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Protecting human health and safety during severe and extreme heat events

A national framework

Commonwealth Government

November 2011

Important notice

This Report has been prepared by PricewaterhouseCoopers Australia (PwC) for the purposes of providing advice to government on the effectiveness of heatwave response systems across the Preparedness, Prevention, Response and Recovery (PPRR) spectrum and to provide recommendations on areas for improvement and/or development to identify and address gaps. It is not to be used for any other purpose.

The Report has been prepared by PwC in collaboration with the Australian Government (through the Department of Climate Change and Energy and Efficiency) in accordance with the Terms of Reference and the Terms and Conditions contained in the Service Engagement between the Department of Climate Change and Energy Efficiency and PwC dated 24 December 2010. PwC sought advice on the development of the Report through the establishment of an Advisory Group, comprised of relevant experts external from PwC.

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Foreword

Heatwaves kill more Australians than any other natural disasters. They have received far less public attention than cyclone, flood or bushfire – they are private, silent deaths which only hit the media when morgues reach capacity or infrastructure fails. There has never been a national study which uses a common definition of heatwaves and directly comparable mortality data. Australia has no national heatwave plan. This report remedies these deficiencies and recommends strategies for the national, state and local governments as well as for citizens.

Working with support from the Commonwealth Government and the Bureau of Meteorology, PwC has demonstrated that heatwaves have led to considerable excess deaths in Melbourne, Adelaide, Brisbane, Sydney and Perth over the past 50 years. These deaths are likely to increase with population growth, ageing and climate change. By 2050 an extreme heat event in Melbourne alone could typically kill over one thousand people in a few days if we don't improve the way we forecast, prepare for and manage these events. It is likely that Brisbane would face a similar death toll, with Adelaide, Sydney and Perth also increasingly impacted. To put this in perspective 173 people died in the Black Saturday fires in Victoria in 2009 and 35 in the floods in Queensland in 2010-11. However more than 370 people died from extreme heat in Victoria in the same week as the Black Saturday fires. The morbidity impacts from future extreme heat events are likely to also be very large. Those who are affected come disproportionally from the vulnerable groups in our community.

Much is being done, but there is much more we can do to make our cities, our homes and businesses, our infrastructure and our citizens more resilient. Central to this effort will be the development of a national Excessive Heat Factor forecasting framework which recognises local differences in heat conditions and experience – fortunately this report suggests that with the right support the Bureau of Meteorology could provide this tool quite rapidly. With this early warning, and making intelligent use of conventional and social media, emergency services, social and health workers, families and carers will be in a much better position to respond.

This is the second report in PwC's thought leadership program which was prompted by the loss of life and property which resulted from the record temperatures recorded across southern Australia in February 2009. Our first report *Effective Disaster Recovery* was published in July 2010.

PwC is pleased to be able to make this contribution to addressing issues of genuine national importance and would like to thank the Commonwealth Government for its generous financial co-contribution, the Bureau of Meteorology for its outstanding work with the PwC team and those who generously gave their time to be part of our advisory committee or to participate in our consultations across governments at all levels and with the community.

Roger Beale AO
Chair of the Advisory Committee
Principal, PwC

November 2011

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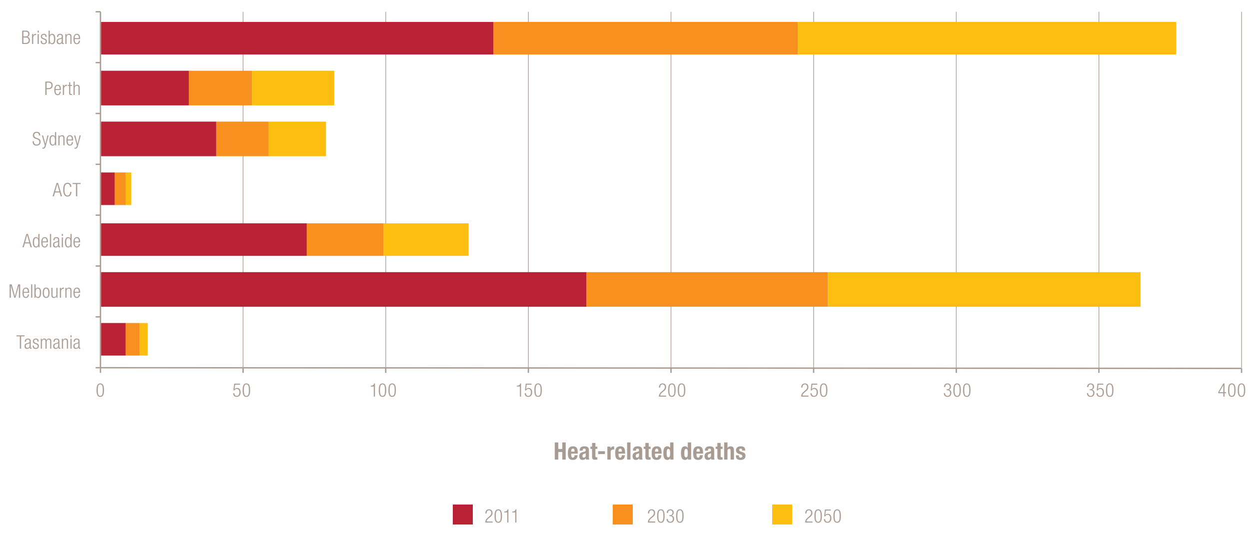
Executive summary

Heat events have killed more people than any other natural hazard experienced in Australia over the past 200 years.[1] A number of Australian cities (Melbourne, Brisbane and Adelaide in particular) have experienced significant deaths in heat events since the turn of the century, like those of January 2009. It is likely that this story is repeated in a number of major regional centres. Population growth and ageing, increasing urbanisation and climate change will add to the risks. Making our cities, buildings and infrastructure more resilient to heat events and improving the way we protect vulnerable members of our community is an important public policy issue. Good practice examples from Australia and abroad suggest that this is achievable. This report suggests some ways to improve how it is done in Australia.

Population growth alone suggests that deaths associated with top heat events[2] are likely to more than double by 2050 if we do not improve the way we handle these events (Figure 1).

Climate change could greatly increase the death toll. Modelling a 'middle of the road' climate change scenario for Melbourne suggests that, by the middle of the twenty first century, there could be a death toll two to three times higher in these top heat events than we have experienced to this point unless we improve the way we prevent, prepare for and respond to heat events (Figure 2). There is no reason to suppose that other susceptible cities and regional centres would not also be exposed to significantly higher risks as a result of climate change.

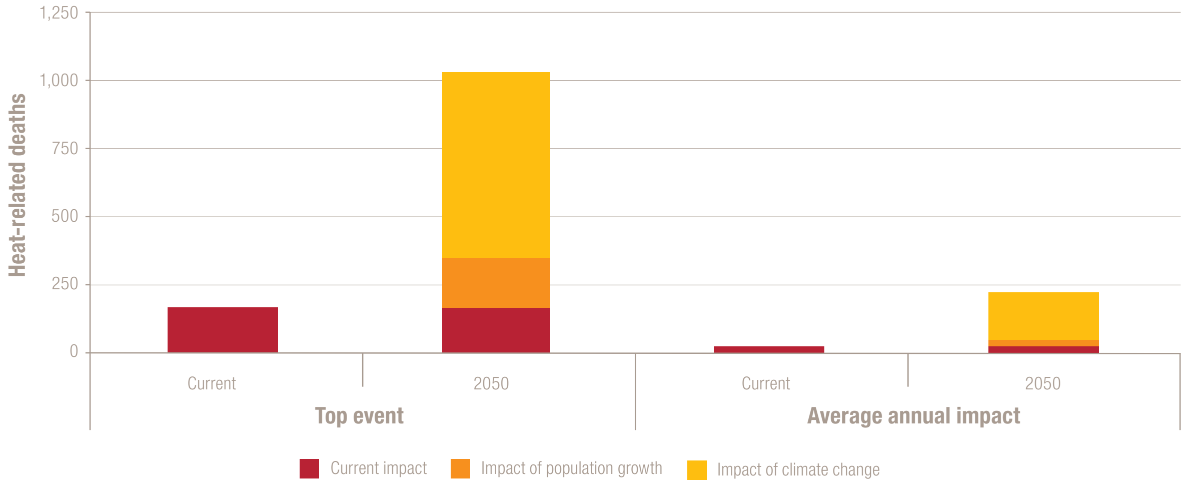
Figure 1: Estimates of heat-related deaths associated with top heat events



1 Coates, L. (1996). 'An overview of fatalities from some natural hazards in Australia', in *Conference on Natural Disaster Reduction 1996*, edited by R. Heathcote, C. Cuttler and J. Koetz, Institution of Engineers Australia, Barton, ACT.

2 'Top heat events' are infrequent, extreme heat events that have significant health, social and/or economic impacts on a particular community.

Figure 2: Current and projected mid-century impacts by source of increase in Melbourne



Heat events have had an equally dramatic impact overseas. The extreme heat event that 'scorched' France during August 2003, for example, 'induced a wave of excess short-term mortality estimated at approximately 15 000 deaths' – making it one of 'the gravest health catastrophes France has ever known.'[3] Athens, Chicago, Moscow, Shanghai and a number of smaller cities have seen large numbers of deaths in heat events in the last two decades. Handling heat events has become an important public health issue across the world.

Australia has begun to take greater action. Triggered by events in South East Queensland in February 2004 and South East Australia in January 2009, governments and community organisations have developed response and planning arrangements to manage the risks posed by heat events. While this progress is welcome, there is still more to be done – particularly through focusing on longer-term measures and greater cross-jurisdictional collaboration and community engagement.

PwC wanted to make a contribution to this important issue and has collaborated with the Commonwealth Government and a range of stakeholders across Australia to co-develop this report.

In this study, we establish the case for a national framework to reduce important risks posed by heat events. This framework seeks to build on the significant progress that has already been achieved – at the Commonwealth, state and territory and local levels. Our case for action rests on three pillars:

1 The impacts of heat events can be devastating and wide-ranging, with some members of our community more at risk than others.

Heat events may not scar the physical landscape in the same way that other natural hazards do, but they can have a range of devastating impacts. These can be both direct and indirect, as well as health related, social and economic in nature.

It is important to note that not all heat events are created equal. They exist on a continuum, varying in terms of their impact. At one end, the potential impacts include increased rates of morbidity, as well as a range of social and economic effects (e.g. increased rates of violent crime). As we move along the continuum, the possible impacts of heat events become more *severe* with the potential to cause unexpected deaths. At the very end of the continuum are those heat events that, while rare, can potentially have *extreme* impacts on morbidity, mortality and the broader social and economic fabric. The consequences of such events tend to be systemic and exacerbate each other (e.g. electricity load shedding triggered by an extreme heat event can limit the ability of individuals to stay cool using electrical appliances).

While much attention is focused on mortality, it is important to recognise that the morbidity impacts of heat events can be significant – in terms of their physical and/or psychological toll and the strain that is placed on health and emergency services. It is also worth bearing in mind that in Australia heat events are often accompanied by bushfires. The cumulative impacts on health and emergency services can be severe.

2 The incidence of severe and extreme heat events in Australia has been considerable and is projected to increase.

We undertook modelling to understand the past and potential future impact of heat events on the Australian population. This modelling used the 'excessive heat factor' (EHF) index, developed by John Nairn and his colleagues at the Bureau of Meteorology, and mortality statistics provided by the Australian Bureau of Statistics. Greater detail about how we conducted the modelling is outlined in Chapter 3 and Appendices B and C.

3 National Institute of Public Health Surveillance. (2003). *Annual Report 2003*. Paris.

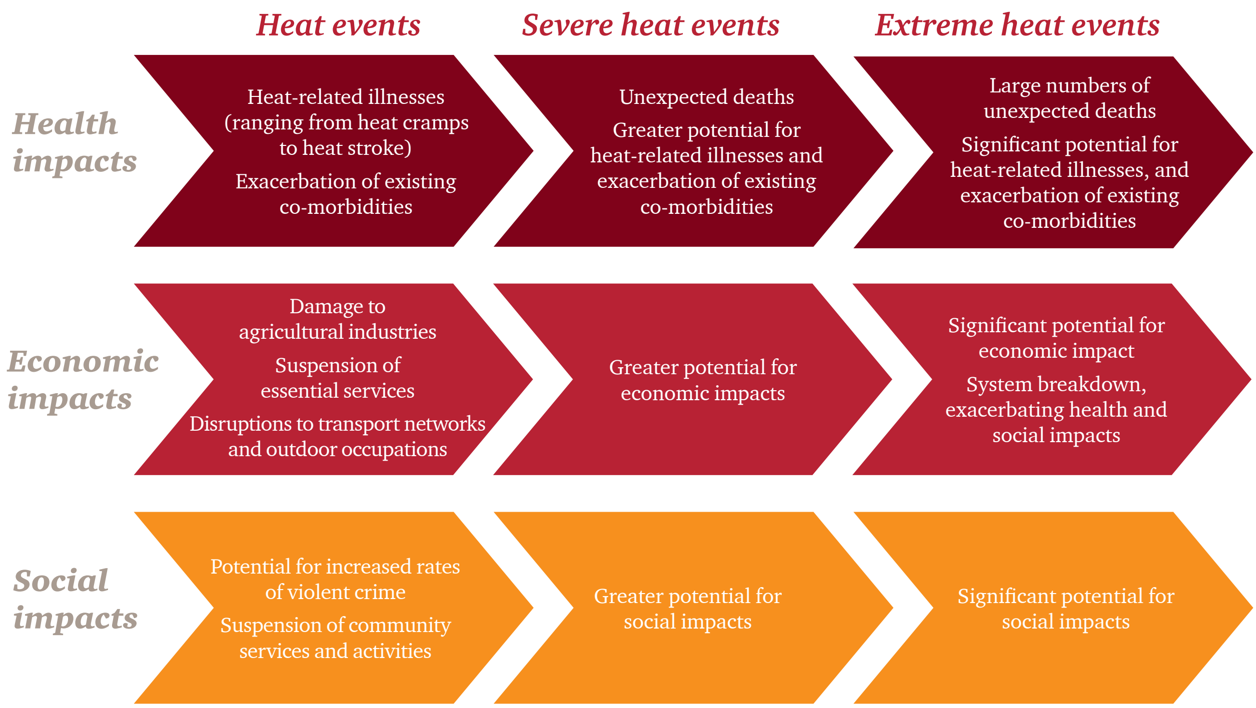
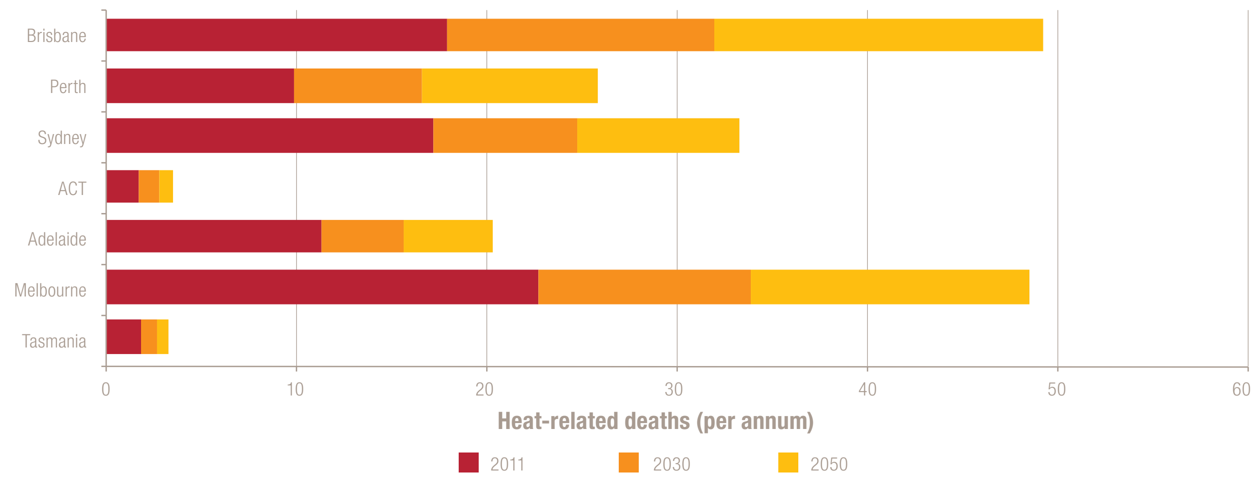


Figure 3: Estimated average number of heat-related deaths per annum



Key findings from our modelling include:

- Heat events occur more frequently in the southern regions of Australia. The more humid climate in the tropics precludes significant temperature variations and, as a result, the frequency and intensity of heat events in the north are low.
- There is a strong correlation between EHF and excess deaths for both Adelaide and Melbourne.
- Southern Queensland recorded both moderate EHF values and significant excess deaths arising from past events – indicating the combined climatological, demographical and socio-economic factors that make this part of the population particularly sensitive.

Our model indicates that, based on the 2011 population, there are an average of approximately 80 excess deaths associated with heat events each year across the major capital cities.[4] Taking into account changes in population size and demographic composition, we estimate this annual average number of heat-related deaths will increase to between 120 and 130 in 2030, and to between 170 and 200 in 2050. As Figure 3 illustrates, we estimate Brisbane and Melbourne will account for the majority of heat-related deaths in 2030 and 2050.

It is worth noting our estimates of annual average heat-related deaths slightly mask the potential impact of heat events. The average captures years that may have only minor heat events, as well as years like 2009, which experience extreme heat events with significant levels of associated mortality.

4 Includes Adelaide, Brisbane, Melbourne, Perth and Sydney, as well as the Australian Capital Territory and Tasmania.

We also undertook some preliminary modelling to understand how climate change might affect mortality associated with heat events. Data provided by the Bureau of Meteorology (drawn from a range of climate change projections) suggest:

- the number of heat wave days (ie those with a EHF greater than zero) is expected to increase significantly over the twenty first century
- the potential for extreme heat events is also likely to increase.

Our preliminary modelling for Melbourne suggests that, by the middle of the twenty first century, climate change may result in an annual average number of heat-related deaths *five times greater* than in the scenarios that do not consider climate change.

3 While progress has been made in improving institutional arrangements, gaps remain. Addressing these gaps, and sharing good practice, would provide the community with a stronger foundation.

Governments and community organisations have expended significant effort in developing arrangements to manage the risks associated with heat events. A majority of state and territory governments have developed (or are developing) specific heat event plans and associated response frameworks. Considerable research has also been undertaken by governments and universities to understand the scale and impacts of heat events in Australia.

Although governments have made significant achievements to date, improvements could be made to ensure heat event risks are managed as effectively and efficiently as possible. These include:

- Greater national consistency in key elements underpinning planning and response arrangements – particularly around heat event definitions, and methodologies for forecasting heat events and triggering public warnings.
- Providing the community with a comprehensive understanding of the risks associated with heat events.
- Ensuring there is sufficient focus on long-term outcomes – such as encouraging cultural change in how people perceive and act during heat events, and implementing structural changes that would reduce the impact of future events.

Our research also uncovered a range of good practice in current planning and response arrangements. These are summarised in Table 1.

A plan for action

Our analysis indicates that the impacts of heat events can be devastating, and these impacts are likely to increase due to demographic shifts and the changing climate. Accordingly, we propose the establishment of a national framework for severe and extreme heat events. This framework would not seek to replace the current system under which significant progress has been made at the Commonwealth, state and territory and local levels. Rather, it would seek to build on what has already been achieved – by facilitating collaboration between governments and community organisations to address identified gaps and share good practice.

Before a national framework can be established, governments and community organisations must first concentrate on building a common understanding of heat event risks and their future management. To construct this common understanding, we propose Australian governments undertake four steps:

1. Agree a national definition of what constitutes a heat event, allowing for two categories of heat event (severe and extreme).
2. Agree a nationally consistent approach to measuring and predicting heat events.

   Once agreed, the Bureau of Meteorology should assume responsibility for developing a heat event warning system and collaborate with the states and territories in implementing this system.
3. Undertake a comprehensive assessment of heat event risks, over the short, medium and long terms, and at the national, state and territory and regional levels.
4. Develop an Australian heat event strategy, falling under the *National Strategy for Disaster Resilience*.

   This should emphasise the concept of shared responsibility and explore means of leveraging the latent and actual potential of not-for-profit organisations and the broader community to support and complement heat event response arrangements.

Table 1: Summary of good practice

1	Ensuring heat event plans have a whole-of-jurisdiction focus.
2	Nominating a hazard leader to have ultimate responsibility for heat event planning across the jurisdiction.
3	Employing real-time surveillance of heat event impacts.
4	Ensuring heat event plans recognise and reflect regional differences.
5	Focusing heat event planning and response arrangements on those most at risk.
6	Providing technical guidance to bodies that may otherwise lack the necessary capacity to plan for, and respond to, heat events.

All relevant parties (drawn from Australia's three tiers of government and the community services sector) will need to agree the content of the Australian heat event strategy. Nonetheless, we have identified a range of actions that could help reduce the impacts of heat events and support individual and community resilience. These actions include:

- Committing to good practice planning and governance arrangements for heat events.
- Developing nationally consistent core educational material for heat events that can be built on to reflect local differences and arrangements.
- Exploring the potential of emerging communication technologies (including social media) as a means of improving the community's ability to manage heat event risks.
- Considering heat event risks in capital and operational planning for transport and electricity supply infrastructure, including the role of smart grids in protecting power supply for at-risk individuals during load shedding.
- Exploring the potential for new or existing programs to modify older buildings to improve the thermal comfort of at-risk individuals.
- Considering heat event risks in urban planning and development approval processes as well as urban landscaping and water policies.
- Establishing a research program to address knowledge gaps.

In addition to the steps outlined above, we propose what could form as a basic structure of a national framework for severe and extreme heat events. This basic structure comprises a set of five principles (Table 2) and guidance for government and the community across the plan, prevent, prepare, respond and recover framework (Table 3).

Table 2: Key principles of a national framework for severe and extreme heat events

1	Prioritise individuals, communities and locations most at risk.
2	Recognise regional differences and circumstances, and harness the actual and latent capacity of social networks and local institutions.
3	Recognise interdependencies between planning, prevention, preparedness, response and recovery.
4	Enable a response that is integrated (using appropriate segments of the community and levels of government) and scalable (recognising that the impacts of heat can be severe and extreme).
5	Be affordable and achievable.

Table 3: Planning, Prevention, Preparedness, Response and Recovery

	National	*State and territory*	*Local*	*Individual and community*
Planning	Agree national definition for heat events and establish national warning system. Undertake comprehensive assessment of heat event risks. This assessment should be reviewed and updated every three to five years. Develop and maintain an Australian heat event strategy.	Develop a heat event planning framework that is commensurate with identified risks. If a specific heat event plan is developed, this should: • be consistent with broader emergency management arrangements • have a state-wide focus and consider the full spectrum of government and non-government measures • nominate a hazard leader, that is responsible for the plan, providing supporting to other agencies, and ensuring functional plans are consistent and do not overlap • acknowledge that heat events will often occur together with bushfire and infrastructure outages which will also place pressures on emergency services • be reviewed on a regular and transparent basis. Essential, emergency, health and social services to undertake workforce protection planning for heat events.	Ensure planning arrangements for heat events are commensurate with identified risks, and in line with the roles and expectations assigned to them as part of their relevant state or territory's broader planning arrangements. Essential, emergency, health and social services to undertake workforce protection planning for heat events.	Develop personal, family or community plan to respond to heat events.
Prevention	Explore potential for national and cross-jurisdictional programs and regulation to reduce the impacts of heat events.	Explore potential for jurisdictional programs and regulation to reduce the impacts of heat events.	Explore potential for local programs to reduce the impacts of heat events.	Explore ways of reducing the impacts of heat events at the personal, family and/or community level.
Preparedness	Develop and maintain nationally consistent education material.	Embed nationally consistent education material in targeted and seasonal communication campaigns. Coordinate database of individuals identified as being most at risk during a heat event – to support response and recovery.	Embed nationally consistent education material in targeted and seasonal communication campaigns. Contribute to at-risk database.	Understand heat event risks and what can be done to help at-risk family members, friends and neighbours.

	National	*State and territory*	*Local*	*Individual and community*
Response	Bureau of Meteorology notifies relevant jurisdictions and Emergency Management Australia about impending heat event (in line with agreed thresholds and forecast period). Bureau of Meteorology remains closely engaged during response. Broader Australian government to provide support, if required.	Activate relevant response plan, depending on warning level provided by Bureau of Meteorology. Response should align with standard emergency management practice. Appropriate warnings and messages provided to community, at-risk individuals, and those responsible for at-risk individuals. Initiate real-time data collection and monitoring of heat event impacts.	Activate relevant response plan, depending on warning level provided by Bureau of Meteorology and broader jurisdictional arrangements. In alignment with broader jurisdictional arrangements, engage with community, at-risk individuals, and those responsible for at-risk individuals. Contribute to real-time data collection and monitoring of heat event impacts, if required.	Activate personal, family and/or community response plans. Maintain personal health and safety, and that of dependents. Check-up on and monitor at-risk friends, family members and neighbours.
Recovery	Contribute to mandated debrief (led by the state or territory government), if required.	Mandated debrief and review of response – recommendations from which should be used to update heat event planning. Continue to monitor impact.	Contribute to mandated debrief (led by the state or territory government), if required. Continue to monitor impact.	Contribute to mandated debrief, if willing.

Glossary

BOM	Bureau of Meteorology
COAG	Council of Australian Governments
EHF	Excess Heat Factor. An index developed by BOM in order to identify a heatwave event. BOM defines the EHF as 'the combined effect of Excess Heat and Heat Stress calculated as an index to provide a comparative measure of impact, load, duration and spatial distribution of heatwave.' *Maximum EHF* refers to the maximum EHF recorded by BOM for a particular location over a particular period. *Severe EHF thresholds* are values of EHF for each site that are statistically rare in the climate record (using Probability of Exceedance). It is shown later through case studies that this value correlates well with rising incidence of mortality, or severe human health consequence.
enHealth	Environmental Health Committee; a subcommittee of the Australian Health Protection Committee.
Excess heat	Defined by BOM as: 'unusually high heat that is not sufficiently discharged overnight due to unusually high overnight temperature. Maximum and subsequent minimum temperatures averaged over a three day period are compared against a climate reference value. This is expressed as a long term (climate scale) temperature anomaly.'
Heat event	A period of one or more days where the heat pattern within a region has the potential to see adverse health, social and/or economic impacts on a particular community. *Top heat events* are infrequent, extreme heat events that have significant health, social and/or economic impacts on a particular community.
Heat stress	Defined by BOM as: 'a period of heat which is warmer, on average, than the recent past. Maximum and subsequent minimum temperatures averaged over a three day period and the previous 30 days are compared. This is expressed as a short term (acclimatisation) temperature anomaly.'
IPCC	Intergovernmental Panel on Climate Change
NEMC	National Emergency Management Committee
UHI	Urban heat island; an area where temperatures are notably higher as a result of urbanisation.

The case for action

Heat events have killed more people than any other natural hazard experienced in Australia over the past 200 years.[5] *Internationally, the impacts of heat events have been equally dramatic.*

The extreme heat event that 'scorched' France during August 2003 'induced a wave of excess … mortality estimated at approximately 15 000 deaths' – making it one of 'the gravest health catastrophes France has ever known.'[6] Similarly, the Chicago extreme heat event of 1995 resulted in more than 600 excess deaths – the scale of the event was not recognised until the morgues were full.[7]

Despite this, heat events are 'the most under-rated weather hazard in Australia.'[8] They are 'silent killers', lacking a confronting wake of physical destruction associated with other natural hazards.[9] The impacts are dispersed and hidden. They do not produce dramatic news images.

Nonetheless, the Australian community has begun to take action. Triggered by incidents in South East Queensland in February 2004 and South East Australia in January-February 2009, governments and community organisations have developed response and planning arrangements to manage the risks posed by heat events.

While this progress is welcome, there is still much to be done. Longer-term measures to reduce the impacts of heat events have yet to be considered in detail. Furthermore, there are a number of areas where greater collaboration across Australia's three tiers of government could generate meaningful improvements in how the risks associated with heat events are reduced and managed. Such collaboration would be in line with the *National Strategy for Disaster Resilience* (recently released by the Council of Australian Governments (COAG)), which places the concept of 'shared responsibility' at the heart of Australia's approach to emergency management.

> *"Because they lack the spectacular and sudden violence of say, a tropical cyclone or flash flood, and because the related death tolls are not always obvious at first, heatwaves rarely receive adequate attention. However, heatwaves are amongst the most dangerous natural hazards."*
>
> ***Michel Jarraud***
> *Secretary-General*
> *World Meteorological Organisation*

The present report establishes the case for a national framework to reduce and manage what are likely to be increasingly important risks posed by severe and extreme heat events. This framework should build on what has already been achieved at the Commonwealth, state and territory and local levels. Our case for action rests on three central pillars:

5 Coates, L. (1996). 'An overview of fatalities from some natural hazards in Australia', in *Conference on Natural Disaster Reduction 1996*. edited by R. Heathcote, C. Cuttler and J. Koetz, Institution of Engineers Australia, Barton, ACT.

6 National Institute of Public Health Surveillance. (2003). *Annual Report 2003*. Paris.

7 Dematte, J. E., K. O'Mara, J. Buescher, C. G. Whitney, S. Forsythe, T. McNamee, r. B. Adiga, and I. Maurice Ndukwu. (1998). 'Near-Fatal Heat Stroke during the 1995 Heatwave in Chicago', *Annals of Internal Medicine*, 129(3):173-81.

8 Bureau of Meteorology (n.d.), 'Heatwaves', www.bom.gov.au/wa/sevwx/perth/heatwaves.shtml. Accessed on: 2 May 2011.

9 Luber, G. & McGeehin, M. (2008), 'Climate change and extreme heat events', *American Journal of Preventative Medicine*, 35(5):429-35; World Meteorological Organisation. (2007), 'WMO to provide guidance for heat health warning systems', media release, www.wmo.int/pages/mediacentre/press_releases/pr_781_en.html, accessed on: 2 May 2011.

The ***impacts of heat events*** *can be devastating and wide-ranging,with some members of our community more at risk than others.*

The ***incidence of severe and extreme heat events*** *in Australia has been considerable and is projected to increase.*

While progress has been made in improving ***institutional arrangements****, gaps remain. Addressing these gaps, and sharing good practice, would provide the community with a more secure foundation.*

Before we explore these pillars in detail, we first propose a working definition of what constitutes a heat event.

Defining heat events

At present, there is no nationally or internationally agreed definition of what constitutes a heat wave or heat event. A key reason for this is that impact of heat events tends to be specific to the environment in which they occur and the associated climatology.[10] For example, days of high temperature experienced in South East Australia will have a different impact on the population to those same temperatures in the northern Australia. This is largely because humans acclimatise to heat over time, and buildings, infrastructure and lifestyles also accommodate high temperatures if they happen regularly.

For the purposes of this report, we consider a heat event to be:

A period of one or more days where the heat pattern within a region has the potential to see adverse health, social and/or economic impacts on a particular community.

It is important to note that not all heat events are created equal. They exist on a continuum, varying in terms of their impact. At one end, the potential impacts include increased rates of morbidity, as well as a range of social and economic effects (e.g. increased rates of violent crime). As we move along the continuum, the possible impacts of heat events become more *severe*. More specifically, they have the potential to cause unexpected deaths.

The other end of the continuum represents those heat events that, while rare, can potentially have *extreme* impacts on morbidity, mortality and the broader social and economic fabric. The consequences of such events tend to be systemic and exacerbate each other (e.g. load shedding triggered by an extreme heat event can limit the ability of individuals to stay cool using electrical appliances). We discuss the continuum of heat events and their impacts in more detail in Chapter 2.

10 Commonwealth of Australia, Bureau of Meteorology. (2011). 'First Heatwave for Adelaide in 2010', media release, http://reg.bom.gov.au/announcements/media_releases/sa/20100115_First_Heatwave_SA_Jan.shtml, accessed on 16 February 2011; CSIRO & BOM (2009)., 'Modelling and Understanding High Impact Weather', extended abstracts of the third CAWCR Modelling Workshop, 30 November – 2 December 2009, Melbourne, Australia.

In order to recognise heat events historically, and to discuss potential future incidents in a meaningful and nationally relevant manner, we have adopted the 'excessive heat factor' (EHF) index, developed by John Nairn and his colleagues at Bureau of Meteorology, as a point of reference. EHF is based on maximum and minimum daily temperatures in each specific location and considers their relativities to recent and historical temperatures. It captures the inability to shed heat load when minimum temperatures remain high. Given its temperature basis, EHF can be forecast in the same manner as temperature. Later in this report, we discuss in more detail the utility of EHF in forecasting heat events.

