone (BPZ) where possible. Any trees that might impact the building if they fell should be removed. Fine fuels should be managed within 20m of the building. It is recommended to create and maintain a BPZ around any structures. Within the BPZ: • No vegetation should be within 10m of a building (noting that in small plots this may prove difficult to achieve);

Element	Recommended material	Extreme heat resilience rating	Bushfire resilience rating	Flood resilience rating	Comments and intent
					• Beyond 10m of the building, tree crowns are recommended to be separated 5m to provide wind protection during a bushfire; and • Shrubs should not be planted in clumps. References: Department of Fire & Emergency Services. (2014). The Homeowner's Bushfire Survival Manual. Government of Western Australia. Perth, Australia; Government of South Australia Department of Planning, Transport and Infrastructure (2016). *Yankalilla Council Development Plan;* Government of South Australia Department of Planning, Transport and Infrastructure (2017). *Victor Harbour Council Development Plan;* Government of South Australia Department of Planning, Transport and Infrastructure (2017). *Mount Barker Council Development Plan;* Government of South Australia Department of Planning, Transport and Infrastructure (2017). *Adelaide Hills Development Plan;* Government of South Australia Department of Planning, Transport and Infrastructure (2018). *Alexandrina Council Development Plan;* and Personal communication with Bushfire Building Council of Australia [BBCA] (2019).
Floor height	N/A	N/A	N/A	N/A	All floor levels must be at or above the 2050 100 Year ARI level + 0.5m. All materials (structural elements or components) used below this level should be flood resilient. Avoiding the hazard in the first place is the most effective way to achieve flood resilience. A freeboard of 0.5m above the 100 Year ARI level will avoid the 1 in 100-year flood *now*, but as the climate changes we can expect flood heights to increase. The prudent approach would be to apply a principle of building the floor height as high as possible within other design constraints. The use of fill should be avoided unless it can be demonstrated that flood impact will not increase elsewhere.

Element	Recommended material	Extreme heat resilience rating	Bushfire resilience rating	Flood resilience rating	Comments and intent
					References: Insurance Council of Australia (2019); and Lismore City Council (2012). *Lismore Development Control Plan – Part A: Flood Prone Lands*
Continued function of infrastructure components	N/A	N/A	N/A	N/A	Any components of infrastructure (e.g. electrical system components, HVAC equipment) that could fail to function or may result in contamination (e.g. sewage connections) when inundated during flood events must be located above or protected to the 2050 100 Year ARI level + 0.5m. References: Hawkesbury-Nepean Floodplain Management Steering Committee (2006). *Reducing Vulnerability of Buildings to Flood Damage: Guidance on Building in Flood Prone Areas*; Personal communication with Bushfire Building Council of Australia [BBCA] (2019); Pittwater Council (2015). *Pittwater 21 Development Control Plan – Hazard Controls*; Wollongong City Council (2009). *Wollongong Development Control Plan 2009 – Chapter E13: Floodplain Management*; and Woollahra Municipal Council (2015). *Woollahra Development Control Plan 2015*.
Structural soundness	N/A	N/A	N/A	N/A	All buildings and structures must be able to withstand floodwater, debris and buoyancy up to and including the 100 Year ARI level + 0.5m. Including, for example, external fuel tanks or water tanks may require anchoring. References: Brisbane City Council (2014). *Brisbane City Plan 2014: Flood planning scheme policy – Brisbane City Council planning scheme*; Hawkesbury-Nepean Floodplain Management Steering Committee (2006). *Reducing Vulnerability of Buildings to Flood Damage: Guidance on Building in Flood Prone Areas*; Lismore City Council (2012). *Lismore Development Control Plan – Part A: Flood Prone Lands*; Wagga Wagga City Council (2010). *Wagga Wagga Development Control Plan 2010 as amended – Section 4 – Environmental Hazards and Management*;

Element	Recommended material	Extreme heat resilience rating	Bushfire resilience rating	Flood resilience rating	Comments and intent
					Wollongong City Council (2009). *Wollongong Development Control Plan 2009 – Chapter E13: Floodplain Management*; and Woollahra Municipal Council (2015). *Woollahra Development Control Plan 2015.*
Prevention of debris accumulation and ember entry	N/A	N/A	N/A	N/A	The house should be designed to minimise the accumulation of debris (i.e. simple structures). All external windows and doors (including frames), vents, weep holes and other openings should be covered with 1.8mm steel-wire mesh screens or bushfire shutters to prevent ember entry. Areas under decks or floors and sub floor supports should be enclosed with fly wire or non-combustible sheeting. Place non-combustible weather stripping around doors and windows or use silicon if any gaps remain. References: Green Cross Australia (2017). *Harden Up: Protecting Queensland*. Retrieved from http://hardenup.org/; Government of South Australia (2012). *Minister's Code: Undertaking development in Bushfire Protection Areas*; Government of South Australia Department of Planning, Transport and Infrastructure (2014). *Port Lincoln Council Development Plan;* Government of South Australia Department of Planning, Transport and Infrastructure (2015). *Barunga West Council Development Plan;* Government of South Australia Department of Planning, Transport and Infrastructure (2015). *Kangaroo Island Council Development Plan;* Government of South Australia Department of Planning, Transport and Infrastructure (2016). *Adelaide Hills Council Development Plan;* Government of South Australia Department of Planning, Transport and Infrastructure (2017). *Adelaide (City) Development Plan;* Government of South Australia Department of Planning, Transport and Infrastructure (2017). *Victor Harbour Council Development Plan;* Insurance Institute for Business & Home Safety (2017). *Fortified Home*. Retrieved from https://disastersafety.org/fortified/fortified-home/; Personal communication with Bushfire Building Council of Australia [BBCA] (2019); and Victoria State Government (2014). *Victoria Planning Provisions 52.47 Planning for Bushfire*.

