

CLIMATE CHANGE AND THE NSW/ACT BUSHFIRE THREAT: UPDATE 2016



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Climate Change and the NSW/ACT bushfire threat: Update 2016 by Professor Lesley Hughes and Dr David Alexander.



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Key Findings

1

Climate change is already increasing the risk of bushfires in New South Wales (NSW) and the Australian Capital Territory (ACT).

- › Since the 1970s, extreme fire weather has increased across large parts of Australia, including NSW and the ACT.
- › Hot, dry conditions have a major influence on bushfires. Climate change is making hot days hotter, and heatwaves longer and more frequent, with increasing drought conditions in Australia's southeast.
- › The 2015/16 summer was Australia's sixth hottest on record and in NSW and the ACT the mean maximum temperatures were 1.4°C and 1.9°C above average, respectively. February 2016 was also the driest that NSW has experienced since 1978. Hot and dry conditions are driving up the likelihood of dangerous fire weather in NSW and the ACT.

2

In NSW and the ACT the fire season is starting earlier and lasting longer. Dangerous fire weather has been extending into Spring and Autumn.

- › 'Above normal' fire potential is expected in most of NSW for the 2016-17 bushfire season, because of high grass growth experienced during spring and predicted above average temperatures during summer.
- › In the ACT, predicted hotter and drier weather during summer will produce conditions conducive to bushfire development.

3

Recent severe fires in NSW and the ACT have been influenced by record hot, dry conditions.

- › Record breaking heat and hotter weather over the long term in NSW and the ACT has worsened fire weather and contributed to an increase in the frequency and severity of bushfires.
- › In October 2013, exceptionally dry conditions contributed to severe bushfires on the Central Coast and in the Blue Mountains of NSW, which caused over \$180 million in damages.
- › At the beginning of August in 2014, volunteers were fighting 90 fires simultaneously and properties were destroyed.

4

The total economic costs of NSW and ACT bushfires are estimated to be approximately \$100 million per year. By around the middle of the century these costs will more than double.

- › Bushfires cost an estimated \$375 million per year in Australia. With a forecast growth in costs of 2.2% annually between 2016 and 2050, the total economic cost of bushfires is expected to reach \$800 million annually by mid-century.
- › These state and national projections do not incorporate increased bushfire incident rates due to climate change and could potentially be much higher.
- › In 2003, abnormally high temperatures and below-average rainfall in and around the ACT preceded bushfires that devastated several suburbs, destroyed over 500 properties and claimed five lives. This also had serious economic implications for the ACT with insured losses of \$660 million.

5

In the future, NSW and the ACT are very likely to experience an increased number of days with dangerous fire weather. Communities, emergency services and health services must keep preparing.

- › Fire severity and intensity is expected to increase substantially in coming decades, especially in those regions currently most affected by bushfires, and where a substantial proportion of the Australian population lives.
- › Increased resources for our emergency services and fire management agencies will be required as fire risk increases.

6

This is the critical decade to protect Australians.

- › Australia must strive to cut emissions rapidly and deeply to join global efforts to stabilise the world's climate and to reduce the impact of extreme weather events, including bushfires.
- › Australia's very weak target of a 26-28% reduction in emissions by 2030 compared to 2005 levels – and we are on track to miss even this target – leaves Australia lagging well behind other OECD countries.

Introduction

Residents of New South Wales (NSW) and the Australian Capital Territory (ACT) have often experienced the serious consequences of bushfires. In 2013, bushfires in January and October burnt 768,000 hectares of land and destroyed 279 homes in NSW. Tragically, 2 people lost their lives and damages were estimated to be more than \$180 million.

The Australian population have always lived with fire and its consequences, but climate change is increasing fire danger weather and thus the risk of fires. It is time to think very seriously about the risks that future fires will pose.

This report provides an update to the previous Climate Council report on bushfire risk and NSW and the ACT (NSW: <https://www.climatecouncil.org.au/be-prepared-climate-change-and-the-nsw-bushfire-threat> and ACT: <https://www.climatecouncil.org.au/be-prepared-climate-change-the-act-bushfire-threat>). We begin this report by describing the background context of fire and its history in NSW and the ACT. We then outline the link between bushfires and climate change, before considering how bushfire danger weather is intensifying in NSW and the ACT, and what this means for the immediate future. We explore the impacts of fire on people, property, water supply and biodiversity, before considering the future implications of bushfires for NSW and ACT fire managers, planners and emergency services.