Project overview

Many factors influence the health impacts from heat events including city size and structure, urban density, micro-climates, demography, and public awareness. The resilience of social welfare, health, emergency services, energy and transport systems are critical. As heat events increase in frequency, and a range of factors (such as Australia's ageing and increasingly urban population) increase their potential impact, a coordinated approach is required to prevent loss of life and injury on a larger scale.

While recognising the work done by many jurisdictions, we propose that a national framework is required – one that is based on available evidence and lessons from previous events, and seeks to harness the potential of the Australian community to play a key role in the mitigation of the worst impacts of such events. To design such a framework PwC drew together a small group of experts to inform this work. The membership of this advisory group is listed below.

PwC undertook its research (including extensive consultations) and analysis under the guidance of this group. We are also grateful for the invaluable work provided by John Nairn and BOM.

Roger Beale AO (Chair) Principal, PwC	**Jess Fritze** Independent consultant Policy Analyst, Victorian Council of Social Services
Anne Barker Managing Director City West Water	**John Nairn** Deputy Regional Director, South Australia Bureau of Meteorology
Catherine Farrell Director, Settlements and Infrastructure Department of Climate Change and Energy Efficiency	**Lin Hatfield Dodds** National Director UnitingCare Australia
Chris Bennett Partner, PwC Government Sector Leader	**Mike Rothery** First Assistant Secretary National Security Resilience Policy Division Attorney-General's Department
David Prestipino Director, Disaster Resilience Policy Section Attorney-General's Department	**Neville Smith** Acting Deputy Director Bureau of Meteorology
James van Smeerdijk Partner, PwC	**Peter Whelan** Chair, Victorian Electricity Emergency Committee (Jemena)
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Others involved from PwC

Michelle Hughes Director, Economics & Policy	**Rosi Winn** Director, Actuarial
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Impacts of heat events

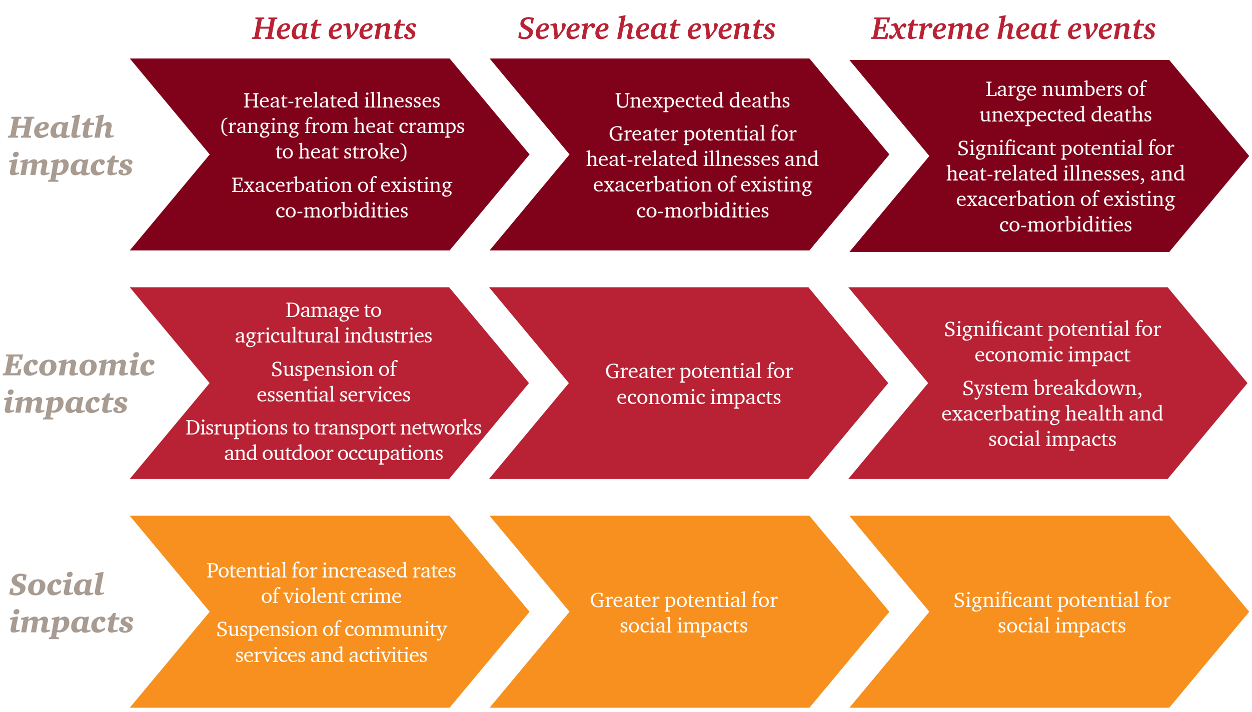
Heat events may not scar the physical landscape in the same way that other natural hazards do, but they can have a range of devastating impacts. These can be both direct and indirect, as well as health, social and economic in nature.

Heat events exist on a continuum (Figure 4). All heat events have the potential to affect morbidity, as well as induce such social impacts as increased rates of violent crime, and such economic impacts as disruptions to electricity and transport networks. Heat events may be considered *severe* when they not only impact on morbidity, but also start causing unexpected deaths.

It is also possible for heat events to be *extreme*. These tend to be outliers, in that they occur only rarely. The potential impacts of extreme heat events, however, are intense and overwhelming. Such events have previously been associated with large numbers of unexpected deaths, as well as significant fractures in infrastructure networks and community services. These fractures can, in turn, limit the ability of individuals to stay cool, further exacerbating the health and social impacts of high temperatures. It is this potential for system breakdown that makes extreme heat events so destructive.

In this chapter, we explore the available evidence about the impacts of heat events – drawing on academic research and government studies. We first outline the health, social and economic impacts of heat events. Following this, we discuss how heat events do not affect all individuals equally – different groups are more at risk than others. As such, we highlight a range of factors that are likely to increase a person's susceptibility to heat events.

Figure 4: Continuum of heat events and their impacts



Health and safety impacts

The most documented impact of heat events is their potential to degrade the physical and psychological health and wellbeing of individuals within communities. As Luber and McGeehin state, 'prolonged exposure to high temperatures can cause heat-related illnesses'.[11] These range in severity from heat cramps and heat syncope to heat exhaustion and heat stroke (see Appendix A for more detail) – marked by the body's progressive inability to thermoregulate (ie maintain normal temperature). Heat stroke is a medical emergency and, if left untreated, can lead to death.[12]

Indirect impacts that severe heat events can have on human health and safety include:

- *Infrastructure failures* – heat events can disrupt electricity supply and public transport networks, impeding the ability of individuals to manage prolonged high temperatures. As the Victorian Government notes, 'power outages will impact on people's ability to run air conditioners and public transport disruptions will hinder people's ability to reach a cooler location.'[13]
- *Reduced community capacity to respond to heat events* – during periods of high temperatures, there is increased demand for ambulance and hospital emergency services. 'As a heatwave continues the capacity of these services to meet such high demand is often seriously compromised, potentially resulting in extended response times, overstretched or even non-existent services.'[14]
- *Health and wellbeing of support services* – it is important to recognise that, during heat events, a number of basic public services still need to be provided. Indeed, demand for some services – such as health and emergency care and emergency track work (ie replacing buckled rail lines) – is likely to increase due to a heat event. Staff providing these services may face a range of adverse health effects caused by prolonged exposure to high temperatures. The relevant organisations also face challenges in ensuring they have sufficient occupational health and safety procedures in place to uphold the health and wellbeing of their workforce, while continuing to provide an appropriate level of necessary services.

Social impacts

Heat events can have a range of social impacts. Unfortunately, researchers have not examined these impacts to the same level of detail as health and safety impacts. Social impacts that the literature and stakeholders have highlighted include:

- There is considerable evidence to suggest there is a link between heat and crime, although the topic is still subject to debate.[15] It has been suggested that there is an increase in aggressive crimes in hot weather, such as: rioting and civil unrest;[16] higher levels of street violence, attacks and homicide;[17] road rage;[18] and domestic violence.[19] Simister and Cooper suggest that unusually hot days trigger an increase in the production of stress hormones (particularly adrenaline).[20] This can result in aggression, leading to observed increases in violent crime.
- Home and work security has the potential to be compromised, as people leave windows open in an attempt to cool their houses and workplaces.
- Some stakeholders have noted a potential for the closure of community social activities as a result of high temperatures, although literature on this topic is sparse. Stakeholders have also suggested the potential for business closures, with resultant knock-on effects for owners and employees, especially in low-income areas.
- Low-income households that rely on airconditioning might suffer economic hardship because of large energy bills.

11 Luber, G. & McGeehin, M. (2008), 'Climate change and extreme heat events', *American Journal of Preventative Medicine*, 35(5):429-435.

12 Victorian Government Department of Human Services. (2009). *January 2009 Heatwave in Victoria: An Assessment of Health Impacts*. Melbourne.

13 Victorian Government Department of Health. (2011). *Heatwave Plan for Victoria: Protecting health and reducing harm from heatwaves*. Melbourne.

14 Cusack, L, C. de Crespigny and P Athanasos. (2011). 'Heatwave, mental health – substance use', in *Introduction to Mental Health – Substance Use*, edited by David Cooper, Radcliffe Publishing, Abingdon.

15 *Ibid*.

16 Rotton, J. and E.G. Cohn. (2000).'Weather, disorderly conduct and assaults: From social contact to social avoidance', *Environment and Behaviour*, 32(5):651-673; Rotton, J. and E.G. Cohn , (2000). 'Violence is a curvilinear function of temperature in Dallas: A replication', *Journal of Personality and Social Psychology*, 78(6):1074-1081.

17 BOM (nd). 'The heatwave threat', www.bom.gov.au/wa/sevwx/perth/heatwaves.shtml, accessed on: 10 May 2011.

18 Kenrick, D.T. and S.W. MacFarlane. (1986). 'Ambient temperature and horn-honking: A field study of the heat/aggression relationship', *Environment and Behaviour*, 18(2):179-191.

19 Auliciems, A. and L. Di Bartolo. (1995). 'Domestic violence in a subtropical environment: police calls and weather in Brisbane', *International Journal of Biometeorology*, 39: 34-39.

20 Simester, J. and C. Cooper. (2005).'Thermal Stress in the USA: effects on violence and employee behaviour', *Stress and Health 21(1): 3-15*.

Economic impacts

Similar to social impacts, the economic impacts of severe heat events tend to be under-examined relative to health and safety impacts. Table 4 provides a summary of those economic impacts that have been identified in the literature, and raised with us during consultations.

Table 4: Economic impact on industries affected by severe heat events and the knock on impacts

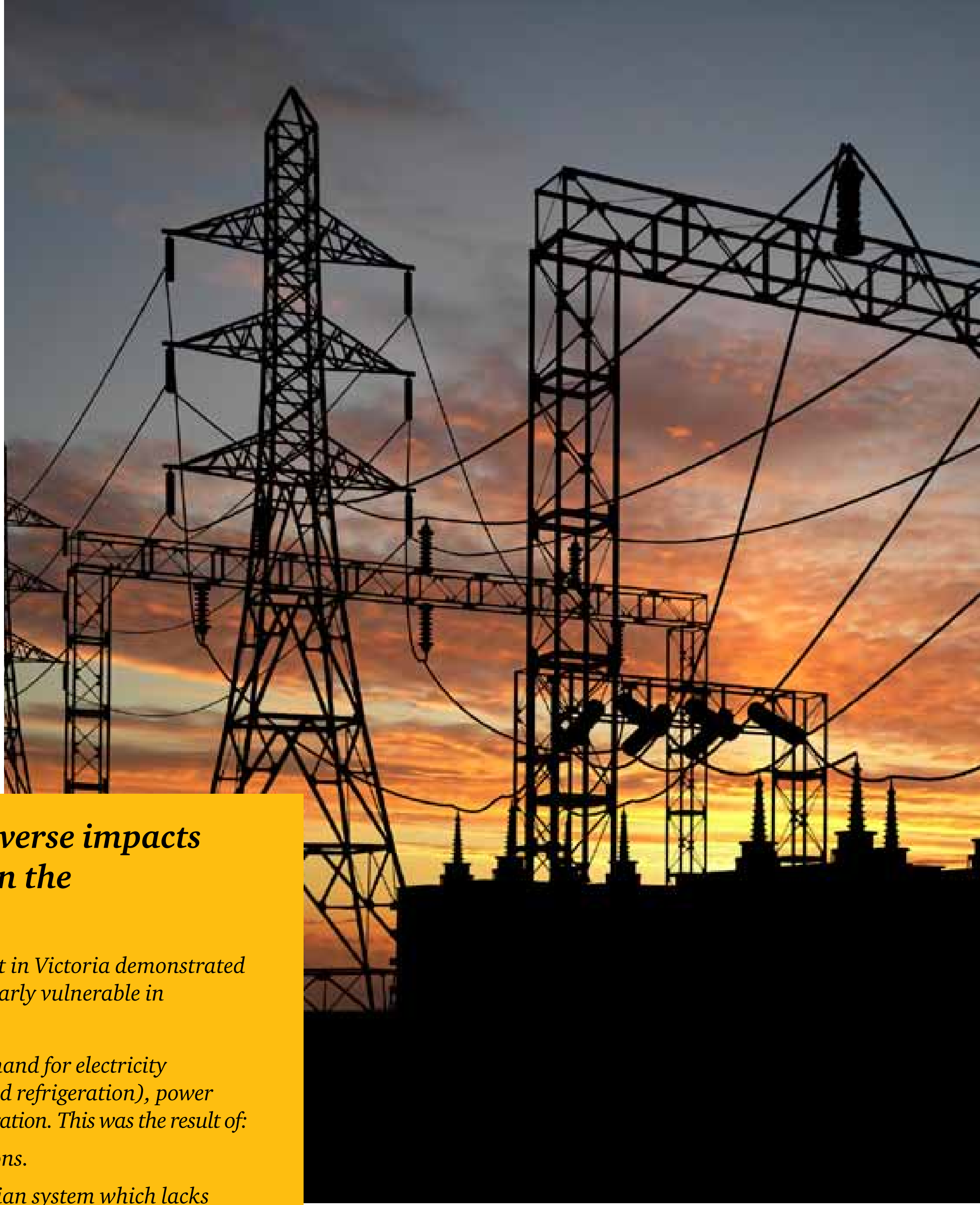
Industry	*Impact*	*Knock on impacts*
Infrastructure	Temporary suspension of services.	Energy, water and wastewater, and information and communication technology systems failure exacerbate the effect of high temperatures on health. These failures can have multiple consequences for other businesses in our now highly interdependent economy. Box 1 on the following page provides further detail about the adverse impacts of severe heat events on the electricity sector.
Transport[21]	Disruptions to transport may occur through, for example, buckling of train tracks, 'bleeding' of bitumen on roads, and traffic signal failure. During the 2009 Victorian heat event, the most affected form of transport infrastructure were railways, with only 64 per cent of train services running on some days.	Transport disruptions are likely to increase absenteeism, impede the movement of goods, and increase reliance on motor vehicles, compounding the urban heat island effect.
Agriculture and forestry[22]	Agricultural crops, stocks and forests may be harmed by heat events. Such losses in the 2003 European severe heat event were estimated at US $15bn (although this value is confounded by damage due to drought and wildfire).	Impacts include increased food prices. For example, in the 2010 Russian heat event the Russian Government banned grain exports, resulting in a dramatic increase in their prices on global commodities markets. It can be hard to distinguish the impact of heat events on agriculture from extended periods of drought.
Manufacturing	Industrial mechanical failure may result from the operation of machines outside of standard temperatures.	Downtime on machines may limit business operations, reducing profitability. This may in turn lead to the reduced supply of goods.
Construction[23]	Construction and other outdoor occupations are likely to be severely disrupted as staff productivity decreases and the risk of adverse health consequences increases.	Lost labour hours resulting from a heat event will have negative economic impacts.
Other[24]	Prolonged high temperatures may aggravate ongoing subsidence by exacerbating dry soil conditions, leading to building damage and damage to underground pipes.	Adverse impacts including injury and lost productivity where structural damage occurs.

21 NCCARF. (2010). 'Impacts and adaptation response of infrastructure and communities to heatwaves: the southern Australian experience of 2009' www.isr.qut.edu.au/downloads/heatwave_case_study_2010_isr.pdf, accessed on: 1 July 2011; Victorian Government Department of Transport. (2009). *The Department of Transport (DoT) response to the Rail Advisory Services (RAS) review of the resilience and performance of the Victorian passenger rail system when operating under extreme weather conditions,* Melbourne.

22 Gosling, T. and J. Barton. (2010). 'Russian heatwave and fires hit economy', *The Daily Telegraph*, 1 September, www.telegraph.co.uk/sponsored/russianow/society/7975232/Russian-heat-wave-and-fires-hit-economy.html; Stern, N. (2006). *Stern Review Report on the Economics of Climate Change*, London.

23 BOM (nd). 'The heatwave threat', www.bom.gov.au/wa/sevwx/perth/heatwaves.shtml, accessed on: 10 May 2011.

24 Environment Agency. (2007). *The Social Impacts of Heat Waves, Bristol*, http://publications.environment-agency.gov.uk/PDF/SCHO0807BNCW-E-E.pdf, accessed on: 1 July 2011.



Box 1: Case study – adverse impacts of severe heat events on the electricity sector[25]

The January 2009 severe heat event in Victoria demonstrated that the electricity sector is particularly vulnerable in high temperatures.

It was found that during record demand for electricity (particularly for airconditioning and refrigeration), power stations were unable to increase generation. This was the result of:

- *Unfavourable operating conditions.*
- *The inherent set-up of the Victorian system which lacks a redundancy factor for extreme events and insufficient systems that could cope with higher temperatures.*
- *Shutdown of the Basslink connection due to heat thresholds being reached.*

Rolling blackouts were initiated and an estimated 500,000 residents were without power at one time during the crisis. The inability to map where all 'at-risk' individuals were located, meant that a potential for extreme adverse impacts existed.

The effect of power cuts also had wider economic implications for industry, communication and ICT systems (which typically require both power and airconditioning).

Victoria is not alone with a similar situation observed in Queensland in 2004 and France in 2003, where nuclear power stations were forced to shut down because river water coolant was too warm.

25 Stern, N. (2006). *Stern Review Report on the Economics of Climate Change*, London; NCCARF. (2010). 'Impacts and adaptation response of infrastructure and communities to heatwaves: the southern Australian experience of 2009' www.isr.qut.edu.au/downloads/heatwave_case_study_2010_isr.pdf, accessed on: 1 July 2011; UNEP. (2004). *Impact of Summer 2003 Heatwave in Europe*, www.grid.unep.ch/product/publication/download/ew_heat_wave.en.pdf, accessed on: 1 July 2011.

Estimating the costs of heat events

Quantifying the costs of heat events can be difficult, due to a lack of available data and established methods of attributing costs. Nonetheless, several studies have sought to quantify the impacts of heat events, focusing on the agricultural and electrical sectors (Table 5). While acknowledging the limitations of these studies, it is clear that heat events can have significant economic costs.

Table 5: Summary of cost estimates[26]

Study	*Location*	*Year*	*Costs*
Lott and Ross	United States	1980	Severe losses to agriculture and related industries – estimated at US $20.0bn in damages and costs (1980$). Also an estimated 10,000 deaths (including heat stress-related).
Lott and Ross	United States	1988	Severe losses to agriculture and related industries – estimated at US $40.6bn in damages and costs (1988$). Also an estimated 5,000 to 10,000 deaths (including heat stress related).
National Weather Service	United States	2006	Estimated total property and crop damage of US $493m.
Nous	Victoria	2007	The loss of electricity associated with a heat event in January 2007 is estimated to have had a total economic cost of AU $501m.
CSIRO	Southern Australia	2009	Financial losses associated with the 2009 extreme heat event, mainly as a result of power outages, transport service disruptions and response costs, are estimated to have been AU $800m.

Groups most at risk

Heat events do not affect all individuals equally. Different groups within our communities are more at risk of adverse health affects due to prolonged exposure to high temperatures than others. The relevant literature (including a broad range of studies undertaken in Australia) identifies a number of factors that appear to increase a person's susceptibility to severe heat events. These range from personal physiological factors (Table 6) to contextual factors (Table 7). These risk factors impede an individual's ability to thermoregulate, whether this results from inherent limitations in their physiological construct, or whether external factors hinder their ability to access appropriate mechanisms to cool their body temperature.

It is important to note that there are considerable interdependencies between risk factors. There is a high probability, for example, that older adults will also have an existing co-morbidity (such as cardiovascular disease). Similarly, a person living in poverty is less likely to have access to airconditioning and transport than other Australians.

26 COPA COGECA 2003: Assessment of the impact of the heatwave and drought of the summer 2003 on agriculture and forestry; Institute for Sustainable Resources, Queensland University of Technology, 2010, Impacts and adaptation response of infrastructure and communities to heatwaves: the Southern Australian experience of 2009; Lott, N., and T. Ross, 2006: Tracking and evaluating U.S. billion dollar weather disasters, 1980-2005. Combined preprints: 86th AMS Annual Meeting, Atlanta, Georgia, 29 January – 2 February 2006, [CD-ROM], American Meteorological Society, Boston, MA; NOAA NWS, Summary of Natural Hazard Statistics for 2006 in the United States, 2006; The Nous Group, 2007, Review of the 16 January 2007 electricity supply interruptions in Victoria.

Table 6: Physiological factors that can affect an individual's vulnerability to heat events

Risk factor	*Description*
Age[27]	Older adults – physiological changes, particularly to renal function and electrolyte homeostasis, increase risk. These changes may be compounded by existing co-morbidities, limited mobility, socio-economic status and reduced perception of temperatures. Infants and children – developing physiology and a reliance on others to regulate appropriately their thermal environments places infants and children at increased risk.
Gender[28]	Studies are inconclusive as to whether gender is a risk factor. Several studies suggest females are at a slightly higher risk than males during heat events. The apparent correlation, however, may be linked to the extended life expectancy of women.
Existing co-morbidities and associated medication[29]	Existing co-morbidites can impede a person's ability to behave appropriately, reduce body heat, maintain cardiac output and maintain plasma volume and sweat during heat events. Particular health systems at risk from existing co-morbidities include: • Cardiovascular (e.g. cardiovascular disease, hypertension, coronary artery disease, congestive heart failure and ischemic heart disease). • Respiratory (e.g. chronic lower respiratory diseases and bronchitis). • Endocrine (e.g. diabetes mellitus). • Mental and behavioural disorders (e.g. schizophrenia and delusional disorders). • Renal (e.g. acute renal failure, electrolyte imbalance, nephritis and nephrotic syndrome). Medications may exacerbate risk by impeding physiological mechanisms to respond and maintain water and salt balances. Some medications can lose efficacy when exposed to temperatures above 25°C.
Acclimatisation[30]	The impacts of heat events can be more devastating early in summer, when populations have yet to become accustomed to high temperatures. Research suggests it takes approximately two to six weeks for individuals to acclimatise. Those living in relatively warmer climates (such as the Northern Territory) appear to tolerate a higher heat threshold than those in cooler areas (such as Tasmania). Those living in warmer climates also tend to modify their behaviour to respond appropriately to higher temperatures. Northern Hemisphere tourists can be exposed to risk in the Australian tropics for both acclimatisation and behavioural reasons.

27 Basu, R. (2009). High ambient temperature and mortality: a review of epidemiologic studies from 2001 to 2008, *Environmental Health*, 8,40; Ebi, K. & Meehl, GA. (2007). Heatwaves & global climate change – the heat is on: climate change & heatwaves in the Midwest. Arlington: Pew Center on Global Climate Change; Flynn, A., McGreevy, C. & Mulkerrin, E.C. (2005). Why do older patients die in a heatwave? *QJM*, 98(3), 227-229; Menne, B., Apfel, F., Kovats, S. & Racioppi, F. (eds). World Health Organisation – Europe (WHO) (2008). Protecting Health in Europe from climate change, Copenhagen: WHO; Reid, C.E., O'Neill, M.S., Gronlund, C.J., Brines, S.J., Brown, D.G., Diez-Roux, A.V. & Schwartz, J. (2009). Mapping community determinants of heat vulnerability, *Environmental Health Perspectives*, 117(11), 1730-36; World Health Organisation – Europe (WHO). (2009). Improving public health responses to extreme weather/heat-waves – EuroHEAT: Technical summary. Copenhagen: WHO.

28 Fouillet, A., Rey, G., Laurent, F., Pavillon, G., Bellec, S., Guihenneuc-Jouyaux, C., Clavel, J., Jougla, E. & Hemon, D. (2006). Excess mortality related to the August 2003 heatwave in France. *Int Arch Occup Environ Health*, 80, 16-24; Vaneckova, P., Hart, M.A., Beggs, P.J. & de Dear, R.J. (2007). Synoptic analysis of heat-related mortality in Sydney, Australia, 1993-2001, *International Journal of Biometeorology*, 52, 439-451.

29 Basu, R. (2009). High ambient temperature and mortality: a review of epidemiologic studies from 2001 to 2008, *Environmental Health*, 8,40; Crichton, Brian (2004), 'Keep in a cool place: exposure of medicines to high temperatures in general practice during a British heatwave', *Journal of the Royal Society of Medicine*, 97(7):328-9; Department of Health Victoria (DH). (2010). Staying healthy in the heat – Fact sheet for clinicians. Melbourne: DH; Fouillet, A., Rey, G., Laurent, F., Pavillon, G., Bellec, S., Guihenneuc-Jouyaux, C., Clavel, J., Jougla, E. & Hemon, D. (2006). Excess mortality related to the August 2003 heatwave in France. *Int Arch Occup Environ Health*, 80, 16-24; Kovats, R.S., Hajat, S. & Wilkinson, P. (2004). Contrasting patterns of mortality and hospital admissions during hot weather and heatwaves in Greater London, UK, *Occupational and environmental medicine*, 61(11), 893-8; Luber, G. & McGeehin, M. (2005). Climate change and extreme heat events, *American Journal of Preventative Medicine*, 25(5), 429-35; Matthies, F., Bickler, G., Cardenosa Marin, N. & Hales, S. (eds). World Health Organisation – Europe (WHO) (2008). Heat-health action plans. Copenhagen: WHO; Nicholls, N., Skinner, C., Loughnan, M. & Tapper, N. (2007). A simple heat alert system for Melbourne, Australia, International Journal of Biometeorology.

30 Basu, R. (2009). High ambient temperature and mortality: a review of epidemiologic studies from 2001 to 2008, *Environmental Health*, 8, 40; Knochel, J.P. and G. Reed. (1994). Disorders of heat regulation. In: M.H. Maxwell, C.R. Kleeman, RG Narins, eds. *Clinical disorders of fluid and electrolyte metabolism*, 5th ed. New York, McGraw-Hill Inc Knowlton, K., Rotkin-Ellman, M., King, G., Margolis, H.G., Smith, D., Solomon, G., Trent, R. & English, P. (2009). The 2006 California heatwave: impacts on hospitalisations and emergency department visits. *Environmental Health Perspectives*, 117(1), 61, 61-67; Smoyer, K. 1998. A comparative analysis of heatwaves and associated mortality in St. Louis, Missouri – 1980 and 1995; World Health Organisation (WHO) (2004). Heat-waves: risks and responses. Copenhagen: WHO.

Table 7: Contextual factors that can affect an individual's vulnerability to extreme heat events

Risk factor	*Description*
Geographical location[31]	Individuals living in high-density areas are at greater risk during heat events as a result of the 'urban heat island' (UHI) effect. In urban areas, buildings trap hot air, ground structures (e.g. bitumen) reduce radiation loss, and vehicles, buildings and other activities generate additional heat. Consequently, temperatures within urban areas are higher than non-urban areas – and tend to remain higher for longer periods, as heat cannot be displaced.
Access to airconditioning[32]	Individuals appear to be at a higher risk of mortality when they either do not have access to airconditioning or have impeded access to airconditioned dwellings and spaces. Stakeholders noted a number of cases where certain individuals did not use airconditioning during a heat event because they did not fully understand how to use their airconditioning unit, or were worried about the financial cost of doing so.
Outdoor exposure and confined spaces[33]	Individuals participating in strenuous outdoor activities (e.g. labour or sport), undertaking unusual outdoor exertion (for example, stranded rail passengers who have to walk to safety), exposed to high levels of reflective/radiative heat (such as those working on roofing or tourists in places like Uluru Kata Tjuta National Park) or in exposed confined spaces with inadequate ventilation (like roof voids), place increased strain on their ability to thermoregulate and maintain a fluid and electrolyte balance.
Education surrounding heat events[34]	A lack of education surrounding heat events and how to respond appropriately places individuals at an increased risk during such events. Conclusions as to the impact of the level of schooling being a risk factor however are varied. This is the result of confounding factors such as socio-economic status and geographic location.
Social interaction/ isolation[35]	The link between an individual's level of social interaction and susceptibility to heat events is unclear. Studies in the United States found a link between isolation and morbidity and mortality. Studies in the United Kingdom and Italy, however, did not. What is recognised is that those with multiple risk factors (e.g. age or co-morbidities) require increased monitoring during heat events. These individuals will thus be at a heightened risk when they are also socially isolated.
Socio-economic status[36]	The link between socio-economic status and associated poverty as a direct key risk factor is not clear. Studies in the United States and China identified a relatively modest increase in the mortality rate of disadvantaged populations. Other studies, however, 'show that there is no modification of the temperature-mortality relationship by socio-economic status in the European context.' Compounding risk factors (e.g. poor housing, high urbanisation, limited airconditioning and education) may impede lower socio-economic groups from responding adequately to heat events.
Transport accessibility/ mobility	The ability to move to cooler environments to assist in thermoregulation is of particular issue where individuals have compounding risk factors (e.g. older adults, individuals with disabilities and underlying co-morbidities affecting mobility).

31 Huang, W., Kan, H. & Kovats, S. (2010), The impact of the 2003 heatwave on mortality in Shanghai, China, *Scientist of the Total Environment*, 408, 2418-20; Loughnan, M. (2009). 'Hot spots' project: Spatial vulnerability to heat events in Melbourne Australia. Clayton: Monash University; Tan, J., Zheng, Y., Song, G., Kalkstein, L.S., Kalkstein, A.J. & Tang, X. (2007). Heatwave impacts on mortality in Shanghai, 1998 and 2003, *International Journal of Biometeorology*, 51, 191-200; Tan, J., Zheng, Y., Tang, X., Guo, C., Li, L., Song, G., Zhen, X., Yuan, D., Kalkstein, A.J., Li, F & Chen, H. (2010). The urban heat island and its impact on heatwaves and human health in Shanghai, *International Journal of Biometeorology*, 54, 75-84.

32 Reid, C.E., O'Neill, M.S., Gronlund, C.J., Brines, S.J., Brown, D.G., Diez-Roux, A.V. & Schwartz, J. (2009). Mapping community determinants of heat vulnerability, *Environmental Health Perspectives*, 117(11), 1730-36; Tan, J., Song, G., Kalkstein, L.S., Kalkstein, A.J. & Tang, X. (2007). Heatwave impacts on mortality in Shanghai, 1998 and 2003, *International Journal of Biometeorology*, 51, 193-200; Woodruff, R., Hales, S., Butler, C. & McMichael, A. for the Australian Conservation Foundation and the Australian Medical Association. (2005). Climate change health impacts in Australia – Effects of dramatic CO2 emission reductions. Technical report. National Centre for Epidemiology and Population Health, Canberra; Vaneckova, P., Hart, M.A., Beggs, P.J. & de Dear, R.J. (2007). Synoptic analysis of heat-related mortality in Sydney, Australia, 1993-2001, *International Journal of Biometeorology*, 52, 439-451.

33 Belshaw, C. (2009). 'Preventing heat stroke in Australian communities', *ANJ*, 16(7): 28-31; Luber, G. & McGeehin, M. (2005). Climate change and extreme heat events, *American Journal of Preventative Medicine*, 25(5), 429-35.

34 Reid, C.E., O'Neill, M.S., Gronlund, C.J., Brines, S.J., Brown, D.G., Diez-Roux, A.V. & Schwartz, J. (2009). Mapping community determinants of heat vulnerability, *Environmental Health Perspectives*, 117(11), 1730-36.

35 Reid, C.E., O'Neill, M.S., Gronlund, C.J., Brines, S.J., Brown, D.G., Diez-Roux, A.V. & Schwartz, J. (2009). Mapping community determinants of heat vulnerability, *Environmental Health Perspectives*, 117(11), 1730-36.

36 Luber, G. & McGeehin, M. (2005). Climate change and extreme heat events, *American Journal of Preventative Medicine*, 25(5), 429-35; Reid, C.E., O'Neill, M.S., Gronlund, C.J., Brines, S.J., Brown, D.G., Diez-Roux, A.V. & Schwartz, J. (2009). Mapping community determinants of heat vulnerability, *Environmental Health Perspectives*, 117(11), 1730-36; World Health Organisation – Europe (WHO). (2009). 'Improving public health responses to extreme weather/heat-waves – EuroHEAT: Technical summary', Copenhagen: WHO.

