SYNTHESIS SUMMARY 1

Heat and heatwaves

Heatwaves are Australia's deadliest climate events, but this is not always reflected in media and community responses. Projections show we can expect more frequent and hotter extreme hot days and nights and, as a result, we might expect more heat-related deaths in the future.

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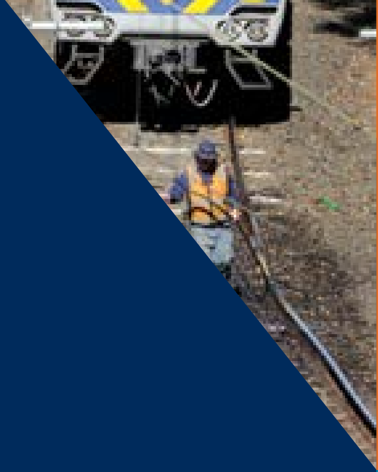


About this summary

About this series

Between 2008 and 2013, the Australian Government funded a large nationwide Adaptation Research Grant Program (the ARG Program) in climate change adaptation. The Program was managed by the National Climate Change Adaptation Research Facility (NCCARF). It resulted in over 100 research reports that delivered new knowledge on every aspect of adaptation. The aim of the Program was to help build a nation more resilient to the effects of climate change and better placed to take advantage of the opportunities.

This series of Synthesis Summaries is based on research findings from the ARG Program, augmented by relevant new literature and evidence from practitioners. The series seeks to deliver some of the policy-relevant research evidence to support decision-making for climate change adaptation in Australia in a short summary. It takes an approach identified through consultation with relevant stakeholders about the needs of the intended audience of policymakers, decision-makers and managers in the public and private sectors.

This summary addresses adaptation to more frequent and intense episodes of extreme heat. The opening pages provide the context, including the nature and impacts of heatwaves ('Why we need to adapt'), followed by a synthesis of research findings around the impacts and adaptation response to extreme heat and heatwaves ('The research base …'). It concludes with a summary of how this new research knowledge might help address key adaptation policy challenges. This final section is informed by a workshop held with practitioners ('Evidence-based policy implications').

This brief was developed by NCCARF staff, with input on the policy challenges developed in workshops held in Mackay (Queensland), Adelaide (South Australia) and Cardinia Shire (Victoria) in December 2015. The workshop was attended by practitioners, policymakers and managers from within local, state and federal government organisations, community service organisations, not-for-profit organisations and universities.

The key research reports used to develop this summary are highlighted in Section 4. To see all reports from the ARG Program, please visit: **www.nccarf.edu.au/adaptation-library.**

Key findings

Five principal adaptation challenges emerge from the research evidence:

1. Improve messaging and communication: Climate change is likely to bring more intense, longer lasting and more frequent heatwaves. Individuals and communities that are aware of these increased risks will be empowered to take steps to build resilience.

2. Consider heat in planning and development: Building design has a strong influence on the cooling needs of occupants. For new constructions, there is an opportunity to consider extreme heat and human comfort in building design. Broader planning and design of urban precincts can similarly affect how heat is experienced in built-up areas and buildings. New developments can include best practice design features to improve building performance, but this is more challenging in existing building stocks and built-up areas.

3. Define roles and responsibilities: Extreme heat impacts and potential approaches to both reducing those impacts and responding during extreme heatwaves fall across a broad range of sectors and organisations. The challenge of coordinating responses and ensuring that the most appropriate governance arrangements are in place was highlighted in the extreme heatwave experienced in southern Australia in 2009.

4. Improve existing building stock and infrastructure: Much existing housing stock is poorly designed for extreme heat and heatwaves. There are known approaches to improving heat gain efficiency of existing housing, but they are not effective in all building designs. Occupant behaviour and knowledge of how best to cool existing buildings can also reduce the impact of extreme heat.

5. Take account of heat in workplace health and safety: For both the general workforce and those service organisations responding to extreme heatwaves, increased heat can affect the health and productivity of workers. The challenge is to create strategies that allow work to continue safely.

1. Why we need to adapt

1.1 The climate context

Hot days, hot nights and extended periods of hot weather (heatwaves) are one of the most obvious and direct effects of climate change. Australia's average daily maximum temperature has increased by 0.8 °C, and average overnight minimums have increased by 1.1 °C. This has been accompanied by increases in the duration, intensity and frequency of heatwaves across many parts of Australia. In the last decade we have seen some record-breaking summer temperatures (see Box 1).

If global emissions of greenhouse gases continue to increase at the current rate, then we can expect annual average temperatures to increase by 2.6–4.8 °C above 1986–2005 level by 2100.[11] Accompanying this is an expected increase in extremely hot days (Table 1) and heatwaves.

While most heatwaves are of a low intensity and cause few significant health risks, the most severe and extreme heatwaves affect vulnerable people and are capable of causing widespread impacts. The severity of a heatwave is relative to the length of time it persists and the recent temperature patterns (i.e. has it recently been warm?). To assist in providing severe heatwave warnings, the Bureau of Meteorology has developed and adopted a heatwave intensity methodology that considers the local climate context (see Box 2) and has proven to be robust in both tropical and temperate regions.[18]

Relative humidity is known to create considerable discomfort for individuals and can be an important consideration in assessing the human health effects of heatwaves. It is not as well observed or forecast as temperature is, so it is not used in heatwave warnings.[17] The most extreme heatwaves tend to occur during drought conditions, when humidity is low.