1. The Nature of Bushfires

Fire has been a feature of the Australian environment for at least 65 million years (Cary et al. 2012). Human management of fires also has a long history, starting with fire use by Indigenous Australians ('fire-stick farming') up to 60,000 years ago. Typically, 3 to 10% of Australia's land area burns every year (Ellis et al. 2004).

In Australia, the Forest Fire Danger index (FFDI) is used to measure the degree of risk of fire in our forests (Luke and Macarthur 1978). The Bureau of Meteorology (BoM) and fire management agencies use the FFDI to assess fire risk and issue warnings. The index was

originally designed on a scale from 0 to 100, with fires between 75 and 100 considered 'extreme'. The unprecedented ferocity of the 2009 Black Saturday bushfires in Victoria saw a new 'catastrophic' category added to the FFDI for events exceeding the existing scale.

Since 1926, NSW has experienced 27 significant bushfire events that have affected hundreds of thousands of hectares of land, killed livestock and destroyed thousands of homes (NSW PRS 2014). Since 1901, bushfires have claimed 77 and 5 civilian lives in NSW and the ACT, respectively (Blanchi et al. 2014). NSW and the ACT account for 12% of Australian bushfire deaths (Blanchi et al. 2014).

Figure 1: Helicopter preparing to drop water on a developing bushfire at Lane Cove National Park in Sydney in February 2009.



Bushfires have claimed 82 civilian lives in NSW and the ACT since 1901.

Fire is a complex process that is very variable in space and time. A fire needs to be started (ignition), it needs something to burn (fuel) and it needs conditions that are conducive to its spread (weather and topography) (Figure 2). Fire activity is strongly influenced by weather, fuel, terrain, ignition agents and people. The most important aspects of weather that affect fire and fuels are temperature, precipitation, wind and humidity. Once a fire is ignited, very hot days with low humidity and high winds are conducive to its spread. The type, amount, and moisture level of fuel available are also critical determinants of fire behaviour, extent and intensity (Climate Council 2014a). The relationship between rainfall and fuel is complex. Wet seasons can lead to increased plant growth and therefore increase fuel buildup in the months or years before a fire is ignited (Bradstock et al. 2009). Warmer temperatures and low rainfall in the period immediately preceding an ignition, however, can lead to drier vegetation and soil, making the existing fuel more flammable. Warmer temperatures may also be associated with a higher incidence of lightning activity (Jayaratne and Kuleshov 2006), increasing the risk of ignition.

In the temperate forests of NSW and the ACT, fire activity is strongly determined by weather conditions and the moisture content of the fuel. As fire weather conditions become more severe, fuel moisture content declines, making the fuel more flammable. By contrast, in arid regions, vegetation and thus fuel in most years is sparsely distributed and fires, if ignited, rarely spread far. In Australia's southeast, fires are common in the heathlands and dry sclerophyll forests (Clarke et al. 2011; Bradstock et al. 2012).

People are a very important component of the fire equation. Many fires are either deliberately or accidentally lit, and in places where population density is high, the probability of a fire igniting increases close to roads and settlements (Willis 2005; Penman et al. 2013). Some of Australia's most catastrophic bushfires have been ignited by powerline faults. But people also play an important role in reducing fire risk, by vegetation management including prescribed burning to reduce fuel load and conducting fire suppression activities. Interventions such as total fire ban days also play a pivotal role in reducing ignitions under dangerous fire conditions.

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 2: The main factors affecting bushfires including: (i) ignition, (ii) fuel, (iii) people and (iv) weather.

2. What is the Link Between Bushfires and Climate Change?

A fire needs to be started (ignition), it needs something to burn (fuel) and it needs conditions that are conducive to its spread (weather) (see Section 1). Climate change can affect all of these factors in both straightforward and more complex ways.

The role of climate change in ignition is likely to be relatively small compared to the fuel and weather, but may still be significant. For example, lightning accounts for ~27% of the ignitions in the Sydney region (Bradstock 2008) and the incidence of lightning is sensitive to weather conditions, including temperature (Jayaratne and Kuleshov 2006). Climate change can also affect fuel. For example, a lack of rainfall can dry out the soil and vegetation, making existing fuel more combustible. But whilst climate change can affect ignition and fuel, it is the impact of climate change on weather that has the most significant influence on fire activity.

The long-term trend towards a warmer climate due to increasing greenhouse gas emissions is making hot days hotter, and heatwaves longer and more frequent, increasing bushfire risk.