Element	Recommended material	Extreme heat resilience rating	Bushfire resilience rating	Flood resilience rating	Comments and intent
Roof colour	N/A	5*	N/A	N/A	Light colours (upper solar absorptance ≤ 0.4) and a reflective surface are recommended as they will minimise heat gain and allow for a reduction in the thickness of insulation required (refer to roof system R-value element) and minimise urban heat island effect. References: Australian Building Codes Board (2019). National Construction Code Volume Two. Osmond, P. & Sharifl, E., (2017). *Guide to Urban cooling strategies.*
Guttering	Aluminium guttering, sumps and downpipes with bushfire-compliant ember guard	N/A	5	N/A	Gutters and leaf guards should be made of non-combustible materials. Leaf guards should have a maximum aperture of 1.8 mm to prevent ember attack. Gutter leaf guards will protect from aggregation of fuel. Variants: painted steel guttering. References: Brisbane City Council (2014) *Brisbane City Plan 2014: Bushfire planning scheme policy – Brisbane City Council planning scheme*; Green Cross Australia (2017). *Harden Up: Protecting Queensland*. Retrieved from http://hardenup.org/; Government of South Australia (2012). *Minister's Code: Undertaking development in Bushfire Protection Areas*; Government of South Australia Department of Planning, Transport and Infrastructure (2014). *Port Lincoln Council Development Plan;* Government of South Australia Department of Planning, Transport and Infrastructure (2015). *Barunga West Council Development Plan;* Government of South Australia Department of Planning, Transport and Infrastructure (2015). *Kangaroo Island Council Development Plan;* Government of South Australia Department of Planning, Transport and Infrastructure (2016). *Adelaide Hills Council Development Plan;* Government of South Australia Department of Planning, Transport and Infrastructure (2017). *Adelaide (City) Development Plan;*

Element	Recommended material	Extreme heat resilience rating	Bushfire resilience rating	Flood resilience rating	Comments and intent
					Government of South Australia Department of Planning, Transport and Infrastructure (2017). *Victor Harbour Council Development Plan;* Government of Western Australia Department of Planning, Lands and Heritage - Western Australian Planning Commission (2017). *Guidelines for Planning in Bushfire Prone Areas*; Insurance Council of Australia (2017). *Building Resilience Knowledge Database*. Retrieved from http://www.buildingresilience.org.au/brkd; Insurance Institute for Business & Home Safety (2017). *Fortified Home*. Retrieved from https://disastersafety.org/fortified/fortified-home/; and Standards Australia (2009). Construction of buildings in bushfire-prone areas (AS3959); and Personal communication with Bushfire Building Council of Australia [BBCA] (2019)
Internal linings	Concrete block	N/A	N/A	5	A hard, impermeable product that is not damaged from inundation is recommended. It is recognised that this product/method of building will require extra considerations for inclusion of services such as electrical and communications wiring. Homeowners can choose to render internal walls as well. Variants: stone Reference: Insurance Council of Australia (2017). *Building Resilience Knowledge Database*. Retrieved from http://www.buildingresilience.org.au/brkd
Wall insulation	Closed cell rigid insulation	5*	N/A	4	To improve flood resilience, closed cell rigid insulation is recommended, such as XPS and EPS. Glasswool should be avoided as it disintegrates in an inundation scenario. The wall insulation should have sufficient R-value to achieve a minimum total wall system R-value of 2.8. If materials and wall build-up recommended in Table 1 are used, the thickness of the insulation should be 75cm. Wall insulation is less important from a bushfire perspective as the focus of bushfire resilience in the first instance is to prevent ember entry by creating a non-

Element	Recommended material	Extreme heat resilience rating	Bushfire resilience rating	Flood resilience rating	Comments and intent
					combustible and sealed building envelope. However, PIR foam is likely to combust and produce toxic fumes when used in high bushfire risk areas and is therefore not recommended though it performs well in response to an inundation scenario. References: Australian Building Codes Board (2019). National Construction Code Volume Two. Hawkesbury-Nepean Floodplain Management Steering Committee (2006). *Reducing Vulnerability of Buildings to Flood Damage: Guidance on Building in Flood Prone Areas*; and Personal communication with Bushfire Building Council of Australia [BBCA] (2019)
Internal wall coverings	Paint	N/A	N/A	4	Paint is recommended based on cost and ease of replacement if required. Reference: Insurance Council of Australia (2017). *Building Resilience Knowledge Database*. Retrieved from http://www.buildingresilience.org.au/brkd
Window frame	Aluminium with thermal break	5*	4	N/A	Windows present a risk of breaking and fire penetrating the internal areas of houses. The AS3959 standard and the Australian Window Association guidelines for windows in bushfire prone areas should be considered. A thermal break is recommended to reduce heat loss in winter and heat gain in summer. Variants: timber-covered aluminium windows References: Australian Window Association. *A Guide to Windows and Doors in Bushfire Prone Areas*. Retrieved from https://www.qbcc.qld.gov.au/sites/default/files/A%20Guide%20to%20Windows%20and%20Doors%20in%20Bushfire%20Areas.pdf Insurance Council of Australia (2017). *Building Resilience Knowledge Database*. Retrieved from http://www.buildingresilience.org.au/brkd

Element	Recommended material	Extreme heat resilience rating	Bushfire resilience rating	Flood resilience rating	Comments and intent
					Sustainability Victoria (2019). Window frames. Retrieved from https://www.sustainability.vic.gov.au/You-and-your-home/Building-and-renovating/Windows/Window-frames
Window glazing	Double pane window with 6mm exterior toughened glass and bushfire-compliant mesh	5*	5	N/A	Windows present a risk of breaking and fire penetrating the internal areas of houses. The AS3959 standard and the Australian Window Association guidelines for windows in bushfire prone areas should be considered. Dual-pane windows are required for thermal performance purposes. Tempered glass windows are preferred. The use of high SHGC and low U-value glazing is recommended as well as external solar shading on northerly windows. The house should be designed to minimise the accumulation of debris. All external windows should be covered with steel-wire mesh with a maximum aperture of 1.8mm or bushfire shutter to prevent ember entry. Rating to BAL40 recommended. Place weather stripping around doors and windows if any gaps remain. Other types of mesh, such as nylon, can build in a risk. Stainless steel will protect from ember attack. Consider also the framing that the mesh is housed in for its ability to withstand heat. BAL40 compliant window shutters are preferred. BAL40 compliant mesh is the minimum. References: Insurance Council of Australia (2019); Australian Building Codes Board (2019). National Construction Code Volume Two; Australian Window Association. *A Guide to Windows and Doors in Bushfire Prone Areas.* Retrieved from https://www.qbcc.qld.gov.au/sites/default/files/A%20Guide%20to%20Windows%20and%20Doors%20in%20Bushfire%20Areas.pdf; Insurance Institute for Business & Home Safety (2017). *Fortified Home*. Retrieved from https://disastersafety.org/fortified/fortified-home/; Personal communication with Bushfire Building Council of Australia [BBCA] (2019); and Standards Australia (2009). Construction of buildings in bushfire-prone areas (AS3959)