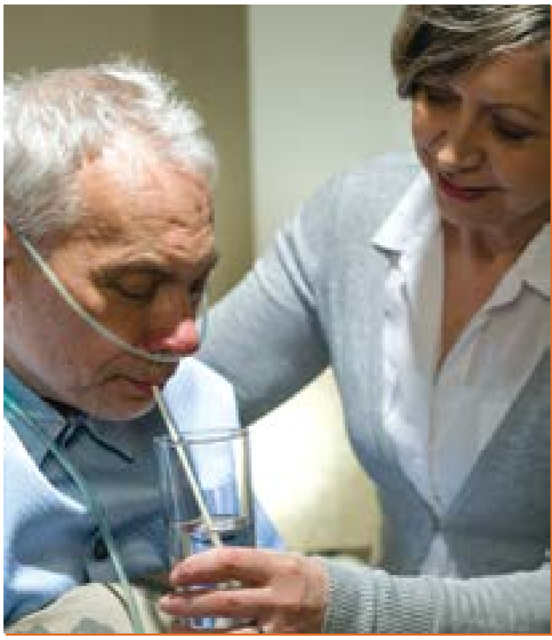
1.2 Key risks

A great deal was learned in the extreme heatwave that affected Adelaide and Melbourne and large rural areas of southern Australia in the summer of 2009.[19] While the deadly bushfires that followed (Black Saturday fires) were devastating, the death toll from the heatwave was in fact greater, with 374 deaths attributed to excess heat in Victoria alone.[19] Power outages, strains and stresses on service organisations, large spikes in hospital admissions and ambulance call outs and economic losses in the vicinity of $800 million (across both Melbourne and Adelaide) all resulted from extremely hot days and nights.[19] The event highlighted many of the key risks of extreme heat and, in particular, a number of critical interdependencies, such as the transport system on electricity supply.

The primary direct risks from increased heat and severe and extreme heatwaves are likely to be in the health, infrastructure and primary production sectors and to individual plant and animal species, with many indirect, flow-on effects and interdependencies (Figure 1).

Table 1 The average number of extremely hot days (>35 °C) currently experienced in key cities around Australia, and the predicted average under climate change in 2030 and 2090.[11]

Location	Present day	2030	2090 (low emissions)	2090 (high emissions)
Adelaide, SA	20	26	28	47
Alice Springs, NT	94	113	119	168
Amberley, Qld	12	18	18	55
Cairns, Qld	3	5.5	5.5	265
Canberra, ACT	7.1	12	13	29
Darwin, NT	11	43	52	265
Hobart, Tas	1.6	2	2	4.2
Melbourne, Vic	11	13	14	24
Perth, WA	28	36	37	63
Sydney, NSW	3.1	4.3	4.5	11



BOX 1 Australian records broken in the summers of 2012–13 and 2013–14.

2012–13 saw:[6,7,9]

- the hottest summer on record
- the hottest month on record (January 2013)
- the hottest day on record
- the hottest summer on record for Australian sea surface temperatures
- the hottest night on record at 7 locations
- the hottest day on record at 43 locations

2013–14 saw:[2,8]

- 11 days above 42 °C in Adelaide
- the driest summer on record for 45 locations in Queensland and 38 in New South Wales
- Sydney's driest summer in 27 years
- 20 days above 35 °C in Canberra