The 2013 October bushfires in the Blue mountains of NSW illustrate the role of weather conditions in affecting fire severity. The bushfires were preceded by the warmest September on record for the state, the warmest 12 months on record for Australia, and below average rainfall in forested areas, leading to very dry fuels (Bushfire CRC 2013). Very hot, dry and windy days create dangerous bushfire weather. The most direct link between bushfires and climate change therefore comes from the relationship between the long-term trend towards a warmer climate due to

increasing greenhouse gas emissions, which are increasing the amount of heat in the atmosphere, in turn leading to increased incidence of very hot days. Put simply, climate change is increasing the frequency and severity of very hot days (IPCC 2013), and is driving up the likelihood of dangerous fire danger weather (see Box 1). The latest IPCC report confirms with high confidence that climate change is expected to increase the number of days with very high and extreme fire weather, particularly in southern Australia (IPCC 2014).

Figure 3: Firefighters using a monitor (high-capacity water gun) while fighting a fire at Mt. Riverview in the Blue Mountains in October 2013.



BOX 1: EXTREME HEAT

Climate change is now making hot days hotter, heatwaves longer and more frequent, and drought conditions have been increasing in Australia's southeast.

While hot weather has always been common in Australia's southeast, it has become more common and severe over the past few decades, including in NSW and the ACT. The southeast of Australia has experienced significant warming during the last 50 years (Timbal and Drosowsky 2012). The 2015/16 summer was Australia's sixth hottest on record (BoM 2016a) and in NSW and the ACT the mean maximum temperature was 1.4°C and 1.9°C above average, respectively (BoM 2016b; BoM 2016c). There were several heatwaves during summer, while February 2016 was also the driest that NSW has experienced since 1978 (BoM 2016b).

Heatwaves are becoming more intense over time, with average heatwave intensity increasing

in Sydney by 1.5°C, since 1950 (BoM 2013a; Climate Council 2014b). Eight out of ten of the hottest years on record in NSW and the ACT have occurred since 2002 (BoM 2016d; Figure 4). Record high temperatures occurred in 2013, which proved to be Australia's hottest year on record, with the mean maximum temperature during the year 1.45°C above average (BoM 2014a; Climate Council 2014c). The monthly mean average temperature record for NSW in September 2013 was shattered by a 4.68°C increase above average temperatures (BoM 2014b).

The IPCC projects with virtual certainty that warming in Australia will continue throughout the 21st century and predicts with high confidence that bushfire danger weather will increase in most of southern Australia, including NSW and the ACT (IPCC 2014). The direct effects of a 3 - 4°C temperature increase in the ACT could more than double fire frequency and increase fire intensity by 20% (Cary and Banks 2000; Cary 2002).