Element	Recommended material	Extreme heat resilience rating	Bushfire resilience rating	Flood resilience rating	Comments and intent
External door	Solid timber door with bushfire-compliant mesh	N/A	5	N/A	Flush, solid timber door with BAL40-compliant mesh to increase bushfire resilience rating. As much bushfire protection as possible is preferred. Other types of mesh, such as nylon, can build in a risk. Stainless steel will protect from ember attack. Consider also the framing that the mesh is housed in for its ability to withstand heat. The house should be designed to minimise the accumulation of debris. All external doors, and other openings should be covered with 1.8mm steel-wire mesh screens or bushfire shutter to prevent ember entry. Place weather stripping or silicone around doors if any gaps remain. BAL40 compliant window shutters are preferred. BAL40 compliant mesh is the minimum. Variants: fire door or aluminium-framed glass door with non- timber door frames. N.B. bushfire-compliant mesh is required to achieve a high bushfire resilience rating. References: Insurance Council of Australia (2019); Standards Australia (2009). Construction of buildings in bushfire-prone areas (AS3959); Green Cross Australia (2017). *Harden Up: Protecting Queensland*. Retrieved from http://hardenup.org/; and Personal communication with Bushfire Building Council of Australia [BBCA] (2019).
Floor finishes	Polished concrete	5	N/A	4	Polished concrete floor receives the highest resilience rating and is resilient to flood and bushfire. This type of floor can provide good thermal performance if passive design principles are applied and adhered to. Variants: ceramic tiles, slate and hardwearing floor covering (e.g. vinyl tiles, linoleum); however, these alternative materials may require replacement in some flood scenarios and are therefore not considered as resilient as polished concrete.

Element	Recommended material	Extreme heat resilience rating	Bushfire resilience rating	Flood resilience rating	Comments and intent
					Reference: Insurance Council of Australia (2017). *Building Resilience Knowledge Database*. Retrieved from http://www.buildingresilience.org.au/brkd
Decks, patios and verandas	Concrete slab on ground	N/A	5	N/A	Non-combustible materials should be used for all structures to minimise fire spread (includes decking, verandas, fencing and supports). Variants: If structures or building elements connected to the house or within 10m of the house are to be included, they must be made of non- combustible materials. References: Brisbane City Council (2014) *Brisbane City Plan 2014: Bushfire planning scheme policy – Brisbane City Council planning scheme*; Government of South Australia (2012). *Minister's Code: Undertaking development in Bushfire Protection Areas*; Government of South Australia Department of Planning, Transport and Infrastructure (2014). *Port Lincoln Council Development Plan;* Government of South Australia Department of Planning, Transport and Infrastructure (2015). *Barunga West Council Development Plan;* Government of South Australia Department of Planning, Transport and Infrastructure (2015). *Kangaroo Island Council Development Plan;* Government of South Australia Department of Planning, Transport and Infrastructure (2016). *Adelaide Hills Council Development Plan;* Government of South Australia Department of Planning, Transport and Infrastructure (2017). *Adelaide (City) Development Plan;* Government of South Australia Department of Planning, Transport and Infrastructure (2017). *Victor Harbour Council Development Plan;* Government of Western Australia Department of Planning, Lands and Heritage - Western Australian Planning Commission (2017). *Guidelines for Planning in Bushfire Prone Areas*; Green Cross Australia (2017). *Harden Up: Protecting Queensland*. Retrieved from http://hardenup.org/; Insurance Institute for Business & Home Safety (2017). *Fortified Home*. Retrieved from https://disastersafety.org/fortified/fortified-home/; and

Element	Recommended material	Extreme heat resilience rating	Bushfire resilience rating	Flood resilience rating	Comments and intent
					Personal communication with Bushfire Building Council of Australia [BBCA] (2019);
Water supply	N/A	N/A	N/A	N/A	Houses should have a dedicated water supply for firefighting purposes with appropriate connections for use by rural fire service. A minimum of 5,000 litres must always be available with adequate pressure and flow (minimum of 10 litres per second at 200kPa). References: Brisbane City Council (2014) *Brisbane City Plan 2014: Bushfire planning scheme policy – Brisbane City Council planning scheme*; Cassowary Coast Regional Council (2014). *Cassowary Coast Regional Council Planning Scheme*; Government of South Australia (2012). *Minister's Code: Undertaking development in Bushfire Protection Areas*; Government of South Australia Department of Planning, Transport and Infrastructure (2015). *Barunga West Council Development Plan;* Government of Western Australia Department of Planning, Lands and Heritage - Western Australian Planning Commission (2017). *Guidelines for Planning in Bushfire Prone Areas*; Sunshine Coast Council (2014). *Sunshine Coast Planning Scheme 2014*; and Victoria State Government (2014). *Victoria Planning Provisions 52.47 Planning for Bushfire*.
External rafters and beams or soffits openings protected	Non-combustible material	5*	5	N/A	Eaves should be lining with a non-combustible material (e.g. steel, fibre cement) to prevent the spread of fire. Eaves should also be designed in accordance with passive design principles to maximise thermal benefits. Reference: Cement Concrete & Aggregates Australia. (2009). *Building in Bushfire-prone Areas*.
Roof system R-value	N/A	5*	N/A	N/A	For best performance in climate zone 6 and as per the building code, achieve a minimum total R-value of 4.6. The roof insulation is key to achieving the minimum required R-value.