The Australian heat experience

Measuring heat events

Understanding the frequency of past heat events provides context to future projections and highlights the potential for adverse impacts to communities in the absence of mitigation strategies.

Previously, researchers have generally explored the impact of heat events by applying heatwave definitions based on temperature thresholds over a defined period.[37] While this research is valuable, there are limitations in using such definitions to identify heat events. First, as we note above, the impacts of heat events tend to be specific to the environment in which they occur and the associated climatology. Heat event definitions thus need to be able to recognise and reflect local conditions. Applying some existing temperature-based definitions universally can prove problematic in this regard. In 2010 Tong, Wong and Barnett, for instance, 'investigated the relationship between heatwaves and health outcomes using ten different heatwave definitions in Brisbane.'[38] Amongst their conclusions they found that 'small changes in the definition of heatwaves can lead to considerable differences in the risk assessment for heatwaves' and that 'some commonly-used heat wave definitions do not appear to suit Brisbane.'[39]

Second, there is not an exact relationship between high temperatures and adverse impacts. Research indicates that adverse impacts are likely to occur when:

- high temperatures are unusual relative to space and time (people are thus less likely to be acclimatised to the high temperatures)
- minimum temperatures remain high overnight, limiting opportunities for relief.[40]

The potential for adverse impacts can also be influenced by different geographies and their associated climates.

Thus, in order to recognise heat events historically and to discuss potential future incidents in a meaningful and nationally relevant manner, we have adopted EHF, developed by John Nairn and his colleagues at BOM. This index identifies heatwaves according to the following definition: 'A three day period where the average combined effect of excess heat and heat stress are unusual with respect to the local climate.'[41]

BOM defines EHF as: 'The combined effect of Excess Heat and Heat Stress calculated as an index to provide a comparative measure of impact, load, duration and spatial distribution of heatwave.'[42] It is based on maximum and minimum daily temperatures in each specific location and is a combination of a Heat Stress index, which considers the anomaly compared to recent temperatures, and an Excess Heat index, which measures the anomaly relative to historical temperatures. We have provided further information on the construct of EHF in Appendix B.

37 Bi P, Parton KA, Wang J, Donald K. Temperature and direct effects on population health in Brisbane, 1986-1995. *Journal of Environmental Health*. 2008 Apr;70(8):48-53; Bi P, Williams S, Loughnan M, Lloyd G, Hansen A, Kjellstrom T, et al. The effects of extreme heat on human mortality and morbidity in Australia: Implications for Public Health. *Asia Pacific Journal of Public Health*. 2011 Jan 19;23(Supp 2):27S-36S; Guest CS, Willson K, Woodward AJ, Hennessy K, Kalkstein LS, Skinner C, et al. Climate and mortality in Australia: retrospective study, 1979-1990, and predicted impacts in five major cities in 2030. *Climate Research*. 1999;13:1-15; Hansen AL, Bi P, Ryan P, Nitschke M, Pisaniello D, Tucker G. The effect of heatwaves on hospital admissions for renal disease in a temperate city of Australia. *International Journal of Epidemiology*. 2008 Aug 18;37(6):1359-65.

38 Tong, S., X. Y. Wang and A. G. Barnett. (2010). Assessment of Heat-Related Health Impacts in Brisbane, Australia: Comparison of Different Heatwave Definitions, PLoS One. 5(8):1-5.

39 Tong, S., X. Y. Wang and A. G. Barnett. (2010). Assessment of Heat-Related Health Impacts in Brisbane, Australia: Comparison of Different Heatwave Definitions, PLoS One. 5(8):1-5.

40 CSIRO & Bureau of Meteorology, 'Modelling and Understanding High Impact Weather': extended abstracts of the third CAWCR Modelling Workshop, 30 November – 2 December 2009, Melbourne, Australia; Commonwealth of Australia, Bureau of Meteorology. (2011). First Heatwave for Adelaide in 2010. Media release, Accessed from: http://reg.bom.gov.au/announcements/media_releases/sa/20100115_First_Heatwave_SA_Jan.shtml, on 16 February, 2011.

41 From John Nairn of BOM by correspondence 10/5/2011.

42 From John Nairn of BOM by correspondence 10/5/2011.

BOM is considering using EHF to describe heatwaves, for its forecasting services, and to underpin its climate change projections. We consider EHF to be a superior means of measuring the scale of heat events. The reasons for this include:

- It *reflects the community's experience* with heat events – EHF captures when high temperatures are unusual relative to space and time (and thus whether individuals are likely to have acclimatised) and the inability to shed heat load when minimum temperatures remain high.
- It *differentiates more clearly significant events* from business-as-usual events – while focusing on temperature thresholds can provide a sense of when a heat event has occurred, EHF, because it captures the inability to shed heat load when minimum temperatures remain high, is able to provide a sense of the magnitude of heat event impacts.
- It has *strong correlation to excess mortality* (as we highlight below).
- It is *predictable* – thus allowing it to form the basis of a heat event warning system.

It is important to note, however, that our use of EHF in this report is experimental and has not been subject to peer review. Further analysis of EHF is required before other relevant bodies can rely on it for measuring the scale of heat events.

Past heat events

To consider the frequency and nature of past heat events across Australia we considered the climatology of selected locations nationwide, including all capital cities and a number of regional locations.

Our initial analysis considered daily maximum and minimum temperature observations and the duration of heat events defined as days exceeding a temperature threshold. This analysis highlighted the variation in climatology across Australia and the difficulty of assuming a definition for a heat event based on temperature alone. We then extended the analysis to include information on the EHF index, which responds to variation in observed temperatures in each location. The EHF provides a clearer indication of the occurrence of past events than can be seen from the temperature alone. Appendices B and C detail the results of this analysis for a selection of locations.

Australian EHF experience

Given the range of climates in Australia and the resulting natural ability for significant temperature fluctuations, the range of historic EHF values observed varies considerably by location. Figure 5 illustrates the maximum EHF values recorded by BOM across Australia at every site over the period 1958 to 2009.

Figure 5: Maximum EHF values (1958-2009)

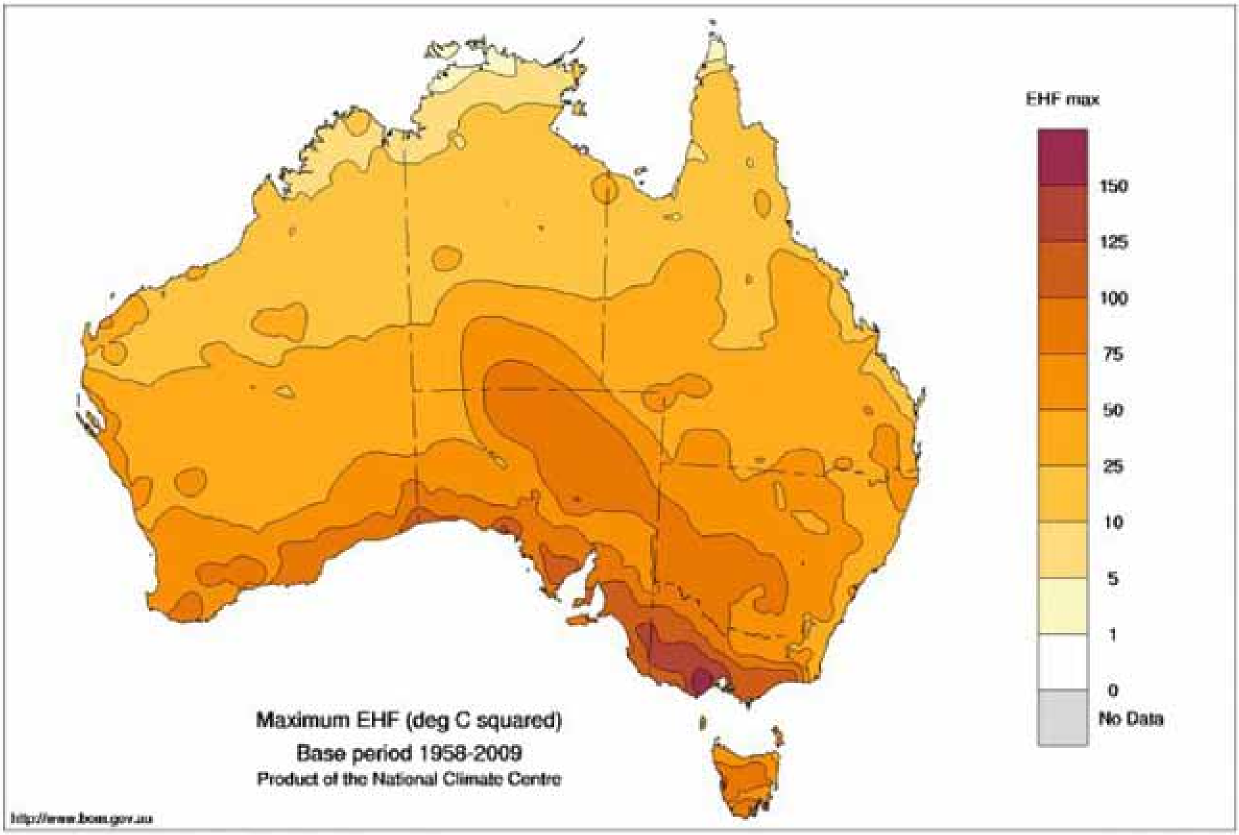


Figure 6: Severe threshold EHF values (1958-2009)

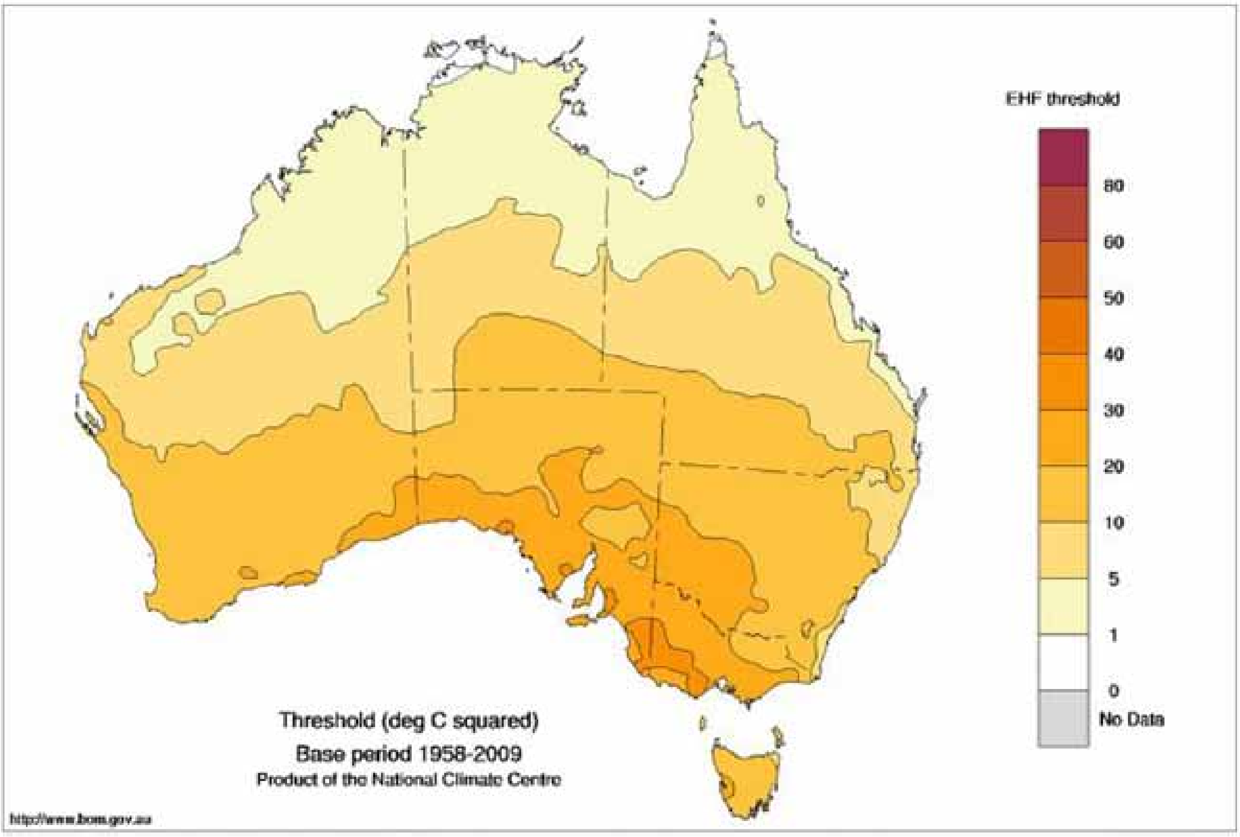


Figure 6 illustrates BOM's proposed severe EHF threshold, which is derived from the distribution of past observations. It provides a location-specific value that is only exceeded on an infrequent basis. The severe EHF thresholds are values of EHF for each site that are statistically rare in the climate record (using Probability of Exceedance). It is shown later through case studies that this value correlates well with rising incidence of mortality, or severe human health consequence. Severe EHF thresholds provide a useful point of reference for the analysis of past events.

Figures 5 and 6 show both the maximum and severe threshold EHF values experienced across the country vary significantly, with higher values further south:

- North of the Tropic of Capricorn, the EHF value rarely exceeds a value of 10. The more humid climate in the tropics precludes significant temperature variations, and, as a result, the frequency and intensity of heat events in the north are low.
- Heat events occur more frequently in the southern regions, where significant temperature variations enable the EHF index to reach values in excess of 100.

While recent events focussed our attention on the potential for heat events in Victoria and South Australia, in the past there have been significant heat events in other areas. For example, Sydney (in 1960 and 1994) and Brisbane (in 1994 and 2004) have recorded major heat events that had material community impacts. In addition, both Perth and Sydney experienced prolonged heat events in early 2011. The impact of these events is still being quantified and, consequently, we have not been able to consider them in this report.

It is important to note that the range of EHFs experienced in each location vary across the country. Each location thus has to determine its own EHF sensitivity.

Impacts of past events

In order to review the health impacts of a number of past events nationwide, we compared mortality data with historical EHF information provided by the BOM.

We recognise that mortality is only one of many possible adverse impacts of heat events. We also recognise that heat events are likely to induce significant morbidity impacts, and mortality is not necessarily the best proxy of these impacts. Nonetheless, we have chosen to focus on mortality as an indicator of heat events because of data availability. More specifically, the Australian Bureau of Statistics has collected daily statistics on mortality for different locations, and has done so using a consistent definition. We required daily information for the purposes of comparison with the climate records. Similar data do not exist with reference to morbidity.

The analysis covered a 20-year period and allowed us to assess the impacts of different levels of EHF in different locations. To determine whether there was any adverse health impact we calculated a baseline 'expected number of daily deaths' for each location and examined the excess over this level. More information on the setting of this baseline is provided in Appendices B and C.

Table 8: Summary of analysis of past heat events

Region	*Locations included (severe EHF threshold(s)*)*	*Nature of heat events experienced*	*Impact on population*
Southern	Victoria (27.5/29.5) South Australia (31.4)	• EHF values regularly exceed 30 and reach 50+ • High EHF values highlight the potential for large temperature shifts	• Strong correlation between EHF and excess deaths for both Adelaide and Melbourne
Temperate (south)	New South Wales (10.8/18.6) Australian Capital Territory (12.3) Tasmania (17.0) South Western Australia (15.4)	• EHF values in the range of 20-40 experienced in many locations • Although high EHF values occur regularly they are not as extreme as further south • There are notable differences in the EHF experienced in the different locations, as represented by the differing thresholds	• The population impact of the largest historic events is less pronounced than for the Southern region
Temperate (north)	Southern Queensland (4.5/6.2)	• Moderate EHF values in the range of 5-10 experienced • Higher values occur infrequently	• Significant excess deaths arising from past events indicating that the population may be more sensitive to excess heat • This may partly be due to a difference in age profile of the population • Tourism and related lack of acclimatisation may contribute
Tropical	Tropical Queensland (2.9) Tropical Western Australia (2.6) Northern Territory (0.8)	• Very low EHF values in the range of 0-5 experienced, very rarely exceeding a value of 10 • Evidence that heat events are not experienced in this region • A response for this region is likely to be linked to seasonal ambient temperatures as opposed to heat events	• Sparseness of population makes analysis of this region more complex • Very difficult to identify any heat-related excess deaths in extreme northerly locations • Queensland experience may be impacted by tourism effects

**Note: the thresholds shown are the values over the sites we have selected for analysis in each location. A more complete view of the threshold range in each location is displayed in Figure 6.*

The experience during the 2009 heat event (Box 2) provides a useful illustration of using EHF as a measure of heat event impacts.

Box 2: Case study – The January 2009 extreme heat event

The January 2009 heat event was the most extreme heat event to impact the southern Australian states in recent years. The meteorological observations during this time were exceptional in comparison to those experienced historically. During this time, much of southern Australia experienced temperatures 12-15°C above normal, with unusually high night-time temperatures.[43]

The effect of the heat event on the cities of Melbourne and Adelaide was significant, with regional areas of Victoria, South Australia and New South Wales also significantly affected. There were widespread adverse health impacts with dramatic increases in mortality, increases in emergency department presentations and high demands placed on a number of other health services.

The climatic conditions underlying the 2009 heat event started to emerge around 22 January with extreme heat conditions recorded over broad areas from 26 January to 2 February before gradually dissipating.

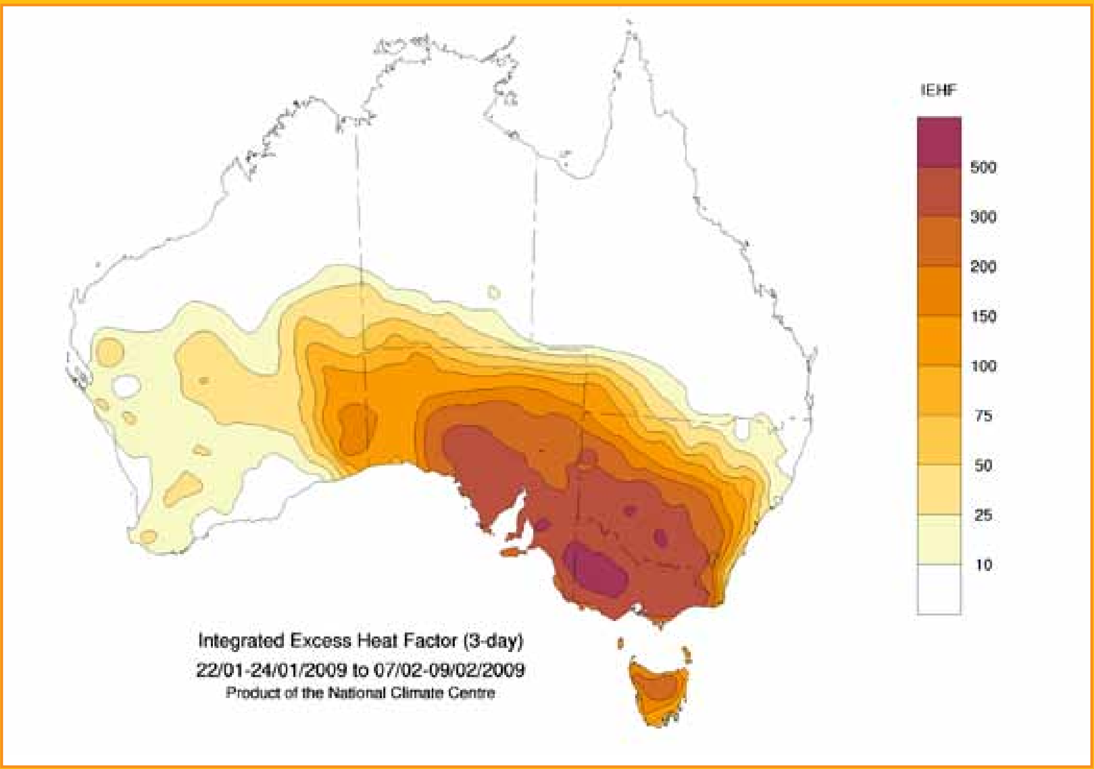
The table following shows the conditions recorded during the 2009 heat event in selected locations with an illustration of the total EHF heat load for the whole country. This gives a measure of the impact of the event on the population.

Location	Max daily temperature	Highest min daily temperature	Max daily EHF value	Total EHF event load
Melbourne	46.4	25.7	129.7	338.6
Horsham	47.6	28.8	127.1	399.6
Adelaide	45.7	33.9	123.0	454.6
Sydney	33.5	22.9	23.7	78.0
Wagga Wagga	45.2	28.5	53.2	428.5

Note: The 'heat load' of an event is the sum of all EHF values across the duration of an event in that location.

At the peak of the heat event, the EHF value recorded in Melbourne was 129.7, the second highest value since records began.

It is interesting to note that while temperatures over 40ºC were recorded in parts of Sydney (being nearly as high as those in Melbourne and Adelaide), the EHF values were not so high and nor were the observed impacts.



43 BOM. (2009). 'The exceptional January-February 2009 heatwave in south-eastern Australia', www.bom.gov.au/climate/current/statements/scs17d.pdf, accessed on: 1 July 2011.

Future severe heat events

Heat events can range from sudden increases in temperature that are short-lived, to sustained periods of heat that have a significant impact on the community. Our analysis has shown that both types of heat events result in excess mortality and need to be considered together to fully comprehend the potential future impact of heat events.

To assess the potential future impact of heat events on the population of Australia, we built a model that captures the link between EHF and mortality and applies this to future populations. The model projects excess deaths by applying adjustments to standard mortality for different climate condition scenarios. We developed results by location and population subgroup, with subgroups determined based on the risk factors that can affect an individual's vulnerability to heat events. We derived mortality loadings for different climate scenarios from the analysis above. Relative mortality adjustments for each at-risk group have been established based on the findings from our literature review.

This model has focused primarily on the five capital cities and two small states that are most impacted by heat events - Melbourne, Adelaide, Sydney, Brisbane, Perth, the Australian Capital Territory and Tasmania. We have not been able to include regional areas owing to the data limitations described earlier.

We calibrated the model to historical data from a number of past heat events for each location. The low frequency of heat events and considerable variation in past experience made the calibration challenging. Our approach attempted to achieve a reasonable balance between the experience from different events and also to draw on the experience from other similar locations in selecting the model parameters. Appendix C contains further details of how this model has been developed.

The nature of the model is that the fit cannot be exact in each location for all past events. For example, the fitted model understates the observed excess mortality in Melbourne but overstates it slightly in Adelaide for the 2009 severe heat event.

The resultant model incorporates the unique nature of each capital city, both in terms of climate, population size and demographic composition. There are other potentially relevant factors that cannot be captured in the model owing to a lack of available data. These include, for example, urban heat islands and localised temperature variations, duration of event, effects of strain on service providers, prevalence of cooling systems, impact of infrastructure and power supply failures, and effects of current resource management and mitigation strategies.[44] These factors may explain some of the variation in observed population impacts during past events.

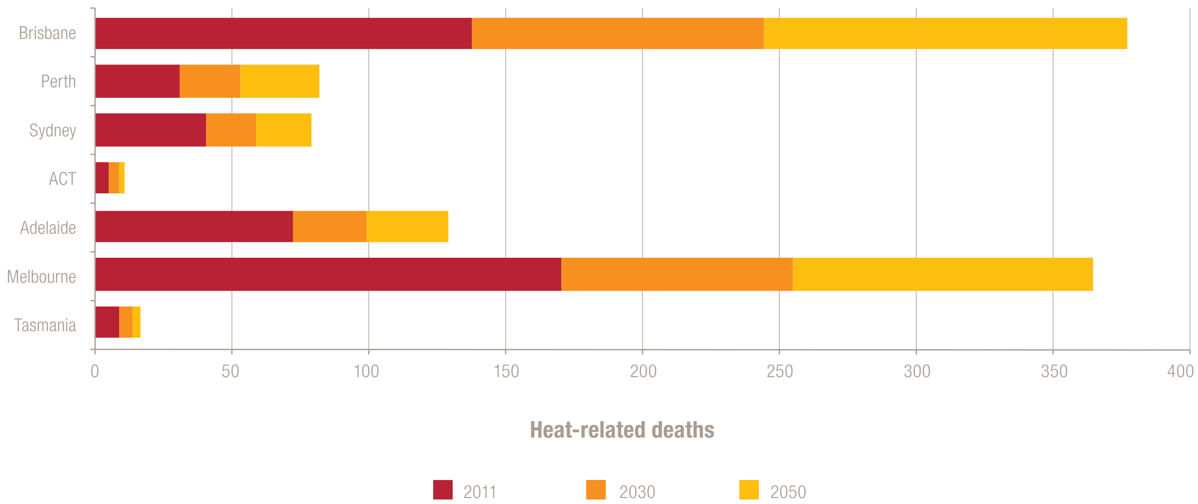
Model results

Our model assesses the potential impact of severe heat events on the population today and the expected population in 2030 and 2050. To our knowledge, this is the first time that a model of this nature has been developed, considering multiple regions of Australia on a consistent basis.

Before presenting the results of the model, it is important to note the inherent uncertainty associated with modelling future experience. In this case, uncertainty arises from the challenges in identifying excess mortality, fitting the model and the inherent variations in the climate experience – the climate history we have used may not be long enough to capture extreme events in all locations. Thus, it is important to exercise a degree of caution in interpreting the model findings.

Past experience suggests that large 'headline' events may only occur one to two times a decade. The impact of smaller events, however, may also be important. Consequently, we have presented our results both by considering what may happen if the largest past event observed over the period 1981 to 2009 were to occur in the future (Figure 7) and as an annualised average impact (Figure 8).

Figure 7: Estimates of heat-related deaths, based on highest historic EHF load (1981-2009)



Note: The figures shown are for each location individually. Since events of this severe nature will not occur at the same time in all locations it is not appropriate to total these figures.

44 Our model results represent scenarios where current response and mitigation strategies in each location are maintained in their current form. The modification of mitigation strategies and the implementation of a national framework has the potential to lead to improved human health outcomes.

The model indicates that the cities currently most likely to see the largest impacts from individual heat events are Brisbane, Adelaide and Melbourne. The 2009 event highlighted the susceptibility of Melbourne and Adelaide to heat events. The inclusion of Brisbane is more unexpected, though the city did experience a number of heat events over the past 20 years (Box 3).

In each location, the growth in expected deaths over the period 2011 to 2050 reflects the expected growth and demographic shift. The increase is biggest in rapidly growing regions such as Queensland.

Our model indicates that, based on the 2011 population, the annualised average mortality impact of heat events is approximately 80 excess deaths on average across all capital cities. In practice, this excess mortality does not emerge in a steady way with regular excess deaths each year. Rather, it materialises in a combination of infrequent large events with high impacts, together with some more regular mid-range events. The results for the more temperate locations, such as Perth and Sydney, illustrate the contribution of these mid-range events.

In 2030 the number of heat-related deaths is estimated to increase by approximately 50 per cent to between 120 and 130, increasing by a further 50 per cent to between 170 and 200 deaths in 2050. Capital cities represent two thirds of Australia's population, so it is possible to scale up the results presented by a factor of around 50 per cent to get an indication of the potential impact of heat events for all of Australia.

Box 3: Modelling results for Brisbane

Our model indicates that Brisbane, along with Adelaide and Melbourne, is likely to see the largest impacts from individual heat events. Brisbane's inclusion in this list is unexpected, given that the northern areas of Australia generally do not experience the same large variations in temperature as southeast Australia.

It should be noted, however, that Brisbane experienced a number of heat events over the past 20 years, the excess mortality of which is estimated to be approximately 50 to 100 people per event. Our analysis suggests that, although the EHF index has lower values further north, the population is more sensitive to small increases in the index. This may be a reflection of the warmer underlying climate and of the narrower range of the EHF index. This increased sensitivity is recognised in our model parameterisation.

Figure 8: Estimated average number of heat-related deaths per annum

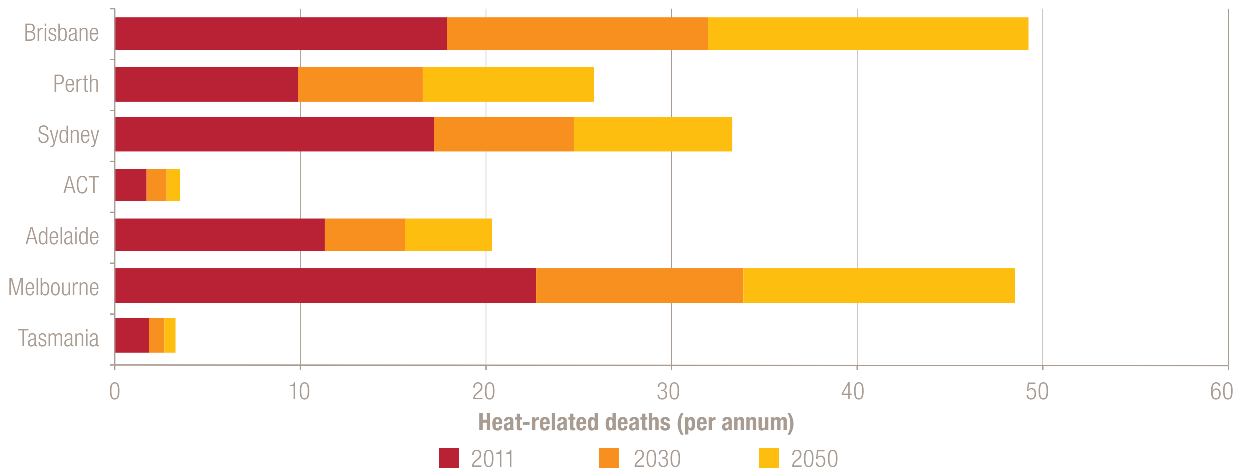
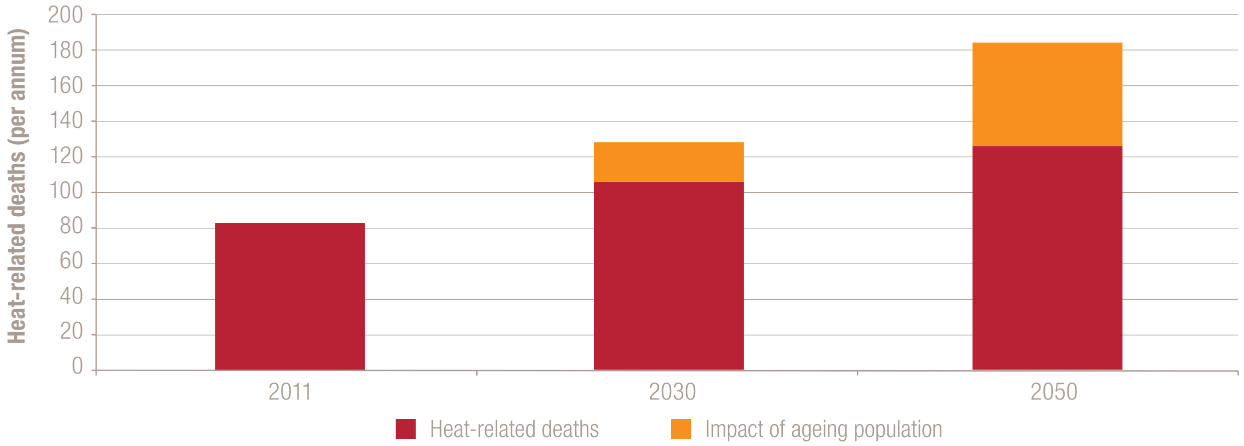


Figure 9: Contribution of ageing to estimated annualised average heat-related deaths (seven locations)



The impact of an ageing population

Part of the dramatic increase in heat-related deaths expected in 2030 and 2050 is due to changes in population demographics, in particular, an ageing population results in a higher proportion of the population in a group that is at high risk of adverse impacts from severe heat events. Figure 9 separates the ageing impact from that of population growth alone. Over the period to 2030, approximately 50 per cent of the expected increase in heat-related deaths is a result of ageing, with this accounting for 60 per cent of the increase to 2050.

Other factors such as trends in population health (obesity, diabetes, cardiovascular disease) may influence these results. Exploring such factors would be an area for further research.

The impact of climate change

We developed the results above assuming that our experience of future heat events is similar to that in the recent past. We now consider the extent to which these results would vary in the advent of climate change. Our assessment of the potential impact of climate change draws on the work of a number of organisations who have developed climate projections.

The Intergovernmental Panel on Climate Change (IPCC) is the leading international body on climate change and produces a number of different reports including the latest IPCC Fourth Assessment Report. However, these reports are limited in their projections for Australia, particularly at a regional scale.