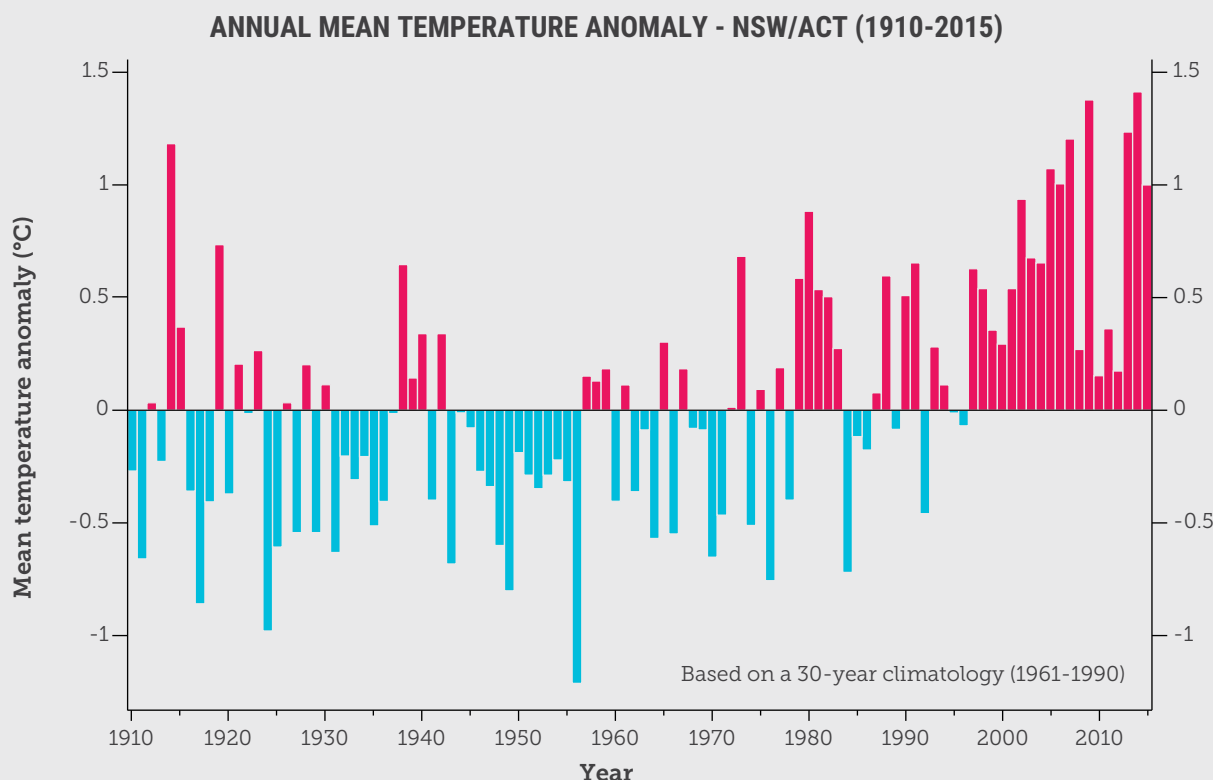


Figure 4: NSW/ACT increasing heat (BoM 2016d). Blue bars indicate years where annual temperatures were below average, and red bars indicate years with above average temperatures.

While there have been relatively few 'attribution' studies on bushfires, which quantify the probability that a bushfire was made more likely because of climate change, there is increasing evidence of the effects of climate change on worsening fire weather and the length of fire seasons. For example, a recent study by Abatzoglou and Williams (2016) of Western US wildfires has linked climate change to producing more than half of the dryness (fuel aridity) of forests since the 1970s, a doubling of the forest fire area since the mid-1980s, and an increase in the length of the fire season. In Northern California in 2014, the second largest fire season in the state in terms of burned areas occurred (Figure 5). Yoon et al. (2014) demonstrate that the risk of such bushfires in California has increased due to human-

induced climate change. Most recently, in May 2016, an extreme wildfire forced the entire town of Fort McMurray, Canada of almost 90,000 people to be evacuated. The conditions leading to the wildfire were exacerbated by climate change and El Niño, which resulted in a drier than normal winter and reduced snowpack; moisture which normally limits the impacts of wildfires (Climate Central 2016; Independent 2016; New Yorker 2016). Attribution of climate change on fire events in Australia is harder because of highly erratic climate and short historical length (Williamson et al. 2016), but recent severe ecological impacts of 21st century fires in the Victorian Alps and Tasmania is unprecedented in recent history and is consistent with climate change (Bowman and Prior 2016).

Figure 5: Fire burns in the Klamath National Forest in Northern California in 2014. This was the second largest fire season on record in the entire state in terms of burned areas. The risk of such bushfires in California has increased due to climate change.



3. Observations of Changing Bushfire Danger Weather in NSW and the ACT

Since the 1970s, there has been an increase in extreme fire weather, as well as a longer fire season, across large parts of Australia, particularly in southern and eastern Australia (CSIRO and BoM 2016). Increasing hot days, heatwaves and rainfall deficiencies in NSW and the ACT are driving up the likelihood of extreme fire weather in the state.

Much of eastern Australia has become drier since the 1970s, with the southeast experiencing a drying trend due to declines in rainfall combined with increased temperatures (BoM 2016e; Climate Commission 2013). Since the mid-1990s, southeast Australia has experienced a 15% decline in late autumn and early winter rainfall and a 25% decline in average rainfall in April and May (CSIRO and BoM 2014).

The upcoming 2016/17 bushfire season in NSW and the ACT is set to be a potentially damaging one. September was the wettest and second wettest on record for NSW and the ACT, respectively (BoM 2016f; BoM 2016g). These wet conditions led to substantial grass growth (increase in fuel

loads). October rainfall was 15% and 30% less than average for NSW and Canberra, respectively (BoM 2016h; BoM 2016i).

Dry conditions are set to continue into summer, with BoM (2016j) predicting above average dry conditions and above average temperatures for the December–February period for the ACT and virtually all of NSW. These tinderbox conditions have led to the Bushfire and Natural Hazards CRC (2016) releasing a November update to their seasonal bushfire outlook, which shows the majority of NSW has 'above normal' fire potential, meaning that there is an increased risk of bushfires (Figure 6). In the ACT, the forecast warmer and drier than average conditions will provide conditions conducive to the development of bushfires.

Bushfires this season have already burned land and damaged some buildings in the NSW regions of Hunter, Port Stephens and Cessnock. In Sydney's west, bushfires threatened homes and led to evacuations in Londonderry and Llandilo. The trend of warmer and drier than average weather conditions mean both NSW and the ACT are extremely vulnerable to bushfires this summer.

