# THE BURNING ISSUE: CLIMATE CHANGE AND THE AUSTRALIAN BUSHFIRE THREAT

CLIMATECOUNCIL.ORG.AU

# Thank you for supporting the Climate Council.

The Climate Council is an independent, crowd-funded organisation providing quality information on climate change to the Australian public.

Published by the Climate Council of Australia Limited

ISBN: 978-0-9944195-7-6 (print)
978-0-9944195-8-3 (web)



—

Image credit: Cover photo "Cessnock Bush Fire 18-01-2013" by Flickr user Quarrie Photography licensed under CC BY-NC-ND 2.0.

This report is printed on 100% recycled paper.

facebook.com/climatecouncil
info@climatecouncil.org.au
twitter.com/climatecouncil
climatecouncil.org.au

Professor Lesley Hughes
Climate Councillor

Jacqui Fenwick
Researcher, Climate Council

# Contents

# Key Findings

## 1 Record-breaking spring temperatures in 2015, exacerbated by climate change, have driven an early start to the bushfire season in Australia.

- The maximum temperatures in Melbourne on October 5th and 6th were the hottest ever recorded for the first week of October while temperatures were at least 12°C above average for most of southern Australia on at least one day during that week.
- Globally, seven months this year have broken their monthly temperature records and 2015 is very likely to surpass 2014 as the hottest year on record.
- Longer, hotter and more intense heatwaves, and more frequent and severe droughts, are driving up the likelihood of very high bushfire risk, particularly in the southwest and southeast of Australia.

## 2 North America has faced a deadly bushfire season in 2015.

- The North American bushfires have been driven by years of severe drought in combination with warmer temperatures, a situation Australia is likely to face with increasing frequency in future.
- Between January and October of 2015, over 50,000 bushfires burned over 38,000 $km^2$ of land – an area more than half the size of Tasmania, making it one of the worst bushfire years on record in the US.

## 3 Australia's bushfire preparedness is at risk from climate change as bushfire seasons increasingly lengthen and overlap with fire seasons in the Northern Hemisphere.

- Large areas of southeast and southwest Australia are facing above-average bushfire potential for the 2015/2016 summer. Most of the southeast coast of Australia is expected to experience above normal bushfire potential due to a long-term rainfall deficit, relatively low soil moisture, and relatively warm conditions predicted for the summer.
- Globally, the length of the fire weather season increased by nearly 19% between 1979 and 2013. Longer fire seasons will reduce opportunities for controlled burning and increase pressure on firefighting resources.
- Some of Australia's key firefighting aircraft are leased from overseas and are contracted to North American firefighting services during their summer. The fire seasons of the two hemispheres – and the demand for these critical shared firefighting aircraft – will increasingly overlap, challenging such arrangements.
- During the past decade, state fire agencies have increasingly needed to share personnel and other firefighting resources during peak demand periods. This pressure will continue to intensify and the number of professional firefighters will need to double by 2030 to meet demand.

## 4 Stronger climate change action is needed to reduce bushfire risk.

- Australia's emissions reduction target of 26-28% on 2005 levels by 2030 is not sufficient to protect Australians from worsening bushfires and extreme weather events.
- Australia must cut emissions more rapidly and deeply to join global efforts to stabilise the world's climate and the vast majority of Australia's fossil fuel reserves must stay in ground.

# 1. Bushfires in Our Own Backyard

**Australia is a fire prone country. Bushfires have been a feature of the Australian environment for at least 65 million years and will continue to feature in the future (Cary et al. 2012).**

Australians are not strangers to the serious consequences of bushfires (see, for example, Figure 1). Between 3 and 10% of Australia's land area burns every year (WALIA 2013). Western Australia, alone, can experience thousands of bushfires in a season - in 2012-2013, more than 3,800 bushfires burned across the State (ANAO 2015; BNH CRC 2015). Over the past decade alone, large and uncontrollable fires have devastated many parts of the country, taking lives and destroying homes. Bushfires in Australia have accounted for more than 800 deaths since 1850 (Cameron et al. 2009; King et al. 2013). The economic impact of bushfires is very high from the costs of bushfire management and suppression, as well as lost and damaged infrastructure and businesses. Recovery costs can also be substantial. The total economic cost of bushfires in Australia, under current conditions, is estimated to average around $337 million per year (Deloitte 2014). In addition, bushfires have considerable unquantified costs including those of social disruption and trauma, opportunity costs for volunteer firefighters,

**Figure 1:** An Australian bushfire in 2007.

## The economic costs of bushfires is very high.

fixed costs for firefighting services, government contributions for rebuilding and compensation, impacts on health, and ecosystem services (King et al. 2013).

Bushfire threat is typically associated with very hot (above average temperatures), dry (less than 20% humidity), and windy (above 12-15 km per hour) conditions and high fuel loads (BoM 2009; BoM 2013; Geoscience Australia 2015). The climate influences all of these factors and is the primary control on fire activity (Dennison et al. 2014).

Human activities, such as the burning of coal, oil and gas are causing dramatic changes to the climate system, which is having direct and indirect impacts on fire danger weather and fuel conditions (Climate Council 2013). In particular, hot days are becoming hotter, and heatwaves are becoming longer, more frequent and more intense (Perkins and Alexander 2013). The IPCC has predicted with high confidence that bushfire danger weather in Australia will increase in the future (IPCC 2014a).

## Burning fossil fuels for electricity influences fire danger weather.

**Figure 2:** Bushfire smoke above the Great Western Highway during the Blue Mountains, NSW, fires of October 2013 (Photo by Gary P Hayes Photography – garyphayes.com/photography).

# Globally, 2015 is on track to be the hottest year on record.

The last two years have been no exception to the recent warming trends. 2014 was the hottest year on record globally and was the 38th consecutive year with above average global temperatures (NASA 2015; NOAA 2015a). In Australia, 2014 was the third hottest year on record, with an annual national temperature 0.91°C above average (CSIRO and BoM 2014). 2015 is shaping up to be another hot year for Australia, and has brought record-breaking heat worldwide. Globally, seven of the first nine months of 2015 have been the warmest on record (NOAA 2015b).

Any impact of climate change on rainfall is also particularly important for bushfire conditions. Over the longer term, southern Australia has experienced a drying trend, characterised by a 10-20% reduction in cool-season rainfall in the past few decades (BoM 2014a; CSIRO and BoM 2015).

Since the start of 2014 Australia has experienced a significant number of major bushfires. In 2014 and early 2015, 18 bushfire events were declared national disasters (Disaster Assist 2015; Table 1). These bushfires affected more than 65 local government areas, causing millions of dollars worth of damage.

**Table 1:** Number of bushfires declared as national disasters, and the number of local government areas severely affected by these bushfires, for four states (NSW, SA, VIC and NT) for 2014 and the first half of 2015. **Source:** Disaster Assist (2015).

| State | Number of bushfires declared national disasters (2014 - early 2015) | Number of local government areas affected |
|---|---|---|
| NSW | 10 | 23 |
| SA | 2 | 17 |
| VIC | 4 | 25 |
| NT | 2 | 3 |

## BOX 1: SOUTH AUSTRALIAN BUSHFIRE 2015

In January 2015, a severe South Australian bushfire caught the nation's attention. The Sampson Flat bushfire caused devastation in the Adelaide Hills region. It was active for six days, burning 12,500 ha of land, 27 homes, numerous sheds and killing 900 head of livestock (Slattery et al. 2015). The insured value of damages from the fire was $36.6 million (Insurance Council of Australia 2015).

**Figure 3:** A forest in Kersbrook, South Australia, following the January 2015 bushfires.

Climate change is also having an impact on the length of the Australian fire season which now extends beyond summer, into October and March, in many regions (Clarke et al. 2013). Analysis of global climate data has shown that the frequency of long fire weather seasons has increased in eastern Australia - as shown in Figure 4 (Jolly et al. 2015). Longer fire seasons will reduce opportunities for controlled burning and increase pressure on firefighting resources (Matthews et al. 2012, IPCC 2014a).

The east of the country, where around 77% of the population live (VIC, NSW, ACT and QLD), is most likely to be affected by changes to the bushfire season length in future (ABS 2015; Jolly et al. 2015).