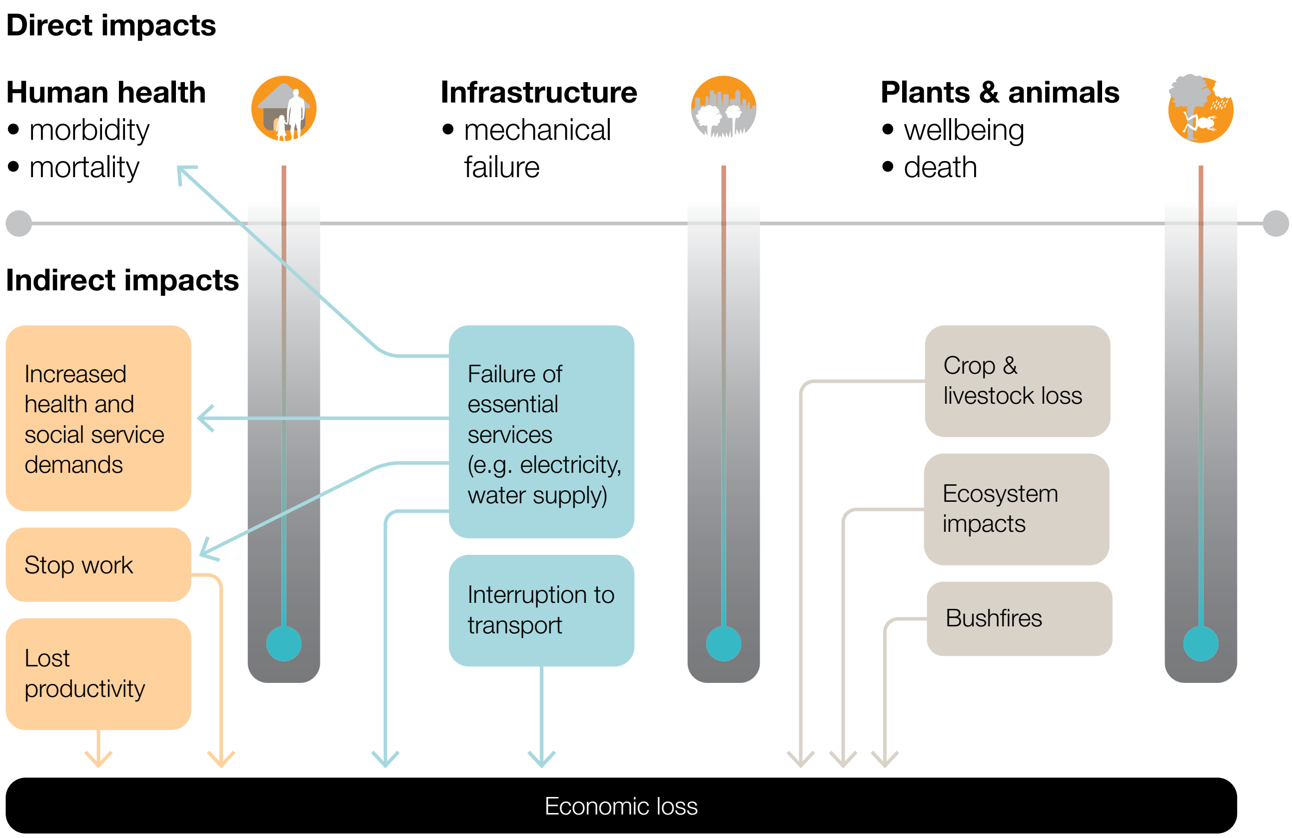


Figure 1 Schematic showing the direct and indirect impacts of extreme heat.

Box 2 Definitions of heatwaves and heatwave intensity developed by the Australian Bureau of Meteorology; these form the basis of warnings.[18]

Excess heat factor (EHF): A measure of excess heat (the long-term temperature anomaly characterised by each location's unique climatology of heat: is the temperature unusual for that place?) and heat stress (the short-term temperature anomaly measuring recent thermal acclimatisation: has it been gradually warming, allowing people to acclimatise?).

Heatwave: A period of at least three days where the combined effect of excess heat and heat stress is unusual with respect to the local climate. Both maximum and minimum temperatures are used in this assessment.

Severe heatwave: An event where EHF values exceed a threshold for severity that is specific to the climatology of each location. Vulnerable people are at greatest risk.

Extreme heatwave: An event where EHF values are well in excess of the severity threshold, resulting in widespread adverse outcomes. The general population faces health risks.

Health

Heatwaves have caused more deaths in Australia over the past 200 years than any other climate-related hazard[10], and projections of heat-related deaths suggest an increase of 1250 deaths per year in 2070 and as many as 8628 deaths in 2100.[4] Direct health impacts include cardiac arrest, heat stroke and dehydration, while secondary impacts can include gastroenteritis and organ damage as a result of dehydration. Heatwaves are known to have effects on behaviour and negative impacts on mental health.[19] In addition, widespread impacts on comfort, including heat stress, can be expected, with associated increased pressures on electricity supply for air-conditioning, emergency services and health services.

Infrastructure

Increased heat and extreme heatwaves can impact on the performance of infrastructure. For example, in the 2009 heatwave:

- electricity supply was interrupted due to equipment failure
- transport failed, particularly trains, partly because of buckling of rail lines
- air-conditioning failed
- bitumen melted.

Plants and animals

Heat-related mass mortality in individual animal species (e.g. flying foxes) has been recorded for some time. Likewise, plants can die following extreme heat events, with some species more vulnerable than others. The long-term outcomes of such events include changes in species assemblages, extinction of the most vulnerable species and increased forest fuel levels – with the latter being a risk factor in bushfires.

Severe and extreme heatwaves can also have significant impacts on agricultural crops and livestock. High temperatures over several days can substantially reduce crop yield and affect the health and wellbeing of stock.

2. The research base informing adaptation to extreme heat

The impact of extreme heat is something of a proverbial 'house of cards' with a strong set of interconnections between sectors and cascading impacts. A failure or stress on one sector can exacerbate effects in other sectors. Adaptation responses are likely, therefore, to be a combination of responses that consider building design and comfort, strategies for service providers, behavioural change and targeted solutions for vulnerable people.

2.1 Building, infrastructure and city design

Design features can target improved energy efficiency, and the National Construction Code prescribes minimum standards of efficiency that must be met. Alternatively, design can target heat reduction. While the two are not mutually exclusive, energy efficiency does not necessarily deliver heatwave mitigation. There is an opportunity to adopt additional building guidelines that focus on heat reduction (e.g. increasing the rating of insulation and including reflective foil) that would add a small to negligible increase in construction costs.[20] Choice of construction material and methods is important, but geographically specific, for example, the use of insulated brick cavities in Melbourne greatly reduces overheating. High night-time temperatures are known to be a major factor in health issues and mortality, so design and building use should target both day and night usage.