In order to address this issue, CSIRO and BOM have been working to develop climate change projections for Australia. Their Climate Change in Australia Technical Report 2007 is based on an ensemble of global climate change models and the IPCC's Special Report on Emissions Scenarios (SRES) six emission scenarios (B1, A1T, B2, A1B, A2 and A1FI). It includes animations mapping temperature increase from 2000-2100 and is currently the most recent modelling conducted by CSIRO. Unprecedented levels of climate change evaluation have taken place over the last twelve years in the form of these multi-model (ensemble) 'intercomparisons' and the data used in this review is the result of such modelling. Additional sources of data include Garnaut's Climate Change Review and supporting documents, a wealth of resources produced by the CSIRO and BOM, as well as journal articles.

Temperature trends at a national level

Increases in average temperatures can have a large impact on extreme daily temperatures.[45] Since 1910, the Australian annual average temperature has increased by 0.9°C and the average maximum temperature has risen 0.6°C. The number of days over 35°C has increased by one day per decade and the number of hot nights over 20°C has increased by 1.8 nights per decade over a similar period from 1957 to 2004.

Research suggests that as temperatures increase, heat waves in Australia will become more intense and increase in duration.[46] Climate models indicate that the frequency and duration of extreme events in Australia such as extreme heat events and heat waves are likely to increase in the future, although with significant regional variation. The north-west is expected to warm more quickly than the rest of Australia, and inland areas will experience greater warming than coastal regions.[47]

Projected temperature increase is used in the *Climate Change in Australia Technical Report 2007* to calculate the average number of days per year over 35°C at 14 sites (including eight capital cities). This is calculated for the 'present' (1971-2000), 2030 and 2070, for the low (10th percentile), median (50th percentile) and high (90th percentile) of the A1B, B1 and A1F1 scenarios. Under all three scenarios, the number of days per year over 35°C increases significantly, with a marked increase projected for Darwin in particular.

Warm nights are defined as the percentage of days when the minimum temperature is greater than the 90th percentile of values for 1961-1990. An increase in the number of warm nights of 15-50 per cent is projected throughout Australia by the end of the twenty first century.

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45 CSIRO & BOM. (2007) Climate Change in Australia: Technical report 2007, CSIRO, Melbourne.

46 Alexander, L.V. & Arblaster J.M. (2009). 'Assessing trends in observed and modelled climate extremes over Australia in relation to future projections' International Journal of Climatology, 29(3):417-435.

47 Garnaut R. (2008), 'Ch 5 – Projecting Australian Climate Change', The Garnaut Climate Change Review, http://www.garnautreview.org.au/pdf/Garnaut_Chapter5.pdf, accessed on: 1 June 2011.

Heatwave trends

Our modelling of the impact of heat events is based on EHF. We are not aware of any research previously undertaken to study how EHF is expected to vary under the different climate scenarios or analyse the impact of climate change on the pairing of daily minimum and maximum temperatures. Further research on this topic would enhance understanding of the extent of future heat events.

Our ability to undertake quantitative modelling of the extent to which climate change could impact our results is constrained by this gap in the published research. To support our work, BOM have considered the outputs from the ensemble of models for the A1B climate change scenario (a mid emissions scenario), capturing the likely impact of climate change on the city of Melbourne. They have translated these outputs into the EHF excess heat indices. The model outputs cover the future periods 2041 to 2060 to represent mid-century, and 2081 to 2100 to represent the end of the century. The model also shows the twentieth century from 1961 to 2000.

Table 9 outlines the summary results for Melbourne. We have shown the ensemble model results and those for the MIROC High resolution model (MIROCh), which BOM has identified as being the most representative single model within the suite of models, based on comparisons to the actual observations. In addition, the actual observations (AWAP data) for the historic period 1981 to 2000 are shown.

In addition to the summary results in table 9 BOM reviewed the expected duration of heat events. Figure 10 shows how the frequency of heat events of a specified duration is projected to increase over time.

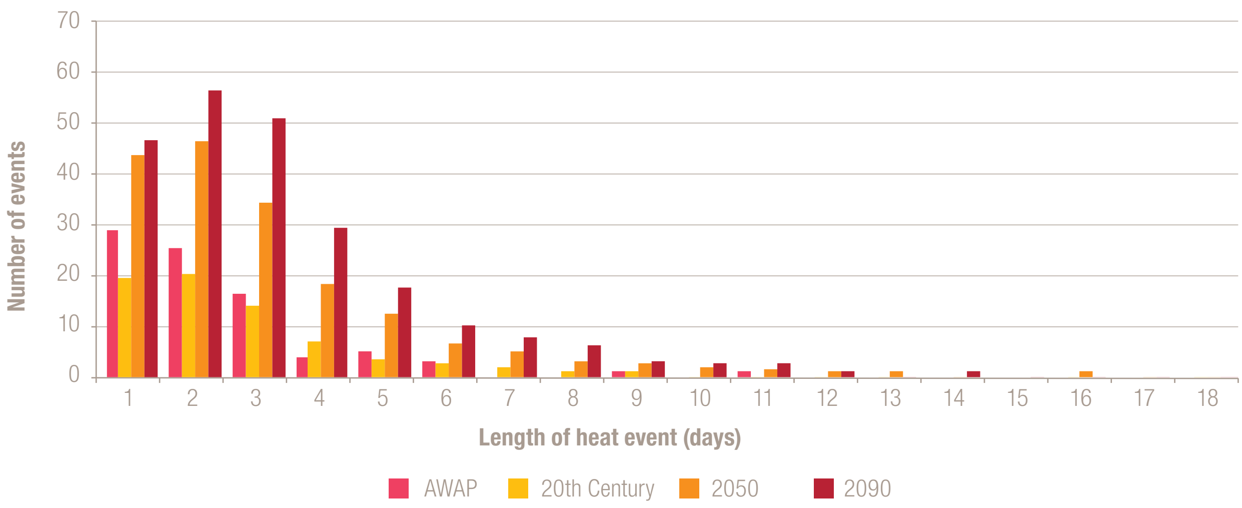
Table 9: Summary of climate models EHF results

	Ensemble model*				MIROC High resolution model		
	AWAP	** 20th Century	Mid 21st Century (2050)	End 21st Century (2090)	** 20th Century	Mid 21st Century (2050)	End 21st Century (2090)
Years considered	**1981 – 2000**	**1961 – 2000**	**2041 – 2060**	**2081 – 2100**	**1961 – 2000**	**2041 – 2060**	**2081 – 2100**
Average EHF	12.3	13.6	13.1	12.9	11.6	13	12.2
Total heatwave days (EHF>0)	213	201	508	760	167	685	1,179
Standard Deviation	12.8	16.4	16.3	16.7	13.1	18.9	19.1
Maximum EHF	69.8	105.6	102.4	130.6	84.6	130.6	189.1
99th percentile EHF value	55	74.5	74.8	77.7	59	89.9	99.8

** The following models contribute to the ensemble results: BCCR, CMA, CNRM, CSIRO1, CSIRO2, GFDL1, GFDL2, GISS, IAP, INGV, IPSL, MIROCh, MIROCm, MPI, MRI, PCM1 and Had.*

*** The 20th Century results cover a 40 year period, but have been adjusted to a 20 year period to be comparable with the other results.*

Figure 10: Duration of heat events from ensemble climate model



The results from the ensemble model show the number of heat wave days (those with EHF greater than zero) is expected to increase significantly over the twenty first century. The number of heatwave days experienced during the twentieth century averaged around 10 per annum. This is projected to increase to around 25 per annum by 2050 and 38 per annum by the 2090. Heat waves are also projected to increase in duration over time, with more events of 10 days and longer.

The MIROC high resolution model results suggest a much greater increase in the total heat wave days expected: increasing by over 300 per cent from the 213 experienced in the twentieth century to an estimated 685 by 2050, and a further 70 per cent to approximately 1,180 by 2090.

Results for the upper end of the EHF distribution illustrate the potential for extreme heat events and are shown in the maximum EHF and 99th percentile EHF outputs. These figures may be capturing the natural variability we see in Australia's highly variable climate. As such large events are very rare they may not be represented consistently within a 20-year dataset; this means there is more uncertainty in the climate model results and less reliance can be placed on comparisons between results for different periods.

Notwithstanding these inherent limitations, we can see that in both the ensemble and MIROCh models the maximum and 99th percentile EHF outputs are expected to increase in the future. By the end of the century the size of the increase in the maximum EHF is around 30 per cent in the ensemble model; the results for the models underlying this would extend either side of the figure with some of the individual models producing results which are comparable to the increase of over 100 per cent seen in the MIROCh results.

These results indicate that concern over the potential for increased incidence of heatwaves is warranted, noting that further research would be needed to extend this work nationally and refine it to enhance our understanding of the likely extent of future heat events.

These results indicate that concern over the potential for increased incidence of heatwaves is warranted.

Application of climate scenarios within our impacts model

We are unable to use the ensemble climate model results as inputs to our impact model since more detailed information would be required than is available at the current time. We have, however, been able to consider the results from the MIROCh climate change model discussed, and this has enabled us to consider the potential impact of a future heat event in Melbourne. Given the uncertainties associated with using a single model, these results should be taken only as a broad indication of the potential order of impacts.

We have considered the impact of the top event over each period and the average annual impact of heat events. A summary of EHF inputs used is shown in Table 10, together with the observed data for 1981-2000.

Based on these inputs our model suggests that, by the middle of the twenty first century, climate change may result in large heat events having two to three times greater impact than in the scenarios which do not consider climate change. The annualised impact is even greater, being perhaps five times greater than at present. This reflects the increased frequency as well as the increased severity of expected heat events.

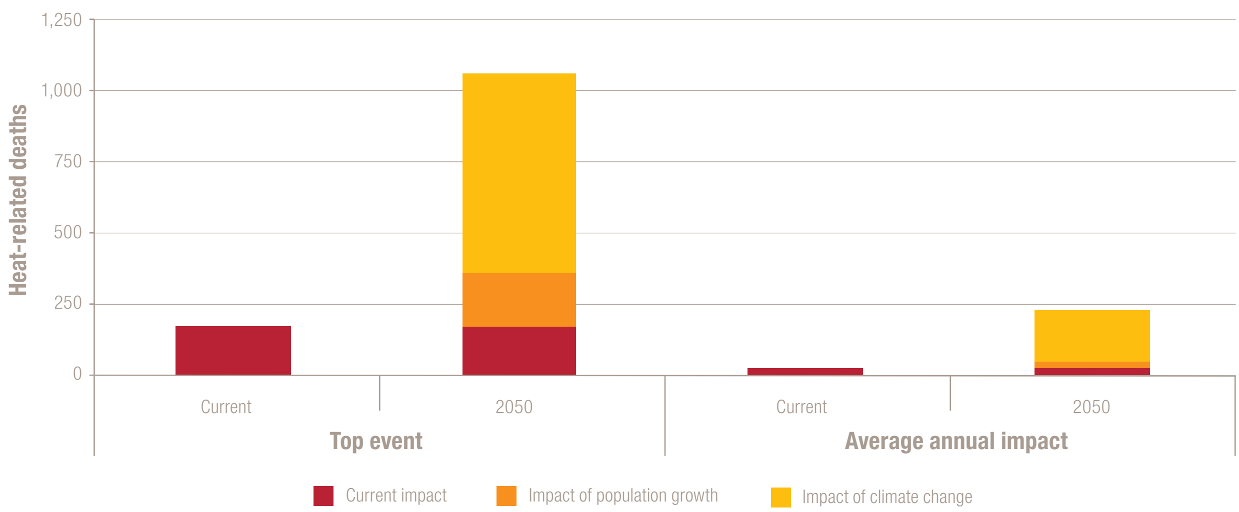
The combined effect of climate change and population growth (including ageing) impacts is illustrated in Figure 11.

Our modelling suggests that, in the absence of further mitigation, the impact of future heat events may far exceed that which we have seen to date. This finding supports the need for coordinated planning and response arrangements to limit the impact of such future events on the population. Further research using other climate change models is required, however, to confirm these conclusions.

Table 10: Summary of projected heatwave experience (MIROCh)

EHF Band	AWAP	MIROC High resolution model		
	1981-2000	20th Century	Mid 21st Century (2050)	End 21st Century (2090)
Top event:				
Duration (days)	11	11	19	24
Maximum EHF during top event	n/a	64	121	189
Total EHF load	n/a	367	963	665
Annual average:				
Heatwave (days)	11	8	34	59
Estimated annual EHF load	n/a	250	1,200	2,300

Figure 11: Current and projected mid century impacts by source of increase



Heat event emergency responses

It is clear that heat events have a range of adverse impacts on the community. The available evidence also suggests that the impact of heat events on mortality in Australia has been considerable, and is projected to increase in the future.

These findings raise the question: how sufficient are current institutional arrangements to manage the risks posed by heat events? Our analysis revealed that there is broad understanding across Australia about heat events and their potential impacts (particularly in the context of climate change). This is based on significant research, undertaken within state and territory governments and Australian universities. We also found that governments and community organisations have put in place, or are developing, planning and response arrangements specific to heat events. These arrangements exhibit aspects of good practice and demonstrate the commitment of the relevant bodies to protect the health and safety of Australians.

This progress notwithstanding, we have identified a number of gaps in current institutional arrangements. If these gaps were addressed, and good practice more effectively shared, the community's ability to manage the risks posed by heat events would be strengthened.

In this chapter, we detail our analysis of existing emergency responses for heat events. We provide a brief overview of response and planning arrangements across all three levels of government, before focusing on identified gaps and aspects of good practice. Furthermore, in order to provide a better understanding of what the community could be doing to mitigate the impacts of heat events, we discuss a range of priority mitigation areas, as nominated by stakeholders and the broader academic literature.

Current arrangements

The Commonwealth Government does not have any specific planning and response arrangements in place for heat events. Though it is committed to supporting the states and territories 'in developing their capacity for dealing with emergencies and disasters, and provides physical assistance to requesting States or Territories when they cannot reasonably cope during an emergency.'[48] The states and territories are constitutionally responsible for emergency management in Australia – including planning for, and responding to, heat events. Our conversations with stakeholders revealed near-universal recognition of the risks posed by heat events. Planning and response arrangements for these events, however, vary across the jurisdictions.

At present, four states and territories have developed and released heat event plans (Table 11). Generally, these plans do not override each jurisdiction's general emergency management arrangements. Rather, they outline the specific measures that each jurisdiction does to prepare for, and respond to, heat events over and above their general emergency management arrangements. New South Wales is currently in the process of developing a heat wave sub-plan, which will fall under its State Disaster Plan. The remaining jurisdictions rely on their general emergency management arrangements to manage the risks posed by heat events.

48 Attorney-General's Department. (2011). 'Emergency management in Australia'. www.ema.gov.au/www/emaweb/emaweb.nsf/Page/Emergency_Management, acessed on: 17 May 2011.

Table 11: Summary of existing governance and planning arrangements for heat events

Jurisdiction	*Name of plan*	*Broader context*	*Responsible agency*
New South Wales	Heatwave sub-plan (under development)	Will fall under the State Disaster Plan	n/a
Queensland	Heatwave Response Plan	Falls under the Queensland Disaster Plan	Queensland Health Other relevant agencies are required to develop their own functional heatwave plans
South Australia	Extreme Heat Plan	Falls under the State Emergency Management Plan	SA State Emergency Service Other relevant agencies are required to develop their own functional heatwave plans
Victoria	Heatwave Plan for Victoria	Complements the Emergency Management Manual Victoria	Victorian Department of Health Other relevant agencies are required to develop their own functional heatwave plans
Western Australia	Operational Directive on heatwave policy	n/a	Western Australian Department of Health

At the local government level, planning and response arrangements for heat events do exist, but are not consistent from jurisdiction to jurisdiction. In some states (such as Victoria and South Australia), local governments are required to develop heat event plans in line with broader jurisdictional arrangements. In other parts of the country, local government planning for heat events can be more ad hoc – dependent on the technical capacity of the councils and their perception of the risks posed by heat events.

In addition to activity at the state and territory, local and Commonwealth Government levels, COAG recently adopted the National Strategy for Disaster Resilience (the Strategy), which provides a resilience-based framework complementary to the state and territory plans that provide operational guidance. Developed by the National Emergency Management Committee (NEMC), which is comprised of experts from Commonwealth, state and territory and local governments, the Strategy further conceptualises COAG's agreement in 2009 that 'the future direction for Australian emergency management should be based on achieving community and organisational resilience.'[49] Key elements of the Strategy include:

- It maintains that 'application of a resilience-based approach is not solely the domain of emergency management agencies; rather, it is a shared responsibility between governments, communities, businesses and individuals'.[50]
- It focuses on 'priority areas to build disaster resilient communities in Australia', such as the centrality of risk assessment of disaster management, the importance of communication and education, and the potential for land-use planning 'to prevent or reduce the likelihood of hazards impacting communities.'[51]

The Strategy refers to 'extreme weather events' (particularly noting the possible impact that climate change could have on the frequency or severity of such events), but does not deal directly with heat events.

Gaps and good practice

Through our extensive consultation with stakeholders and our analysis of available documentation, we have identified a number of gaps and aspects of good practice[52] in current planning and response arrangements for heat events in Australia.

Gaps

On the whole, impressive strides have been made in developing plans and procedures to address the unique challenges posed by heat events, while building on existing emergency management arrangements. There are, however, a number of areas where improvements could be made to ensure risks are managed as effectively and efficiently as possible.

The first of these possible areas of improvement is *greater national consistency in key elements underpinning planning and response arrangements for heat events*. Our analysis revealed a number of differences in the 'foundations' of planning and response arrangements across Australia. For example, as noted earlier, there is no nationally agreed definition of what constitutes a heat event. Likewise, there is no consistent approach to determining when a heat event is likely to occur, or to using this information to trigger response arrangements and public warnings. Table 12 provides a summary of the various activation arrangements currently used by those jurisdictions with specific heat event plans.

49 NEMC. (2011). National Strategy for Disaster Resilience. Canberra.
50 NEMC. (2011). National Strategy for Disaster Resilience. Canberra.
51 NEMC. (2011). National Strategy for Disaster Resilience. Canberra.
52 It is important to note that 'good practice' in this context refers to elements of current warning and response arrangements that are effective and of high quality – though are not necessarily the best or only means of mitigating extreme heat events. We identified 'good practice' based on suggestions of stakeholders and the relevant literature, as well as by drawing on our experience of other regulatory and response frameworks.

Stakeholders maintained that greater consistency in these foundational elements would be beneficial because it would:

- Help ensure there is a common understanding across Australia about what a heat event is, what different warnings mean, and what has to be done once a heat warning is announced. Such common understanding would be particularly helpful for individuals visiting from another state or territory during a heat event.
- Facilitate the sharing of tools and good practice across jurisdictions.
- Allow jurisdictions to achieve greater economies of scale in other aspects of their planning and response arrangements. For instance, one stakeholder suggested that, once jurisdictions had an agreed definition and approach to warning and notification, they could concentrate on developing a suite of common educational tools to support their respective planning and response arrangements.

A second area for improvement in current planning and response arrangements is *providing the community with a comprehensive understanding of the risks associated with heat events*. A clear message that arose from our consultations was that the quality of planning and response arrangements for heat events is dependent on the quality of the risk assessment underpinning those arrangements. One stakeholder noted, for example, that it is already possible to reduce the impacts of heat events on critical infrastructure. Infrastructure managers need, however, greater clarity about the future risk posed by heat events so they can build this into their capital and operational plans.

Some jurisdictions have already assessed, or are in the process of assessing, the risks posed by heat events. There would appear benefit, however, in undertaking a national risk assessment (albeit focused at the regional level). Such a risk assessment would achieve economies of scale and be able to pool scarce technical expertise from across the country.

A final area for improvement in current planning and response arrangements is *ensuring there is sufficient focus on long-term outcomes*. At present, most jurisdictions are focused on their immediate response arrangements – what they will do once a heat event has been declared, and what they can do to make their response as effective as possible. While these are admirable goals, less effort has been dedicated to:

- implementing structural changes (e.g. to regulation/standards or to actual infrastructure) that would reduce the impact of heat events.
- encouraging cultural change in how people perceive and act during heat events.
- understanding the long-term impacts of heat events and, in turn, how these can and should be addressed.

Table 12: Summary of activation methods used across jurisdictional heatwave plans

Jurisdiction	*Coverage*	*Warning levels*	*Unit of measurement*	*Expected length of event*	*Forecast period*
Queensland	Southeast Queensland	Heat warning	Apparent temperature	2 days +	1-4 days
		Extreme heat warning	Apparent temperature	2 days +	1-4 days
South Australia	South Australia	Extreme heat advice	Average daily temperature	3 days +	3-5 days
		Extreme heat watch	Average daily temperature	3 days +	48-72 hours
		Extreme heat warning	Average daily temperature	3 days +	0-48 hours
Victoria	Victoria (separated into nine regions)	Heat Health Alert	Average daily temperature	1 day +	Up to 6 days
Western Australia	Perth	Alert	Maximum temperature	1 day +	Advent
		Standby	Average daily temperature	1 day +	1-6 days
		Response	Average daily temperature	3 days +	Arrival

Good practice

There is considerable good practice that exists across current planning and response arrangements for heat events. Examples of this good practice include:

- *A statewide focus* – South Australia's Extreme Heat Plan provides a mechanism to coordinate the preparation and response of all relevant agencies and community organisations. This statewide focus helps to ensure that the full range of direct and indirect impacts of heat events are considered, and that the full spectrum of government and community responses can potentially be brought to bear during a heat event.
- *The nomination of a 'hazard leader'* – the South Australia State Emergency Service (SES) is nominated as the Hazard Leader for 'extreme weather' in South Australia. The SES is thus responsible for reviewing and updating the state's Extreme Heat Plan on an annual basis, and working with other relevant bodies to develop their functional heatwave plans. These arrangements provide a strong institutional foundation for heat event planning in South Australia, and help to ensure functional heat event plans are consistent and avoid duplication.
- *Real-time surveillance* – the New South Wales government has established a Public Health Real-Time Emergency Department Surveillance System (PHREDSS). It provides 'daily monitoring of Emergency Department visits presenting with various health problems grouped into syndromes.'[53] Real-time surveillance not only improves the capacity of health systems to respond to heat events (both in terms of speed and suitability), it also collects valuable data that can be used to inform heat event planning and the development of mitigation programs.
- *Recognition of regional differences* – the Victorian heatwave planning framework divides the state into nine weather forecast districts (based on boundaries previously established by the Country Fire Authority, the Department of Environment and Sustainability and the Bureau of Meteorology). Each district has its own heat health temperature threshold, recognising 'the higher temperatures experienced in northern parts of Victoria.'[54]
- *Focusing on those most at risk* – most planning and response arrangements have mechanisms that ensure those most at risk are prioritised during heat events. The Telecross REDi system in South Australia is particularly notable in this regard (see Table 12). It should be noted that the Telecross REDi approach (which centralises the identification and prioritisation of at-risk individuals at the state level) is only one means of focusing on those most at risk. Other mechanisms may be more effective and efficient, depending on jurisdictional circumstances.
- *Provision of technical guidance* – as part of its broader heatwave framework, the Victorian Government has developed a planning guide for local government. This guide helps to overcome some of the technical and resource constraints faced by local councils, as well as encouraging consistency in local council arrangements.

53 NSW Health. (2010). 'Guideline – Public Health Real-time Emergency Dept Surveillance System (PHREDSS) Public Health Unit Response'. 1 July, Available from: www.health.nsw.gov.au/policies/gl/2010/pdf/GL2010_009.pdf.

54 Victorian Government Department of Health. (2010). Heat Health Alert System 2010-2011. Melbourne.

Box 4: Lessons learned – phone check-ins provide successful reassurance on at-risk individuals

South Australia, Australia
Telecross REDi service (run by the Australian Red Cross)

In 2009, the South Australian government approached the Australian Red Cross to amend their existing Telecross system for the purpose of addressing at-risk individuals in the community during severe heat events. The Telecross system provided reassurance phone calls to those nominated on a register. The adapted system, Telecross REDi consists of three phones calls made to check on the health and wellbeing status of registrants. Individuals on the system, generally those that are isolated, aged or experience mental illness or have a disability are either self-referred, or referred through agencies such as the Royal District Nursing Service. Where issues are identified, the call is escalated and appropriate responses are made. Those consulted with believe the system is effective, highlighting that opportunities exist to use other communication mediums potentially in addition to telephone calls, where they are not deemed appropriate.

Paris, France
Phone register (run by the Social Services Agency)[55, 56]

In 2003, 15,000 deaths were registered relating to the severe heat event experienced in France, 1,294 of these in Paris alone. Nine months following, the Paris Mayor's Office invited 400,000 Parisians to register with the City's Social Service Agency. In 2006, the plan was activated and 13,000 registrants were phoned every other day to check on their health and well being. Where assistance was assessed as needed, registrants were evaluated again by physicians – this led to approximately 800 evaluations, 200 call backs, 30 transportations to cool areas, and 18 received urgent medical attention.

Lessons:

- Developing a register of at-risk individuals and developing methods to 'check up' on their health status appears to be an effective tool to mitigate adverse impacts during heat events.
- Consideration should be given, however, to managing the costs of establishing and maintaining a register and the privacy of at-risk individuals. Some jurisdictions, for example, may wish to create a centralised register while others may prefer to use existing arrangements at the local level.
- Consideration should also be given to ensuring phone check-in services are coordinated and avoid unnecessary overlap. Stakeholders highlighted that, in some cases, phone check-in services can become counter-productive if at-risk individuals are contacted too much by different agencies/individuals.
- Opportunities exist to explore innovative adaptations of such phone systems through advanced technology.

Priority mitigation areas

During our analysis of available documentation and discussions with key stakeholders, we were presented with a number of suggestions about what government should be doing to mitigate the impacts of heat events. In order to provide the community with a better understanding of what can be done, we distilled this information into a series of priority mitigation areas. These represent, from our perspective, 'good practice' and should form the basis of future attempts to manage the risks posed by severe heat events.

The priority mitigation areas we have identified generally fall into one of two categories: decreasing exposure to high temperatures, and managing the impacts of high temperatures (Table 13).

Table 13: Key mitigation areas identified and the respective priority areas

Key mitigation areas	*Priority areas*	
Decrease exposure to high temperatures	• Buildings • Urban ecology and planning • Transport	• Improving access to cooling • Electricity supply
Manage the impacts of high temperatures	• Education • Maintaining responder capacity	• Community response

55 Cadot, E., Rodwin, V.G. & Spira, A. (2007). In the heat of the summer – lessons from the heatwaves in Paris, Journal of Urban Health: Bulletin of the New York Academy of Medicine, 84(4): 466-468.

56 Fouillet, A., Rey, G., Laurent, F., Pavillon, G., Bellec, S., Guihenneuc-Jouyaux, C., Clavel, J., Jougla, E. & Hemon, D. (2006). Excess mortality related to the August 2003 heatwave in France. Int Arch Occup Environ Health, 80, 16-24.

Decreasing exposure to high temperatures

The following priority areas can help decrease the exposure of at-risk individuals and communities to heat events.

Buildings

Building orientation, design and materials used in construction can all heavily influence the impact of heat events on the indoor as well as outdoor environment. Mitigation of, and adaptation to heat events can be improved where buildings can adequately protect inhabitants from the worst impacts by adjusting indoor temperatures.[57] Table 14 highlights an example of several design aspects that may reduce the impact of high temperatures.

Consultations highlighted that new homes being developed, particularly in estate areas, may not be built to respond appropriately to heat events; lacking, for example, eaves of sufficient length, spaces surrounding housing structures and sufficient green spaces to provide adequate shade and cooling. This being said, new dwellings would need to abide by the energy efficiency provisions of the Building Code of Australia. These provisions should positively affect the thermal comfort of residents.

Urban ecology and planning

As previously highlighted, high density living places individuals at risk due to the related urban heat island (UHI) effect. The form and intensity of the UHI within each major city will vary temporally and spatially, as a result of meteorological, geographical (e.g. elevation, sea breezes, frontal and rainfall patterns) and urban development characteristics.[59]

Urban planning and development processes, however, can be used to:

- reduce the UHI effect – ie through building structure materials used in new developments, landscaping and the development of green spaces
- respond to the UHI effect – ie through specific policies and programs recognising that those within urban areas are at an increased risk during extreme heat events.

Table 14: Design aspects to decrease exposure to high temperatures [58]

Design aspect	*Description*	*Environmental benefit*	*Individual benefit*
Green roofs	Roof of a building that is partially or completely covered with vegetation	Carbon sequestration, water retention, energy conservation, reduced greenhouse gas emissions, UHI mitigation	Reduce heat-related illnesses, increase thermal comfort
Use materials with low thermal mass / increase albedo	The reflecting power of a surface. Increasing reflectivity over absorption in building materials	Reduce energy use and greenhouse gas emission, UHI mitigation	Reduce heat-related illnesses, increase thermal comfort
Use building compliance standards that promote environmental design	Six Star building ratings (accepted in all states except Tasmania and the NT), LEED (Leadership in Energy and Environmental Design) compliance standards	Increase building energy efficiency, reduce energy use and greenhouse gas emissions	Reduce heat-related and respiratory illnesses, positive aspects of increased natural light in workplace
Building insulation	Any object used to insulate buildings. Insulation can reduce heat gain	Increase energy efficiency of buildings, reduce energy use and greenhouse gas emissions	Increase thermal comfort, reduce heat-related illnesses and respiratory illnesses

57 Kinney, P.L., O'Neill, M.S., Bell, M.L. & Schwartz, J (2008). Approaches for estimating effects of climate change on heat-related deaths: challenges and opportunities, *Environmental Science & Policy*, 11(1): 87-96.

58 Harlan, S.L. & Ruddell, D.M. (2011). Climate change and health in cities: impacts of heat and air pollution and potential co-benefits from mitigation and adaptation, *Current opinion in Environmental Sustainability*, 3(3):126-134; Kinney, P.L., O'Neill, M.S., Bell, M.L. & Schwartz, J (2008). Approaches for estimating effects of climate change on heat-related deaths: challenges and opportunities, *Environmental Science & Policy*, 11(1): 87-96; O'Neill, M.S., Carter, R., Kish, J.K., Gronlund, C.J., White-Newsome, J.L., Manarolla, X., Zanobetti, A. & Schwartz, J.D. (2009). Preventing heat-related morbidity and mortality: New approaches in a changing climate, *Maturitas*, 64(2), 98-103.

59 Coutts, A.M., Beringer, J. & Tapper, N.J. (2009). Changing urban climate and CO2 emissions: Implications for the development of policies for sustainable cities, *Urban policy and research (in press)*, Routledge, Taylor and Francis Group.

> *"Sixty percent of the global population will reside in urban centres by 2030 and an overwhelming majority of urbanisation is expected to occur in low and middle-income countries"*
>
> *Worldwatch Institute – cited in Harlan & Ruddell, 2011, p.126*

Urban design can also play an important role more broadly in mitigating the impact of heat events, including:

- high density communities with mixed land use and good connectivity promote active transport such as walking and cycling, which can assist in addressing several co-morbidities which place individuals at risk in heat events.
- promoting social cohesion and networks where urban design provides sufficient public spaces, reducing the risk for those otherwise socially isolated.
- reducing emissions and greenhouse gases and subsequent demands on energy sources. This can allow electricity and water to be devoted to essential services such as hospitals and community centres during severe heat events.

Transport

Access to transport has a direct benefit in severe heat events by enabling people to move quickly to cooler areas or airconditioned buildings, and maintaining contact with family, friends and broader support networks. Heat events, however, can constrain the capacity of transport networks through such phenomena as road 'bleeding', rail buckling and system or machine malfunction. There is thus scope for transport infrastructure managers and operators to consider the resilience of transport networks during heat events – particularly in the context of whether public transportation systems are capable of providing appropriate services to at-risk individuals during prolonged periods of high temperature.

Box 5: Lessons learned – how Shanghai responded to urban development to improve outcomes from severe heat[60]

In 1998, Shanghai experienced a devastating heatwave. Recognising its size, urbanisation and density predisposed Shanghai to the UHI effect, several initiatives were run including:

- Shanghai Municipal government adopted strategic planning to landscaping surrounding urban modernisation.
- Establishing a heat/health watch warning system with associated education to the public on the dangers of excessive heat.

Five years on, in 2003 Shanghai recorded the hottest summer in over 50 years. Despite the at-risk population remaining consistent, there was a reduced number of deaths. Literature suggests this might be linked to the establishment of a warning system as well as an increase in:

- the urban green area within Shanghai from 19.1 to 35.2 per cent.
- airconditioners from 68.6 per 100 households in 1998 to 135.8 per 100 households.
- the average per capita living space within Shanghai from 9.7m^2 in 1998 to 13.8m^2 in 2003.

Lesson:

A strategic focus on increasing 'green' space in urban areas, an increase in size of living space (and therefore ventilation) as well as improved airconditioning, may be linked to reduced mortality rates during extreme heat events.