# The fire season in eastern Australia has lengthened.

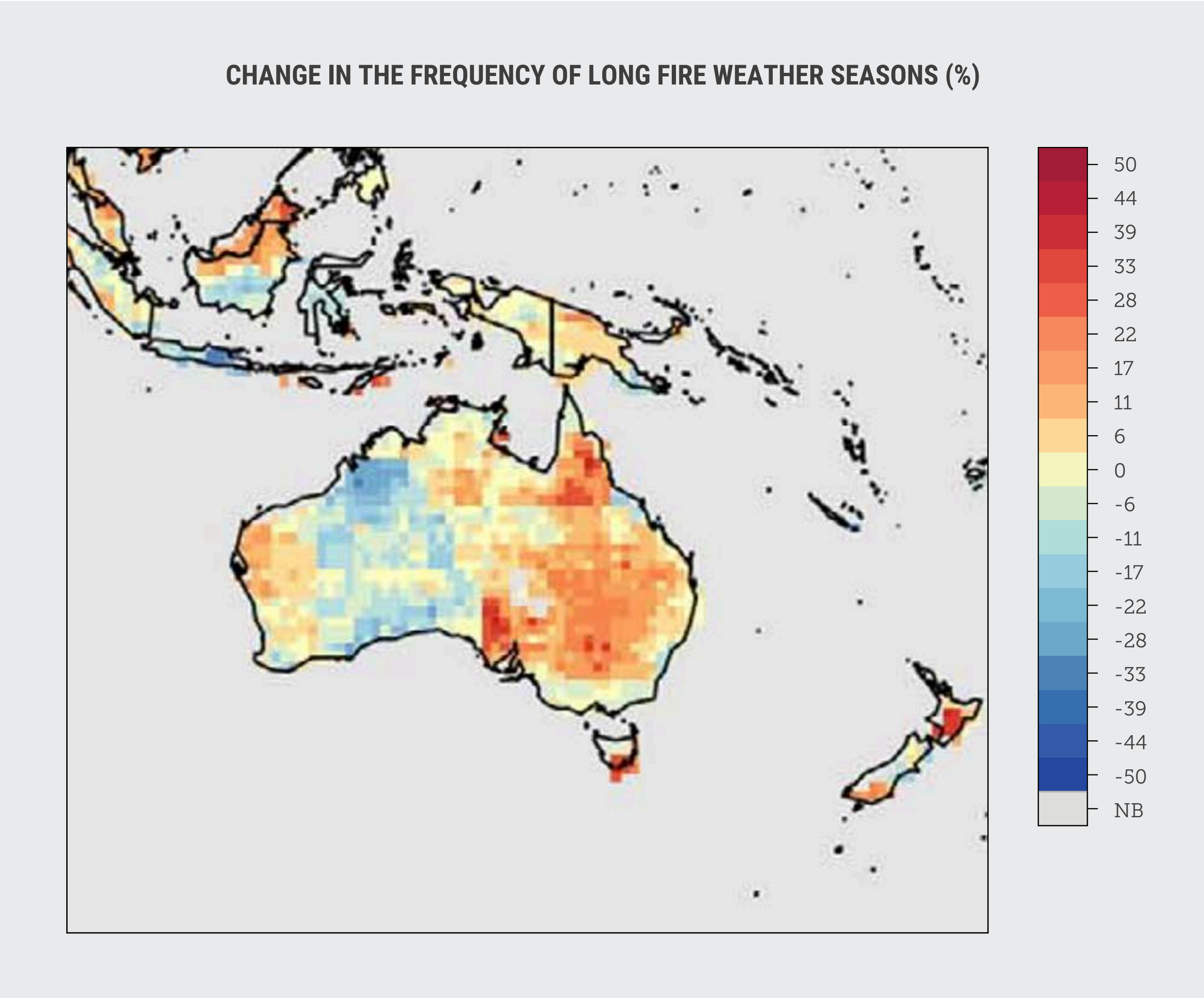



**Figure 4:** Change in the frequency of long fire weather seasons between the period 1979-1996 and the period 1996-2013.
**Source:** Adapted from Jolly et al. 2015.

# 2. Climate Change is Affecting Australian Bushfires

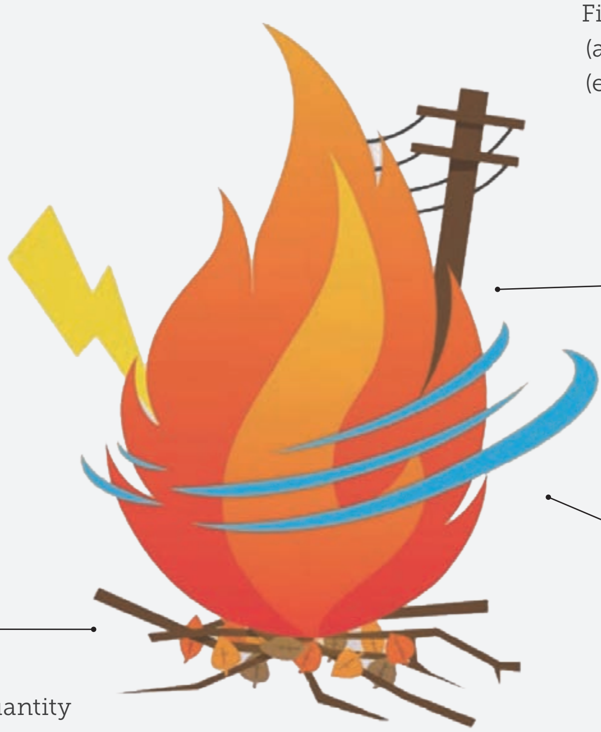
**A fire needs to be started (ignition), it needs something to burn (fuel) and it needs conditions that are conducive to its spread (weather) (Bradstock et al. 2014; Figure 5).**

Climate change can affect all of these factors in both straightforward and complex ways. While a fire must be ignited, the larger determinant of whether a fire will take hold is the fuel and weather.

## MAIN FACTORS AFFECTING BUSHFIRES

**1 | Ignition**
Fires can be started by lightning or people, either deliberately or accidentally.

**3 | People**
Fires may be deliberately started (arson) or be started by accident (e.g. by powerline fault). Human activities can also reduce fire, either by direct suppression or by reducing fuel load by prescribed burning.



**2 | Fuel**
Fires need fuel of sufficient quantity and dryness. A wet year creates favourable conditions for vegetation growth. If this is followed by a dry season or year, fires are more likely to spread and become intense.

**4 | Weather**
Fires are more likely to spread on hot, dry, windy days. Hot weather also dries out fuel, favouring fire spread and intensity.

**Figure 5:** Main factors affecting bushfires.

## Ignition

The primary ignition source for bushfires in Australia is humans (Flannigan et al. 2013). Lightning plays a much smaller role, accounting for around a quarter of fire ignitions in some regions, but lightning-caused fires contribute significantly to the area burnt, especially in remote locations (Willis 2005; Bradstock 2008; Bradstock 2010; Attiwill and Adams 2011; BNHCRC 2011). The incidence of lightning is sensitive to weather conditions, including temperature (Jayaratne and Kuleshov 2006). It has been estimated that a 5-6% increase in global lightning activity could occur for every 1°C warming (Price and Rind 1994). As climate change continues to increase temperatures globally it is possible that the number of bushfires ignited by lightning will increase (Groot and Flannigan 2014), but the extent of this impact is unclear.

## Fuel

The type, amount, and moisture level of fuel available are critical determinants of fire behaviour, extent and intensity. The impacts of a changing climate on fuel are complex. For example, changes in atmospheric carbon dioxide levels may enhance fuel loads by increasing vegetation productivity in some regions (Bradstock 2010; IPCC 2014a). Regional increases in rainfall may dampen the risk of bushfires in the same year, but increase fire risk in subsequent seasons. In arid areas of central Australia, for example, rainy years can enhance fire danger in the following years due to increased plant growth and hence fuel loads (Harris et al. 2008). Other parameters that are influenced by climate change such as temperature, seasonality and extreme weather events, can all have an impact on plant growth and the condition of fuel.

Figure 6: A tree catches alight during Australian bushfires of 2007.

# Climate change is driving up the likelihood of very high fire danger weather.

It is clear that changes to the climate – and increasing atmospheric carbon dioxide levels driving these changes - will have an impact on fuel and therefore on bushfires in Australia. Because of the complex relationship, however, it is not possible to determine how — or in what direction — a changing climate will affect the amount and condition of the fuel in a particular region.

## Weather

Weather has a very strong influence on bushfires and is directly affected by climate change. Once a fire is ignited, very hot days with low humidity and high winds are conducive to its spread. Any impact of climate change on heat, moisture or wind is therefore going to directly affect the spread and staying power of a bushfire.

The frequency, duration and intensity of extreme weather events, such as extreme heat and heatwaves, are affected by climate change (IPCC 2014a). The annual number of record hot days across Australia has doubled since 1960 (CSIRO and BoM 2012). Over the period 1971-2008, the duration and frequency of heatwaves increased and the hottest days during a heatwave became even hotter (Perkins and Alexander 2013; Climate Council 2014). A study into Australia's record hot year in 2013 found that the heat events in that year would be expected only once every 12,300 years in the absence of climate change (Lewis and Karoly 2014). A similar study found the events to have been virtually impossible without the influence of a changing climate (Knutson et al. 2014). At higher temperatures, fuel is 'pre-heated' and is more likely to ignite and to continue to burn (Geoscience Australia 2015). The impact of climate change on extreme weather, increasing the number of hot days and heatwaves, is driving up the likelihood of very high fire danger weather.

Recent decades have also seen a drying trend in the southeast and southwest of Australia, characterised by declining rainfall and soil moisture (CSIRO and BoM 2014). In very dry conditions, with relative humidity less than around 20%, fuel dries out and becomes more flammable (BoM 2009). Climate change is likely making drought conditions in these regions of Australia worse. Contributing to this drying is a southward shift of fronts that bring rain to southern Australia in the cooler months of the year (CSIRO and BoM 2015). This shift is consistent with the changes in atmospheric circulation expected in a warmer climate (Climate Commission 2013). In the southeast and southwest of Australia, it is very likely that an increased incidence of drought - coupled with consecutive hot and dry days - will result in longer fire seasons and an even larger number of days of extreme fire danger (e.g. Clarke et al. 2011). A study into forested regions of Australia found that, in the majority of cases, years with drought conditions resulted in a greater area of burned land (Bradstock et al. 2014).

Local wind conditions are important for the spread and endurance of a bushfire. Wind speeds above 12-15 km per hour increase the rate of fire spread, with a doubling of the wind speed quadrupling the rate of spread (BoM 2009; Geoscience Australia 2015).

# 3. Bushfires are a Global Problem

**Bushfires - also known as 'forest fires', 'wildfires' or 'brushfires' - are common in many regions of the world. Globally, about 350 million hectares are burned each year (Giglio et al. 2013; Jolly et al. 2015) - an area roughly comparable to that of India (Flannigan et al. 2013).**

Climate change is expected to increase the length of fire seasons in many places by increasing the frequency and duration of fire weather conditions each year. Globally, the length of the fire weather season has already increased by nearly 19% between 1979 and 2013 and this trend is expected to continue over the coming decades (Jolly et al. 2015).