Building guidelines currently use historic climate conditions (typical meteorological year – TMY) to generate thermal models for evaluating the energy demand of a building. These guidelines are unlikely to be adequate for future climate change conditions. Modeling suggests that existing housing would require more cooling energy in the future than current design standards provide.[20]

Older buildings generally fall short of present day energy efficiency standards and can be poorly designed for extreme heat. Experimental data show that retrofitting many of these older homes has some potential to decrease heat gain; however, the level of improvement will depend on specific house design and location.[3] Housing types in climate zones with hot and humid summers (e.g. Townsville) are most vulnerable. In these locations, housing retrofits cannot sufficiently mitigate against severe heat-related health risk, and air-conditioning is increasingly required to maintain safe indoor temperatures for occupants.[3] In more moderate climates (e.g. Melbourne), basic retrofits can largely ameliorate climate change in the short term. Government-provided housing stock contains some housing that presents an immediate risk to vulnerable residents and needs to be reassessed for its suitability for these residents. Other housing can be prioritised for retrofitting and will provide value in reducing the heat risk.[3] This type of analysis could be used for a rapid assessment of risk and prioritisation of retrofit options.

While retrofitting of building stock can reduce heat gain, external building features and landscapes can also contribute to cooling design. Design guidelines, particularly in the case of public housing where residents may not be able to afford to use mechanical cooling or are more vulnerable to extreme heat, should include provision for outdoor landscaping to cool buildings[14] and should consider public cool places for respite.

Warming also means energy use will change. Both Sydney and Brisbane are expected to treble cooling loads by 2070 (Figure 2).[3]

2.2 Comfort, behaviour and health

We have a reasonable understanding of what physically makes someone vulnerable to extreme heat (see Figure 3), with pre-existing medical conditions a leading risk factor for morbidity and mortality in extreme heat. We can calculate the conditions at which it becomes difficult to maintain a stable body core temperature through the Discomfort Index, with values greater than 28 representing a severe heat load and an increased risk of heat illness.[3] Factors such as wind and humidity can contribute to discomfort of individuals, as does exposure (e.g. being outdoors) and activity.

Exposure to heat can be managed through building design, as discussed above, and through behavioural change. Behaviour can describe how people manage their shelter and its cooling potential or how they choose activities and manage their own