60 Huang, W., Kan, H. & Kovats, S. (2010), The impact of the 2003 heatwave on mortality in Shanghai, China, Scientist of the Total Environment, 408, 2418-20; Tan, J., Zheng, Y., Song, G., Kalkstein, L.S., Kalkstein, A.J. & Tang, X. (2007). Heatwave impacts on mortality in Shanghai, 1998 and 2003, International Journal of Biometeorology, 51, 191-200; Tan, J., Zheng, Y., Tang, X., Guo, C., Li, L., Song, G., Zhen, X., Yuan, D., Kalkstein, A.J., Li, F & Chen, H. (2010). The urban heat island and its impact on heatwaves and human health in Shanghai, International Journal of Biometeorology, 54, 75-84.

Improving access to cooling

A lack of, or impeded, access to airconditioning can increase a person's susceptibility to heat-related illness. Consequently, '[i]ncreasing the proportion of the population who have domestic airconditioning (or other mechanical ventilation units) appears an intuitively simple adaptive strategy for reducing the risk of exposure to heatwaves.'[61] However, literature does caution the use of airconditioning units, highlighting that they:

- place increasing demands on energy sources already potentially strained within a heat event (see 'Infrastructure' section)[62]
- may increase the UHI effect through increased heat production through running airconditioning, particularly overnight[63]
- have the potential to alter physiological acclimatisation that will be necessary if there is an increasing prevalence of extreme heat events in the future[64]
- may not reduce the risk even where airconditioning units are available. Research on the St. Louis heatwave highlighted that individuals at risk, particularly older adults, may not use available airconditioning during extreme heat events. This may be due to either their inability to recognise the need for airconditioning, or alternatively, their reluctance to use it given the high associated costs and their fixed low incomes.[65]

Based on our discussions with key stakeholders, there does appear scope to develop programs aimed at improving access to airconditioning. These programs, however, should be:

- targeted at those most at risk (rather than aimed at the general population)
- broader than simply installing airconditioner units – stakeholders nominated, for example, that there would be value in developing programs to educate at-risk groups about how best to use airconditioners, and to provide financial assistance to certain at-risk groups so they can use their airconditioners without worrying about, or suffering from, financial stress.

Electricity supply

Heat events can place considerable strain on electricity supply networks. During periods of prolonged and unusual high temperatures, demand for electricity generally increases, as individuals and organisations rely more heavily on airconditioning and other cooling devices. Exacerbating this, high temperatures can constrain transmission capacity, reducing the amount of electricity that can be supplied to consumers. In these situations, load shedding (or rolling blackouts) may be necessary until supply is once again able to meet demand. Load shedding can reduce the ability of at-risk groups to stay cool, and can hinder the ability of the boarder emergency management system to respond to heat events (e.g. by affecting power supply to ICT systems, hospitals and transport networks).

Studies have highlighted a number of means by which the resilience of electricity supply networks can be enhanced to manage the risks associated with heat events (and climate change more broadly). Proposed measures include greater:

- consideration of severe heat event risks by infrastructure managers in designing future additions to networks and upgrading existing capacity – particularly interstate interconnectors[66]
- uptake of smart meters and smart appliances – as *Scientific American* states, smart grids are 'expected to have a major impact on how we cope, energy-wise, with many long, hot summers to come, levelling peak demand for electricity with the help of smart appliances (including home chargers for the fleet of electric cars on the way) programmed to dial down energy usage when the grid is threatened with an overload.'[67]

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61 Woodruff, R., Hales, S., Butler, C. & McMichael, A. for the Australian Conservation Foundation and the Australian Medical Association. (2005). Climate change health impacts in Australia – Effects of dramatic CO2 emission reductions. Technical report. National Centre for Epidemiology and Population Health, Canberra.

62 Loughnan, M. (2009). 'Hot spots' project: Spatial vulnerability to heat events in Melbourne Australia. Clayton: Monash University.

63 World Health Organisation (WHO) (2004). Heat-waves: risks and responses. Copenhagen: WHO.

64 Loughnan, M. (2009). 'Hot spots' project: Spatial vulnerability to heat events in Melbourne Australia. Clayton: Monash University.

65 Smoyer KE. (1998) A comparative analysis of heatwaves and associated mortality in St. Louis, Missouri--1980 and 1995. Int J Biometeorol. 42(1), 44-50.

66 Garnaut, Ross (2007), Garnaut Climate Change Review, Cambridge University Press, Melbourne.

67 Greenemeier, Larry (2010), 'How will the smart grid handle heatwaves?', Scientific American, 27 July. Available from: www.scientificamerican.com/article.cfm?id=smart-grid-heat-wave.

Managing the impacts of high temperatures

There are a number of measures that the community can undertake to ensure that its response arrangements are able to manage the impacts of heat events effectively.

Education

Responding effectively to severe heat events requires more than institutional arrangements. It ultimately requires individuals, families and communities to understand:

- what heat events are
- what impacts they can have
- what they can do to mitigate these impacts – both for themselves and for groups most at risk in the community.

Government and community organisations can attempt to engender such cultural change through campaigns aimed at educating the community. The New South Wales Government, for example, has developed a 'Beat the Heat' educational campaign, aimed at improving individual understanding about how they can avoid heat-related illnesses. Box 6 outlines the key messages of the Beat the Heat campaign.

The recently released review of the Victorian Government heatwave framework also highlights the importance of ensuring that educational resources for heat events are widely accessible. The review noted in particular that the target audience of heat event educational resources should be as broad as possible (including, for example, culturally and linguistically diverse (CALD) groups, Aboriginal and Torres Strait Islander groups, and specific at-risk groups). Jurisdictions should also embrace a broad range of formats (such as 'proformas for newsletters, "on hold" phone messages, newspaper advertisements, and radio messages', as well as targeted television campaigns).[68]

Education campaigns can also be targeted at those providing services to at-risk groups. The Victorian Department of Human Services undertakes such campaigns, providing advice to 'community residential services for Victorians with disabilities' about 'managing clients and identifying planning implications to minimise the health impacts of a heat wave.'[69]

"The [2009] heatwave [in Victoria] resulted in higher power usage and network faults, including the unavailability of the Bass Link to Tasmania. As a result, load shedding was necessary to keep the electricity system running. In addition to the load shedding, localised distribution network failures also contributed substantially to the decline in supply reliability."

Australian Energy Regulator

68 Access Economics and the National Ageing Research Institute. (2011), Evaluation of the Victorian Government Heatwave Framework. Prepared for the Department of Health Victoria. January.

69 Victorian Government Department of Health. (2011). Heatwave Plan for Victoria: Protecting health and reducing harm from heatwaves. Melbourne.

Box 6: Key messages of New South Wales' Beat the Heat campaign

- Drink plenty of water.
- Minimise physical activity.
- Check on elderly friends, neighbours and relatives, especially if they live alone.
- If you have an airconditioner, make sure it is working before you need it.
- If you don't have airconditioning, spend time in a cool place like a library, shopping centre or cinema. Try to go early, so you're not outside in the middle of the day.
- Plan your day around the heat – avoid being outdoors between 11am and 3pm.
- Avoid alcoholic, hot or sugary drinks.
- Take cool showers or baths.
- Wear light coloured, loose fitting clothes made from natural fibres like cotton.
- Cool your house by shading windows, shutting curtains and, if it's safe to do so, opening windows at night to let in cool air.

> *"[there is a need to not only] develop, implement and evaluate heat health response plans at the community level, but also to re-evaluate community needs on a regular basis"*
>
> *Yardley et al., 2010, p.677*

Maintaining responder capacity

Providers of essential and community services face unique challenges during severe heat events. On the one hand, they need to maintain a level of service during severe heat events to support the community and help those affected by the heat. However, operating in high temperatures can potentially affect the health and safety of their workforces.

The majority of stakeholders noted that essential and community service providers should develop workforce protection plans for severe heat events – including the development of relevant occupational health and safety procedures and workforce coordination. For example, during periods of severe heat, organisations may seek to put on more staff and/or rotate staff during the hottest time of the day to minimise individual staff exposure to high temperatures.

Community responses

The relevant literature supports that most heat risk factors are place specific to the extent that communities inherently differ socially, economically and geographically from one another.[70] Literature has linked such variations within communities to the extent of adverse affects occurring within past heat events. As a result, responses and frameworks which are developed for, and directed by each community will be important to mitigate adverse effects.

While national directives are important, this recognises the community best understands, and is best placed to implement appropriate and needed responses at the local level.[71 72] Planning should be dynamic and evidenced-based for the related community. Consultations with community service organisations highlighted the need for localised strategies, recognising that they may also empower communities, and that resilience may be strengthened through the development of local networks.

Given that communities change over time, the plans and frameworks should be living documents, where review occurs in a timely manner[73]. This should allow responses to be community specific and responsive to changes in community demographics and needs into the future.

70 Uejio, C.K., Wilhelmi, O.V., Golden, J.S., Mills, D.M., Gulino, S.P. & Samenow, J.P. (2010). Inter-urban societal vulnerability to extreme heat: The role of heat exposure and the built environment, socioeconomics, and neigborhood stability, Health and Place, 17(2): 498-507.

71 Harlan, S.L. & Ruddell, D.M. (2011). Climate change and health in cities: impacts of heat and air pollution and potential co-benefits from mitigation and adaptation, Current opinion in Environmental Sustainability, 3(3):126-134.

72 O'Neill, M.S., Carter, R., Kish, J.K., Gronlund, C.J., White-Newsome, J.L., Manarolla, X., Zanobetti, A. & Schwartz, J.D. (2009). Preventing heat-related morbidity and mortality: New approaches in a changing climate, Maturitas, 64(2), 98-103.

73 Yardley, J., Sigal, R.J. & Kenny, G.P. (2010). Heat health planning: The importance of social and community factors, 21(2): 670-679.

A plan for action

Over the past decade, extreme heat events in southeast Queensland in 2004 and southeast Australia in 2009 have demonstrated the tragic potential of prolonged exposure to unusually high temperatures. Following these events (and drawing on broader perspectives of the risks involved), governments and community organisations across the country have instituted and expanded planning and response arrangements to protect the health and safety of Australians during future heat events.

While elements of these arrangements represent good practice, some areas could be improved to ensure risks are managed as effectively and efficiently as possible. The need for such enhancements is particularly pressing, given our modelling suggests that mortality associated with heat events is likely to increase due to demographic shifts and the changing climate.

In this chapter, we outline how government and the broader community can better manage and reduce the risks posed by heat events. Our 'plan for action' seeks to establish a national framework for severe and extreme heat events. To create this national framework, we propose Australian governments undertake a number of steps to ensure that the national framework has a firm and sustainable basis. We also suggest a number of actions that could be adopted to reduce the impacts of heat events and support individual and community resilience.

Following this, we propose what could form as the basic structure of a national framework for severe and extreme heat events. More specifically, we detail a set of five principles that could govern the framework, as well as a set of tasks that ideally would occur as government and the community prepare, prevent, respond and recover from heat events.

Steps to establish the foundation of a national framework for heat events

Our analysis has revealed that, while many governments and community organisations have begun planning and preparing for heat events, they have generally done so separately from each other. As a result, response arrangements for heat events are based on different understandings of what heat events are and how they can best be managed. For example, there is no common definition of what constitutes a heat event. Nor is there a consistent approach to determining when a heat event is likely to occur, or how this information should be used to trigger response arrangements and public warnings.

Before a national framework can be established, relevant parties must first concentrate on building a common understanding of heat event risks and their future management. To construct this common understanding, we propose Australian governments undertake the following steps.

Agree a national definition of what constitutes a heat event

A national definition is required to:

- ensure there is common understanding about what heat events are
- allow for the development of other foundational components of the framework (e.g. a national assessment of the risks posed by heat events)
- facilitate broader consistency in the development and application of measures to address heat events – across different levels of government and non-government organisations.

Recognising that heat events can vary in their intensity (and, in turn, their impacts on human health and safety), the national definition should establish categories of heat events. This would allow planning and response arrangements to be scalable and thus tailored to identified risks. We propose that two categories of heat events should be established: severe heat events, and extreme heat events.

Agree a nationally consistent approach to measuring and predicting heat events

The detail of this approach will be driven by the agreed national definition of what constitutes a heat event. We believe there would be significant benefit, however, in using the BOM's EHF summary index as the basis of any national approach – given its ability to account for local and contextual factors in anticipating adverse impacts caused by heat events.

In line with observed good practice in Victoria, the national approach to measuring and predicting heat events should incorporate regional-specific thresholds. These would recognise that different areas across Australia have different experiences with extreme temperature variation and different levels of acclimatisation. Regional-specific thresholds would also ensure that emergency management arrangements can be tailored to address risks at a more granular level than that of an entire state or territory – which should, in turn, allow for a more efficient and effective response.

Once the national approach is agreed, BOM should have responsibility for developing a warning system for heat events, and integrating this system into its general suite of warning arrangements. The states and territories, meanwhile, would have responsibility for ensuring that their emergency management arrangements are capable of recognising and acting on heat event-related warnings issued by BOM.

Assess heat event risks

A third foundational step is for the Commonwealth Government to facilitate and publish a comprehensive assessment of the risks associated with heat events. This should assess heat event risks over the short, medium and long term, and at the national, state and territory and regional levels. The risk assessment should aim to provide the general community and their representatives with an authoritative and detailed understanding of the nature and scale of the hazard. It is also intended that the risk assessment would inform and underpin emergency management planning by government and non-government bodies.

Undertaking the risk assessment at the national level would allow Australian governments to achieve economies of scale, and to pool scarce technical expertise. Given its existing range of technical expertise, BOM would be well positioned to facilitate a risk assessment of heat events on behalf of the Commonwealth Government. The process of assessing heat event risks should also draw on broader expertise available across other Commonwealth agencies, the state and territory governments, non-government organisations and relevant research bodies. To ensure that it reflects best available knowledge and science, the risk assessment should be reviewed and updated on a regular basis (e.g. every three-to-five years).

Develop an Australian heat event strategy

The purpose of this strategy document is to articulate what Australia will do, from a whole-of-nation and long-term perspective, to better prevent, prepare, respond and recover from heat events. Informed by the risk assessment outlined, the strategy would fall under and complement the National Strategy for Disaster Resilience. As such, it would emphasise the concept of 'shared responsibility' – that is, 'where political leaders, governments, business and community leaders, and the not-for-profit sector all adopt increased or improved emergency management and advisory roles, and contribute to achieving integrated and coordinated disaster resilience.'[74] Given particular segments of society are more at risk from heat events than others – particularly elderly Australians, those with an existing co-morbidity, and those from a lower socio-economic background – there would be merit in ensuring that the Australian heat event strategy is aligned with the Australian Government's social inclusion agenda. There would also be merit in ensuring the Australian heat event strategy is aligned with the Australian Government's national urban policy – specifically, *Our Cities, Our Future: A National Urban Policy for a productive, sustainable and liveable future*.

It is the opinion of our project advisory group that not-for-profit organisations in particular can and should play a key role in responding to future heat events. These groups generally have considerable expertise in dealing with individuals most at risk during a heat event, and often have established relationships with these individuals. Harnessing this knowledge and these relationships would seem an intuitive and efficient starting point to directing resources to those in need.

Our project advisory group is also of the opinion that there is considerable potential for the broader community to support and complement heat event response arrangements. If government can engage with, and build the capacity of, individuals, then government could increasingly rely on individuals, families and community groups to manage some heat event risks. For instance, government could focus on educating Australians about:

- the dangers posed by heat events – not only for themselves, but for families and friends likely to be at risk.
- simple steps they could take to protect themselves (e.g. drink plenty of water and avoid outdoor activity) and at-risk family and friends (e.g. maintain contact and possibly visit to ensure their living environments are sufficiently cool).

74 COAG (2011), *National Strategy for Disaster Resilience, Canberra.*

Box 7: An example of a possible future targeted approach for at-risk individuals

Ms C is a 27-year-old single mother of Max (three) and Tara (five). Six months ago, Max developed a number of medical conditions including a chronic renal condition. At this time, Ms C had to give up the minimal employment she had been able to engage in to care for Max full time. Due to her lack of income and having no family support in Melbourne, housing became an issue and she approached Charity X for assistance. Charity X was able to find appropriate accommodation for Ms C and her children, which, due to recent changes in standards was equipped with appropriate heating and cooling systems. While working with Ms C and her family her contact at Charity X asked her permission to highlight her at-risk status on a central database so that additional assistance could be offered in case of natural disaster or other extreme circumstances. Ms C agreed. When an extreme heat event alert was put out to all relevant agencies from the Bureau of Meteorology, Royal District Nursing (having Ms C's risk status highlighted by the central data base) contacted Ms C to talk about what Max's needs might be in the coming weather and to organise a visit. The nurse was also able to reassure Ms C that she would be able to apply for a rebate to reimburse her for the cost of keeping the house at a suitable temperature (e.g. through increased use of airconditioning) during the heat event.

Stronger societal bonds and support would not only help address an identified risk factor of heat events, but also potentially reduce the demands on formal government arrangements during such hazards. This would allow government to focus its efforts on those most at risk – such as, individuals with few societal connections and existing co-morbidities (Box 7).

Given the role it currently plays in providing direction and advice on emergency management issues, and its authorship of the *National Strategy for Disaster Resilience*, there would be benefit in NEMC taking responsibility for the development of the Australian heat event strategy. This would also ensure that the strategy development process would have Ministerial Council oversight (specifically, Ministerial Council for Police and Emergency Management – Emergency Management) and be aligned with broader COAG objectives and priorities. NEMC should establish formal arrangements with enHealth to ensure the Australian heatwave strategy is able to draw on sufficient environmental health expertise.

All relevant parties will need to agree the content of the Australian heat event strategy. Nonetheless, through our analysis of the available literature and consultation with key stakeholders across Australia, we have identified a range of actions that could help reduce the impacts of heat events and support individual and community resilience. We propose that these actions should form the basis of the Australian heat event strategy. Drawing on the evidence outlined in the previous chapter, we detail our proposed actions, as follows.

Commit to good practice planning and governance arrangements for heat events

Australia's emergency management arrangements – in general and as they specifically relate to heat events – already display aspects of good practice. These aspects should form the basis of all planning and response arrangements for heat events across Australia. Expressed as prescriptions, they include:

1. States and territories should ensure that planning and response arrangements for severe heat events in their jurisdictions are appropriate and commensurate with identified risks. This should ensure that jurisdictions retain significant flexibility to plan for, and respond to, severe heat events, while taking into account differences that exist between regional environments (and temperature variations), legislative responsibilities and agency structures.
2. If a state or territory decides to develop and implement a severe heat event plan, this should:
   - a be consistent with and complement the jurisdiction's broader emergency management arrangements
   - b have a state-wide focus and consider the full spectrum of government and non-government measures
   - c nominate a hazard leader that would be responsible for developing and maintaining the state-wide plan, providing support to other agencies in developing their functional plans, and ensuring that functional plans are consistent and do not unnecessarily overlap
   - d be reviewed on a regular and transparent basis, drawing on feedback from all relevant bodies (from within and outside government).
3. Local governments and community organisations often have a role in providing services to the community and to at-risk groups in particular. They should seek to ensure that their planning arrangements for severe heat events are commensurate with identified risks, and in line with the roles and expectations assigned to them as part of their relevant state/territory's broader planning arrangements.

Develop nationally consistent core educational material for heat events that can be built on to reflect local differences and arrangements

A number of stakeholders noted that there would be benefit in developing a national set of educational materials for heat events, given:

- heat event risks, and measures to mitigate these risks, are likely to be similar across the country
- the potential for jurisdictions to achieve economies of scale and share costs in the development of such materials.

In line with observed good practice at the state and territory level, such nationally consistent education material would be targeted at:

- individuals – informing them about the impacts of heat events, and everyday actions they can take to manage impacts (including providing assistance to family and friends likely to be at risk)
- individuals and organisations that provide services to at-risk groups – with the intention of enhancing their capacity to identify and manage heat event risks.

Explore the potential of emerging communication technologies (including social media) as a means of leveraging the community's ability to manage heat event risks

Emerging communication technologies (such as text messaging, Facebook and Twitter) appear to offer significant potential in terms of their ability to leverage family and friendship ties during a heat event. For instance, using these technologies (and traditional media), government could implement a multi-channel and multi-target communication strategy. The objective of which would be to better enable individuals to assume responsibility for at-risk friends and family members (Box 8). Examples of key messages to be communicated regarding the risk posed by severe heat events and appropriate ways to respond already exist. Adapting these for a variety of modalities and audiences should be relatively straightforward and has the potential to mobilise significant capacity for care, freeing central community services to focus on those requiring more significant levels of assistance or with fewer social supports.

Emerging communication technologies, and the wealth of knowledge that is increasingly available via the internet, also provide significant opportunity for individuals and community groups to develop their own planning and response arrangements for heat events. Such arrangements may be relatively simple (e.g. a family decided to stay indoors once a heat event emergency has been declared) or increasingly complex (e.g. a group of volunteers using a mixture of social media and physical visits to check up on newly arrived refugees – who would likely be unaware of Australia's climate conditions).

Consider heat event risks in capital and operational planning for transport and electricity supply infrastructure, including the role of smart grids in protecting power supply for at-risk individuals during load shedding

Our analysis has revealed the potential risks that heat events can pose to transport and electricity supply networks. These risks are only likely to grow as the climate continues to change, and the frequency and duration of heat events increase. Once the Australian government undertakes a comprehensive assessment of heat event risks, managers of transport and electricity supply infrastructure should ensure the results of this risk assessment are reflected in their capital and operational planning.

Relevant infrastructure managers and state and territory agencies should also investigate the potential for smart meters and appliances to manage the impacts of heat events on electricity supply.

Box 8: An example of a possible future resilient community response

Mr B is 75 years old and has been suffering from congestive heart failure for several years. Listening to ABC radio in the evening Mr B hears that a severe heat warning has been issued for his local area over the weekend and that those at risk of adverse affects should take precautions. On retiring to bed at 8pm Mr B cannot resist a last look at his email. After opening his iPad, Mr B finds a number of messages from his grandchildren regarding arrangements for the weekend. A Facebook alert has been received by each of them informing them of the factors that increase risk of adverse heat events for the elderly and encouraging them to consider assistance that may be required by relatives and friends in the area affected. When a royal district nursing service contacts Mr B to see how he is managing he is able to reassure them that he will be spending some time with his family.

Explore potential for new or existing programs to modify older buildings to improve the thermal comfort of at-risk individuals

New residential buildings are required to adhere to the energy efficiency provisions of the Building Code of Australia. These provisions indirectly provide some protection for residents from heat stress. Older buildings, however, can suffer from design or material flaws that can negatively affect the thermal comfort of residents. There is potential for government and community organisations to address design and material flaws of older dwellings owned or used by at-risk individuals. Such flaws could be addressed directly (e.g. by increasing eaves overhang, and/or installing insulation) or indirectly (e.g. by installing cooling systems, such as fans or airconditioners).

The home modification and maintenance element under the Home and Community Care (HACC) program would appear to be a prospective starting point to modify older buildings to improve the thermal comfort of at-risk individuals.

Consider heat event risks in urban planning and development approval processes as well as urban landscaping and water policies

How cities are designed can play an important role in reducing the UHI effect and, in turn, the impact of heat events. Examples from around the world – such as in Shanghai and Chicago – highlight possible approaches that could be taken, such as increasing vegetation and rooftop gardens.

Once the Australian government undertakes a comprehensive assessment of heat event risks, state and territory governments and local councils should ensure the results of this risk assessment are reflected in their urban planning and development approval processes.

Establish a research program to address knowledge gaps

Our research has revealed that there are a number of aspects about heat events that remain under-examined or unexplored – particularly around:

- *Cooling rooms* (ie airconditioned government or community centres where individuals most at-risk can congregate during heat events). While many stakeholders highlighted cooling rooms as a possible means of mitigating heat event impacts, questions remain about:
  - their effectiveness (particularly given that travelling to a cooling room may expose individuals to higher temperatures), and
  - legal culpability (e.g. to what extent is the operator of a cooling room responsible for the health and safety of people using the cooling room?).
- *Accurately and consistently attributing morbidity and mortality to heat events.*
- *The impacts of heat events over the long term.* Numerous stakeholders noted that there is a lack of research about how heat events affect individuals and communities in the long-term.

There would be value in the NEMC (as custodian of the Australian heat event strategy) further defining these (and other) knowledge gaps, and establishing a research program to address them over a defined period.

The basic structure of a national framework

In the following sections, we propose what could form the basic structure of a national framework for severe and extreme heat events. More specifically, we detail a set of five principles that could govern the framework, as well as a set of tasks that ideally would occur as government and the community prepare, prevent, respond and recover in relation to heat events.

Principles of a national approach

Principles are vital to any policy and regulatory framework. They provide the foundation stones on which a framework can be built, as well as an intellectual (and often moral) beacon to guide how others should implement the framework. Drawing on our extensive research and the expertise of our Advisory Group members, we have developed the following principles for the national framework.

Prioritise individuals, communities and locations most at risk

As we detailed earlier, not every person is equally at risk during a severe heat event. Due to a range of possible factors (Table 15), some individuals, communities and locations are more at risk than others. Prioritising those identified as being most at risk should help ensure that planning and response arrangements are effective, efficient and have the greatest consequence.

Recognise regional differences and circumstances, and harness the actual and latent capacity of social networks and local institutions

There is no universal severe heat event experience. Nor is there a 'one size fits all' approach to managing severe heat event risks. Each region of Australia has a different climate. The nature, frequency and intensity of severe heat events thus differs from region to region. Likewise, jurisdictional arrangements and support networks vary across Australia. Planning and response arrangements need to adapt to and leverage these differences in order to manage risks effectively.

This notwithstanding, there are common areas of strength across Australia. Social networks – ranging from family ties to sporting clubs to mass websites such as Facebook – provide unique means of connecting people and have the potential to buttress individual and community resilience during natural disasters. Likewise, local institutions, which often have intimate knowledge of local conditions and those most at risk, have significant potential to inform planning arrangements and support response and recovery activities.

Recognise interdependencies between planning, preparation, prevention, response and recovery

The planning, preparedness, prevention, response and recovery framework underpins emergency management in Australia. It is important in implementing this framework that each element is not considered separately, but the interdependencies between the elements are recognised. For instance, sufficient investments in prevention can reduce the demands on response during a severe heat event. The effectiveness of investments in prevention, however, is dependent on the quality of the planning process.

Enable a response that is integrated (using appropriate segments of the community and levels of government) and scalable (recognising that the impacts of heat can be severe and extreme)

Similar to Australia's general approach to emergency management, arrangements for severe heat events should enable a response that draws on the capacity and expertise of all relevant bodies. Planning and response arrangements should also have the potential to be scalable. While all severe heat events can cause adverse impacts, some severe heat events can be more intense – and devastating than others. Planning and response arrangements should thus be able to differentiate between those heat events that are *severe* and those that are *extreme* – and escalate considerably in the case of the latter.

Table 15: Identified risk factors

Physiological	*Contextual*
Age	Geographical location
Gender	Access to airconditioning
Existing co-morbidities and associated medication	Outdoor exposure
Acclimatisation	Education surrounding heat events
	Social interaction/isolation
	Socio-economic status
	Transport accessibility/mobility

Be affordable and achievable

The community does not have endless resources to dedicate to emergency management. Governments and community organisations thus need to design and implement arrangements for severe heat events that are affordable and achievable – yet are still able to manage identified risks effectively.

Preventing, preparing, responding and recovering from heat events

In Table 16, we provide guidance about what tasks would ideally occur as government and the community plans and responds to future heat events. We have categorised our guidance using the prevent, prepare, respond and recover (PPRR) framework (Table 16), including a specific section that focuses on planning.

Table 16: The PPRR framework[75]

Title	*Description*
Prevention	'Preventing emergencies is referred to as "prevention". Prevention is measures to eliminate or reduce the incidence or severity of emergencies. These measures can be physical or legal measures, such as clearing leaf litter from a household or Total Fire Ban days.'
Preparedness	'The process of preparing for an emergency is called "preparedness". Preparedness is a variety of measures designed to ensure that, should an emergency occur, communities, resources and services are capable of coping with the effects. These measures include different resources, services, and actions.'
Response	'Responding to emergencies is referred to as "response". Response is action taken and measures planned in anticipation of, during, and immediately after an emergency to ensure that its effects are minimised, and that people affected are given immediate relief and support.'
Recovery	'Recovering from emergencies is referred to as "recovery". Recovery is a coordinated process of supporting emergency-affected communities in reconstruction of the physical infrastructure and restoration of emotional, social, economic and physical wellbeing.'

Governments and community organisations thus need to design and implement arrangements for severe heat events that are affordable and achievable – yet are still able to manage identified risks effectively.

75 Attorney-General's Department. (2011). 'Emergency management in Australia'. Available from: http://ema.gov.au/www/emaweb/emaweb.nsf/Page/EmergencyManagement_EmergencyManagementApproaches.

Table 17: Planning, Prevention, Preparedness, Response and Recovery

	National	*State and territory*	*Local*	*Individual and community*
Planning	Agree national definition for heat events and establish national warning system. Undertake comprehensive assessment of heat event risks. This assessment should be reviewed and updated every three to five years. Develop and maintain an Australian heat event strategy.	Develop a heat event planning framework that is commensurate with identified risks. If a specific heat event plan is developed, this should: • be consistent with broader emergency management arrangements • have a state-wide focus and consider the full spectrum of government and non-government measures • nominate a hazard leader, that is responsible for the plan, providing supporting to other agencies, and ensuring functional plans are consistent and do not overlap • recognise that heat events will often occur together with bushfire and infrastructure outages which will also place pressures on emergency services • be reviewed on a regular and transparent basis. Essential, emergency, health and social services to undertake workforce protection planning for heat events.	Ensure planning arrangements for heat events are commensurate with identified risks, and in line with the roles and expectations assigned to them as part of their relevant state or territory's broader planning arrangements. Essential, emergency, health and social services to undertake workforce protection planning for heat events.	Develop personal, family or community plan to respond to heat events.
Prevention	Explore potential for national and cross-jurisdictional programs and regulation to reduce the impacts of heat events.	Explore potential for jurisdictional programs and regulation to reduce the impacts of heat events.	Explore potential for local programs to reduce the impacts of heat events.	Explore ways of reducing the impacts of heat events at the personal, family and/or community level.
Preparedness	Develop and maintain nationally consistent education material.	Embed nationally consistent education material in targeted and seasonal communication campaigns. Coordinate database of individuals identified as being most at risk during a heat event – to support response and recovery.	Embed nationally consistent education material in targeted and seasonal communication campaigns. Contribute to at-risk database.	Understand heat event risks and what can be done to help at-risk family members, friends and neighbours.

	National	*State and territory*	*Local*	*Individual and community*
Response	Bureau of Meteorology notifies relevant jurisdictions and Emergency Management Australia about impending heat event (in line with agreed thresholds and forecast period). Bureau of Meteorology remains closely engaged during response. Broader Australian government to provide support, if required.	Activate relevant response plan, depending on warning level provided by Bureau of Meteorology. Response should align with standard emergency management practice. Appropriate warnings and messages provided to community, at-risk individuals, and those responsible for at-risk individuals. Initiate real-time data collection and monitoring of heat event impacts.	Activate relevant response plan, depending on warning level provided by Bureau of Meteorology and broader jurisdictional arrangements. In alignment with broader jurisdictional arrangements, engage with community, at-risk individuals, and those responsible for at-risk individuals. Contribute to real-time data collection and monitoring of heat event impacts, if required.	Activate personal, family and/or community response plans. Maintain personal health and safety, and that of dependents. Check-up on and monitor at-risk friends, family members and neighbours.
Recovery	Contribute to mandated debrief (led by the state or territory government), if required.	Mandated debrief and review of response – recommendations from which should be used to update heat event planning. Continue to monitor impact.	Contribute to mandated debrief (led by the state or territory government), if required. Continue to monitor impact.	Contribute to mandated debrief, if willing.

Appendices

Appendix A – Heat-related illnesses

The following table details the escalating symptoms of heat-related illnesses that may be experienced during a heat event.