**Figure 7:** A bushfire threatens homes in Portugal. It is likely that the area burned in southern Europe each year will increase as the climate changes.

# 3.1. Bushfires in Europe and Russia

**In Europe, where an average of 50,000 bushfires burn a total of approximately half a million hectares each year (European Commission 2013; 2014), the number of fires has increased in the last decade (European Environment Agency 2009). Studies have shown that climate change is likely to contribute to an increase in the total burned area in coming decades, by reducing precipitation and increasing temperatures in southern Europe (Amatulli et al. 2013; Khabarov et al. 2014). This increase could be as much as 200% by 2090, compared to 2000-2008, if no adaptation actions are taken and greenhouse gas emissions remain high (Khabarov et al. 2014).**

In Russia, where warming during the last century exceeded average global rates (Roshydromet 2008), severe bushfires - coinciding with abnormally high temperatures - have caused devastation in 2015. Mean decadal air temperatures in April exceeded average temperatures by 4-10°C across most of Siberia (Hydrometeorological Centre of Russia 2015). During this time, Siberian forest fires, stoked by the high temperatures, caused over 30 deaths and 800 hospitalisations, killed over 5,000 sheep and cattle, and destroyed around 1,300 houses, leaving 6,000 people homeless (Liesowska 2015).

The length of the fire weather season globally has increased by almost 19% in the past 30 years.

# 3.2. Devastating Bushfires in North America

**The devastating bushfires ('wildfires') of North America have caught the attention of the world. It is likely that 2015 will be one of the worst years on record for US bushfires in terms of the area burnt. Between January and October of 2015, over 50,000 bushfires burned over 38,000 km$^2$ of land – an area more than half the size of Tasmania (NIFC 2015a; US DoA 2015). Fires have also taken a toll on human life in the US, causing over 1,000 deaths between 1914 and 2014, including 163 in the last decade (NICF 2014).**

The fires have also come at a huge economic cost. Over the last decade, wildfire suppression has cost the US around US$ 1.5 billion (NIFC 2015a) and Canada over US$ 1 billion each year (Jolly et al. 2015). The total costs, including preparedness and direct economic losses, is substantially greater. In 2014 alone, the cost of fire suppression in the US – managing over 63,000 bushfires - was more than US$ 1.5 billion - exceeding the allocated budget by more than US$ 200 million (US DoA 2015).

**Figure 8**: The Chiwaukum Fire, in the state of Washington, the United States, burned more than 14,000 acres of forest in July 2014.

## It is likely that 2015 will be one of the worst years on record for US bushfires with over 38,000 km$^2$ burnt.

Climate change may already be having a major impact on bushfire activity in North America (Clark et al. 2014). Changes to the frequency, extent, and severity of fires reflect long-term global fire trends and are likely to occur with increased temperatures and drought severity (Dennison et al. 2014; Yue et al. 2015). Average temperatures on the US mainland (excluding Alaska) have risen rapidly since the late 1970s, faster than the global rate (US EPA 2015a). 2012 was the warmest year on record for the region and seven of the top 10 warmest years on record have occurred since 1998 (US EPA 2015a). The southwestern states have had an above average annual mean temperature every year since 1998 (NOAA 2015c). In the northwest states, all but one year has had above-average temperatures since 1993 (NOAA 2015c).

In August 2015, almost a third (30%) of mainland US (excluding Alaska) was in drought. For California, 2013 was the driest year since records began, and early 2015 has received under half of the average amount of precipitation (Swain et al. 2014; NOAA 2015d). Washington State, likewise, received only 52% of the state's seasonal average rainfall during the 2015 summer, making it the ninth driest summer on record (NOAA 2015d). Climate change is expected to continue to drive more frequent, intense and longer droughts (IPCC 2014b; Swain et al. 2014; Trenberth et al. 2014; Mann and Gleick 2015). The impact of climate change on temperatures and rainfall is likely to continue to affect North American bushfires in years to come (Yoon et al. 2015).

As well as contributing to high fire danger weather, climate change is also affecting fires in the US indirectly by affecting the flammability of fuel (Dennison et al. 2014). Further, the spread of bark beetles has been exacerbated in a drier, warmer climate, causing increased deaths of drought-stressed trees that in turn provide more fuel (Cal Fire 2013). Climate change is also contributing to a reduction in the snowpack and earlier snow melting, resulting in decreased water availability during hot summer conditions. This, in turn, contributes to an increased bushfire risk, allowing fires to start more easily and burn hotter (WRI 2014; US EPA 2015b). On the fire suppression front, a drier climate has made it harder for some firefighting services to find suitable bodies of water, meaning planes and helicopters are flying longer distances to reload (The Guardian 2014).

## A drier climate makes it difficult for firefighters to find water to tackle bushfires.

# In parts of the US, the bushfire season is now more than a month longer than it was over three decades ago.

There has been an increase in the number of fires, the number of large fires, and the area burnt by bushfires in the US, particularly in the western states (Dennison et al. 2014, Jolly et al. 2015). The number of large fires, averaged across all studied regions, increased at a rate of nearly seven large fires per year between 1984 and 2011 (Jolly et al. 2015). The total fire area also increased by over 355 $km^2$ per year during this period (Jolly et al. 2015) and of the 10 years with the largest acreage burned, nine have occurred since 2000 (US EPA 2015b). Comparisons of the annual area burned (as a proportion of total land area), between 1984 and 1998, and between 1999 and 2013, have shown increases of nearly 4%, with the greatest increase in the west, as shown in Figure 9 (US EPA 2015b). More than half the western states have experienced their largest bushfire on record since 2000 (NOAA 2015e; WRI 2014).

The US has also experienced particularly rapid lengthening of the bushfire season in recent decades. In parts of the country, the bushfire season is now more than a month longer than it was 35 years ago (Jolly et al. 2015).

## BOX 2: PARTNERSHIP BETWEEN AUSTRALIA AND THE US

Bushfires present major challenges for both Australia and the US, and the two countries have a lot to learn from each other's experiences. On July 2015, Victorian and Californian emergency services signed a formal partnership agreement to share information, skills and services. This deal, the first of its kind, is aimed at bolstering the emergency management programs of both countries, particularly with regard to firefighting (EMV 2015).

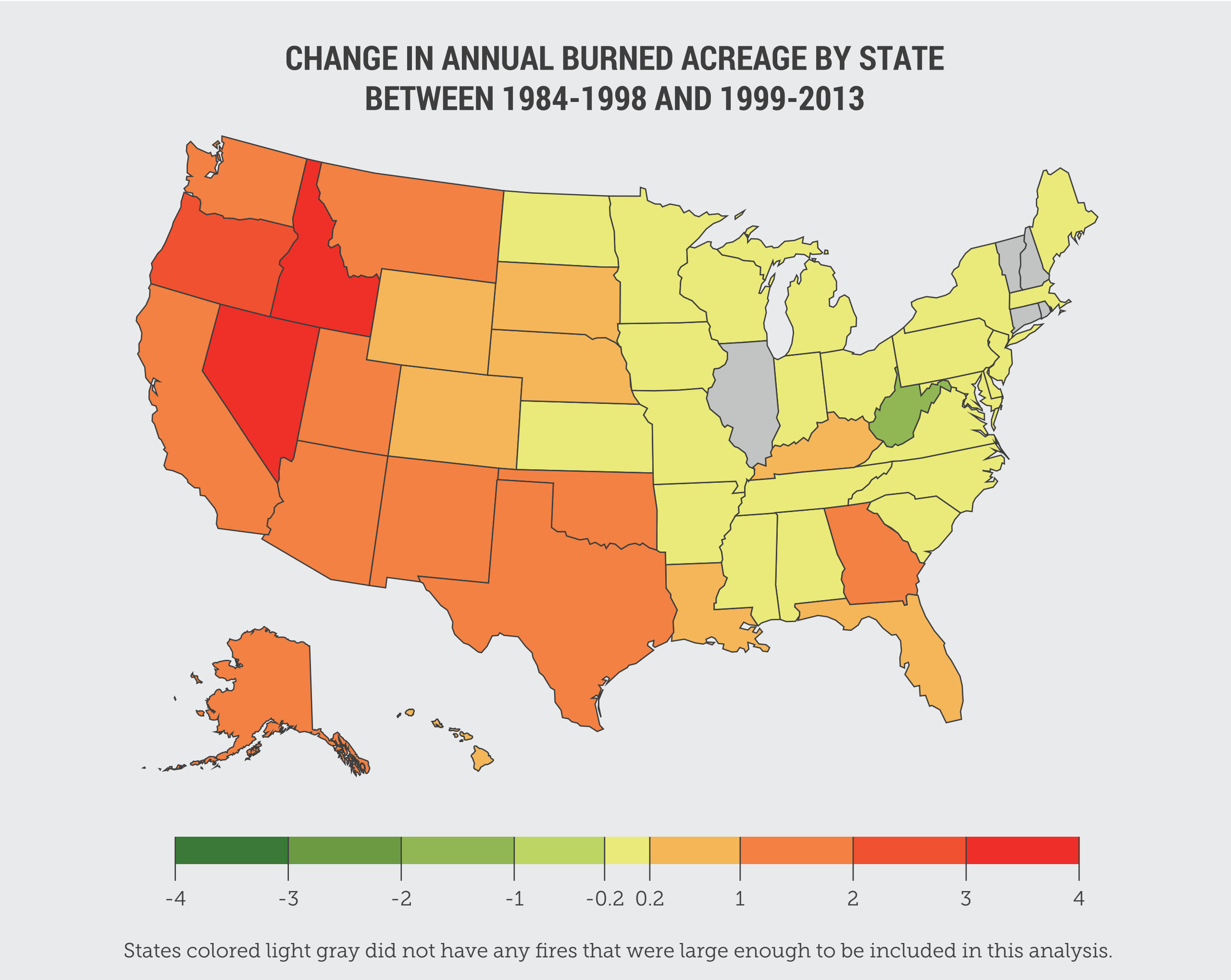



**Figure 9**: Map of the US showing the change in Annual Burned Area between 1984-1998 and 1999-2013, by state (figure adapted from US EPA 2015b).