Element	Recommended material	Extreme heat resilience rating	Bushfire resilience rating	Flood resilience rating	Comments and intent
					Reference: Australian Building Codes Board (2019). National Construction Code Volume Two.
Wall system R-value	N/A	5*	N/A	N/A	For best performance in climate zone 6 and as per the building code, achieve a minimum total R-value of 2.8. Reference: Australian Building Codes Board (2019). National Construction Code Volume Two.
Window system U-value and SHGC	N/A	5*	N/A	N/A	For best performance in climate zone 6 and as per the building code, achieve approximate total system U-value of 3.8 and approximate total system SHGC of 0.68. The glazing performance requirement of each window will vary between dwellings depending on area, facing direction, height and width of window, shading and more. To calculate the ideal characteristics for the windows in a specific location, the glazing calculator in the ABCB website should be used. Reference: Australian Building Codes Board (2019). National Construction Code Volume Two.

*The extreme heat resilience rating is indicative of the performance of wall, roof and window *systems* rather than the performance of each element/material on its own. For example, the resilience of the external cladding material in terms of extreme heat is highly dependent on the quantity of insulation as they both contribute to an overall wall system R-value.

Appendix D - Climate-ready specifications for retrofitting

Similar to new builds, the same principles could be applied in a retrofit context. Given cost, applicability and ease of construction considerations, some elements have a different recommended material in a retrofit context compared to a new build scenario. Table 32 presents those elements with recommendations that differ in the retrofit context. All other recommendations for retrofit are the same as those presented for new builds in Table 31 in Appendix C.

Table 32 - Climate-ready specifications for retrofitting (that differ from those presented in Table 31)

Element	Recommended material	Extreme heat resilience rating	Bushfire resilience rating	Flood resilience rating	Comments and Intent
Proximity to vegetation/ Defendable space	N/A	N/A	N/A	N/A	More flammable species should be removed and the retention of those species with lower flammability and high habitat value should be prioritised. 0-2m from home: Use of hard surfaces is recommended. Combustible mulch product should not be used. Any remaining vegetation in the area must be irrigated, low-growing and non-woody. No shrubs or trees can be in this area. 2m –10m from home: Maintain space between trees, their canopies and shrubs to achieve horizontal and vertical separation. If possible, outbuildings should be located >10m from the home. >10m from home: It is recommended that trees in this area should be located to provide at least 3m between crowns. It is recognised that vegetation recommendations for bushfire may contradict recommendations for extreme heat (e.g. overlapping canopies recommended to reduce heat). Vegetation hazards should be minimised for bushfire while ideally maximising thermal benefits through passive design. Reference: Insurance Institute for Business & Home Safety (2017). *Fortified Home*. Retrieved from https://disastersafety.org/fortified/fortified-home/
Internal wall linings	Fibre cement	N/A	N/A	4	Fibre cement sheet with structural timber bracing receives a resilience rating of 4, while other materials (e.g. block, stone) receive a 5. Due to installation difficulties, fibre cement sheet is recommended in a retrofit scenario. However, if feasible, block or stone should be used to maximise resilience.

Element	Recommended material	Extreme heat resilience rating	Bushfire resilience rating	Flood resilience rating	Comments and Intent
					Application of this material horizontally is recommended to allow partial replacement of the damaged portions in case of flood exposure. Reference: Insurance Council of Australia (2017). *Building Resilience Knowledge Database*. Retrieved from http://www.buildingresilience.org.au/brkd
Windows	Bushfire-compliant mesh	N/A	5	N/A	BAL40-compliant mesh to increase bushfire resilience rating for each window is recommended rather than replacing existing frames and glazing. As much bushfire protection as possible is preferred. Other types of mesh, such as nylon, can build in a risk. Stainless steel will protect from ember attack. Consider also the framing that the mesh is housed in for its ability to withstand heat. BAL40 compliant window shutters are preferred. BAL40 compliant mesh is the minimum. Reference: Insurance Council of Australia (2019); Personal communication with Bushfire Building Council of Australia [BBCA] (2019);and Standards Australia (2009). Construction of buildings in bushfire-prone areas (AS3959).
External door	Bushfire-compliant mesh	N/A	5	N/A	BAL40-compliant mesh to increase bushfire resilience rating for each door is recommended rather than replacing existing doors. As much bushfire protection as possible is preferred. Other types of mesh, such as nylon, can build in a risk. Stainless steel will protect from ember attack. Consider also the framing that the mesh is housed in for its ability to withstand heat. BAL40 compliant door shutters are preferred. BAL40-compliant mesh is the minimum Reference: Insurance Council of Australia (2019);

Element	Recommended material	Extreme heat resilience rating	Bushfire resilience rating	Flood resilience rating	Comments and Intent
					Personal communication with Bushfire Building Council of Australia [BBCA] (2019);and Standards Australia (2009). Construction of buildings in bushfire-prone areas (AS3959).
Ground floor enclosure	Bushfire-compliant mesh	N/A	5	N/A	Structure should be built to withstand the forces of floodwater, debris and buoyancy up to and including the 2050 100-year ARI level plus 0.5m. For homes with a raised floor structure, it is recommended to enclose the ground floor structure with bushfire-compliant mesh or masonry. Reference: Insurance Council of Australia (2017). *Building Resilience Knowledge Database*. Retrieved from http://www.buildingresilience.org.au/brkd; and Insurance Council of Australia (2019).
External stairs	Concrete	N/A	5	N/A	Non-combustible materials should be used for all structures to minimise fire spread. When retrofitting a house with stairs, concrete stairs are recommended. Variants: Steel stair supports with steel steps, tile steps or BAL 40 fire rated decking material for steps. References: Brisbane City Council (2014) *Brisbane City Plan 2014: Bushfire planning scheme policy – Brisbane City Council planning scheme*; Green Cross Australia (2017). *Harden Up: Protecting Queensland*. Retrieved from http://hardenup.org/; Government of South Australia (2012). *Minister's Code: Undertaking development in Bushfire Protection Areas*; Government of South Australia Department of Planning, Transport and Infrastructure (2014). *Port Lincoln Council Development Plan;* Government of South Australia Department of Planning, Transport and Infrastructure (2015). *Barunga West Council Development Plan;* Government of South Australia Department of Planning, Transport and Infrastructure (2015). *Kangaroo Island Council Development Plan;* Government of South Australia Department of Planning, Transport and Infrastructure (2016). *Adelaide Hills Council Development Plan;* Government of South Australia Department of Planning, Transport and Infrastructure (2017). *Adelaide (City) Development Plan;*