Table 18: Escalating symptoms of heat-related illnesses

Name	*Description*
Heat rash	Small red itchy papules appear on the face, neck, upper chest, under breast, groin and scrotum areas. Attributed to heavy sweating during hot/humid weather.
Heat oedema	Oedema of the lower limbs, usually within the ankles. Attributed to heat-induced peripheral vasodilatation and retention of water and salt.
Heat cramps	Painful muscular spasms occur, most often in the legs, arms or abdomen, usually at the end of sustained exercise. Attributed to dehydration, loss of electrolytes through heavy sweating and muscle fatigue.
Heat syncope	Brief loss of consciousness or orthostatic dizziness. Common in individuals with cardiovascular disease or taking diuretics, before being acclimatised. Attributed to dehydration, peripheral vasodilation and decreased venous return, reducing cardiac output.
Heat exhaustion	Symptoms include intense thirst, weakness, discomfort, anxiety, dizziness, fainting and headache. Core temperature may be normal, subnormal or slightly elevated (less than 40°C). Pulse is thready with postural hypotension and rapid shallow breathing. There is no mental status alteration. Attributed to water and/or salt depletion resulting from exposure to high environmental heat or strenuous physical exercise.
Heat stroke	Body temperature rapidly increases to greater than 40°C and is associated with central nervous system abnormalities, such as stupor, confusion or coma. Hot dry skin, nausea, hypotension, tachycardia and tachypnoea are often present. Results from exposure to a high ambient temperature (classic heat stroke) or secondary to vigorous physical activity (exertional heat stroke) overwhelming the heat dissipating mechanisms.

Appendix B – Climatic conditions

Excess Heat Factor (EHF)

The Commonwealth Government Bureau of Meteorology (BOM) has developed excess heat indices. Analysis of historical index data shows high correlation with impacts of severe heat events, and is currently being proposed as the key indicator in predicting future extreme heat events.

The summary index, called the EHF, consists of maximum and minimum temperatures, considering their relativities to recent and historical temperatures in that location and captures the inability to shed heat load when minimum temperature remains high. The Excess Heat Factor (EHF) value is constructed by multiplying a factor that represents a short-term temperature anomaly factor (heat stress) by a long-term temperature anomaly (excess heat). These factors are defined as follows:

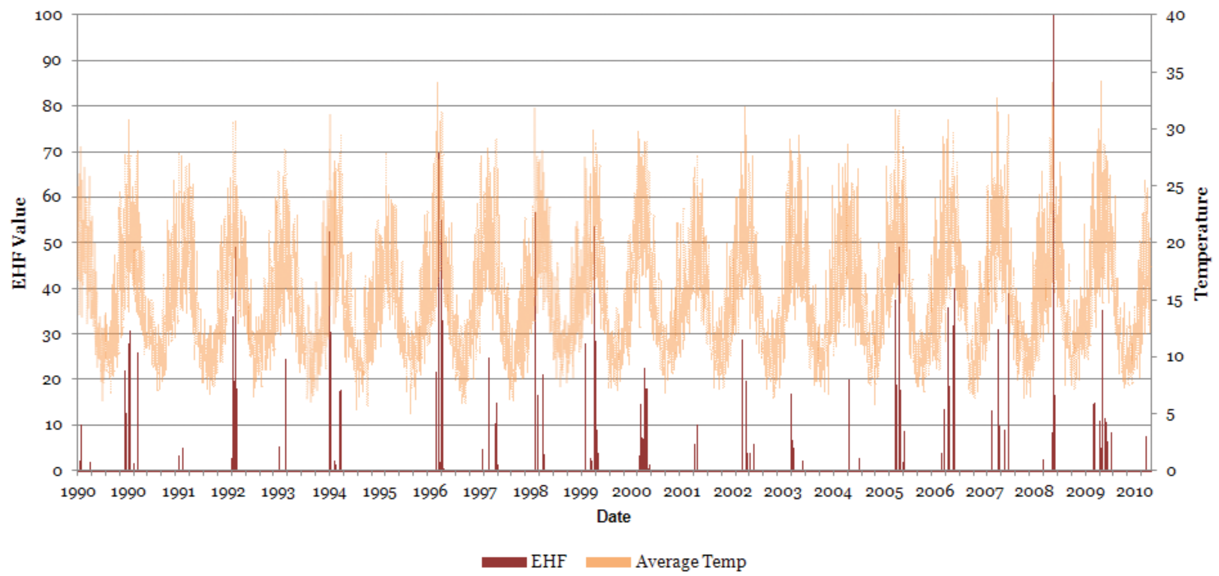
Excess heat: Unusually high heat that is not sufficiently discharged overnight due to unusually high overnight temperature. Maximum and subsequent minimum temperatures averaged over a three day period are compared against a climate reference value. This is expressed as a long term (climate scale) temperature anomaly.

Heat stress: A period of heat which is warmer, on average, than the recent past. Maximum and subsequent minimum temperatures averaged over a three day period and the previous 30 days are compared. This is expressed as a short term (acclimatisation) temperature anomaly.

Excess Heat Factor (EHF): The combined effect of Excess Heat and Heat Stress calculated as an index to provide a comparative measure of impact, load, duration and spatial distribution of heatwave. Heatwave conditions exist when the EHF is greater than zero.[76]

The following graphs show 20 year EHF histories for Melbourne, Sydney and Brisbane and highlight the differences in climatology across Australia and demonstrate the ability of the EHF index to respond to *variation* in observed temperatures in each location highlighting past heat events.

Figure 12: Historical EHF values for Melbourne 1990-2010



Note: EHF values exceeding 100 have not been presented.

76 These definitions are taken from an abstract titled “Heatwave defined as a heat impact event for all community and business sectors in Australia” as submitted by John Nairn of the BOM to the International Conference on Biometeorology to be held in December 2011 and in preparation for submission as a journal article at a later date.

Figure 13: Historical EHF values for Sydney 1990-2010

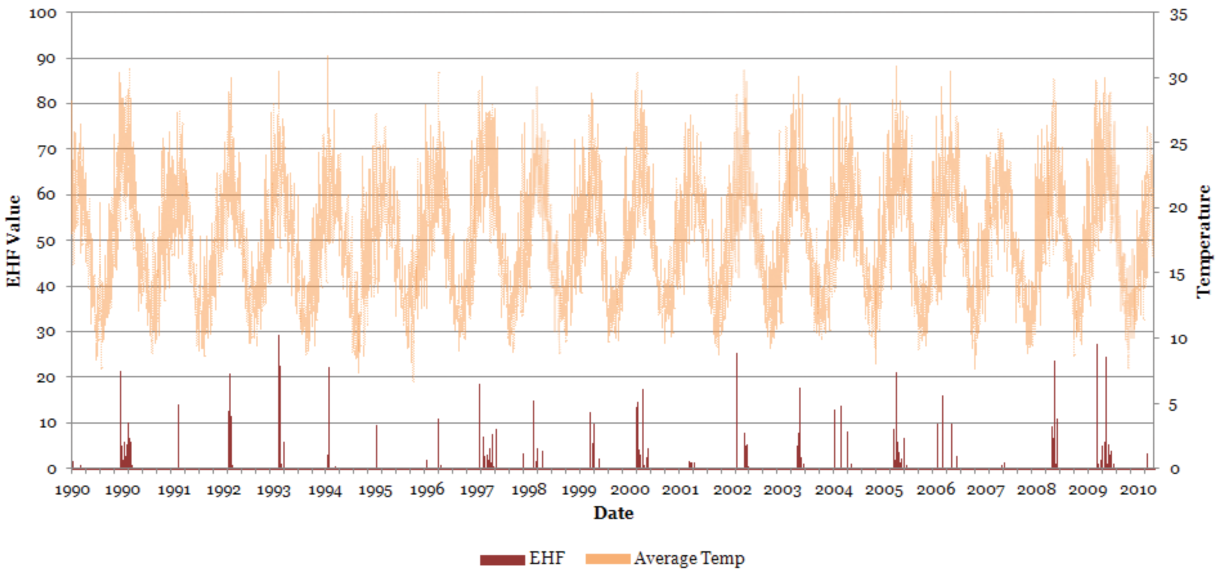
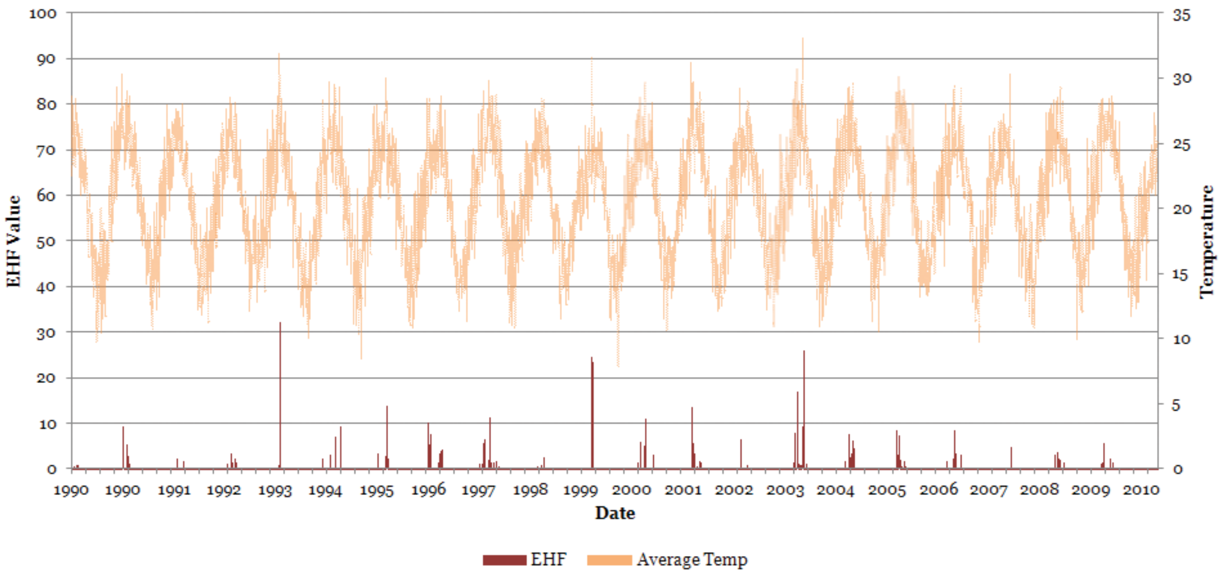


Figure 14: Historical EHF values for Brisbane 1990-2010



Case Studies – evolution of past heat events

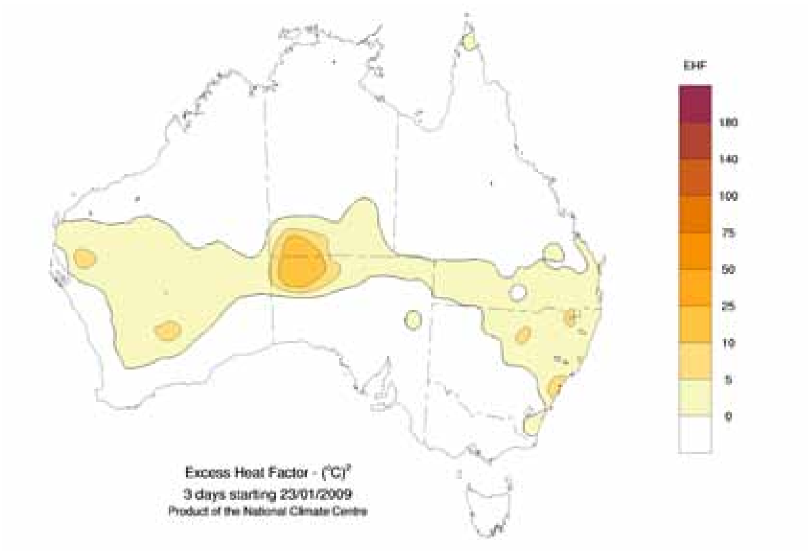
2009 Heat event (Melbourne, Adelaide and southern regions)

Development of heat event

The figures below show a time series of the development of the EHF across Australia during the heat event which occured over the period 23 January to 9 February 2009.

Figure 15: 23-26 January 2009

Heatwave across middle of Australia rapidly spread south and intensified, becoming a severe heatwave over most of South Australia, Victoria and western NSW by 26 January 2009.



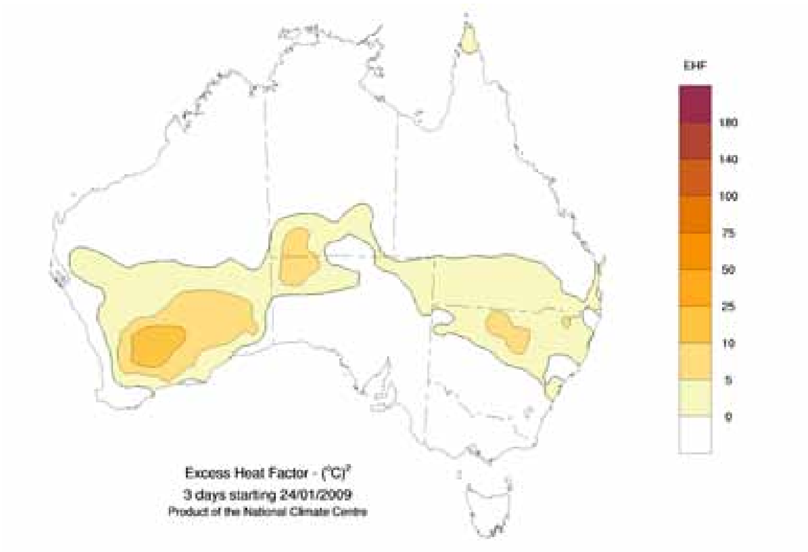
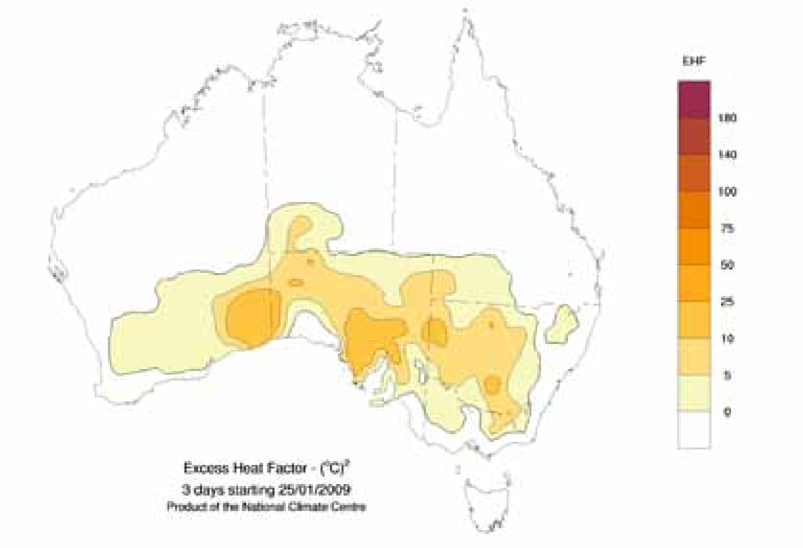


Figure 15: 23-26 January 2009 (continued)



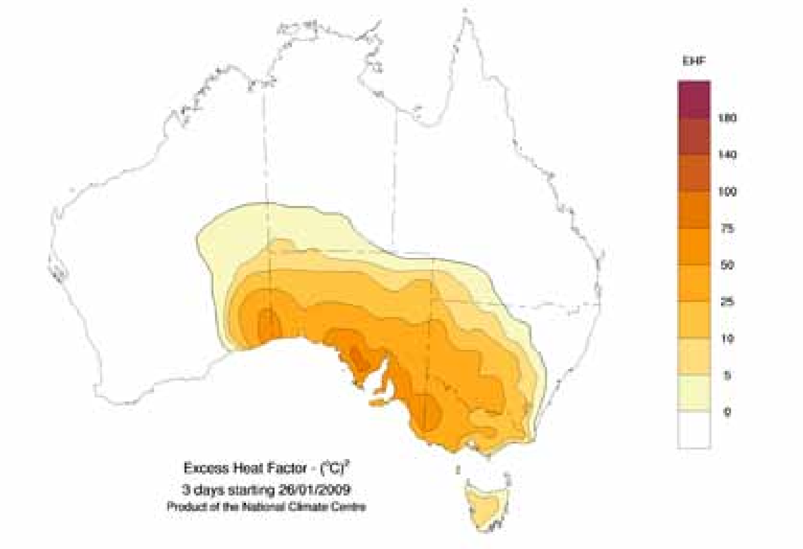


Figure 16: 27-30 January 2009

Severe heatwave conditions become extreme over southern South Australia and Victoria. The EHF values for many locations peak on 28 January.

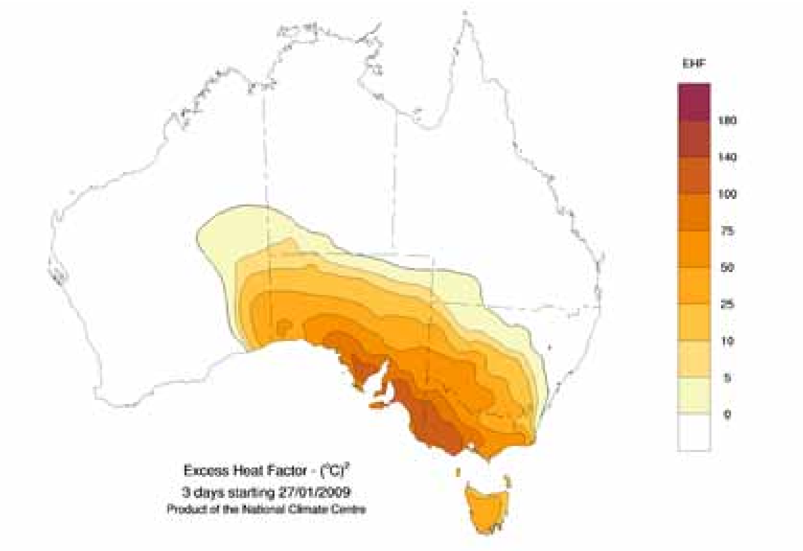
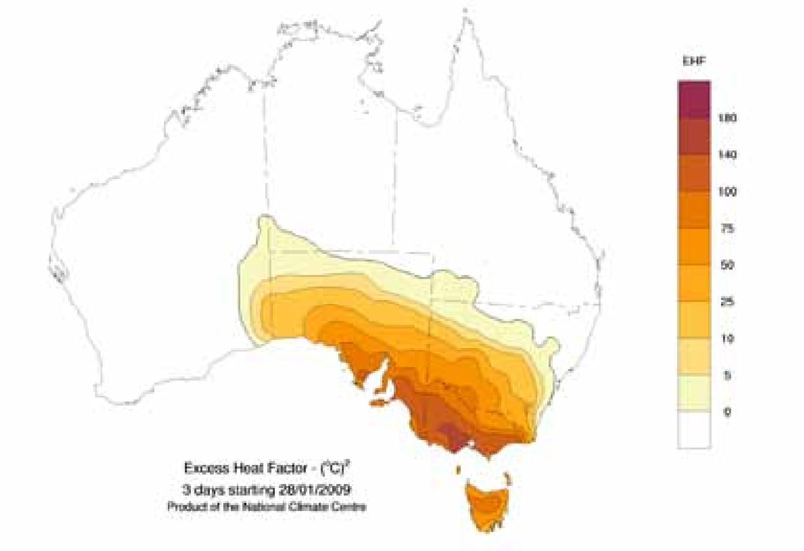
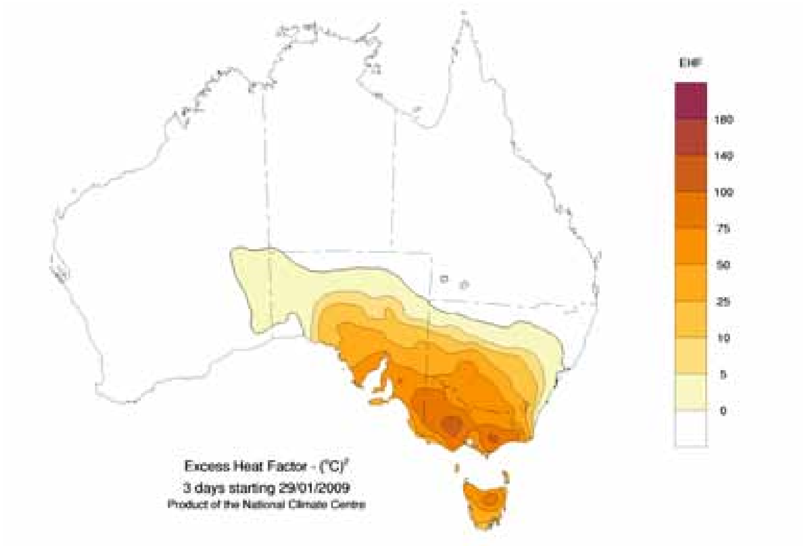


Figure 16: 27-30 January 2009 (continued)





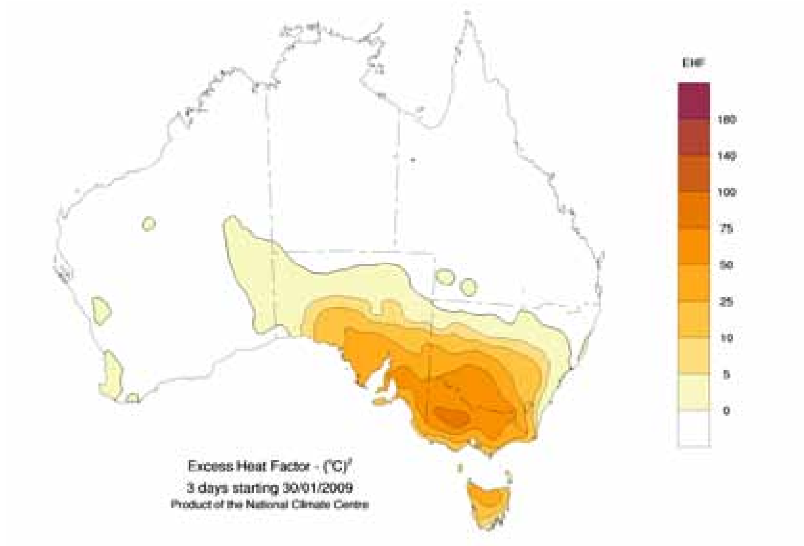
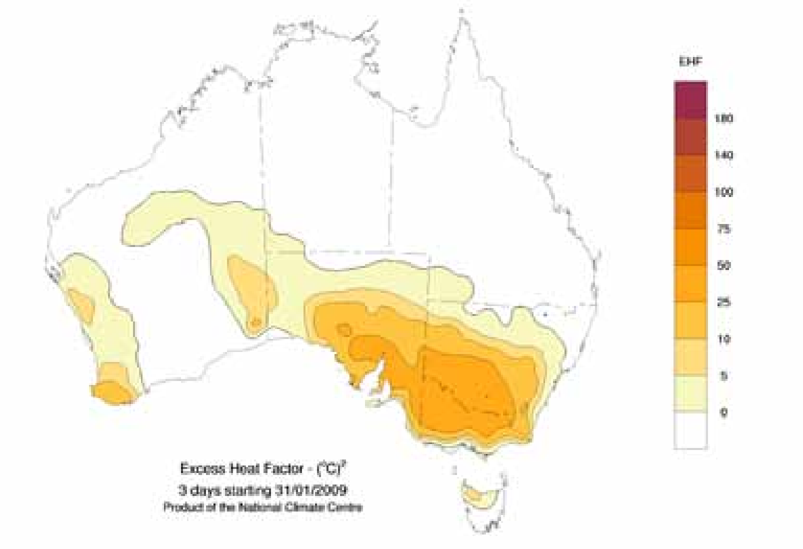
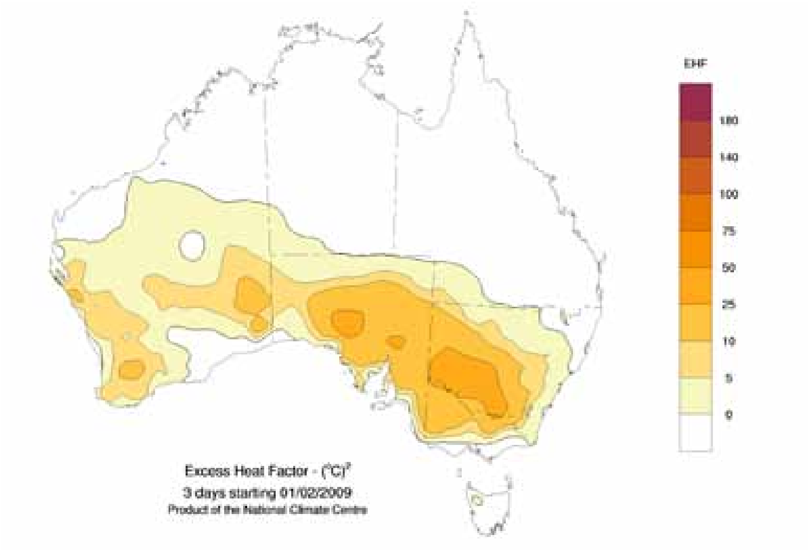


Figure 17: 31 January to 3 February 2009

Extensive area of heatwaves across southern half of Australia. Severe heatwave conditions slowly contract inland.





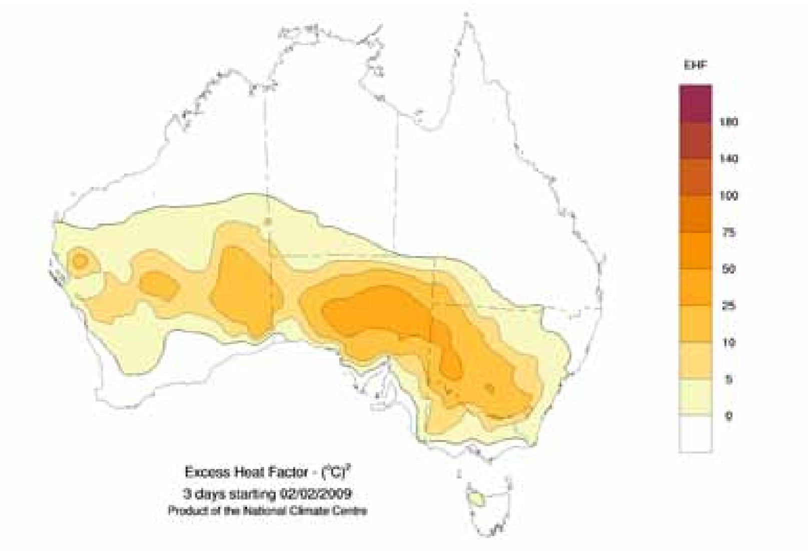


Figure 17: 31 January to 3 February 2009 (continued)

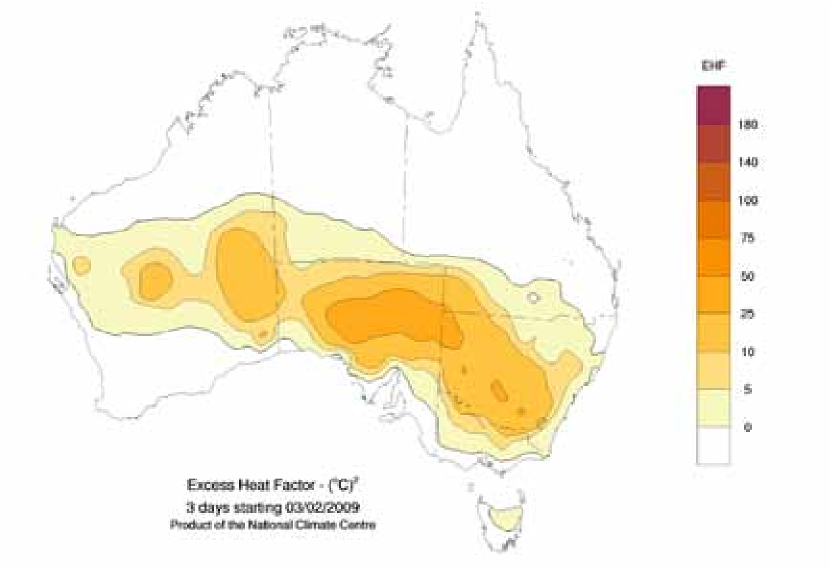
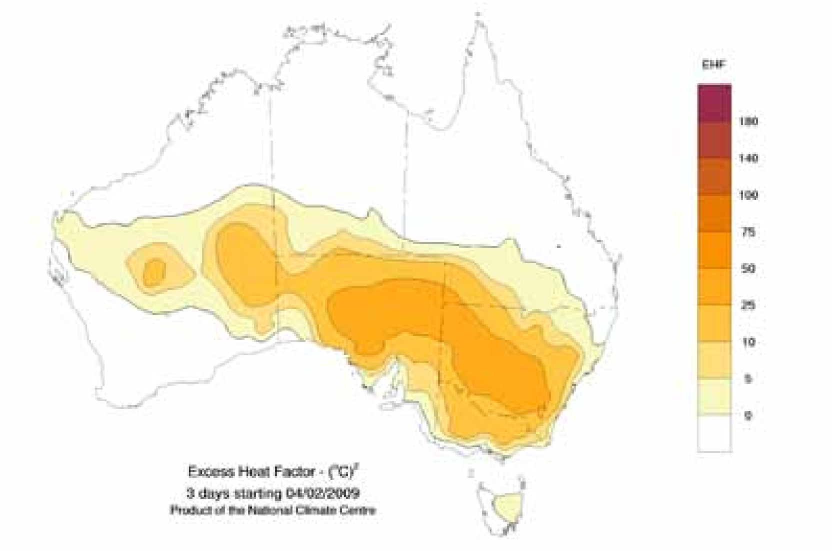


Figure 18: 4-7 February 2009

Southern Australian heatwave slowly eases from the west. Inland severe heatwave conditions contract into NSW before easing.