Increasing frequency and severity of bushfires in the US have important implications for Australian firefighting resources (see Section 4). In addition, the devastating North American bushfires demonstrate the potential result of years of severe drought intersecting with warmer temperatures, a situation that Australia is likely to face with increasing frequency in the future.

Increasing frequency and severity of bushfires in the US could affect Australia's capacity to tackle bushfires in future.

# 4. Preparing for Bushfires in a Changing Climate

**The economic, social and environmental costs of increasing bushfire activity in Australia are potentially immense. To maintain the existing high quality of fire management and minimise these costs it is important that emergency services are well prepared.**

Climate change, and the impacts that it has on bushfires and the bushfire season present a challenge to emergency services, requiring increasingly greater input of resources - both equipment and personnel. During the past decade, state fire agencies have increasingly needed to share suppression resources domestically during peak demand periods (BNHCRC 2012). In October 2013, for example, firefighters from Brisbane, Melbourne and the ACT joined the NSW Fire and Rescue teams to tackle 627 bushfires, burning across more than 160,000 hectares, over 13 days (AFAC 2014).

**Figure 10:** Bushfire smoke over Sydney CBD during the October 2013 Blue Mountain bushfires.

# The number of professional firefighters will likely need to double by 2030.

**Figure 11:** Volunteer firefighters gather at dawn to continue suppressing a bushfire in Finniss, South Australia. Trained firefighters are crucial to protecting Australian properties and lives during the bushfire season each year.

As climate change increases the likelihood of very high fire danger weather (IPCC 2014a) a substantial increase in the number of trained firefighters will be needed. To keep pace with asset growth and population, it has been estimated that the number of professional firefighters will need to increase from approximately 11,000 in 2010 to 14,000 by 2020 and 17,000 by 2030 (NIEIR 2013).

When the increased incidence of extreme fire weather under a realistic warming scenario is also taken into account, a further 2000 firefighters will be needed by 2020, and 5000 by 2030 (NIEIR 2013).

Overall, this represents a doubling of professional firefighter numbers needed by 2030, compared to 2010. These estimates are likely to be conservative because they do not account for the potential lengthening of the fire season. Further, they do not account for the increased pressures on the professional firefighting services due to declining numbers of volunteer firefighters (NIEIR 2013).

It is likely that a longer fire season will also reduce the window of opportunity for hazard reduction at the same time that the need for hazard reduction becomes greater.

# 4.1. What Does the North American Situation Mean for Australia?

**Fire seasons in the northern and southern hemisphere have been at alternative times of year in the past. This has allowed the sharing of equipment and personnel between Australia and North America. Climate change is impacting on the fire seasons in both hemispheres meaning that they will increasingly overlap. This has the potential to decrease the capacity to share resources, putting greater pressure on firefighting equipment and personnel in both Australia and North America.**

Specialised helicopters and planes are integral to Australian firefighting efforts. Aerial firefighting resources (see, for example, Figures 12 and 13) are leased by state and territory services from domestic and international companies each bushfire season. In the 2015-16 season, Australia's leased fleet comprises more than 120 aircraft, including high volume helicopters, firebombing helicopters, air attack supervision helicopters, fixed wing firebombing aircraft, and fixed wing specialist intelligence-gathering aircraft. During the 2013-14 Australian bushfire season, contracted aircraft were required on more than 3,000 occasions, making more than 36,000 firebombing drops and delivering over 86 million litres of fire retardant and suppressant across the country (NAFC 2014).

Some of the largest aircraft in Australia's fleet, including six air-cranes and four large air tankers, are leased from international companies (Kestrel Aviation 2015). During the northern hemisphere summer, these services are contracted to firefighting services in North America. As the climate changes and bushfire seasons continue to lengthen, the fire seasons of the two hemispheres – and the demand for these critical shared firefighting aircraft – will increasingly overlap, challenging such arrangements (Handmer et al. 2012).

## As northern and southern hemisphere fire seasons overlap, fire services will be less able to share resources.

**Figure 12:** Elvis - the Erickson Air-Crane fire bomber – dumping about 9,000L of water to assist Australian firefighters. Specialised firefighting aircraft such as Air-Cranes are loaned for the bushfire seasons in both the northern and southern hemispheres each year.

In addition to the sharing of equipment, the sharing of personnel to assist during peak fire seasons will also be affected. The US-Australia resource-sharing arrangement, which was formalised in 2002 but has been operating informally since 1964, enables states in either country to request additional firefighters to provide fire suppression support at short notice (NIFC 2002). The extreme 2015 bushfire season in the US (see Section 3.2) pushed domestic firefighters to capacity. The length of the fire season and the number and severity of fires required maximum firefighter deployment, resulting in ongoing concerns of fatigue. Seventy-two Australian and New Zealander personnel were deployed in August and September to support US firefighters, particularly in management roles. An additional 104 Australian firefighters were deployed to Canada during the 2015 season, where bushfires were likewise pushing resources to capacity. This support continues the pattern set in previous years, including 2002, 2003, 2006, 2007 and 2008 (NIFC 2015b).

The sharing of firefighting personnel is a two-way arrangement, and firefighters from abroad have assisted in a number of major firefighting operations in Australia. During the 2007 bushfire season, for example, international reinforcements were called in to support Australian firefighters, particularly in Victoria, who had endured more than 40 days fighting fires with little respite. The foreign firefighters included 100 American, 52 Canadian and 116 New Zealand trained personnel (ABC 2007). With bushfires burning across Victoria, Queensland, NSW and South Australia at the time, there was limited scope for interstate support, and the provision of emergency resources from overseas was of benefit to the fire suppression. International reinforcements also assisted Australian firefighters following the 2009 'Black Saturday' bushfire disaster. The US sent 73 personnel, including three Burned Area Emergency Rehabilitation teams, to assist with fire suppression and recovery (NIFC 2015b).

As bushfire seasons lengthen and bushfire weather increases in severity and frequency, there will be more pressure on firefighters and firefighting equipment. Increasingly firefighting services will be less able to rely on help from interstate and across the world as fires occur simultaneously. This is a major challenge for Australia moving forward.

The US-Australia resource-sharing arrangement enables states in either country to request additional firefighters at short notice.

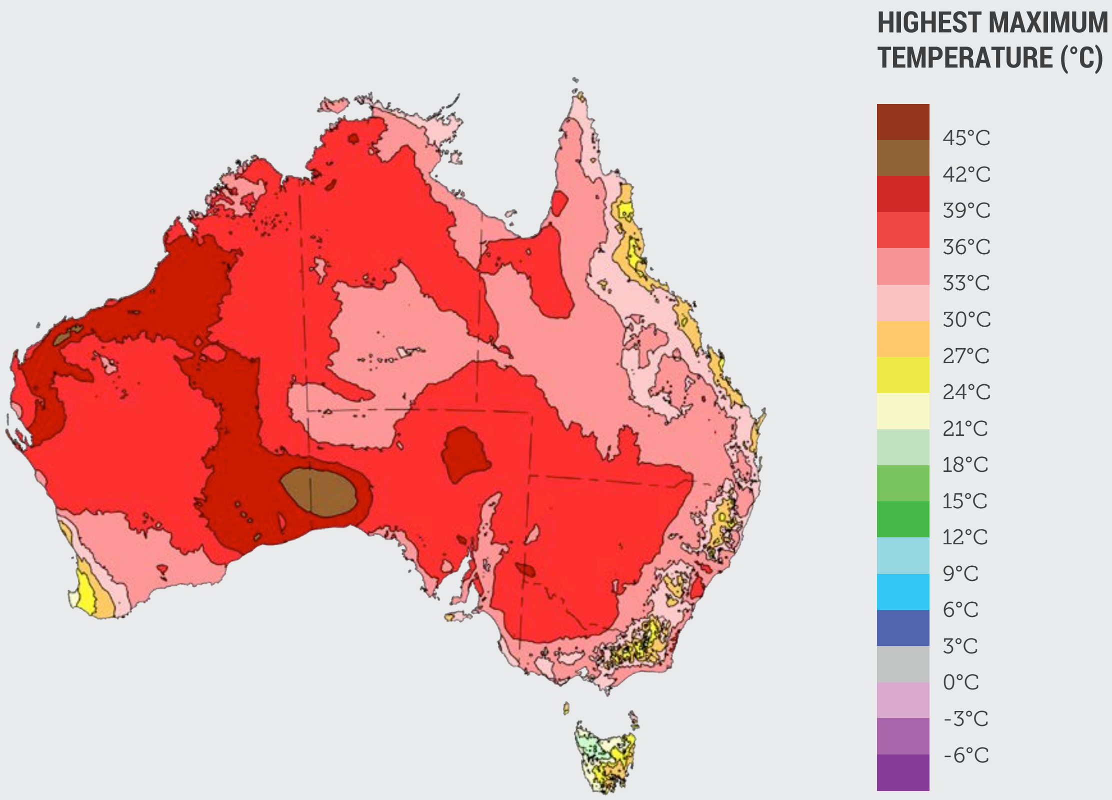
## Having the capacity to respond to increasingly longer and more severe bushfires is a massive challenge for Australia.