Element	Recommended material	Extreme heat resilience rating	Bushfire resilience rating	Flood resilience rating	Comments and Intent
					Government of South Australia Department of Planning, Transport and Infrastructure (2017). *Victor Harbour Council Development Plan;* Government of Western Australia Department of Planning, Lands and Heritage - Western Australian Planning Commission (2017). *Guidelines for Planning in Bushfire Prone Areas*; Insurance Council of Australia (2017). *Building Resilience Knowledge Database*. Retrieved from http://www.buildingresilience.org.au/brkd; and Insurance Institute for Business & Home Safety (2017). *Fortified Home*. Retrieved from https://disastersafety.org/fortified/fortified-home/.
Ceiling lining	Fibre cement sheet	N/A	N/A	4	It is only in extreme cases that the need for a flood resilient roof insulation will be material. This recommendation is not relevant to those properties that do not risk flood heights of this magnitude. Fibre cement sheet is more resilient to flood in an extreme flood situation than other materials and is also preferred for bushfire as it slows down the spread of fire if the building is impacted. However, it is only in extreme cases that the need for a flood resilient ceiling lining will be material. Variants: concrete in situ Reference: Insurance Council of Australia (2017). *Building Resilience Knowledge Database*. Retrieved from http://www.buildingresilience.org.au/brkd
Roof insulation	Closed cell rigid insulation	N/A	N/A	4	This recommendation is not relevant to those properties that do not risk flood heights of this magnitude. For extreme cases, a closed cell rigid insulation is recommended, such as XPS and EPS to improve flood resilience. In relation to bushfire, no ember is considered to enter beyond external materials. However, the following may be taken into account: PIR foam is likely to combust and produce toxic fumes when used in high bushfire risk areas and is therefore not recommended. The roof insulation is key to achieving the minimum required R-value (refer to element: Roof System R- value). The product's specifications should demonstrate the roof complies with the minimum R- value of 4.6 or 5.1 depending on the roof colour. Reference: Australian Building Codes Board (2019). National Construction Code Volume Two.

Element	Recommended material	Extreme heat resilience rating	Bushfire resilience rating	Flood resilience rating	Comments and Intent
					Hawkesbury-Nepean Floodplain Management Steering Committee (2006). *Reducing Vulnerability of Buildings to Flood Damage: Guidance on Building in Flood Prone Areas*;

Appendix E - Economic modelling inputs and assumptions

Cost of materials

The construction costs associated with each element within the considered archetypes were determined primarily using Rawlinsons' Construction Cost Guide 2016. Where costing was not available in this source, other resources were used.

Key considerations include:

- Some materials require additional items for installation (e.g. framing for plasterboard). These costs have been included;
- Materials and associated costs presented correspond to the climate-ready home specification's minimum requirement (e.g. windows and door shutters are recommended but the minimum requirement is to apply 1.8mm mesh; therefore, costs for the mesh are applied);
- Material costs may change depending on the archetype that is being retrofitted; and
- The cost of labour is not included in the new build scenario, as labour is required regardless of type of new build. Cost of labour is included in the retrofit scenarios, as this construction (and therefore cost of labour) would otherwise not occur. Furthermore, retrofit costs differ from new build costs due to some inherent difficulties associated with retrofit.

Table 33 presents the cost of each of the elements for the new build climate-ready home as applied in the economic analysis.

Table 34 presents assumed costs to retrofit an existing home to the climate-ready retrofit specification.

Building and material lifespan

For the purposes of this assessment, the average lifespan of a detached home is assumed to be 50 years (ABCB 2006, FWPA 2011). As such, the costs and benefits are assessed over a 50-year period. Table 35 presents the reference service life of the materials used in the specification. The worst-case scenario has been adopted for application in the economic assessment (i.e. the assessment assumes the minimum lifespan when a range is provided).

Insurance premiums

The economic assessment includes estimated insurance premiums associated with each archetype. To estimate insurance premiums by archetype, the project team tested the five archetypes plus the climate-ready home specification in two addresses per council area using two insurance premium calculators (SGIC and RAA) chosen based on relevance to the study area. The assessed addresses were chosen at random with the following constraints:

- High bushfire risk as identified in the hazard data mapping;
- Potential flood risk as identified in the hazard data mapping; and
- Located within Mount Barker, Alexandrina, Victor Harbor, Yankalilla and Adelaide Hills.

Table 33 – New build climate-ready home costs

Element	Material	Unit	Cost	Material assumptions
Ground floor structure type	Concrete slab on ground	sqm	$82.30	150mm thick.
External wall cladding	Standard brick wall	sqm	$139.30	110mm thick + fair face .
Roof covering	Zinc Aluminium corrugated steel	sqm	$113.00	Timber framed roof comprising trusses, rafters, insulation on mesh, standard fascia with Zinc Aluminium corrugated steel.
Roof insulation	Closed cell rigid insulation	sqm	$57.30	75mm thick.
Guttering	Aluminium	m	$34.40	Gutters, sumps and downpipes all in standard materials.
Gutter mesh	Steel mesh	m	$27.03	1.8mm steel ember guard mesh with components.
Internal linings	Standard block wall	sqm	$150.60	150mm thick + pointing and cleaning down one face.
Wall insulation	Closed cell rigid insulation	sqm	$70.40	2 x 50mm thick.
Internal wall coverings	Paint	sqm	$12.50	Seal and two coats acrylic paint on fair face.
Window frame	Aluminium	No.	$203.00	Sliding, 50% opening.
Window glazing	Toughened glass 6mm	sqm	$267.00	Double pane unit with exterior toughened glass.
Window bushfire protection	Stainless steel mesh	sqm	$58.55	Stainless steel screen BAL40 compliant.
External door	Timber door	No.	$505.00	Standard flush solid timber door 2040 x 820mm.
Door bushfire protection	Mesh	No.	$58.55	Stainless steel screen BAL40 compliant.
Floor finishes	Polished concrete	sqm	$30.50	Finish to a non-slip surface and cost of better aggregate than slab. If a home has a ground floor structure other than concrete slab on ground, then a hardwearing floor covering (e.g. linoleum) is recommended to keep costs down. It should also be noted that timber is becoming more resilient to flood (not to bushfire) from an insurance perspective in that timber is increasingly being repaired rather than replaced.
Decks, patios and verandahs	Concrete	sqm	$82.30	Concrete slab on ground 150mm thick.
External rafters and beams or soffits openings protected	Fibre cement	sqm	$27.00	Eaves treatment: flat sheeting x 4.5mm thick to soffit and 600mm wide.