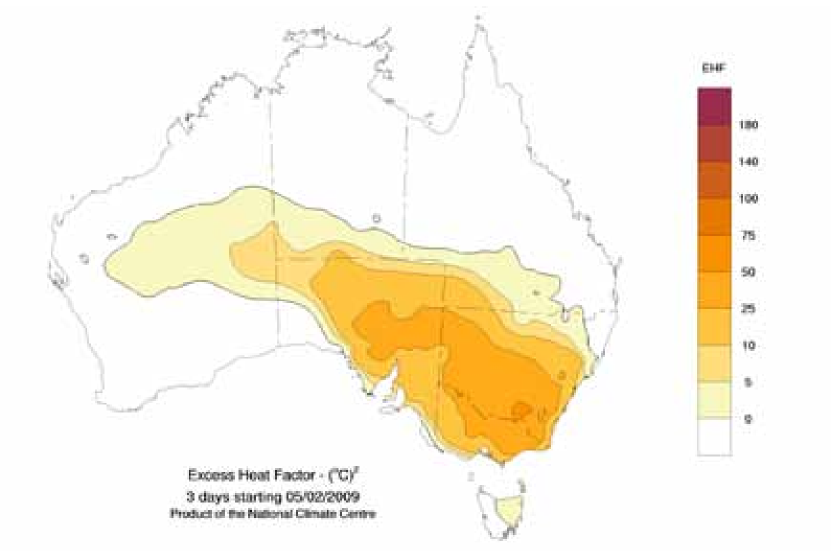
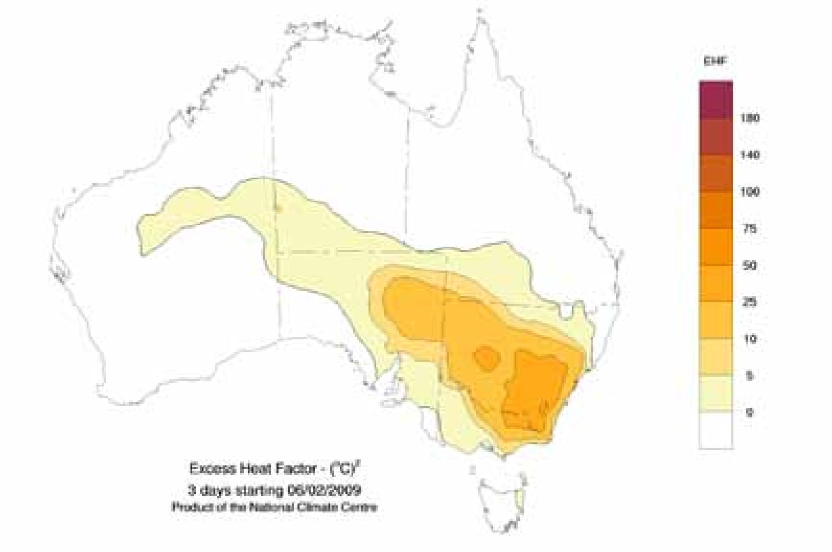
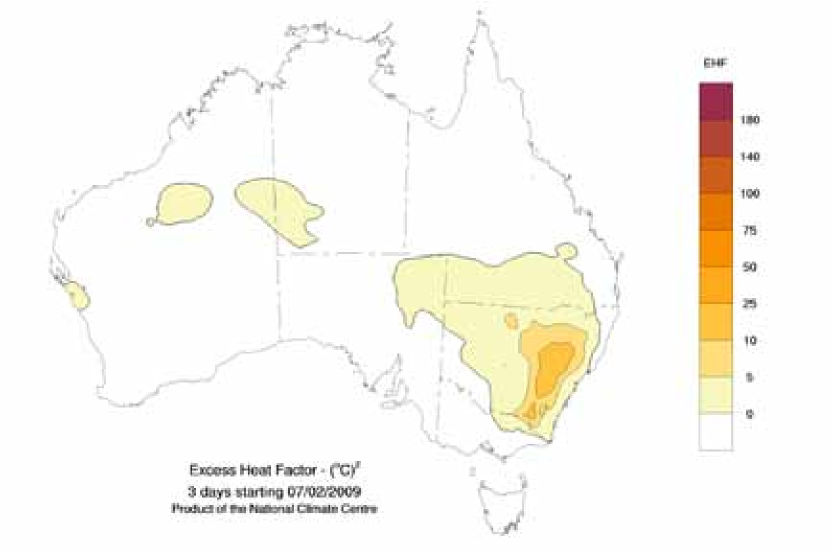


Figure 18: 4-7 February 2009 (continued)



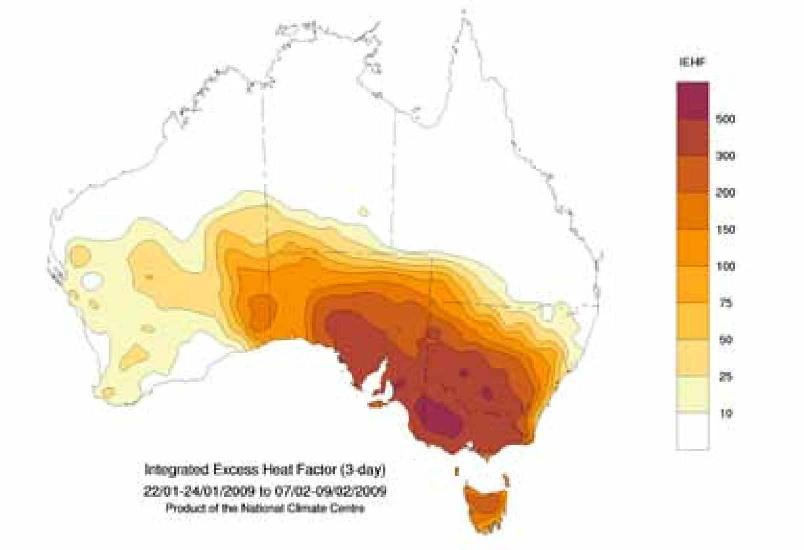


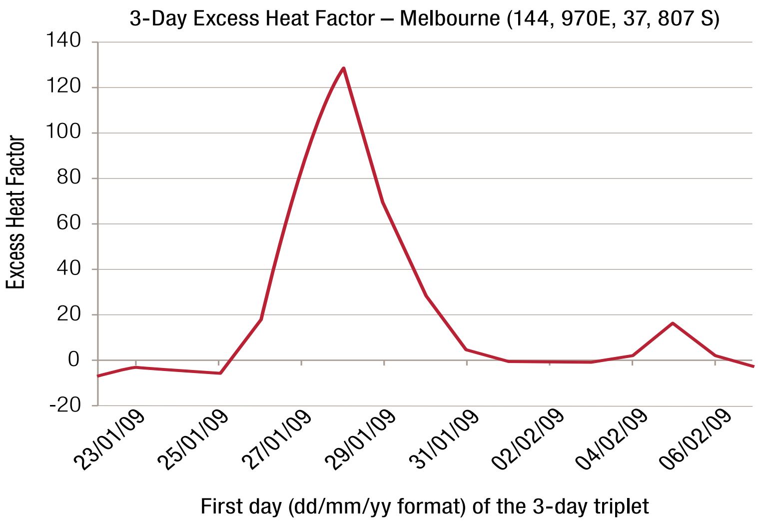
Summary of heat load

The figure below shows the total EHF load during the event and the EHF factor for Melbourne.

Figure 19: 23 January to 7 February 2009

Total Excess Heat Factor Load and Melbourne time series of EHF.





We can see that the overall event load was greatest in Victoria, parts of South Australia and southern inland parts of New South Wales.

Figure 19 shows that the highest daily EHFs were recorded in the southeast corner of the country. However, as the heat event dissipated the heatwave conditions shifted inland generating high event loads over a broader inland area. These inland locations saw an event which was not so extreme at its peak but which lasted longer.

Brisbane 1994

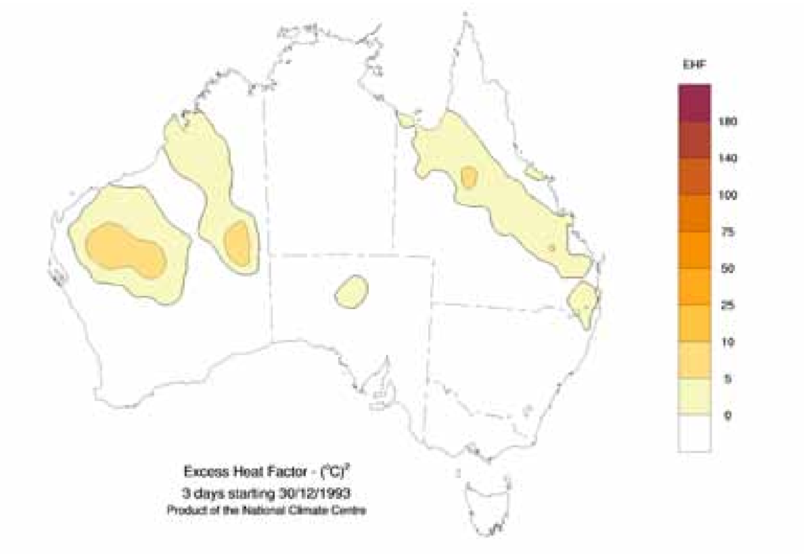
Development of heat event

The figures below show a time series of the development of the EHF across Australia during the heat event which occured over the period 30 December 1993 to 13 January 1994.

Summary of heat load

Figure 20: 30 December 1993 to 2 January 1994

Heatwave conditions gradually develop, predominantly in Queensland and Western Australia.



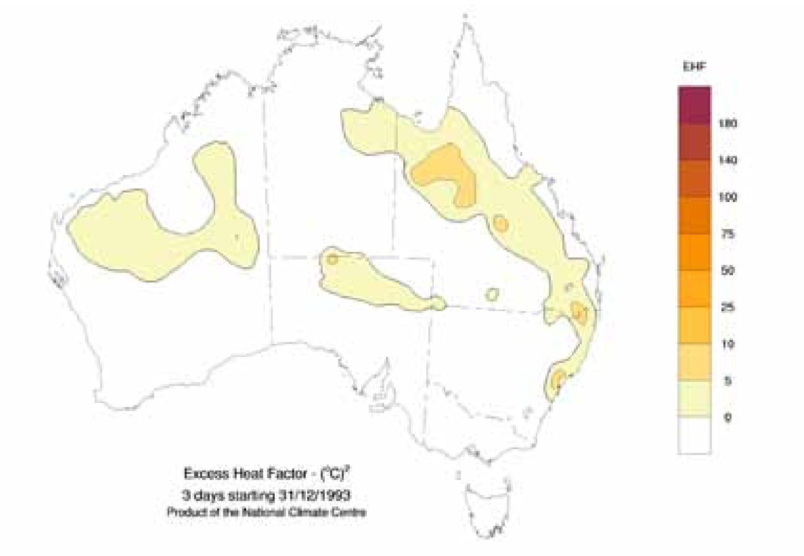
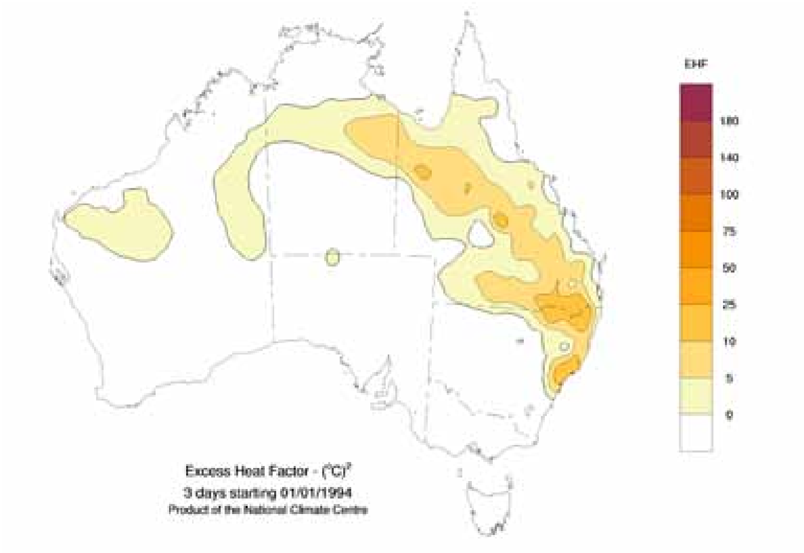


Figure 20: 30 December 1993 to 2 January 1994 (continued)



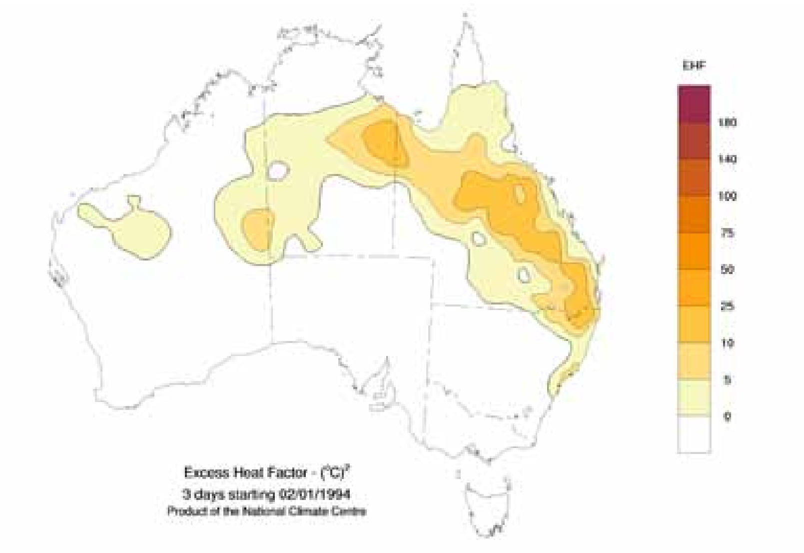
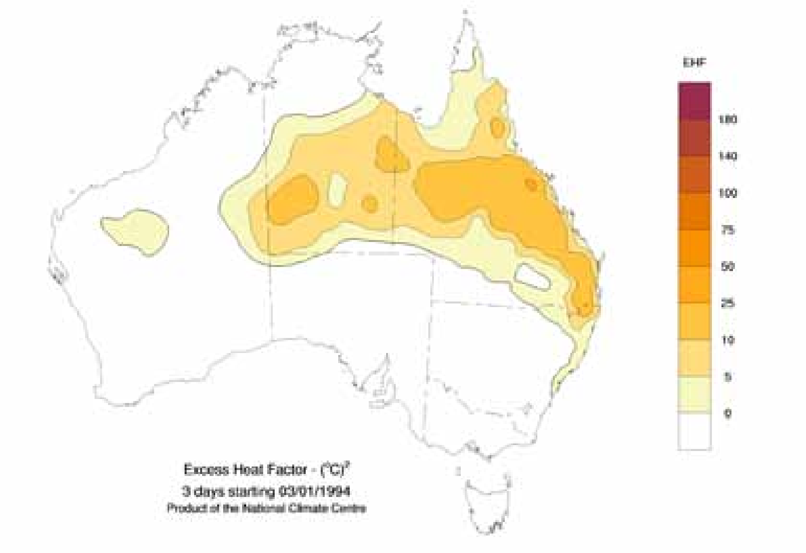


Figure 21: 3-6 January 1994

Increasing intensity of EHF, especially in Queensland near the coast and extending into northern New South Wales.



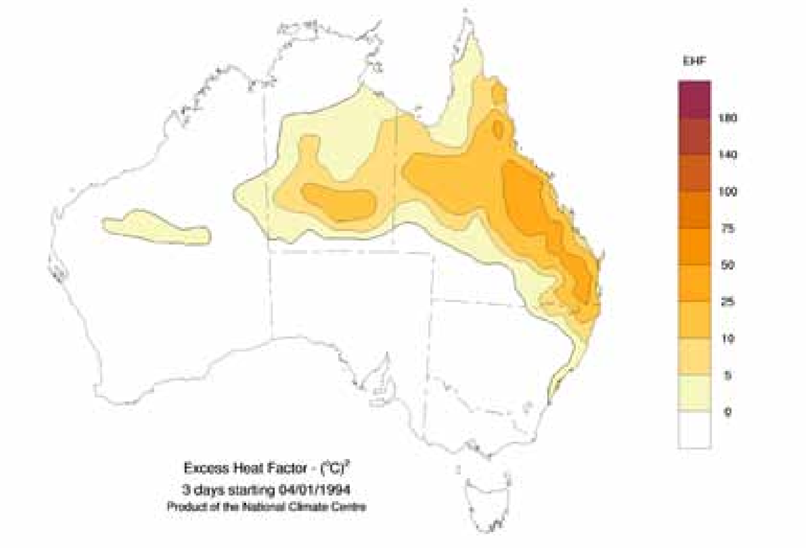
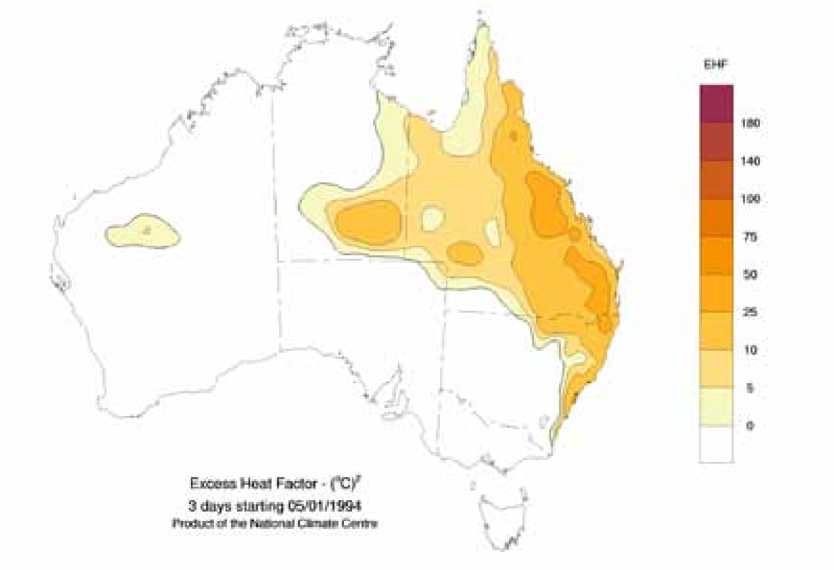


Figure 21: 3-6 January 1994 (continued)



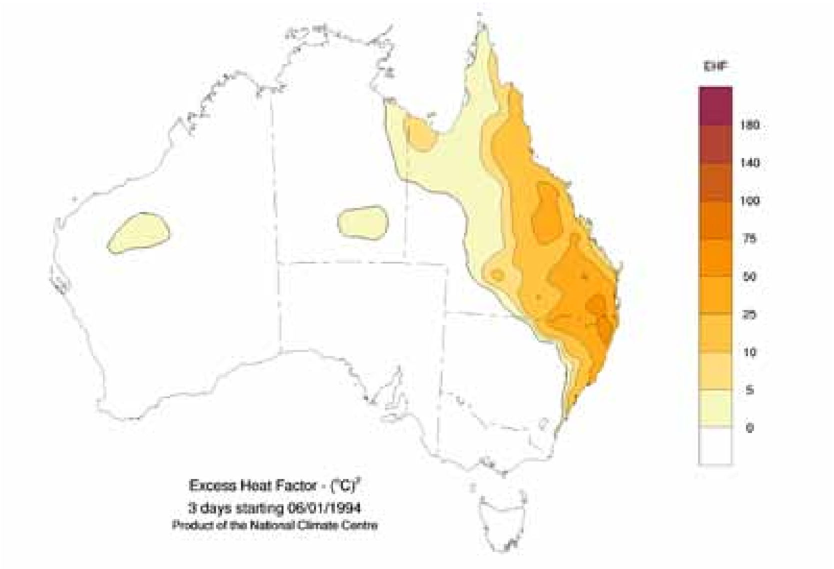
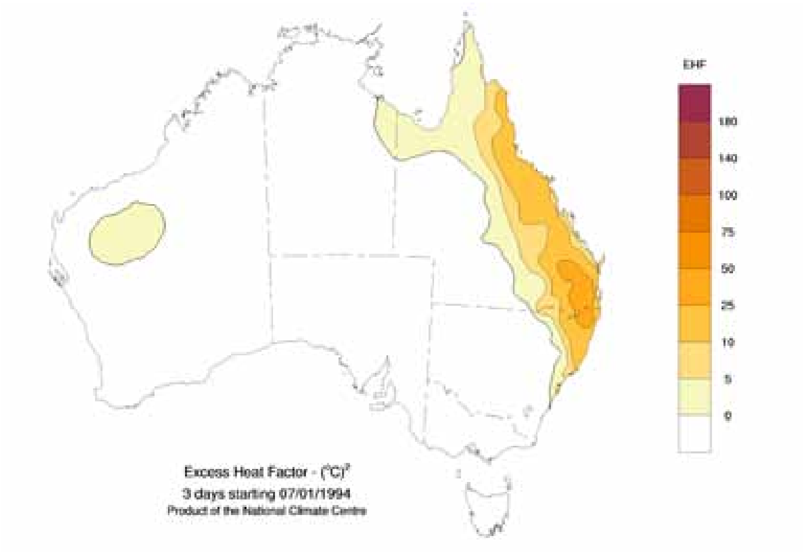
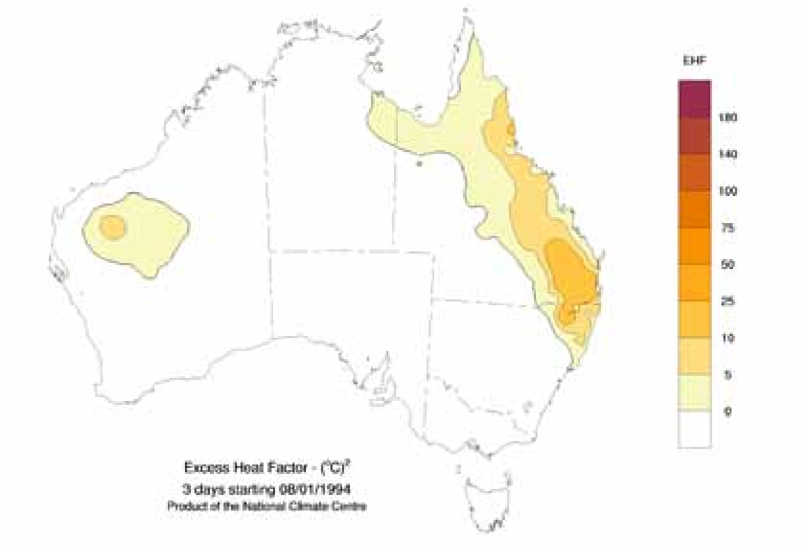


Figure 22: 7-13 January 1994

EHF intensity eases in the east, then redevelops over central Australia. Figure 22 shows that for this event the highest daily EHFs were recorded in the mid north east section of the country with the area around Brisbane being the only location achieving EHF values above 30.





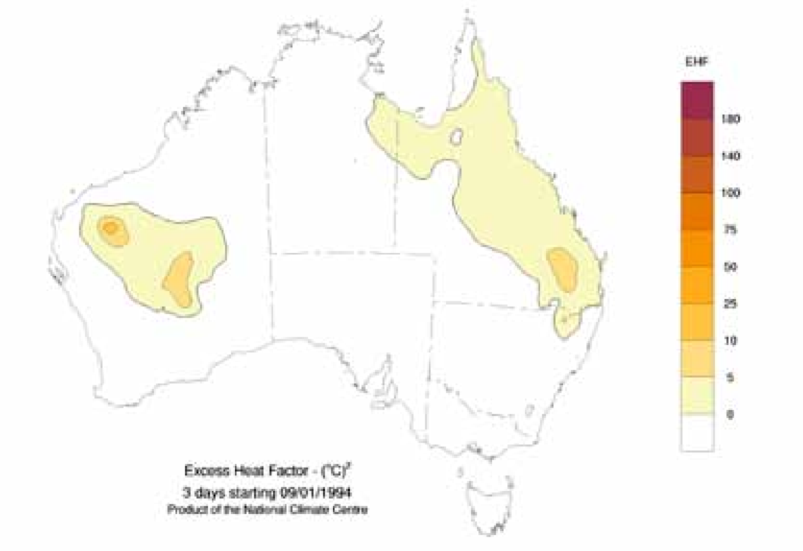
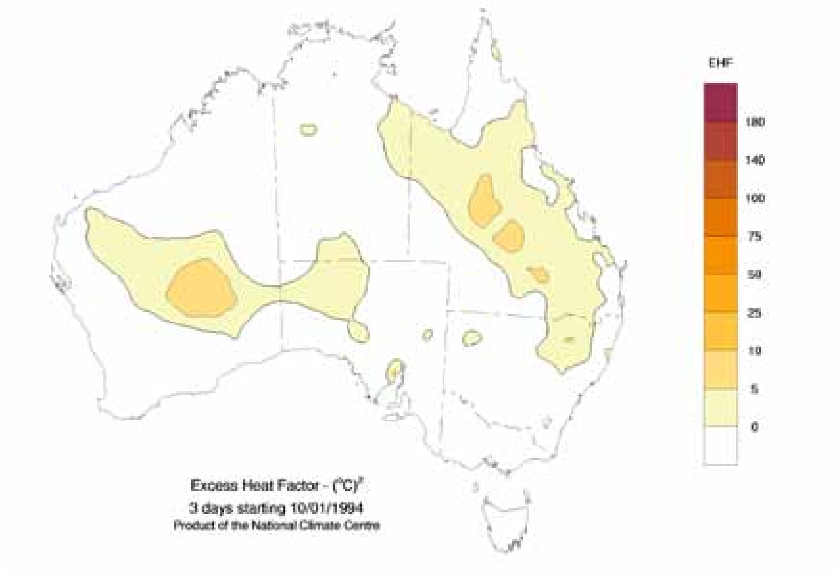


Figure 22: 7-13 January 1994 (continued)



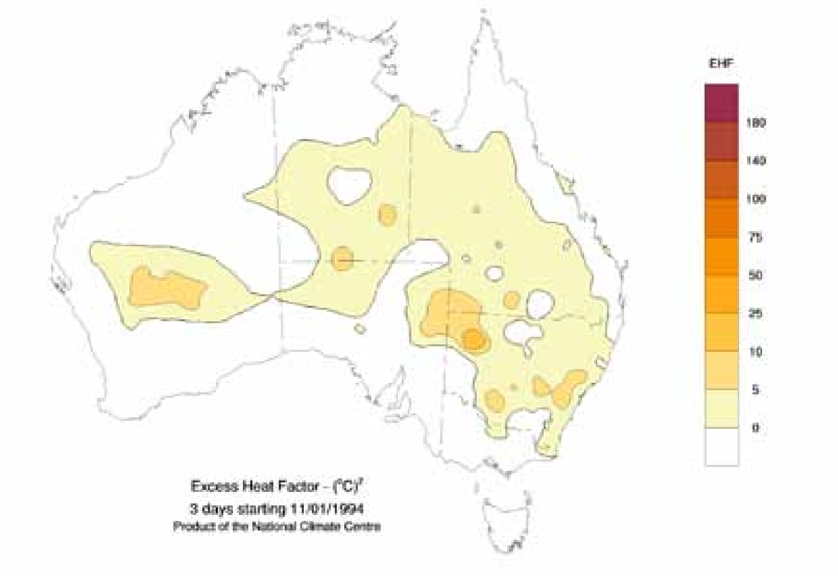
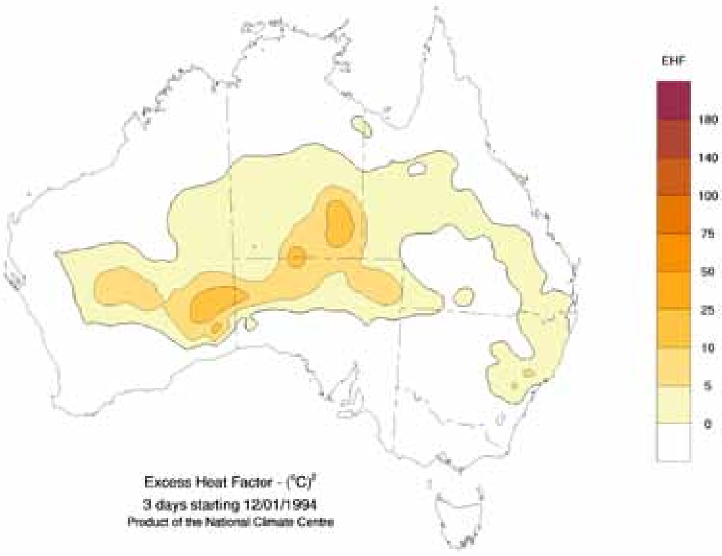
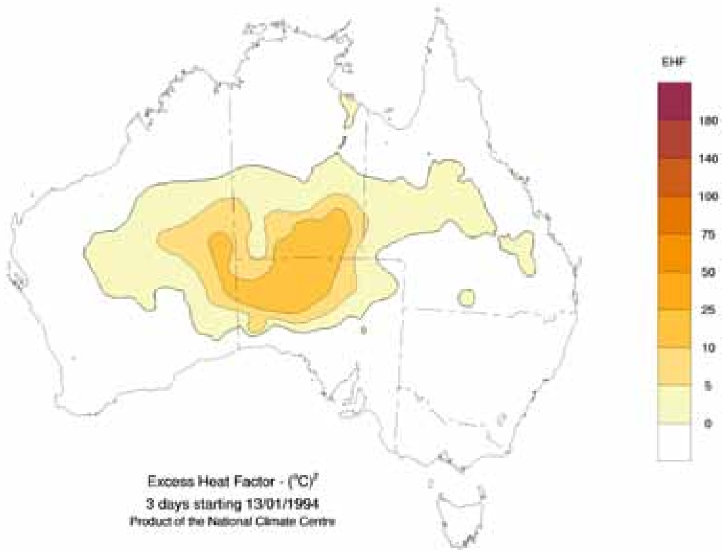


Figure 22: 7-13 January 1994 (continued)

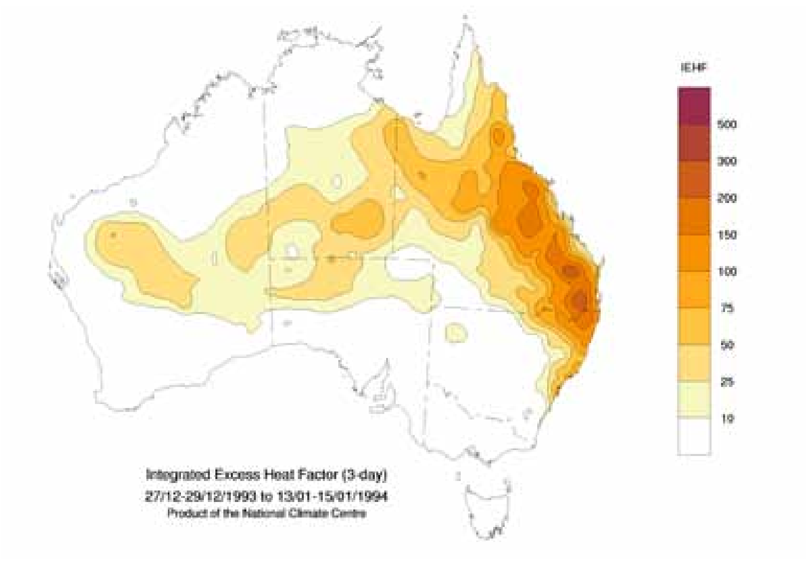


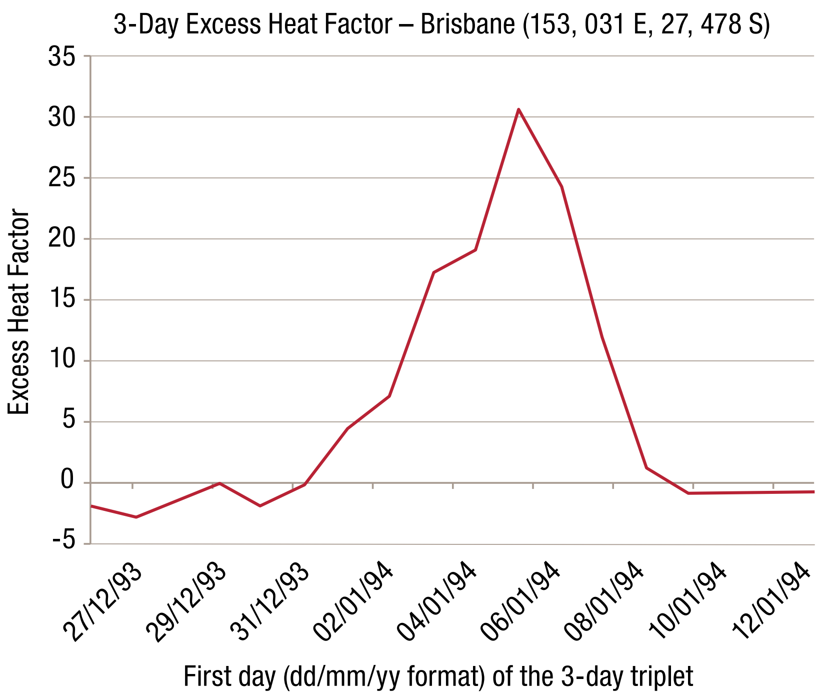


The figure below shows the total EHF load during the event and the EHF factor for Brisbane.

Figure 23: 27 December 1993 to 15 January 1994

Total Excess Heat Factor Load and Brisbane time series of EHF.





From Figures 22 and 23 we can also see that both the daily EHF scores and the overall event EHF load never reach the levels of the Melbourne, Adelaide and southern states event of 2009.

Appendix C – Modelling the impacts of severe heat events

Model overview

This appendix provides the technical details of the modelling undertaken for this report.

This section provides an overview of our severe heat event model; the subsequent sections provide details of how the model's structure and assumptions were developed.

The model analyses the potential impact of heat events on population health, using excess mortality as an indicator of population health risk. Figure 24 illustrates the model structure and analysis undertaken to develop it.

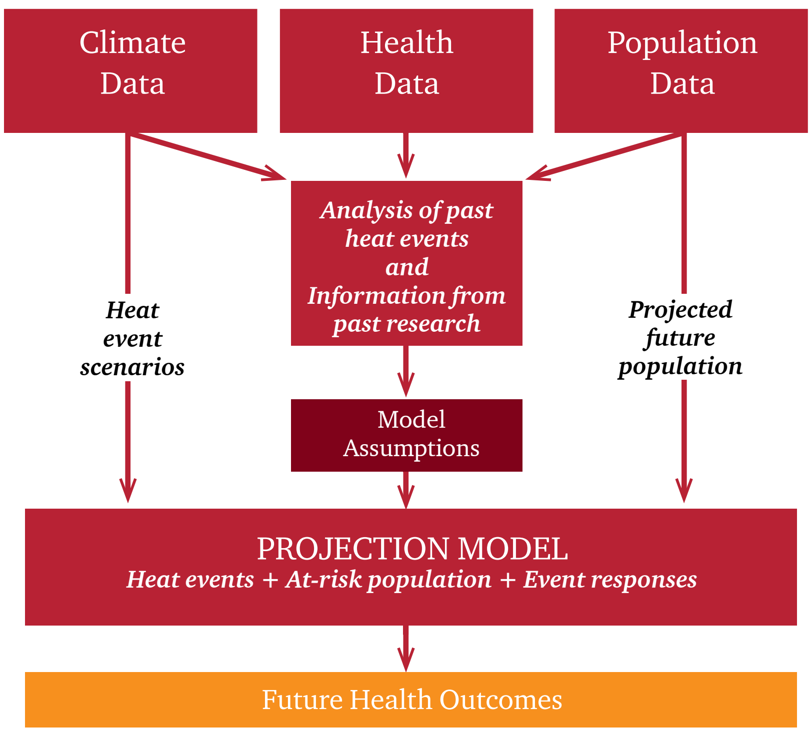
By identifying the expected response of different population subgroups to different heat events, we can assess the potential impact on the future population of different possible climatic scenarios. For example, we can assess what might happen if the conditions seen in the southern regions of Australia during the summer of 2009 occurred again in 2030 or if the conditions seen in the past climatic record were repeated.