**Figure 13:** Precision water bucket drops supporting firefighting efforts in Yosemite National Park, Unites States, during the 2013 bushfire season. Specialised firefighting aircraft are important to firefighting efforts in the United States – particularly with the increasing number of severe fires and increasing length of the bushfire season.

# 5. Outlook for Australia

**BOX 3**

The first week of October 2015 brought record-breaking temperatures and strong winds across much of southeast Australia (BoM 2015d). This followed Australia's third driest September on record. The hot and dry conditions fuelled an early start to the bushfire season in Victoria and New South Wales, with over 200 fires burning across Victoria within just a few days and multiple homes being destroyed (ABC 2015). It is expected that climate change will contribute to an increase in the number of bushfires and length of the bushfire season in this region of Australia (Clarke et al. 2013; Perkins and Alexander 2013; Jolly et al. 2015).




**1st to 6th October 2015 - Australian Bureau of Meteorology**

**Figure 14:** Maximum temperatures recorded during the 1-6 October heat event. Figure from the Bureau of Meteorology (BoM 2015d).

## Hotter, drier conditions mean that fuels are prone to rapid drying with the approach of summer, exacerbating bushfire conditions.

Since 1970, areas of southeast and southwest Australia have experienced decreases in average rainfall accompanied by above average temperatures, with the past decade being the warmest on record in many areas (CSIRO and BoM 2014). The pattern of long-term below-average rainfall and above-average temperatures means that conditions such as soil moisture and fuels are prone to rapid drying with the approach of summer, boosting an active bushfire season (BNHCRC 2015).

It is expected that large areas of southeastern Australia and Western Australia, will be faced with above normal fire potential during the 2015-2016 summer (BNHCRC 2015; Figure 15). This forecast takes into account a number of climate and social factors. Leading into this year, many areas have consistently received below average annual rainfall across successive years. This has produced a cumulative reduction in soil moisture levels and increasingly dry forests and grasslands. Other climate drivers, such as the currently strengthening El Niño event across the Pacific and the warmer waters associated with the Indian Ocean Dipole were taken into account. Non-climatic factors considered in the investigation include the distribution of firefighting resources, previous fire activity and the amount of prescribed burning undertaken prior to the start of the fire season.

Most of the southeast coast of Australia is expected to experience above normal bushfire potential due to a long-term rainfall deficit, relatively low soil moisture, and relatively warm conditions predicted for the summer (BNHCRC 2015). Similarly, in Western Australia, a lack of rainfall, a long-term deficit in the soil moisture, and high fuel loads have led to expectations of an above normal fire potential in the state's southwest.

The 2015-2016 bushfire season will be influenced by an El Niño, which is the phase of the El Niño-Southern Oscillation (ENSO) phenomenon characterised by warm, dry, conditions for eastern Australia

## Large areas of southeastern Australia and Western Australia could experience above normal fire potential during the 2015-2016 summer.

during winter and spring, and an increase in heatwave frequency (Perkins et al. 2015). By September this year, El Niño conditions in the Pacific Ocean had already reached levels not seen since the severe 1997-98 event (BOM 2015a). The link between El Niño events and bushfires is complex, however, some studies have identified a relationship to fire weather conditions and bushfire activity in southeast and central Australia (Harris et al. 2013).

In addition to El Niño, Australian climate is likely to be influenced by a positive Indian Ocean Dipole (IOD) phase in the latter half of 2015 and an ongoing positive Southern Annular Mode phase. Both are generally associated with a decrease in rainfall over parts of central and southern Australia and can therefore have an impact on the bushfire season in these regions (BoM 2015a; BoM 2015e; Perkins et al. 2015). In 2015, however, unusually warm temperatures across much of the Indian Ocean are expected to bring rainfall to central and southwest Australia, reducing the risk of severe bushfire conditions (BoM 2015c).

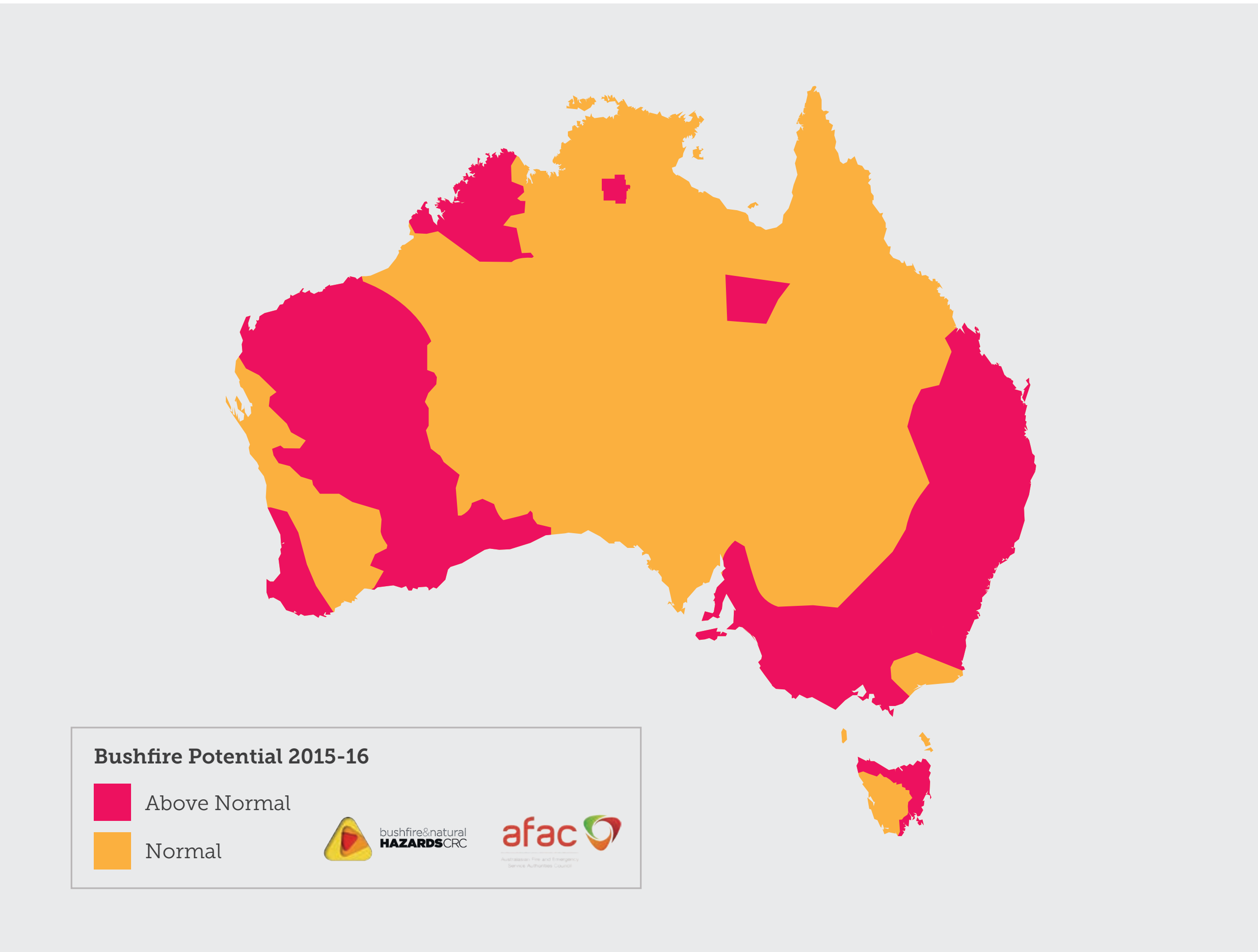



**Figure 15:** Map of the estimated bushfire potential for the 2015-2016 bushfire season across Australia. Figure adapted from BNHCRC 2015.

# 6. Tackle Climate Change to Protect Australians

**Climate change, driven by the burning of coal, oil and gas, is exacerbating bushfire conditions.**

2015 is shaping up to be another hot and dry year for Australia. The summer of 2014–15 was the fifth warmest on record for Australia and both the maximum and minimum temperatures were well above average for the season. Seven of the first ten months of 2015 have now had above average national mean temperatures, including the warmest October on record (BoM 2015b). Winter and autumn rainfall was considerably below the long-term average for Australia as a whole (BoM 2015b). Globally, seven of the first nine months of 2015 have been the warmest on record (NOAA 2015b).

Increasing fire activity in several regions of the world has been influenced by climate change, as has the lengthening of fire seasons in many regions. In Australia, high fire danger weather is increasing in the southeast and fire seasons are lengthening. Australian firefighting resources will be influenced, not just by changes to bushfires in Australia, but also by changes to bushfires and the fire season abroad - particularly in North America.


**Figure 16:** A firefighter looks towards Mt McKay, Victoria, through the haze of bushfire smoke.

# Australian firefighting resources will be influenced by changes to bushfires and the fire season in Australia and abroad.

The emission of greenhouse gases by human activities, mainly carbon dioxide from the burning of coal, oil and gas, is the primary cause of the changes in climate over the past half-century (IPCC 2013). Projections of future climate change and its impacts have convinced nations that the global average temperature, now at 0.85°C above the pre-industrial level (IPCC 2013), must not be allowed to rise beyond 2°C above pre-industrial. Societies will have to adapt to even more serious impacts as the temperature rises towards the 2°C limit. For southeast Australia, this means increased fire danger weather and longer bushfire seasons. Ensuring that this 2°C limit is not exceeded will prevent even worse impacts from occurring, including the crossing of tipping points that could drive the warming trend beyond the limits of human adaptation.