Table 34 – Climate-ready home retrofit costs

Element	Material	Unit	Cost	Material assumptions
External wall cladding	Standard brick wall	sqm	$146.50	Renovation/remedial work: new brick wall 100mm thick in existing building.
Roof covering	Zinc Aluminium corrugated steel	sqm	$120.23	Timber framed roof comprising trusses, rafters, insulation on mesh, standard fascia with steel. Includes pitch's increased cost (6.41%) for a 23 degrees roof (Reference building pitch source: NCC 2019 volume two).
Ceiling lining	Fibre cement sheet	sqm	$50.70	4.5mm thick sheeting, seal and two coats acrylic latex paint.
Guttering	Aluminium	sqm	$34.40	Gutters, sumps and downpipes all in standard materials.
Gutter mesh	Stainless steel	m	$27.03	Steel ember guard mesh with 1.8mm aperture and components.
Internal linings	Fibre cement	sqm	$59.80	4.5mm thick.
Wall insulation	Closed cell rigid insulation	sqm	$70.40	2x50mm thick.
Internal wall coverings	Paint	sqm	$12.50	Seal and two coats acrylic paint on fair face.
Window frame	Aluminium	No.	$203.00	Sliding (50% opening). Frame and fixing in position.
Window glazing	Toughened glass 6mm	sqm	$420.00	Double pane window with exterior 6mm clear toughened glass.
Window bushfire protection	Window bushfire shutter	No.	$1,468.50	BAL40 Roller Shutter for 1 sliding window standard size 944mm x 1210mm.
Door bushfire protection	Door bushfire shutter	No.	$1,594.95	BAL40 Roller Shutter 2040 x 820 standard (with 11mm packing so that roller shutter is not blocked by the door handle).
Floor finishes	Polished concrete	sqm	$30.50	Finish to a non-slip surface and cost of better aggregate than slab. For those archetypes that do not have a concrete slab on ground, the recommended retrofit material is a hardwearing floor covering (e.g. linoleum tiles) at $33.00 per m^2.
Decks, patios and verandahs	Concrete	sqm	$246.00	Renovation/remedial work: new 100mm thick suspended concrete slab including formwork left in.
External rafters and beams or soffits openings protected	Fibre cement	sqm	$27.00	Eaves treatment: flat sheeting x 4.5mm thick to soffit and 600mm wide.
Ground floor enclosure	Brick wall	sqm	$139.30	110mm thick + fair face. Only applicable to some houses.
External stairs	Concrete	m^3	$477.00	Concrete in situ. Only applicable to some houses.

Table 35 – Material lifespans

Material	Assumed service life (years)	Source
External stone cladding	>100	Department of Environment and Heritage (2008) Maintenance and Repair of Older Buildings in South Australia. Adelaide: SA Government.
External brick cladding	>50	Brickworks (2017) Brick Technical Manual. Available at: https://bbp.style/PUBLIC/products/technical-information/australbricks/AB-Bricks-BrickTechnicalManual-NAT.pdf
Concrete roof tiles	50	Certified Roofing (2017) Longevity of metal roof vs tiles. Available at: https://www.certifiedroofing.com.au/longevity-of-metal-roof-vs-tiles/
Terracotta roof tiles	>100	Certified Roofing (2017) Longevity of metal roof vs tiles. Available at: https://www.certifiedroofing.com.au/longevity-of-metal-roof-vs-tiles/
Plasterboard (internal)	50	Gyproc Saint-Gobain (2014) 12.5 mm Gyproc Wallboard EPD.
Fibre cement sheet (external wall covering)	>50	James Hardie (2017) External Claddings EPD
Fibre cement sheet (internal)	>50	James Hardie (2017) External Claddings EPD
Aluminium frame + window	40	Howard, NP, Burgess, J and Lim, C (2007) Comparative service life assessment of window systems. Melbourne: FWPA.
Timber frame + window	15 to >40	WoodSolutions (2012) Timber Windows and Doors - Technical Design Guide. Wood Solutions (2013) Timber service life design - Design guide for durability.
Timber door	15 to >40	WoodSolutions (2012) Timber Windows and Doors - Technical Design Guide. Wood Solutions (2013) Timber service life design - Design guide for durability.
Timber flooring	>50	Assumed from protected timber for internal use: Wood Solutions (2013) Timber service life design - Design guide for durability.
Zinc aluminium coated corrugated steel	40-70	Certified Roofing (2017) Longevity of metal roof vs tiles. Available at: https://www.certifiedroofing.com.au/longevity-of-metal-roof-vs-tiles/
Painted steel gutter	10 to 30	NSW Fair Trading (2011) High Front Guttering Advisory Committee Report on the review and use of high front guttering in New South Wales. Sydney: NSW Government.
Aluminium gutter	10 to 30	NSW Fair Trading (2011) High Front Guttering Advisory Committee Report on the review and use of high front guttering in New South Wales. Sydney: NSW Government.
Glasswool insulation	60	Glava (2019) Glava Glass Wool EPD
Expanded polystyrene insulation	60	EPS Industry Alliance (2017) Expanded Polystyrene Insulation EPD
Broadloom carpet	15	Mohawk (2019) Tufted Nylon Broadloom Carpet on Unibond Plus Air Backing EPD Godfrey Hirst (2019) Synthetic Carpet Maintenance & Guarantee Guide. Geelong: Godfrey Hirst.