Geographic scope

The model sought to cover the entire Australian population. In order to recognise the diversity of climates and the population spread we divided the country into fifteen regions for use in all analysis and modelling. The choice of these regions reflects the major population centres and also recognises that much of the data is categorised by state.

For each region we collated the available information on the population, the climate and past mortality experience. For the climate data we selected a single weather station to provide a broad representation of the range of conditions in that region. The weather stations were selected based on geographic location, population density and data availability.

Figure 24: Illustration of overall modelling approach



The following table outlines these locations and the representative weather station used for climatic observations.

Data

The main sources of data used include:

Population data

1 Population projections produced by the ABS – 3222.0 – Population Projections, Australia, Series B.

2 Historic population statistics from the ABS – 3218.0 – Regional Population Growth 1990-2010.

3 Supplementary population projections (by state) as released by individual state departments of planning.

4 The ABS National Health Survey 2007-2008 has been used to determine the proportion of the population in each existing co-morbidities group.

5 We have used the Australian Taxation Office (ATO) statistics as at 2007-2008 in order to determine the likely future population in low and high income bands.

Climate data

6 BOM daily maximum and minimum temperatures and Excess Heat Factor data 1981-2010 by location was used to determine when historical extreme heat events have occurred, their intensity and duration.

The information provided is based on AWAP (Australian Water Availability Project[77]) gridded data. This data incorporates high quality climate reference station observations, interpolated onto a 25km grid. As a climate reference data set, major capital city observations are not used due to the potential for urban heat island effect.

7 The Commonwealth Government Bureau of Meteorology (BOM) Excess Heat Factor data for Adelaide, Melbourne and Sydney based on the observations from actual observation sites. This data contains observations from when weather records commenced (which varies by location) to the present.

8 The Commonwealth Government Bureau of Meteorology (BOM) Excess Heat Factor draft warning threshold figures by location.

Health data

9 ABS data on daily deaths by location is used to assess the population impacts of historical heat events in terms of excess deaths. This data has been provided from 1990 to 2009, split by capital city and remainder of state where possible.

10 ABS prospective life tables 2004-2051 are used to determine standard mortality by age group for current, 2030 and 2050.

State/Territory	*Location groups*	*Representative weather station (including BOM ref)*
VIC	Melbourne	Melbourne Regional Office 086071
VIC	Victoria	Horsham – Longerenong 079028
SA	Adelaide	Adelaide (Kent Town) 023090
SA	South Australia	Adelaide (Kent Town) 023090
NSW	Sydney	Sydney Observatory Hill 066062
NSW	New South Wales	Wagga Wagga AMO 072150
ACT	Australian Capital Territory	Canberra – Tuggeranong (Isabella Plains) 070339
TAS	Tasmania	Hobart (Ellerslie Road) 094029
WA	South Western Australia	Perth Airport 009021
WA	Perth	Perth Airport 009021
WA	Tropical Western Australia	Broome Airport 003003
QLD	Brisbane	Brisbane – Archerfield Airport 040211
QLD	Southern Queensland	Mount Isa Aero 029127
QLD	Tropical Queensland	Cairns Aero 031011
NT	Northern Territory	Darwin Airport 014015

Note: All state location groups exclude the capital city where it is listed separately

77 Jones, DA, Wang, W, Fawcett, R. (2009). 'High-quality spatial climate data sets for Australia', Australian Meteorological and Oceanographic Journal, 58:233-248.

Analysing response to heat events

Identification of excess deaths

Our severe heat event model analyses the impact of heat events on population health by using excess mortality as an indicator of population health risk. This is an approach used by a number of studies examining the impact of heat on a population, owing to the lack of available data containing figures on heat-related deaths, and the difficulties in attributing heat as a cause of death.

Heat-related deaths = Actual deaths observed – Assumed average daily deaths

In order to determine the number of excess deaths on a given day, it is necessary to determine an average number of deaths that will be used as a baseline. The average number of deaths was determined by analysing ABS data on daily deaths by location alongside figures for the historic population of each location and determining a seasonal daily average mortality rate each year for the summer months impacted by heat events. This mortality rate was then applied to the population in each year being considered to determine an average daily number of deaths by location.

This approach accounts for:

- population changes influencing the number of deaths observed. This is significant in areas that have been experiencing high levels of growth
- past trends in population mortality and changes in demographic mix
- the variation in number of deaths experienced in different seasons throughout the year.

An assumption of this approach is that all excess deaths observed on a given day are due to heat conditions. In order to be comfortable in making this assumption it is important to consider the climatic conditions occurring on a given day. We have therefore analysed data on actual deaths occurring in each location, by pairing it with the EHF values for each location provided by the BOM to consider days that formed part of a heat event.

In reality, there may be other circumstances that influence the number of deaths experienced on a given day. An example would be the bushfires experienced in Victoria following the 2009 heatwave and we have made an adjustment to the deaths data to allow for this impact. No adjustments have been made for the impacts of infrastructure or systems failures.

Analysis of the relationship between mortality and EHF

Our analysis reviewed the relationship between the EHF index and excess mortality over the 20-year period for which we had both mortality and EHF data. Owing to the nature of the data available there are limitations in analysing the experience for regional locations. For the major centres the location of the population aligns well with the location covered by our climate data. For the other locations this is not the case: the population is spread over a broad geographic area and we have only been able to use one representative location for capturing the climatic conditions. As a result we have focussed on the results for the major capital city locations.

Choice of EHF

Firstly, we considered whether EHF or temperature is a better indicator of excess mortality.

Figures 25 and 26 case study the Melbourne and Adelaide 2009 heat wave events respectively, where the excess deaths clearly correspond with high values of the EHF.

These charts suggest that EHF provides a better indication of excess mortality than temperature alone, irrespective of whether the maximum or average daily temperature is used. The correlation between EHF value and excess deaths can also been seen to hold over days of an event, further supporting its use.

Figure 25: Graphs showing EHF value, maximum and mean daily temperature and excess deaths throughout the Melbourne 2009 heatwave

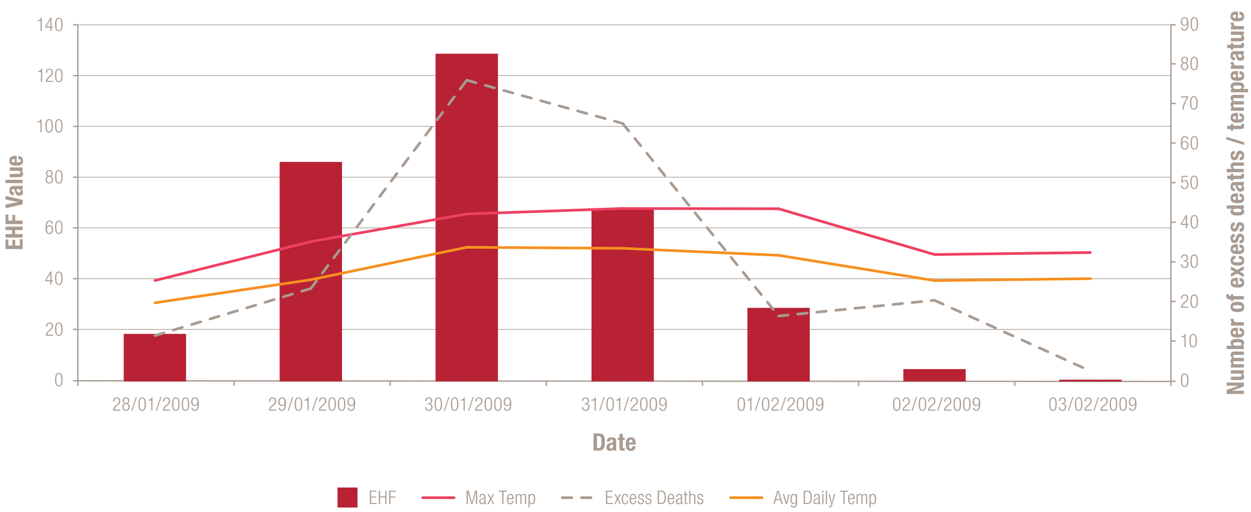
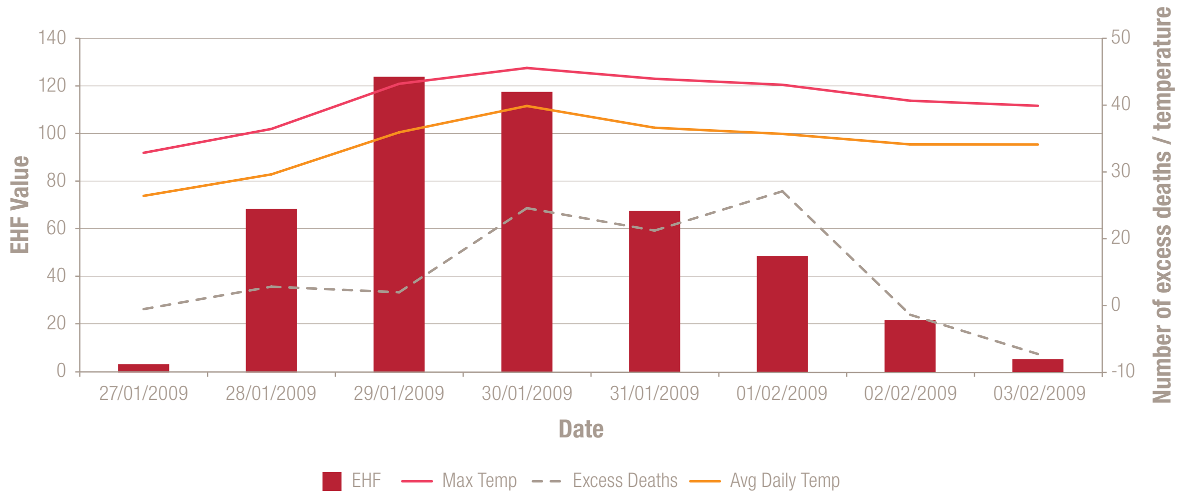


Figure 26: Graphs showing EHF value, maximum and mean daily temperature and excess deaths throughout the Adelaide 2009 heatwave



Choice of thresholds

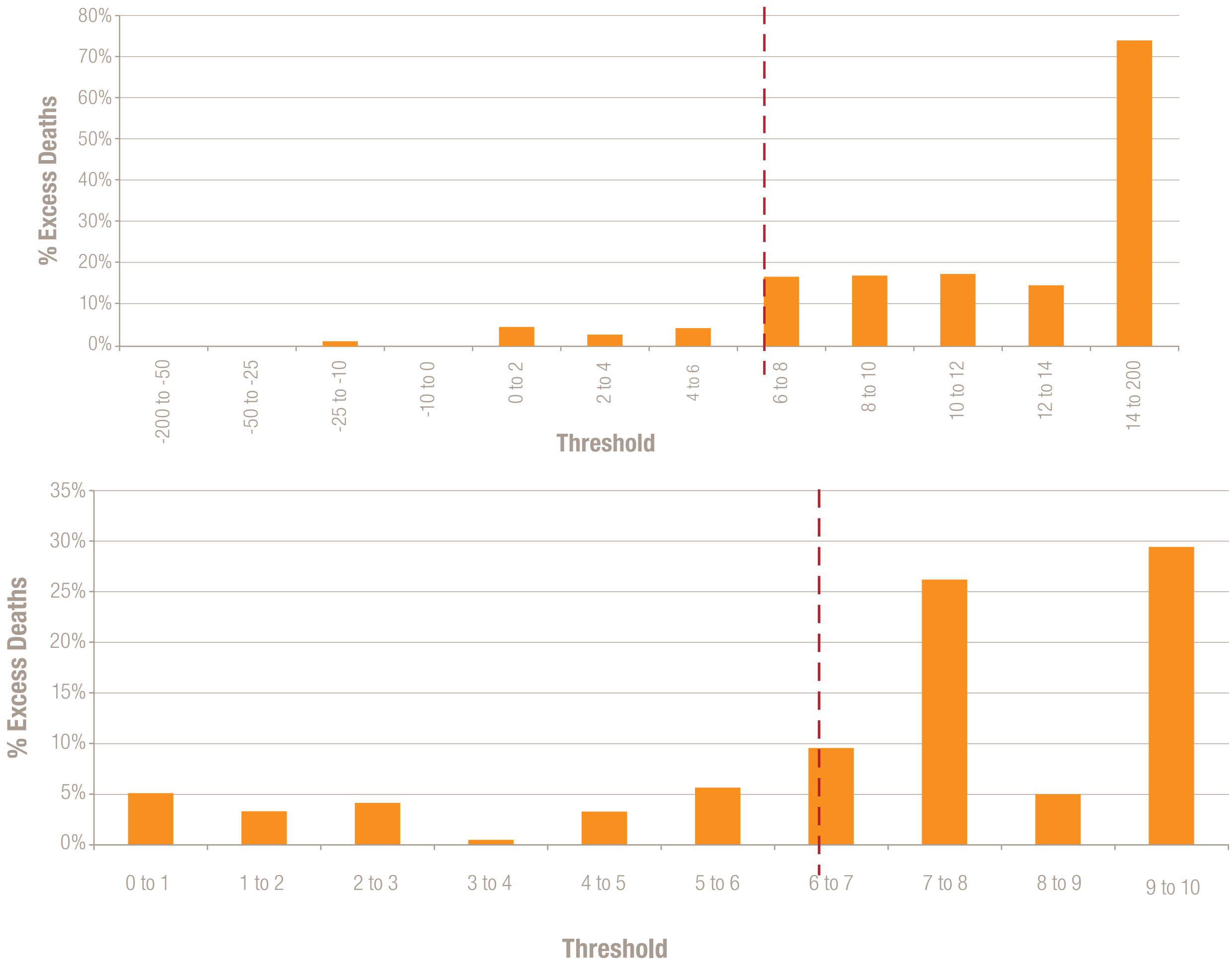
EHF can take a range of values in each location and as it captures a temperature anomaly these values can be both positive and negative. Our model assumes that when the EHF is within a normal range there are no material adverse health effects; these only become significant above some threshold EHF level.

One option for the thresholds is the proposed warning EHF thresholds provided by BOM. These represent the 85th percentile of a fitted Pareto distribution, fitted to historic EHF values for each location. The thresholds for the main population centres are as follows:

We undertook analysis to assess whether these thresholds were appropriate as an indicator for the population response in terms of mortality or whether an alternative threshold was more appropriate. This was done by considering the historic excess deaths observed for bands of days with EHFs in different ranges. As an example, the following chart outlines this analysis for Brisbane. The percentage of excess deaths clearly increases above an EHF value of 6, which compares to the 85th percentile threshold of 6.2. The second chart outlines the same analysis for smaller EHF bandings.

Location	Threshold
Brisbane	6.2
Perth	15.4
Sydney	10.8
ACT	12.3
Adelaide	31.4
Melbourne	27.5
Tasmania	17.0

Figure 27: Graphs of excess mortality by EHF for Brisbane



Note: The results become less reliable for higher EHF values where the data becomes sparse.

This analysis suggested that the BOM thresholds were generally similar for each location to that which would have been selected based on data alone. We therefore adopted these thresholds for the model.

We also noted that the different regions could be categorised into four groups based on these thresholds and these may experience similar conditions. These groups were considered when fitting the models and in developing the model parameters for regions with sparse data.

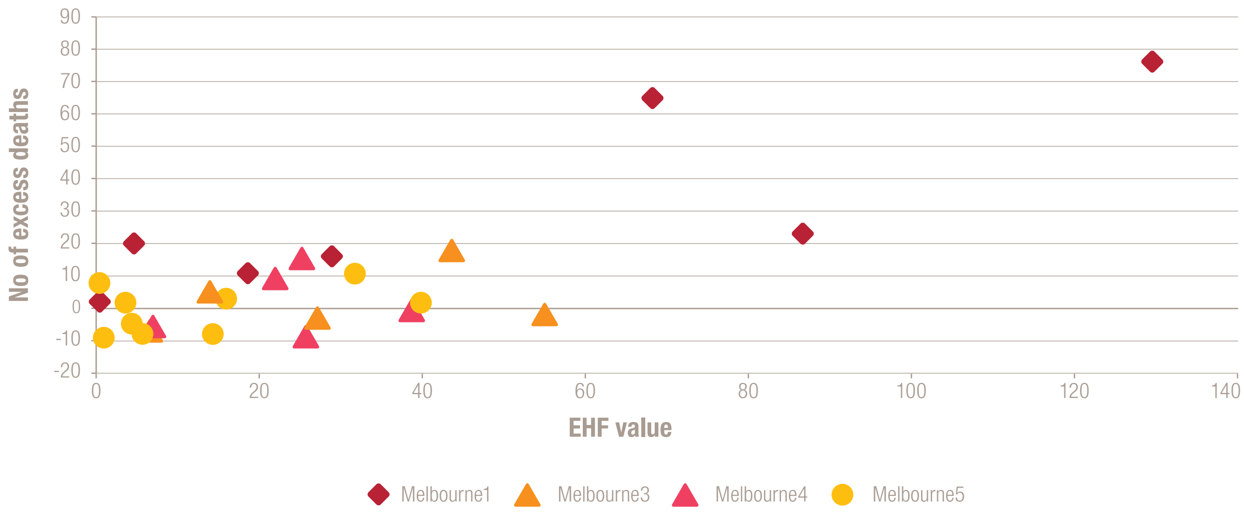
Form of relationship

We considered the relationship for all positive values of the EHF and all values over a range of EHF thresholds. We also examined the relationships between EHF and mortality during the top five events in each location. We have been able to demonstrate that there is a positive correlation between positive values of the EHF and excess deaths, with the number of excess deaths increasing as the EHF value increases. The following graphs illustrate these findings.

Region group	*Locations included (EHF threshold(s)*)*
Southern	Victoria (27.5/29.5) South Australia (31.4)
Temperate (south)	New South Wales (10.8/18.6) Australian Capital Territory (12.3) Tasmania (17.0) South Western Australia (15.4)
Temperate (north)	Southern Queensland (4.5/6.2)
Tropical	Tropical Queensland (2.9) Tropical Western Australia (2.6) Northern Territory (0.8)

Figure 28: Daily EHF value versus daily excess deaths from major historical heat events in Melbourne and Adelaide 1990-2009

Melbourne



Adelaide

Note: The graphs shown are scatter plots of EHF versus excess deaths in Melbourne and Adelaide where each data point represents a day in an historical heat event. The heat events considered are those in the Top 5 ranked heat events over the period 1981 to 2010, that occurred from 1990 to 2009 (the years that it has been possible to obtain ABS deaths data)

In our model we have assumed that the relationship between EHF and excess mortality in each location above the threshold EHF value is linear. While this may be a simplification of the exact functional form of the relationship we have selected it as the most appropriate structure for our high level model. The broadly linear nature of the relationship can be seen in Figure 25 and Figure 28, and also draws on the approach set out in past research for the Commonwealth Department of Health and Ageing[78] and other internationally published articles.

We have noted that there is considerable variation or 'noise', which suggests that there are other factors compounding the relationship. Further research would be required to identify these factors in order to refine the model form and improve the model fit.

Fitting the dose response

We have determined that the population response (described in our model as excess mortality) to changes in the EHF is defined by a threshold, below which no additional deaths are expected, and a dose response, or percentage change in mortality for a unit increase in the EHF. Hence:

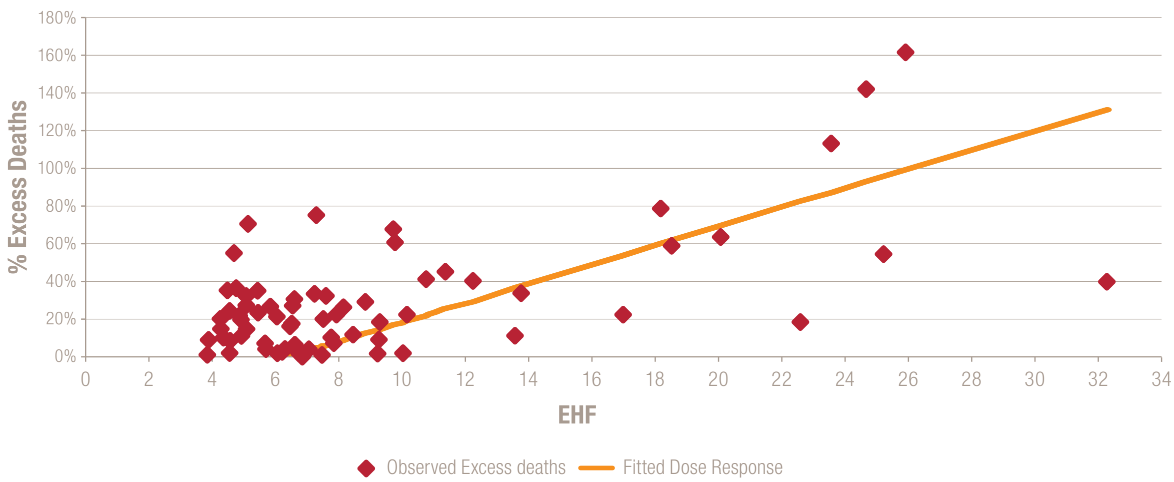
Excess mortality loading(%) = max(EHF – threshold , 0) x dose response(%)

To fit the dose response for each location we analysed the relationship between the EHF index and excess mortality over the 20-year period for all positive values of the EHF and all values over a range of EHF thresholds. We also examined the relationships between EHF and mortality during the top five past heat events in each location.

Our process for determining the appropriate dose response for each location involved:

1. Considering the relationship between percentage excess deaths and EHF and removing outlying observations that would distort the model fit.
2. Fitting a dose response line using a chi squared statistic to achieve an optimal fit.
3. Using the model with the best fit parameter to generate a modelled number of heat-related excess deaths for the top five historic events and comparing the output to actual excess deaths observed.
4. Considering the output of step 3 and making adjustments to improve the fit of the model to past events as necessary.

Figure 29: %Excess deaths vs. EHF – observations and fitted response



78 McMichael, A., R. Woodruffe. P. Whetton, K. Hennessy, N. Nicholls, S. Hales, A. Woodward and T. Kjellstrom. (2003). 'Human Health and Climate Change In Oceania: A Risk Assessment 2002. Available from: www.health.gov.au/internet/main/publishing.nsf/content/2D4037B384BC05F6CA256F1900042840/$File/env_climate.pdf

Each of the steps above was completed for each location, using a range of scenarios for the dose response. One such scenario involved fitting a standard dose response to all locations in each region grouping. In addition, the modelled annual average number of excess deaths was considered against past data over the period 1990 to 2009. Our approach involved getting the best possible fit for all past events in aggregate. This involved achieving a balance where it was necessary to over fit some events and under fit other events.

The following chart for Brisbane, shows the relationship between excess deaths, presented as percentage above expected daily deaths, and EHF values observed. The data points confirm a broadly linear relationship to EHF. The plotted line shows the fitted dose response, the percentage deaths that would be expected to be observed for each EHF value, above the threshold EHF value of 6.2.

The following table outlines the adopted thresholds and dose responses in each location:

Location	Threshold	Dose response
Brisbane	6.2	5.00%
Perth	15.4	1.50%
Sydney	10.8	1.50%
ACT	12.3	1.00%
Adelaide	31.4	1.00%
Melbourne	27.5	1.25%
Tasmania	17.0	1.00%

Mortality displacement

An important secondary outcome from our analysis of the excess deaths data has been the ability to investigate the extent to which the deaths are a "harvesting" effect, or a forward temporal shift in the rate of mortality in the population.

We considered the possibility of a harvesting affect by looking at the excess deaths in the weeks following the extreme heat events, and did not observe an obvious corresponding decrease in excess deaths during the subsequent weeks after a heatwave that would be expected if the excess deaths were purely a result of harvesting.

For example, for the 2009 extreme heat event in Adelaide, and the subsequent weeks, the following excess deaths were observed in the data.

Number of weeks subsequent to the event	Excess deaths
0 (ie the event itself)	61
1	-10
2	17
3	7
4	-1
5	9

Projection model

The projection model uses the EHF as an indicator of heat events and projects excess deaths as a function of this metric.

The model considers two climate scenarios for each location: a past event and an annual distribution. These have been developed by considering a 30 year history of EHF data and from this identifying the largest past event (measured in terms of total heat load) and the average annual pattern of EHF. It is acknowledged that a 30 year history would not capture the most severe historic heat event for each location, however, it gives a good representation of the potential nature of a future severe event. Excess deaths are modelled by applying adjustments to standard mortality in each location to reflect the climate scenario under consideration.

The model considers the parts of the population which are most at risk from heat events (as identified by our literature review) and reflects this by applying different mortality adjustments to each group.

Scenario mortality = Standard mortality x (1 + average adjustment for heat event x combined relative impact factor)

The mortality loadings were developed as follows:

- Average mortality loading has been calculated using the adopted thresholds and dose responses for each location described above.
- Adjustments for population subgroups have been taken from past research.
- Model was calibrated to past experience by assessing the combined impact of these two factors.

The model then uses population projections for 2030 and 2050 to model possible future impacts of heat events given expected population changes for each location.

Population at risk

The population was split into groups according to the risk factors identified in Section 2. These risk factors were adopted based on their potential to significantly influence an individual's response to heat events.

The table below outlines the risk factors and categories used.

Population projections from the ABS were used to determine the likely future population size by gender and age band by state in 2011, 2030 and 2050. These Series B projections contain mid range assumptions regarding fertility, net overseas migration and life expectancy. These projections were supplemented by further state specific projections in order to determine the split of the population into state capitals and regional areas, in line with our location groupings.

We have used ATO statistics as at 2007-2008 in order to determine the likely future population in a low and high income bands. The risk factor for income intends to capture a range of related contextual risk factors such as access to airconditioning and education surrounding heat events.

During our literature review a number of existing medical conditions were identified as placing people at increased risk of heat-related death. These conditions were categorised as either high risk or medium risk by considering available literature[79] on the subject. The categorisation was as follows:

The ABS National Health Survey 2007-2008 was used to determine the proportion of the population in each existing co-morbidities group. This was specific to each location, gender and age band. The nature of the National Health Survey data enabled the population with more than one high risk condition to be identified so they could be assigned to a multiple high risk group. For the purpose of modelling the potential impact of heat events in 2030 and 2050 we have assumed that the proportion of the population in each existing co-morbidities group will remain unchanged by location, gender and age band.

Standard mortality

ABS life tables based on assumed improvements in mortality 2004-2051 were used to determine standard mortality for each gender and age group, both in the present day and for 2030 and 2050. The assumptions used to generate these life tables have been formulated on the basis of demographic trends over the past decade and longer, both in Australia and overseas, in conjunction with consultation with various individuals and government department representatives at the national and state/territory level.

The average mortality rates adopted by age and gender are shown on the following page.

Population risk factors	*Categories*
Age	0-9, 10-49, 50-64, 65-79, 80+
Gender	Male, Female
Income	Low, High
Existing co-morbidities	None, Medium Risk, High Risk, Multiple High Risk

79 Basu, R. (2009). 'High ambient temperature and mortality: a review of epidemiologic studies from 2001-2008'. *Environmental Health* 8(4):1-13; Delaware Department of Natural Resources and Environmental Control. (2011). *Climate Change Delaware's public health*, www.dnrec.delaware.gov/ClimateChange/Pages/Delaware'spublichealth.aspx,accessed March 16, 2011; Hajat, S., R.S., Atkinson, R.W. Kovats, and A Haines. (2002), 'Impact of hot temperatures on death in London: a time series approach', *Journal of Epidemiol Community Health*, 56:367-372; Hansen, A., P. Bi, M. Nitschke, P. Ryan, D. Pisaniello, and G. Tucker. (2008). 'The Effect of Heatwaves on Mental Health in a Temperate Australian City', *Environmental Health Perspectives* 116(10):1369-1375; Knowlton, K., et al. (2009). 'The 2006 Califormnia heatwave: impacts on hospitalisations and emergency department visits' *Environmental Health Perspectives*, 117(1):61-67; Vaneckova, P., M.A. Hart, P.J. Beggs, and R.J. de Dear. (2008). 'Synoptic Analysis of heat-related mortality in Sydney, Australia, 1993-2001', *International Journal of Biometeorology* 52439-451.

Existing co-morbidities risk group	*Medical condition(s)*
High risk	Cardiovascular diseases (including oedema and heart failure, ischemic heart diseases, hypertensive disease, other conditions involving circulatory system) Diseases of genito-urinary system Diseases of respiratory system
Medium risk	Low blood pressure Angina Diabetes mellitus (all types) Mental health conditions
None	All other conditions

Age (years)	2011 Male	2011 Female	2030 Male	2030 Female	2050 Male	2050 Female
0-9	0.0006	0.0005	0.0005	0.0004	0.0004	0.0004
10-49	0.0010	0.0005	0.0008	0.0004	0.0007	0.0004
50-64	0.0044	0.0029	0.0031	0.0022	0.0027	0.0020
65-79	0.0213	0.0129	0.0156	0.0098	0.0134	0.0089
80+	0.1084	0.0910	0.0986	0.0847	0.0910	0.0810

Mortality adjustments for risk factors

Our model incorporates adjustments to standard mortality for the population that fall into different at-risk groups in accordance with the risk factors outlined previously. Literature relating to previous research was used to provide support for relative impact factors for each population subgroup. In particular we used information from Fouillet[80] and Staffogia[81] to establish how different groups of the population respond relative to each other and then scaled to expected standard deaths to achieve an overall neutral effect.

For each risk factor the average impact factor across the total population has been fitted to 100%. A factor of greater than 100% indicates a higher loading on standard mortality. For example, for the purposes of determining the impact of heat on mortality, individuals aged 80+ years will be subject to an increased mortality risk and would have any mortality loading set at 111% of the level applied to the overall population.

Population Risk Factors	Relative impact factors	
Age	Group	Relative Impact Factor
	0-9	68%
	10-49	69%
	50-64	80%
	65-79	92%
	80+	111%
Gender	No adjustment used as reflected in standard mortality	
Income	Group	Relative Impact Factor
	Low income	101%
	High income	96%
Existing co-morbidities	Group	Relative Impact Factor
	None	82%
	Medium risk	90%
	High risk	107%
	Multiple High Risk	115%

80 Fouillet A, Rey, G, Laurent, F, Pavillon, G, Bellec, S, et al. (2006). 'Excess mortality related to the August 2003 heatwave in France', *International Archies of Occupational and Environmental Health*, 80(1):16-24.

81 Staffogia, M, Forastiere, F, Agostini, D, Biggeri, A, Bisanti, L et al. (2006), 'Vulnerability to Heat-Related Mortality: A multicity, population based, case-crossover analysis', *Epidemiology*, 17:315-323.

Appendix D – Stakeholder consultation

A major source of information for this report has been the expertise and experience of key stakeholders across Australia. The following provides a list of the stakeholders we consulted with as part of this project.

Table 19: List of stakeholders consulted as part of this project

Sector	*Organisation*	*Name*
Emergency services	Ambulance Victoria	Greg Sasella
	Australasian Society for Emergency Medicine	Rick Lowen
Essential services	APA Group	Michael Snell
	Australian Energy Market Operator	Richard Robson
	Jemena	Peter Whelan
	Melbourne Water	Konrad Gill
	Powerlink	Peter Dunn
		Sharon Brennan
	Sydney Water	David Parsons
		Jessica Sullivan
Government	Australian Building Codes Board	Matthew McDonald
		Ron De Veer
	Bureau of Meteorology	John Nairn
		Robert Fawcett
		Robin Hicks
	Australian Local Government Association	John Pritchard
	Department of Community Safety (Queensland)	Bruce Grady
		Gary Mahon
	Department of Health (Northern Territory)	Xavier Schobben
	Department of Health (Victoria)	Miranda Fraser
	Department of Health and Human Services (Tasmania)	Steve Smith
	Department of Planning and Community Development (Victoria)	John Ginivan
	Department of Transport (Western Australia)	Kim Stone
	Local Government and Shires Association of NSW	Amy Lovesey
	Municipal Association of Victoria	Derryn Wilson
		James Holman
	Office of the Emergency Services Commissioner (Victoria)	John Schauble
	Office of Environment and Heritage (New South Wales)	Simon Smith
	Queensland Ambulance Service	Gerard Lawler
	Queensland Health	Dorothy Vincenzino
	SA Fire & Emergency Services Commission	Graeme Wynwood
	SA Health	Kevin Buckett
	Tasmanian Climate Change Office	Shona Prior
	Transport SA	Steven Pascale
	WA Health	Andrew Robertson

Sector	Organisation	Name
Health services	Royal Australian College of General Practitioners	Ronald McCoy
		Peter Tait
	Silver Chain	Carole Bain
	Royal District Nursing Service (South Australia)	Judy Smith
Other	Australian National University – National Centre for Epidemiology and Population Helath	Anthony Capon
Social services	Australian Red Cross	John Richardson
		David Militz
	Salvation Army	Susan Reese
		Brad Halse
	Uniting Care Kildonan	Stella Avramopoulos

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