To have a two out of three (66%) chance of staying below the 2°C guardrail, we can emit no more than about 1,000 billion tonnes of $CO_2$ from 2012 until global emissions must be reduced to zero (IPCC 2013). At current emissions levels, we will blow this budget in less than two decades. Based on recent economic analysis (McGlade and Ekins 2015), to have a 50:50 chance of meeting the 2°C limit would require that 38%, at most, of the world's fossil fuel reserves can be burned ("reserves" are the subset of resources that are defined to be recoverable under current economic conditions and have a specific probability of being produced). For a 75% chance of meeting this target, only 23% of reserves can be used. Unfortunately, the rate of increase in global atmospheric carbon dioxide levels continued to rise during the last decade and in 2015 carbon dioxide levels reached a record high of more than 400 parts per million (ppm), compared to pre-industrial levels of 280 ppm (ESRL 2015). Global carbon dioxide emissions from fossil fuel combustion and industrial processes (cement and metal production) increased in 2013 to a new record of around 36 billion tonnes (Gt) $CO_2$, 0.7 Gt higher than the previous year's record (European Commission 2014; Global Carbon Project 2015).

There are some promising signs that progress is being made towards decarbonising the global economy. Leaders of the Group of Seven (G7) nations (Germany, France, Italy, the United Kingdom, Japan, Canada and the United States) have called for a cut in global emissions at "the upper end" of the 40-70% range by 2050, as recommended by the IPCC, and a decarbonisation of the global economy by the end of the century (Jotzo 2015). Thousands of individuals and over 400 institutions, including the world's largest sovereign wealth fund and two of the world's largest pension funds, are divesting from fossil fuel companies, together representing $2.6 trillion of investments (The Guardian 2015a). Today, annual renewable energy capacity additions are outpacing fossil fuels by 40% (IRENA 2014). Renewables have surged globally, driven by supportive policies and the rapidly dropping prices, particularly

**Figure 17 (opposite):** The Blue Mountain bushfires, in October 2013, had devastating consequences, and reinforce the need to act on climate change (Photo by Gary P Hayes Photography – garyphayes.com/photography).

for solar. Last year was the first year in which emissions growth stalled globally, primarily due to clean energy solutions. Despite this progress, however, much more needs to be done, and quickly.

The evidence is clear and compelling. The trend of increasing global emissions must be slowed and halted in the next few years and emissions must be trending downwards by 2020 at the latest if the 2°C guardrail is to be observed. Investments in and installations of renewable energy must therefore increase rapidly. And, critically, most of the known fossil fuel reserves must remain in the ground.

Australia is on the front line of climate change. We must strive to cut our emissions rapidly and deeply to join global efforts to stabilise the world's climate if we are to reduce the risk of even more extreme events, including bushfires. Australia's emissions reduction target of 26-28% reduction in emissions by 2030 compared to 2005 levels leaves Australia lagging behind its major trading allies and partners and is not consistent with effectively tackling climate change. This is the critical decade to get on with the job.

We must cut our emissions rapidly and deeply to stabilise the world's climate.

# References

ABC (Australian Broadcasting Corporation) (2007) 7:30 Report: American Firefighters to Provide Relief in Vic, 15 January 2007, Accessed at http://www.abc.net.au/7.30/content/2007/s1827411.htm.

ABC (2015) Victorian bushfire season starts early, state facing 'long, hot, dangerous summer', 7 October 2015, Accessed at http://www.abc.net.au/news/2015-10-06/victorian-bushfire-season-starts-early-facing-dangerous-summer/6831716.

ABS (Australian Bureau of Statistics) (2015) Australian Demographic Statistics, March 2015, Accessed at http://www.abs.gov.au/ausstats/abs@.nsf/mf/3101.0.

AFAC (Australian Fire and Emergency Service Authorities Council) (2014) Annual Report 2013-2014, Accessed at http://www.afac.com.au/auxiliary/publications/report.

Amatulli G, Camia A and San-Miguel-Ayanz J (2013) Estimating future burned areas under changing climate in the EU-Mediterranean countries. Science of the Total Environment, 450–451:209–222.

ANAO (Australian National Audit Office) (2015) Administration of the Natural Disaster Relief and Recovery Arrangements, Report 34, Emergency Management Australia, Accessed at http://www.anao.gov.au/~/media/Files/Audit%20Reports/2014%202015/Report%2034/AuditReport_2014-2015_34.PDF.

Attiwill P and Adams M (2011) Mega-fires, inquiries and politics in the eucalypt forests of Victoria, south-eastern Australia, *Forest Ecology and Management* 294: 45-53.

BNHCRC (Bushfire and Natural Hazard Cooperative Research Centre) (2011) Fire Note: Predicting Fire from Dry Lightning, Issue 84, Accessed at http://www.bushfirecrc.com/sites/default/files/managed/resource/predicting_fires_from_dry_lightning_0.pdf.

BNHCRC (2012) Fire Note: Fire Development, Transitions and Suppression: An overview, Issue 94, Accessed at http://www.bushfirecrc.com/sites/default/files/managed/resource/fire_note_94_fire_development.pdf.

BNHCRC (2015) Hazard Note: Southern Australian seasonal bushfire outlook 2015-16, Issue 010, Accessed at http://www.bnhcrc.com.au/hazardnotes/010.

BoM (Bureau of Meteorology) (2009) Bushfire Weather, Accessed at http://www.bom.gov.au/weather-services/bushfire/about-bushfire-weather.shtml.

BoM (2013) Submission to the Senate Committee: Environment and Communications Reference Committee, Recent trends in and preparedness for extreme weather events, Accessed at http://www.aph.gov.au/Parliamentary_Business/Committees/Senate/Environment_and_Communications/Completed_inquiries/2010-13/extremeweather/report/index.

BoM (2014a) Highest Maximum temperatures for Western Australia: January 2014, Accessed at http://www.bom.gov.au/cgi-bin/climate/extremes/monthly_extremes.cgi?period=%2Fcgibin%2Fclimate%2Fextremes%2Fmonthly_extremes.cgi&climtab=tmax_high&area=wa&year=2015&mon=1.

BoM (2015a) Australia in summer 2014–15, Accessed at http://www.bom.gov.au/climate/current/season/aus/archive/201502.summary.shtml.

BoM (2015b) Climate Summaries Archive, Accessed at http://www.bom.gov.au/climate/current/statement_archives.shtml?region=aus&period=month.

BOM (2015c) Climate Outlooks – monthly and seasonal, Accessed at http://www.bom.gov.au/climate/outlooks/#/overview/summary/.

BoM (2015d) Special Climate Statement 52 – Early-season heat across southern Australia, 8 October 2015, Accessed at http://www.bom.gov.au/climate/current/statements/scs52.pdf.

BoM (2015e) About the Indian Ocean Dipole, Accessed at http://www.bom.gov.au/climate/IOD/about_IOD.shtml.

Bradstock R (2008) Effects of large fires on biodiversity in south-eastern Australia: disaster or template for diversity? *International Journal of Wildland Fire* 17:809-822.

Bradstock R (2010) A biogeographic model of fire regimes in Australia: current and future implications. *Global Ecology and Biogeography* 19: 145-158.

Bradstock R, Penman T, Boer M, Price O and Clarke H (2014) Divergent responses of fire to recent warming and drying across south-eastern Australia, *Global Change Biology* 20: 1412–1428.

Cal Fire (California Department of Forestry and Fire Protection: Amador-El Dorado Unit) (2013) News Release: Bark Beetles and Drought, January 27 2013, Accessed at http://www.fire.ca.gov/aeu/downloads/MR_barkbeetles_and_drought_2014.pdf.

Cameron P, Mitra B, Fitzgerald M, Scheinkestel C, Stripp A, Batey C, Niggemeyer L, Truesdale M, Holman P, Mehra R, Wasiak J and Cleland H (2009) Black Saturday: the immediate impact of the February 2009 bushfires in Victoria, Australia, *Medical Journal of Australia* 191: 11-16.

Cary GJ, Bradstock RA, Gill AM and Williams RJ (2012) Global change and fire regimes in Australia pp149-170 in Flammable Australia: Fire regimes, biodiversity and ecosystems in a changing world. (Eds Bradstock RA, Gill AM, Williams RJ). CSIRO Publishing, Collingwood, VIC.

Clarke H, Smith P and Pitman, A (2011) Regional signatures of future fire weather over eastern Australia from global climate models. *International Journal of Wildland Fire* 20: 550-562.

Clarke H, Lucas C, Smith P (2013) Changes in Australian fire weather between 1973 and 2010. *International Journal of Climatology* 33: 931-944.

Clark K, Skowronski N, Renninger H and Scheller R (2014) Climate change and fire management in the mid-Atlantic region, *Forest Ecology and Management* 327: 306-315.

Climate Commission (2013) The Critical Decade 2013: extreme weather, Steffen W, Hughes L and Karoly D. Accessed at https://www.climatecouncil.org.au/extreme-weather-report

Climate Council (2013) Be Prepared: Climate Change and the Australian Bushfire Threat, Hughes L and Steffen W. Accessed at https://www.climatecouncil.org.au/be-prepared

Climate Council (2014) Heatwaves: hotter, longer, more often. Steffen W, Hughes L and Perkins S. Accessed at https://www.climatecouncil.org.au/heatwaves-report

CSIRO and BoM (Commonwealth Scientific and Industrial Research Organisation and the Bureau of Meteorology) (2012) State of the Climate 2012, Accessed at http://www.csiro. au/Outcomes/Climate/Understanding/~/ media/8E59FBA4F8A94FE4B84F01E271226316.pdf.

CSIRO and BoM (2014) State of the Climate 2014, Accessed at www.bom.gov.au/state-of-the-climate/ documents/state-of-the-climate-2014_low-res. pdf?ref=button.