Material	Assumed service life (years)	Source
Bushfire window + door mesh (5mm)	40	Australian Window Association (2012) A guide to windows and doors in brushfire prone areas. Gordon: AWA.
External tiles (veranda, flooring)	50	Harris, DD and Fitzgerald, L (2015) A life cycle cost analysis for flooring materials for healthcare facilities. Journal of Hospital Administration, 4(4): 92-100.
Concrete block (wall, internal)	60	Janjua, SY, Sarker, PK and Biswas, WK (2019) Impact of service on the environmental performance of buildings. Buildings, 9(9).
Hardwearing floor covering (e.g. vinyl tiles)	10 to 20	Harris, DD and Fitzgerald, L (2015) A life cycle cost analysis for flooring materials for healthcare facilities. Journal of Hospital Administration, 4(4): 92-100.
Timber decking, untreated woods	10 to 60	Wood Solutions (2013) Timber service life design - Design guide for durability.

Table 36 presents the results of the insurance premium calculators. For each test, all variables remained constant except for address, year of construction and building components, if applicable based on archetype.

The average sum insured for a residential home (only) in the study area is $350,000 (personal communication with Insurance Council of Australia, 2019).[3] As such, all tests were completed using a sum insured value of $350,000 where possible. The SGIC calculator mandated a minimum sum insured of $408,000 for the Lightweight 50s House archetype for all locations except Victor Harbor Home A. The SGIC calculator also mandated a minimum sum insured of $876,000 for the Victorian House archetype for all locations except Victor Harbor Home A, which required a minimum of $803,000. This is likely due to age of these archetypes and location (in the case of the Victor Harbor-specific sum insured) signifying increased costs.

Table 37 presents the average premium for each archetype, as applied in the economic analysis.

[3] It is important to note that while the average sum insured value is $350,000, there are significant issues across Australia with under insuring to reduce premiums. It should therefore be recognised that premiums may in reality be beyond those calculated here; however, the true sum insured value is unknown.

Table 36 – Results of insurance premium calculator tests

Archetype	Results by location using SGIC calculator									
	Mount Barker		Alexandrina		Victor Harbor		Yankalilla		Adelaide Hills	
	Home A	Home B	Home A	Home B	Home A	Home B	Home A	Home B	Home A	Home B
Brick veneer house (1960 - 1980)	$403.24	$416.07	$438.52	$438.52	$382.40	$403.24	$457.77	$443.34	$738.46	$781.67
Modern house (1980 - 2005)	$435.32	$448.15	$472.21	$472.21	$412.87	$435.32	$439.07	$478.63	$794.60	$837.81
Lightweight 50s house (1945 - 1960)	$443.34	$457.77	$483.44	$483.44	$379.17	$443.34	$504.29	$488.25	$810.63	$858.61
Victorian house (1845 - 1954)	$1,015.94	$1,046.42	$1,102.55	$1,102.55	$898.84	$1,015.94	$1,147.45	$1,113.78	$1,829.11	$1,933.18
Contemporary house (2005+)	$374.24	$386.82	$407.26	$407.26	$355.37	$374.24	$426.12	$411.97	$687.04	$728.19
Climate-ready home	$309.07	$319.58	$336.68	$336.68	$293.28	$309.07	$352.46	$340.63	$570.79	$608.34
Archetype	Results by location using RAA calculator									
	Mount Barker		Alexandrina		Victor Harbor		Yankalilla		Adelaide Hills	
	Home A	Home B	Home A	Home B	Home A	Home B	Home A	Home B	Home A	Home B
Brick veneer house (1960 - 1980)	$795.00	$789.00	$875.00	$737.00	$1,139.00	$1,359.00	$739.00	$742.00	$1,146.00	$873.00
Modern house (1980 - 2005)	$776.00	$770.00	$857.00	$719.00	$1,121.00	$1,341.00	$721.00	$725.00	$1,126.00	$853.00
Lightweight 50s house (1945 - 1960)	$759.00	$750.00	$878.00	$701.00	$1,224.00	$1,508.00	$704.00	$707.00	$1,210.00	$855.00
Victorian house (1845 - 1954)	$805.00	$796.00	$921.00	$744.00	$1,266.00	$1,551.00	$747.00	$750.00	$1,256.00	$901.00
Contemporary house (2005+)	$709.00	$704.00	$771.00	$659.00	$980.00	$1,157.00	$660.00	$664.00	$992.00	$774.00
Climate-ready home	$679.00	$674.00	$742.00	$630.00	$951.00	$1,129.00	$632.00	$636.00	$962.00	$744.00

Table 37 – Average insurance premium based on calculator estimates by archetype and as applied in the economic analysis

Archetype	Average Insurance Premium
Brick veneer house	$704.86
Modern house	$711.76
Lightweight 50s house	$732.41
Victorian house	$1,097.14
Contemporary house	$631.43
Climate-ready home	$577.78

Based on historical trends, insurance premiums are expected to quadruple over a 20-year period (personal communication with ICA, 2020). As such, Table 38 provides the premiums associated with each archetype as applied at the end of the 50-year assessment period.

Table 38 – Insurance premiums by archetype as applied in the economic analysis in year 50 (i.e. 2070) based on a quadruple in price every 20 years

Archetype	Average insurance premium
Brick veneer house	$24,811.12
Modern house	$25,053.93
Lightweight 50s house	$25,780.97
Victorian house	$38,619.26
Contemporary house	$22,226.18
Climate-ready home	$20,337.82

Disruption

In addition to insurance costs, it is recognised that there is an additional cost to the homeowner should they experience loss or damage to their home due to bushfire or flood in the form of a range of factors including disruption to routine, mental health and wellbeing, potential inability to go to work, and loss of irreplaceable items.