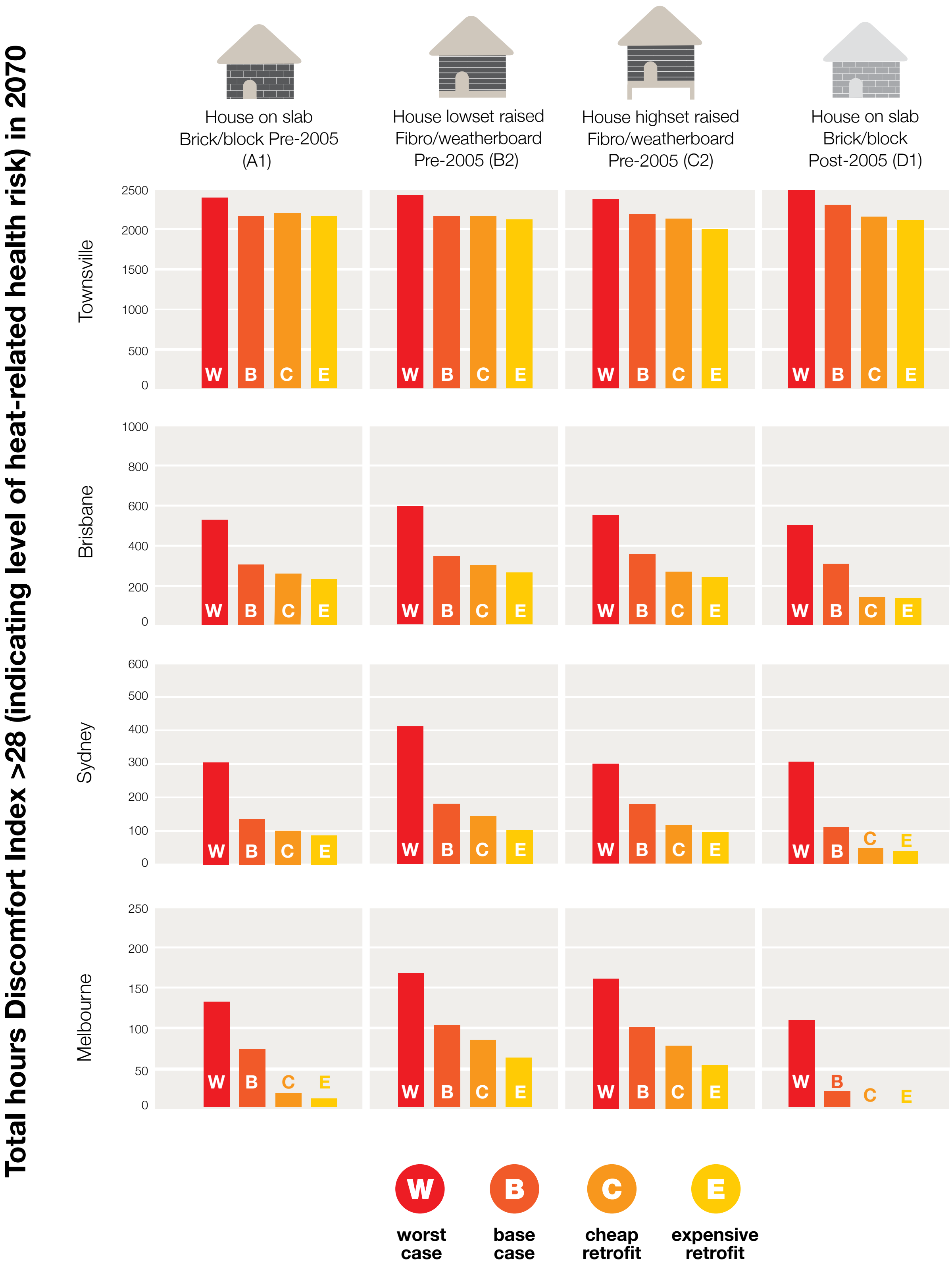


Figure 2 The total number of hours a house heat level poses a health risk for different house construction types in different cities, looking at past and future climate and four retrofit or lack of retrofit scenarios[3]

health. For example, open-air exercise during heatwaves can increase the risk to those who would have otherwise been considered at low risk.[19]

Good building designs can decrease the need for mechanical cooling, and costs can be managed by, for example, only retrofitting one room to create a cool retreat. However, to be effective, occupants need to be educated to understand how the room stays cool on hot days so they manage it correctly (e.g. opening and closing windows and doors). Education and communication have a strong role in influencing behaviour.

2.3 Solutions for vulnerable people

Climate change will affect individuals differently depending on factors such as social disadvantage, health, obesity, age and geography.[16] Those least able to cope are identified as vulnerable.

Vulnerability is determined by a combination of environmental, economic and social factors and depends on exposure, sensitivity and adaptive capacity (Figure 4). Older people, the very young, those with chronic illness, those who are socially isolated and those who have limited means to care for themselves (e.g. residents in aged care, infants) are consistently shown to be more vulnerable to harm than others.[5,15] Cultural and linguistic barriers can also exist.[13] Low cost rental housing stock,