CSIRO and BoM (2015) Climate change in Australia: Projections for Australia's NRM regions, Technical Report, CSIRO and Bureau of Meteorology, Australia.

Deloitte Access Economics (2014) Scoping study on a cost benefit analysis of bushfire mitigation, Australia Forest Products Association, Accessed at http://www.ausfpa.com.au/wp-content/ uploads/AFPA-DAE-report-AmendedFinal-2014-05-27.pdf.

Dennison P, Brewer S, Arnold J, Moritz M (2014) Large wildfire trends in the western United States, 1984–2011, *Geophysical Research Letters*, 41: 2928–2933.

Disaster Assist (2015) Declared national bushfire disasters in 2014 and early 2015, Accessed at http://www.disasterassist.gov.au/Currentdisasters/Pages/default.aspx.

EMV (Emergency Management Victoria) (2015) Victoria Partners with California, Accessed at https://www.emv.vic.gov.au/latest-news/victoria-partners-with-california/.

ESRL (Earth System Research Laboratory) Global Monitoring Division (2015) Trends in Atmospheric Carbon Dioxide, Accessed at http://www.esrl.noaa.gov/gmd/ccgg/trends/global.html#global_data.

European Commission (2013) JRC Technical Report: Forest Fires in Europe, Middle East and North Africa 2012, Report EUR 26048 EN, Publications Office of the European Union, Luxembourg, Accessed at http://forest.jrc.ec.europa.eu/media/cms_page_media/9/FireReport2012_Final_2pdf_2.pdf.

European Commission (2014) Trends in global CO2 emissions: 2014 Report, Lead by the PBL Netherlands Environmental Assessment Agency, Accessed at http://edgar.jrc.ec.europa.eu/news_docs/jrc-2014-trends-in-global-co2-emissions-2014-report-93171.pdf.

European Commission (2015a) Fact Sheet: Fighting forest fires in Europe – how it works, Accessed at http://europa.eu/rapid/press-release_MEMO-15-5411_en.htm.

European Environment Agency (2009) Forest Fires in Southern Europe destroy much more than trees, Accessed at http://www.eea.europa.eu/highlights/forest-fires-in-southern-europe-destroy-much-more-than-trees.

Flannigan M, Cantin A, de Groot W, Wotton M, Newbery A and Gowman L (2013) Global wildland fire season severity in the 21st century. *Forest Ecology and Management*. 294: 54-61.

Geoscience Australia (2015) What Causes Bushfires? Accessed at http://www.ga.gov.au/scientific-topics/hazards/bushfire/basics/causes.

Giglio L, Randerson J, van der Werf G (2013) Analysis of daily, monthly, and annual burned area using the fourth generation global fire emissions database (GFED4), *Journal of Geophysical Research-Biogeosciences* 118: 317-328.

Global Carbon Project (2015) Global Carbon Budget 2014, Le Quéré C, Moriarty R, Andrew R, Peters G, Ciais P, Friedlingstein P, Jones S, Sitch S, Tans P, Arneth A, Boden T, Bopp L, Bozec Y, Canadell J, Chevallier F, Cosca C, Harris I, Hoppema M, Houghton R, House J, Johannessen T, Kato E, Jain A, Keeling R, Kitidis V, Klein Goldewijk K, Koven C, Landa C, Landschützer P, Lenton A, Lima I, Marland G, Mathis J, Metzl N, Nojiri Y, Olsen A, Peters W, Ono T, Pfeil B, Poulter B, Raupach M, Regnier P, Rödenbeck C, Saito S, Salisbury J, Schuster U, Schwinger J, Séférian R, Segschneider J, Steinhoff T, Stocker B, Sutton A, Takahashi T, Tilbrook B, Viovy N, Wang Y, Wanninkhof R, Van der Werf G, Wiltshire A and Zeng N, Earth System Science Data, Accessed at: http://www.earth-syst-sci-data.net/7/47/2015/essd-7-47-2015.html.

Groot W and Flannigan M (2014) Chapter 7: Climate Change and Early Warning Systems for Wildland Fire, in Zommers Z, Singh A (eds.), Reducing Disaster: Early Warning Systems 127 for Climate Change, Accessed at http://climate.ncas.ac.uk/people/allan/Seasonal_Forecasting_papers/deGroot%20and%20Flannigan%20Early%20Warning.pdf.

Handmer J, McKellar R, McLennan B, Whittaker J, Towers B, Duggie J and Woolf M (2012) National Climate Change Adaptation Research Plan: Emergency Management—Revised 2012 Edition, National Climate Change Adaptation Research Facility, Gold Coast, 60pp.

Harris, S, Tapper, N, Packham D, Orlove B and Nicholls, N (2008) The relationship between monsoonal summer rain and dry-season fire activity of northern Australia International, *Journal of Wildland Fire* 17: 674-684.

Harris S, Nicholls N and Tapper N (2013) Forecasting fire activity in Victoria, Australia, using antecedent climate variables and ENSO indices, *International Journal of Wildland Fire* 23: 290-293.

Hydrometeorological Centre of Russia (2015) Climate, Accessed at http://wmc.meteoinfo.ru/climate.

Insurance Council of Australia (2015) Disaster Statistics, Accessed at http://www.insurancecouncil.com.au/statistics.

IPCC (2013) Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and PMP. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IPCC (2014a) Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects: Australasia. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Barros V, Field C, Dokken D, Mastrandrea M, Mach K, Bilir T, Chatterjee M, Ebi K, Estrada Y, Genova R, Girma B, Kissel E, Levy A, MacCracken S, Mastrandrea P, White L (eds.), Cambridge University Press, Cambridge and New York, pp 1371-1438.

IPCC (2014b) Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects: North America. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Barros V, Field C, Dokken D, Mastrandrea M, Mach K, Bilir T, Chatterjee M, Ebi K, Estrada Y, Genova R, Girma B, Kissel E, Levy A, MacCracken S, Mastrandrea P, White L (eds.), Cambridge University Press, Cambridge and New York, pp 1439-1498.

IRENA (International Renewable Energy Agency) (2014), REthinking Energy: Towards a new power system, Accessed at http://www.irena.org/rethinking/IRENA_REthinking_fullreport_2014.pdf.

Jayaratne R and Kuleshov E (2006) The relationship between lightning activity and surface wet bulb temperature and its variation with latitude in Australia. *Meteorology and Atmospheric Physics* 91:17-24.

Jolly M, Cochrane M, Freeborn P, Holden Z, Brown T, Williamson G and Bowman D (2015) Climate-induced variations in global wildfire danger from 1979 to 2013, *Nature Communications* 6: 7537.

Jotzo F (2015) The G7 is right to call for fossil fuel phase-out, but it can happen sooner, The Conversation, 10 June, Accessed at http://theconversation.com/the-g7-is-right-to-call-for-fossil-fuel-phase-out-but-it-can-happen-sooner-42991.

Kestrel Aviation (2015) Services: Emergency Response, Accessed at http://kestrelaviation.com.au/services/emergency-response/.

Khabarov N, Krasovskii A, Obersteiner M, Swart R, Dosio A, San-Miguel-Ayanz J, Durrant T, Camia A and Migliavacca M (2014) Forest fires and adaptation options in Europe, *Regional Environmental Change*, 1-10.

King D, Ginger J, Williams S, Cottrell A, Gurtner Y, Leitch C, Henderson D, Jayasinghe N, Kim P, Booth K, Ewin C, Innes K, Jacobs K, Jago-Bassingthwaighte M and Jackson L (2013) Planning, building and insuring: Adaptation of built environment to climate change induced increased intensity of natural hazards, National Climate Change Adaptation Research Facility, Gold Coast.

Knutson T, Zeng F and Wittenberg A (2014) Multimodel assessment of extreme annual-mean warm anomalies during 2013 over regions of Australia and the western tropical Pacific. *Bulletin of the American Meteorological Society* 95(9): S26-S30.

Lewis S and Karoly D (2014) The role of anthropogenic forcing in the record 2013 Australia-wide annual and spring temperatures. *Bulletin of the American Meteorological Society* 95(9): S31-S34.

Liesowska A (2015) Fire rages on as death toll from two blazes reaches 33, The Siberian Times, 16 April 2015, Accessed at http://siberiantimes.com/ecology/casestudy/news/n0187-fire-rages-on-as-death-toll-from-two-blazes-reaches-33/.

Mann M and Gleick P (2015) Climate change and California drought in the 21st century, *Proceedings of the National Academy of Science* 112: 3858–3859.

Matthews S, Sullivan A, Watson P and Williams R (2012) Climate change, fuel and fire behaviour in a eucalypt forest, *Global Change Biology* 18: 3212-3223.

McGlade C and Ekins P (2015) The geographical distribution of fossil fuels unused when limiting global warming to 2°C. *Nature* 517(7533): 187-190.

NAFC (National Aerial Firefighting Centre) (2014) Annual Report 2014, Accessed at http://www.nafc.org.au/portal/DesktopModules/ViewDocument.aspx?DocumentID=319

NASA (National Aeronautics and Space Administration) (2015) Press Release: NASA, NOAA Find 2014 Warmest Year in Modern Record. Accessed at http://www.nasa.gov/press/2015/january/nasadetermines-2014-warmest-year-in-modernrecord/#.VLlXOSuUfyk.

NIEIR (National Institute of Economic and Industry Research) (2013) Firefighters and climate change: The human resources dimension of adapting to climate change. Final and consolidated report prepared by the National Institute of Economic and Industry Research for the United Firefighters Union of Australia. Submission to the Senate Standing Committee on Environment and Communications' Inquiry into recent trends and preparedness for extreme weather events. February 2013.