Using best practice economic methodologies, Daniel *et al*. (2009) found that an increase in the probability of flood risk of 0.01 in a year is associated with a difference in transaction price of an otherwise similar house of -0.6%. This implies that the marginal willingness to pay for reduced risk exposure is equivalent to 0.6% of the housing price. If people are willing to pay 0.6% *more* for a property with reduced flood risk, we can infer that this value represents those costs that otherwise cannot be valued, such as disruption to routine or mental health impacts should the home be damaged or lost.

Ambrey *et al.* (2017) conducted a study to assess the social cost of the Black Saturday bushfires. The study found the bushfires reduced levels of life satisfaction with an implied willingness to pay of $2,991 annually to reduce by 1% the extent to which an individual's immediate local area was affected by the bushfires.

These studies signal a value of approximately $3,000 per annum to reduce bushfire or flood risk to a home.[4] As a proxy of disruption, the economic analysis accounts for $2,730.91 (the more conservative estimate of the two) on an annual basis to represent the cost of being impacted by a climate hazard event such as bushfire or flood.

The economic analysis also accounts for the underinsurance and the excess a homeowner would need to pay following damage to their home due to bushfire or flood. The average excess in the study area is $500 and, on average, homes are underinsured by 17.5% (personal communication with ICA, 2020). These values are applied over the 50-year period based on the likelihood of each archetype experiencing a climate hazard incidence in any one year. For example, a house in a high bushfire exposure area has a 3-6% chance of being burnt in any one year, with the range relating to the age of the house. This has been applied to each archetype as follows in Table 39.

[4] The median property price in the study area $455,151.93. The application of 0.6% leads to a value of $2,730.91.

Table 39 – Annual likelihood of incidence in any one year in a high-risk bushfire area

Archetype	Average year of construction	Annual likelihood of incidence
Brick veneer house	1970	4%
Modern house	1993	4%
Lightweight 50s house	1953	5%
Victorian house	1900	6%
Contemporary house	2012	3%

Energy savings

In addition to a reduced insurance premium, energy savings are also associated with building to the climate-ready specification. Table 40 presents the average energy use associated with each archetype based on the estimated wall and roof R-value of each archetype.

Table 40 – Energy use and associated cost by archetype based on wall and roof R-value

Archetype	Annual energy use (kWh)	Annual cost associated with energy use ($)
Brick veneer house	6,337	$2,383.98
Modern house	6,337	$2,383.98
Lightweight 50s house	5,176	$1,947.21
Victorian house	5,176	$1,947.21
Contemporary house	5,054	$1,901.31
Climate-ready house	4,911	$1,847.52

The total annual energy use is based on the findings of Bannister *et al.* (2018) which estimates energy use based on wall and roof R-value. The annual cost column applies a cost of $0.3762 per kWh to the annual energy use. The cost estimate is based on the average electricity cost in South Australia in 2019 (Canstar Blue, 2019). The estimated annual cost associated with energy use was used in the economic analysis to demonstrate cost savings of improved thermal performance as aligned to the climate-ready specification.

It is noted that characteristics beyond the wall- and roof-system R-value contribute to the thermal performance of a home; however, the majority of heat flow is related to the roof- and wall-system (Figure 12). Air leakage values for housing are difficult to obtain and are highly dependent on construction quality, cracks and gaps from electrical outlets, switch plates, window frames, TV cables, phone lines and other factors (U.S. Department of Energy, 2018) that go beyond the scope of this study. As such, infiltration values are not considered in this study and it is assumed that the majority of energy-related savings are attributable to wall- and roof-system R-values.

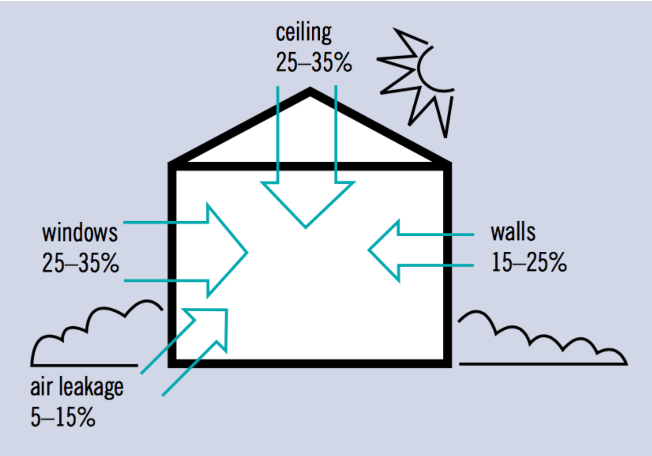

Figure 12 | Heat flow without insulation (SEAV, 2002)

An additional $244 can be saved per year through the installation of double-glazed windows (rather than single pane), as recommended in the climate-ready home specification. A study conducted in Victoria (primarily climate zone 6 as well) found that installing double-glazed windows led to an energy savings of approximately 651 kWh per year (Sustainability Victoria, 2016).

Table 41 – Adopted assumptions in the economic analysis

Assumption	Description
Average building life of detached residential home	50 years (ABCB 2006 and FWPA 2011)
Average age of existing housing stock in the study area	36 years (based on results of the housing typology study)
Cost of materials for each archetype	Costs were applied for each item based on Rawlinsons' Construction Cost Guide 2016, see Section 0 for further details
Average electricity cost in South Australia	$0.3762/kWh (Canstar Blue, 2019)
Average excess in the study area	$500.00
Assumed average insurance premium for Brick Veneer House in study area	$704.86
Assumed average insurance premium for Modern House in study area	$711.76
Assumed average insurance premium for Lightweight 50s House in study area	$732.41
Assumed average insurance premium for Victorian House in study area	$1,097.14
Assumed average insurance premium for Contemporary House in study area	$631.43
Assumed average insurance premium for Climate-Ready House in study area	$577.78
Average amount of underinsurance in Australia	17.5%
Assumed increase in insurance premiums	Insurance premiums were modelled to quadruple over a 20-year period, based on historical trends
Likelihood of a climate hazard (e.g. bushfire, flood) to impact a single home in any one year	3-6% depending on age of dwelling
Assumed value to homeowner of not being impacted by a climate hazard (e.g. bushfire, flood) in any one year, beyond the cost of insurance and/or repair	$2,730.91
Consumer Price Index	2%
Discount rate	7%