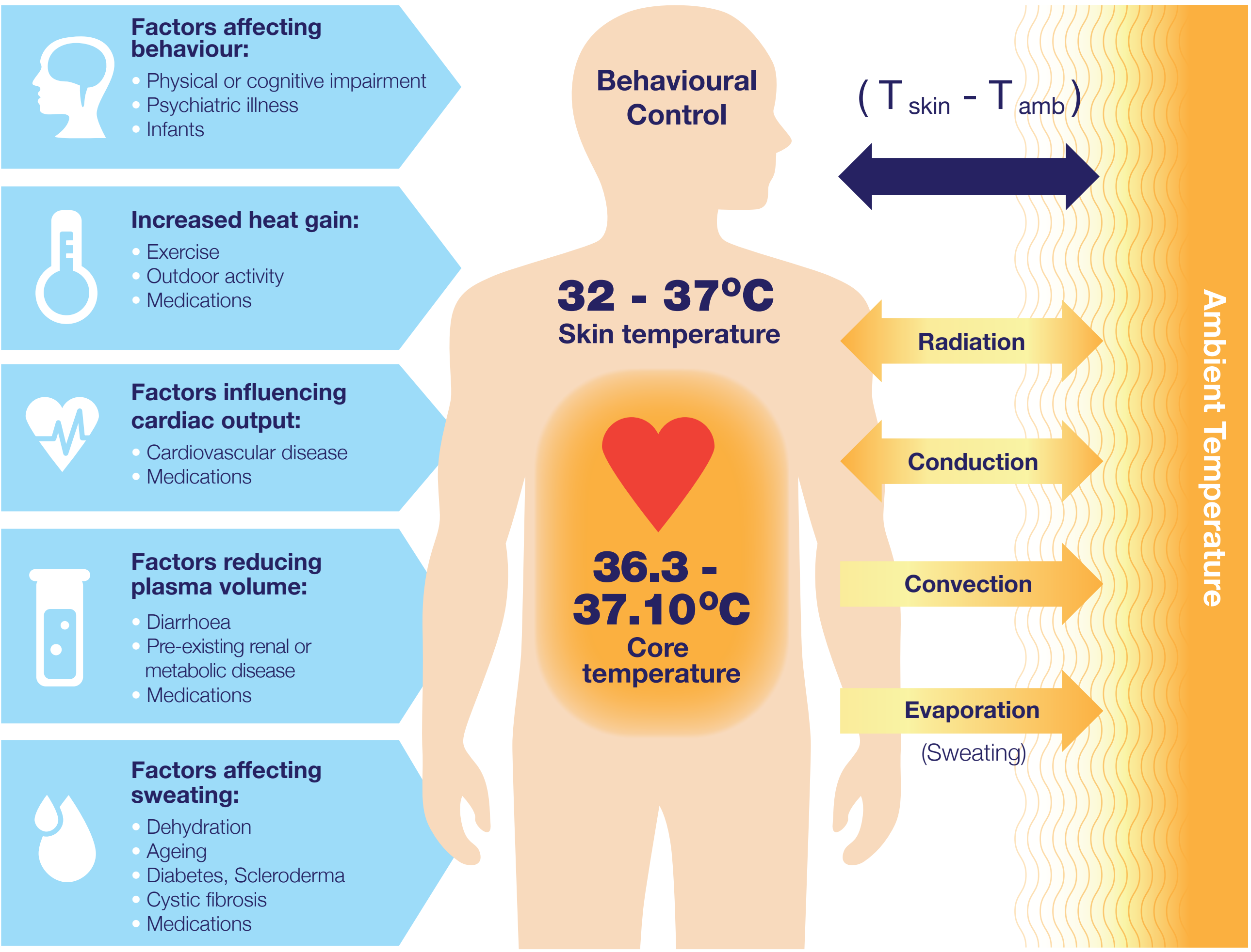


Figure 3 Human responses to high temperatures.[19]

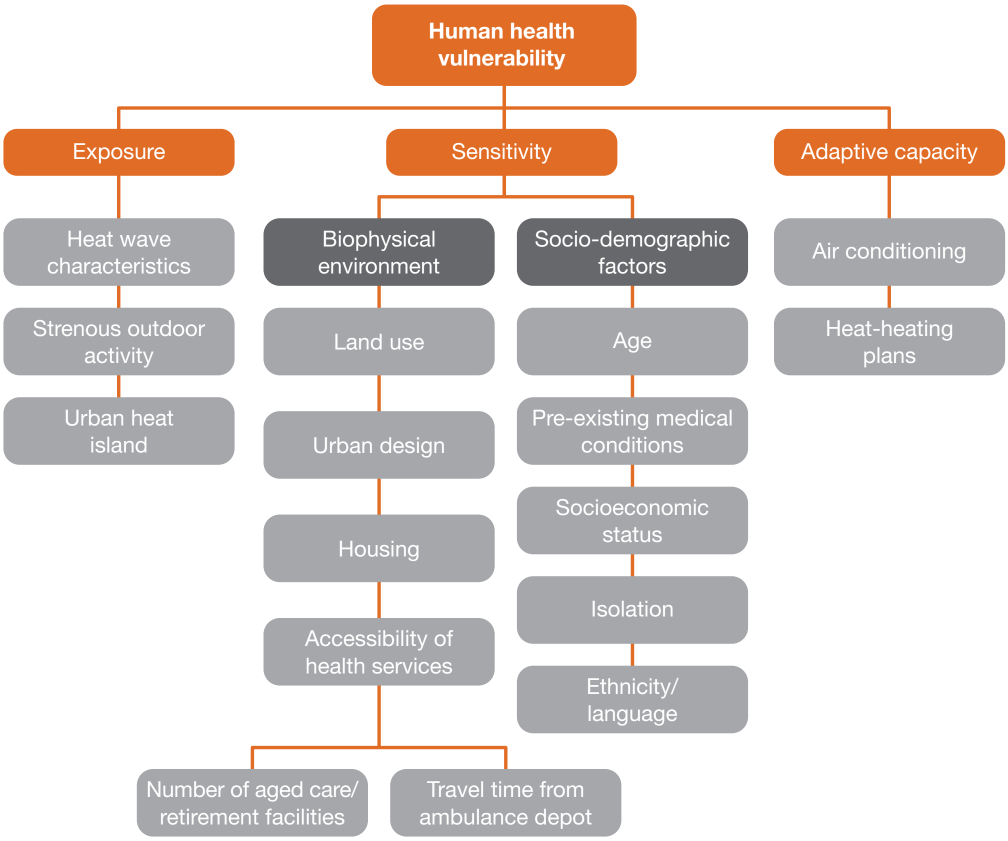


Figure 4 The multitude of factors that create vulnerability to extreme heat events. A full description of each factor can be found in Loughnan and colleagues.[15, pp. 17–26]

which houses many vulnerable people, may be poorly designed or maintained and often lacks cooling features.

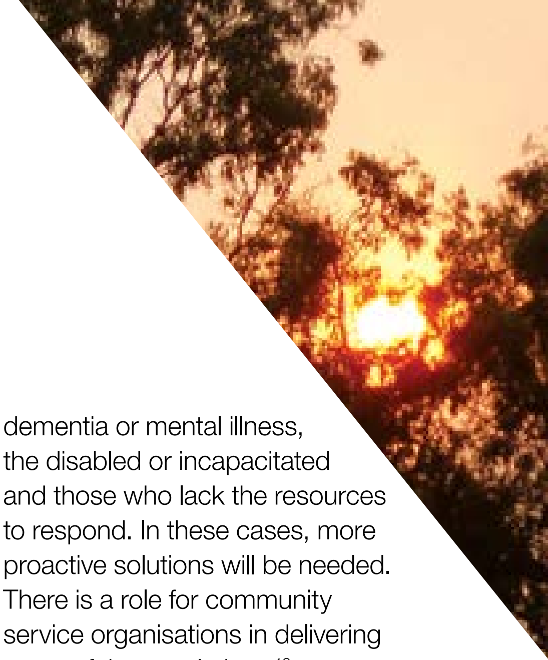
Loughnan and colleagues combined an understanding of morbidity and mortality threshold with a spatial index of vulnerability and future climate to identify areas of high-risk averse health outcomes in each of Australia's capital cities. Such an approach can help in defining the scale of the problem and deciding where resources for education, warning and support services are required.[15]