NIFC (National Interagency Fire Center) (2002) Internation Agreements - Australia, Accessed at http://www.nifc.gov/nicc/logistics/International%20Agreements/Australia%20Support.pdf.

NIFC (2014) Wildland fire fatalities by year, https://www.nifc.gov/safety/safety_documents/Fatalities-by-Year.pdf.

NIFC (2015a) Suppression Costs, Accessed at https://www.nifc.gov/fireInfo/fireInfo_documents/SuppCosts.pdf.

NIFC (2015b) International Support in Wildland Fire Suppression, Accessed at https://www.nifc.gov/fireInfo/fireInfo_international.html.

NOAA (National Oceanic and Atmospheric Administration) (2015a) Global Analysis - Annual 2014, Accessed at http://www.ncdc.noaa.gov/sotc/global/2014/13.

NOAA (2015b) State of the Climate, http://www.ncdc.noaa.gov/sotc/.

NOAA (2015c) Climate at a Glance: Timeseries, Accessed at https://www.ncdc.noaa.gov/cag/time-series/us/108/0/tavg/ytd/12/1950-2015?base_prd=true&firstbaseyear=1901&lastbaseyear=2000.

NOAA (2015d) National Overview - August 2015, Accessed at http://www.ncdc.noaa.gov/sotc/national/201508.

NOAA (National Oceanic and Atmospheric Association) (2015e) Wildfires - annual records, Accessed at http://www.ncdc.noaa.gov/sotc/fire/201113.

Perkins S and Alexander L (2013) On the measurement of heat waves, *Journal of Climate* 26: 4500-4517.

Perkins S, Argüeso D and White C (2015) Relationships between climate variability, soil moisture, and Australian heatwaves, *Journal of Geophysical Research: Atmospheric* 120: 8144–8164.

Price C and Rind D (1994) Possible implications of global climate change on global lightning distributions and frequencies, *Journal of Geophysical Research* 99: 10,823–10,831.

Roshydromet (2008) Assessment Report on Climate Change and its Consequences in Russian Federation, Accessed at http://wmc.meteoinfo.ru/media/climate/obzhee_rezume_eng.pdf.

Slattery S, Fawcett R, Peace M and Kepert J (2015) Meteorology of the Sampson Flat Fire in January 2015, Accessed at http://www.bnhcrc.com.au/search/site/adelaide%20hills.

Swain D, Tsiang M, Haugen M, Singh D, Charland A, Rajaratnam B and Diffenbaugh N (2014) The Extraordinary California Drought of 2013/14: Character, Context and the role of Climate Change, [In, Explaining Extreme Events of 2013 from a Climate Perspective], *Bulletin of the American Meteorological Society* 95: 53-57.

The Guardian (2014) California wildfire rages as firefighters scramble for water amid record drought, 27 June 2015, Accessed at http://www.theguardian.com/us-news/2015/jun/26/california-wildfires-water-shortage-drought.

The Guardian (2015a) Institutions worth $2.6 trillion have now pulled investments out of fossil fuels, 23 September 2015, Accessed at http://www.theguardian.com/environment/2015/sep/22/leonardo-dicaprio-joins-26tn-fossil-fuel-divestment-movement.

Trenberth K, Dai A, van der Schrier G, Jones P, Barichivich J, Briffa K and Sheffield J (2014) Global warming and changes in drought, *Nature Climate Change* 4: 17–22.

US DoA (United States Department of Agriculture) (2015) Forest Service Chief Predicts "Above Normal" Wildland Fire Potential in Much of the West, Media Release 0126.15, Accessed at http://www.usda.gov/wps/portal/usda/usdamediafb?contentid=2015/05/0126.xml&printable=true&contentidonly=true.

US EPA (United States Environmental Protection Agency) (2015a) Climate Change Indicators in the United States: US and Global Temperatures, Accessed at http://www3.epa.gov/climatechange/science/indicators/weather-climate/temperature.html.

US EPA (2015b) Climate Change Indicators in the United States: Wildfires, Accessed at http://www3.epa.gov/climatechange/science/indicators/ecosystems/wildfires.html.

WALIA (Western Australian Land Information Authority) (2013) Landgate FireWatch. Accessed at http://firewatch.landgate.wa.gov.au/landgate_firewatch_public.asp.

Willis M (2005) Bushfire arson: a review of the literature. *Research and Public Policy Series No. 61.* Bushfire CRC, Melbourne. 166 pp.

WRI (World Resources Institute) (2014) Western US Wildfires and the Climate Change Connection, Accessed at http://www.wri.org/sites/default/files/WRI14_Factsheets_Western_US_Wildfires.pdf.

Yoon J, Wang S, Gillies R, Hipps L, Kravitz B and Rasch P (2015) Extreme Fire Season in California: A Glimpse into the Future?. Special Supplement to the *Bulletin of the American Meteorological Society*. 96: 5-10.

Yue X, Mickley L, Logan J, Hudman R, Val Martin M and Yantosca R (2015) Impact of 2050 climate change on North American wildfire: consequences for ozone air quality, *Atmospheric Chemistry and Physics* 15: 13867–13921.

# Image Credits

Cover photo: “Cessnock Bush Fire 18-01-2013” by Flickr user Quarrie Photography licensed under CC BY-NC-ND 2.0.

Page 1: Figure 1 “bushfire (20)” by Flickr user bertknot licensed under CC BY-SA 2.0.

Page 2: Figure 2 photo by Gary P Hayes Photography – garyphayes.com/photography.

Page 4: Figure 3 “TAFE Kersbrook bushfire recovery” by Flickr user TheLeadSA (with CC credit to Jack Baldwin) licensed under CC BY 2.0.

Page 7: Figure 6 “bushfire” by Flickr user bertknot licensed under CC BY-SA 2.0.

Page 9: Figure 7 “Huge forest fire threatens homes in Portugal”, copyright Steve Photography.

Page 11: Figure 8 “Chiwaukum Fire” by Flickr user Washington DNR licensed under CC BY-NC-ND 2.0.

Page 15: Figure 10 “View of Sydney skyline during bushfires (October 17, 2013)” by Flickr user Andrea Schaffer licensed under CC BY 2.0.

Page 16: Figure 11 “6am strike team” by Flickr user robdownunder licensed under CC BY-NC-ND 2.0.

Page 18: Figure 12 “Elvis” by Flickr user Sascha Grant licensed under CC BY-NC-ND 2.0.

Page 20: Figure 13 “California Wildfires” by Flickr user US Air Force licensed under CC BY-NC 2.0.

Page 24: Figure 16 “Mt McKay” by Flickr user Sascha Grant licensed under CC BY-NC-ND 2.0.

Page 25: Figure 17 photo by Gary P Hayes Photography – garyphayes.com/photography.

# Preparing for a Bushfire

**IN AN EMERGENCY, CALL TRIPLE ZERO (106 FOR PEOPLE WITH A HEARING OR SPEECH IMPAIRMENT)**

# 000

## What can I do to prepare for a bushfire?

### INFORM YOURSELF

State Fire Authorities, listed below, have the resources available to help you prepare for a bushfire. Use these resources to inform yourself and your family.

### ASSESS YOUR LEVEL OF RISK

The excellent resources of State Fire Authorities are also available to assist you to assess your level of risk from bushfire. Take advantage of them.

### MAKE A BUSHFIRE SURVIVAL PLAN

Even if your household is not at high risk from bushfire (such as suburbs over 1 km from bushland), you should still educate yourself about bushfires, and take steps to protect yourself and your property. State Fire Authorities have excellent resources available to help you to prepare a bushfire survival plan. Look on your State Fire Authority's website to start or review your plan.

### PREPARE YOUR PROPERTY

Regardless of whether you decide to leave early or to stay and actively defend, you need to prepare your property for bushfire. Check out the excellent resources and guides available on State Fire Authorities websites. An important consideration is retrofitting older houses to bring them in alignment with current building codes for fire risk and assessing the flammability of your garden.

### PREPARE YOURSELF AND YOUR FAMILY

Preparation is not only about the physical steps you take to prepare—e.g., preparingyour house and making a bushfire survival plan. Preparing yourself and your familyalso involves considering your physical, mental and emotional preparedness for a bushfire and its effects. Take the time to talk to your family and to thoroughly prepare yourself on all levels.

## State Fire Authorities

**NSW RFS:**
www.rfs.nsw.gov.au
1800 679 737

**Queensland Fire and Rescue Service**
www.fire.qld.gov.au
13 74 68

**SA Country Fire Service**
www.cfs.sa.gov.au
1300 362 361

**Tasmania Fire Service**
www.fire.tas.gov.au
03 6230 8600

**Country Fire Authority (Victoria)**
www.cfa.vic.gov.au
1800 240 667

**WA Department of Fire and Emergency Services**
www.dfes.wa.gov.au
1300 657 209

**ACT Rural Fire Service**
www.esa.act.gov.au
13 22 81

**Secure NT** (Find the Bush Fires section under 'Preparing for Emergencies')
www.securent.nt.gov.au/index.html

CLIMATE COUNCIL

**NB:** Information correct as of 17/11/15

# Thank you for supporting the Climate Council.

The Climate Council is an independent, crowd-funded organisation providing quality information on climate change to the Australian public.

**CLIMATE COUNCIL**

facebook.com/climatecouncil

twitter.com/climatecouncil

info@climatecouncil.org.au

climatecouncil.org.au

The Climate Council is a not-for-profit organisation and does not receive any money from the Federal Government. We rely upon donations from the public. We really appreciate your contributions.

DONATE climatecouncil.org.au/donate

CLIMATE COUNCIL