Assessing the performance of public housing building types in different areas provides a method for prioritising government-provided housing stock for retrofit, disposal or relocation of the most heat-sensitive residents to low heat-risk properties.[3]

2.4 Strategies for service providers and workers

The experience of the 2009 southern cities highlights the vulnerability of service organisations and emergency services (e.g. ambulance, not-for-profit organisations) to extreme heat. This finding is further supported by a survey of community service organisations at the frontline of support to groups experiencing social disadvantage, poverty and illness.[16]

It is important that these groups build resilience and adaptation plans to minimise the risk of impacting on the most vulnerable during extreme heat. Mallon and colleagues discovered that despite a willingness to respond to climate extremes, most community service organisations lack sufficient human and financial resources, and skill sets, to respond adequately.[16] However, these organisations can provide a unique set of skills and facilities to assist the broader emergency response during and following an extreme event, for example, through providing emergency accommodation, networks of trained volunteers, mental health



professionals and specialist premises, vehicles and equipment for the disabled.

Heat also affects workers, particularly outdoor workers (e.g. in the construction industry).[12] Higher work accident rates, greater fatigue, poor decision-making and increased stress are all outcomes of hot working conditions. It is estimated that lost productivity through impacts on heat-affected workers during 2013–2014 cost Australia USD 6.2 billion.[21] While much of this effect is as a result of working outside or the levels of physical exertion required, it is not the only cause, with poor sleep for indoor workers also affecting work performance.

2.5 Coordination, governance and incentives

As outlined, we understand the factors that make people vulnerable to excess heat, the physical characteristics of shelter that make them hot and the behavioural actions that increase risk. It is therefore a reasonable expectation that, with the right advice, most people should cope sufficiently well with extreme heat. The greatest challenge is in getting that information to those who need it and ensuring they take appropriate action.

In recent years, we have seen new efforts to reduce vulnerability through the development and implementation of adaptation strategies. Heatwave plans have been written by many of Australia's capital cities and large urban centres. Such plans include heatwave prediction (including risk thresholds), heatwave warning strategies and actions to reduce heat-related morbidity and mortality. Likely actions usually include media announcements, buddy systems and home visits for the vulnerable. There are defined thresholds for activating and deactivating the plan and strategies for evaluation and review of the plan and its application. Good governance and suitable institutional arrangements are essential to the success of these efforts, as is a multi-stakeholder process that aims to strengthen partnerships and networks between state and non-state actors.[1] The South Australian and Victorian experiences have been to focus on an 'all hazards' (standard emergency response strategies that can be followed in a range of emergency situations) approach, which sees partnerships between a broad range of authorities and service providers to respond to extreme events.[19]

The private sector (e.g. property owners) can also contribute but may lack incentives to act. For example, there is no incentive for lessors to cool private housing. In such cases, there is a role for government to either provide incentives or to cool public respite areas (e.g. air-conditioned libraries).

There is an important role for communication and education. How the message is formulated and delivered will depend on what is being communicated and to whom. For some members of the community, message and education will not be sufficient. This includes the most vulnerable, for example, those suffering dementia or mental illness, the disabled or incapacitated and those who lack the resources to respond. In these cases, more proactive solutions will be needed. There is a role for community service organisations in delivering many of these solutions.[16]

Figure 5 Media reporting of heatwaves is commonly accompanied by images of people at beaches and reports of people heading to the beach for the hot day. This messaging needs to change to increase the community's understanding of the seriousness of extreme heat and the risk of being outdoors during such weather.

3. Evidence-based policy implications

ADAPTATION CHALLENGE 1:
Improve messaging and communication

Climate change is likely to bring more intense, longer lasting and more frequent heatwaves. Individuals and communities that are aware of these increased risks will be empowered to take steps to build resilience.

Heat tends to be accepted as a normal part of life in Australia, and in many ways the outdoor lifestyle is well-adapted to our hot summers. Nevertheless, intense heatwaves already cause deaths every year among vulnerable sections of the community, and under climate change this situation is likely to become worse without further efforts to adapt. In order to recognise this threat and build resilience, individuals and communities need information.

Delivery of messages through trusted individuals such as GPs, community groups and senior members of religious organisations might greatly enhance the chance of success.

More flexible approaches are required for risk and preparatory communication to ensure messages are suited to the needs of a diverse audience. It is possible a cost–benefit analysis would support the case for investing in risk communication and reducing exposure of communities to the effects of heatwaves.

Information needs to be tailored for vulnerable people, including tourists and new residents, and to focus on behaviour, such as encouraging older people to use air-conditioning (highlighting real cost for short-term use), to turn it on early in the day, to observe passive cooling measures in the home or to move to cool retreats early.

To improve uptake, messaging is likely to be most effective when it includes explanations to help communities understand why particular advice is given, for example, simple explanations of heat stress and its contributory factors in Australia can lead to advice about how to avoid heat stress. This is particularly the case when apparently contradictory advice is given, (e.g. stay inside during a heatwave and do not shelter in your home during a bushfire) for example on how to cope with heat and bushfire, with the potential to cause confusion.

ADAPTATION CHALLENGE 2:
Consider heat in planning and development

Building design has a strong influence on the cooling needs of occupants. For new constructions, there is an opportunity to consider extreme heat and human comfort in building design. Broader planning and design of urban precincts can similarly affect how heat is experienced in built-up areas and buildings. New developments can include best practice design features to improve building performance, but this is more challenging in existing building stocks and built-up areas.

Effective planning and investment in adaptation require good understanding of at-risk areas. Programs that map 'hotspots' or urban heat islands might be used to underpin targeted investment to reduce extreme heat risks. This, in turn, might inform good urban planning or design that uses passive cooling features (e.g. cool breezes, housing aspect, etc.) to better cool developments. Existing mapping efforts in a number of cities and towns can be built upon to this end.

Green infrastructure (which can include trees, wetlands and shading) has been demonstrated to be an important tool in reducing heat, particularly in urban areas. Planning and investing in green infrastructure need to start now in order to reduce the impact of future heat increases. There is a need to educate the community and developers to build understanding of the benefits and services provided by green infrastructure. This can lead to community pressure on developers who will be more likely to incorporate elements of green infrastructure into their designs. Designs that target social connectedness may help foster greater community resilience – a key driver in reducing the risks for vulnerable members of the community. New incentives and regulations may be needed to facilitate the inclusion of green infrastructure. An integrated planning approach would help in the consideration of other factors and stressors, such as ensuring there is availability of water to sustain green infrastructure.

Modern building designs have moved from an emphasis on passive cooling towards the energy-efficient use of air-conditioning and cooling. In a warmer future, building design

criteria are likely to take into account ability to operate in extreme heat, energy efficiency for both hot and cold weather and performance during power outages.

To address the impacts of extreme heat, consideration might also be given to the sustainability of natural and agricultural systems. Shading of land and waterways can provide cool refuges for biota; provision of shade trees for livestock can help with passive cooling; and choice of livestock breed or colour can improve tolerance to heat.

ADAPTATION CHALLENGE 3: Define roles and responsibilities

Extreme heat impacts and potential approaches to both reducing those impacts and responding during extreme heatwaves fall across a broad range of sectors and organisations. The challenge of coordinating responses and ensuring that the most appropriate governance arrangements are in place was highlighted in the extreme heatwave experienced in southern Australia in 2009.

Those who work with the members of our communities who are more likely to be vulnerable to extreme heat (e.g. socially disadvantaged, disabled, elderly, very young) are most likely best placed to help them adapt. Likewise, information channelled through trusted sources is more likely to be acted upon. Building partnerships with and among organisations and groups with existing channels into communities is likely to be an effective strategy. This might include local government, local doctors (messaging), shopping centres (for refuge) and community organisations (checking on or transporting vulnerable people to shelter). Partnerships could also be built between agencies and sectors, such as the Bureau of Meteorology and health service providers.

Governance arrangements to address the impacts of extreme heat need to consider not just the response to heatwaves, but also a broader perspective on planning and preparedness for extreme heat in the future. This might include planning, building design, education and communication and coordinating responses.

ADAPTATION CHALLENGE 4: Improve existing building stock and infrastructure

Much existing housing stock is poorly designed for extreme heat and heatwaves. There are known approaches to improving heat gain efficiency of existing housing, but they are not effective in all building designs. Occupant behaviour and knowledge of how best to cool existing buildings can also reduce the impact of extreme heat.

Prioritising the retrofitting of existing housing (e.g. through provision of insulation and white roofs) should be supported by a baseline understanding of the resilience of existing housing.

Policies that help to change occupant behaviour might include reduced day tariffs for air-conditioning use on extreme heat days, incentives for mitigation measures at the property level (e.g. roof and house colour, ceiling vents) and investment in solar panels to offset air-conditioning use (particularly for vulnerable people). Incentives for retrofitting of existing buildings could be supported by an assessment of the likely cooling and economic benefits. Likewise, if investment in upgrading of social housing were accompanied by an assessment of the cooling and economic value of retrofits, this would help prioritise retrofitting the most viable properties and, where indicated, rehousing of the most vulnerable residents.

Alternatives to complete reliance on the electricity networks, for example through installation of rooftop solar, might help to build resilience to extreme heat hazard by protecting against supply interruptions. As battery storage becomes more affordable, this solution can provide protection around the clock instead of, as at present for most households, only during daylight hours.

ADAPTATION CHALLENGE 5:

Take account of heat in workplace health and safety

For both the general workforce and those service organisations responding to extreme heatwaves, increased heat can affect the health and productivity of workers.[12] The challenge is to create strategies that allow work to continue safely.

Employers might look at new technologies and new ways of working to reduce the impact of extreme heat. This might include investment in improved recovery and cooling technologies for field workers, including improved and heat-friendly personal protection equipment.

Management of rosters and education of clients to reduce expectations of certain services during hot periods where it does not jeopardise the health of others will reduce exposure and limit stress, for example, changes in work times to avoid the hottest part of the day.

Education and retention of an experienced workforce will be important, particularly in emergency service organisations. Running operations from early in the season and endeavouring to retain staff (and knowledge) will improve response and worker safety.

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