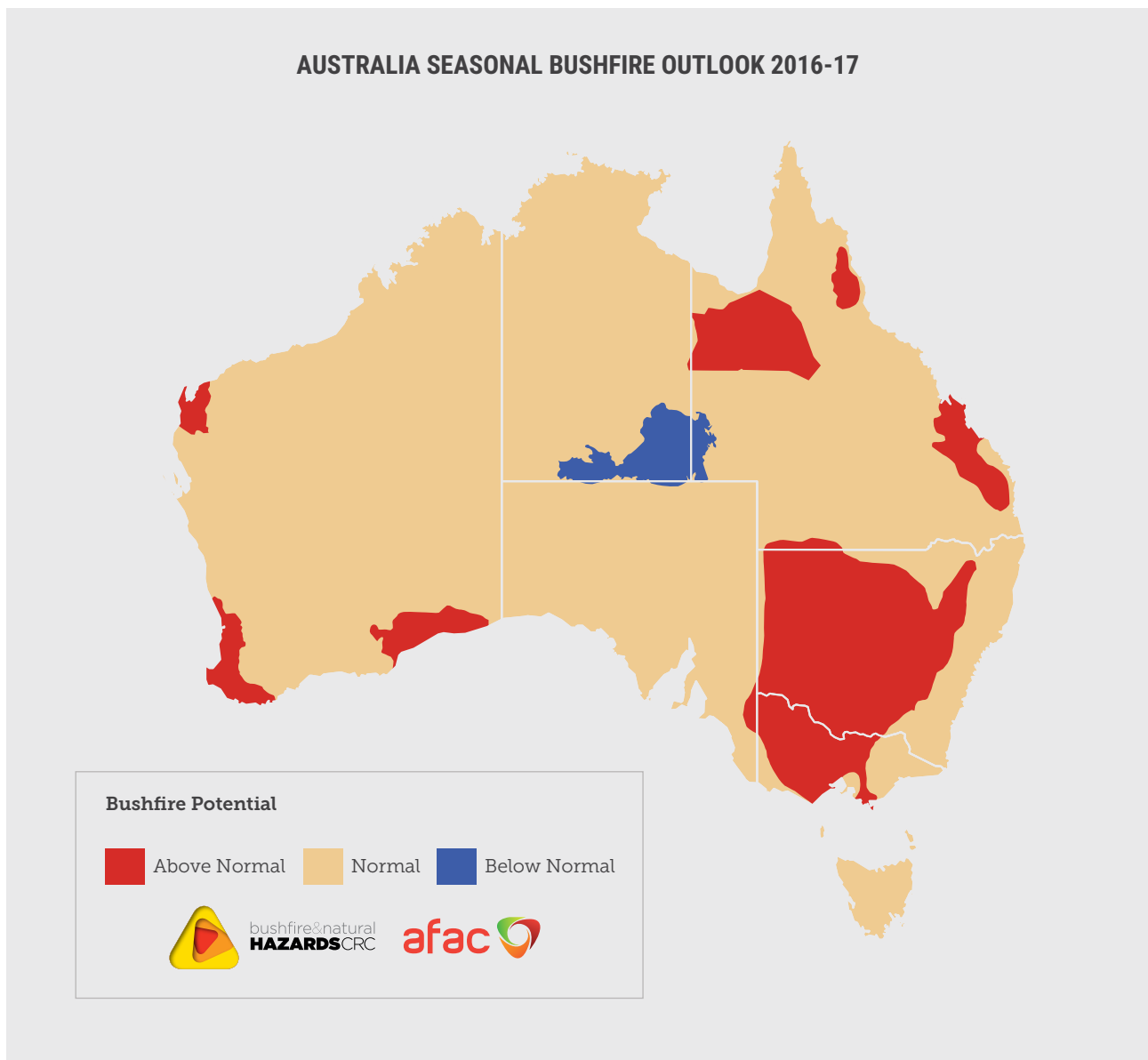


Figure 6: Southern Australia Seasonal Bushfire Outlook (Bushfire and Natural Hazards CRC 2016). Large parts of NSW are expected to have above normal bushfire potential for the 2016/17 summer.

Above average hotter and drier weather during the December–February period in 2016/17, along with high grass growth in spring, means the majority of NSW has above normal fire potential this bushfire season.

The concept of a 'normal' bush fire season is rapidly changing as bushfires continue to increase in number, burn for longer and affect larger areas of land (Bushfire and Natural Hazards CRC 2016). The influence of hotter, drier weather conditions on the likelihood of bushfire spread in NSW and the ACT is captured by changes in the FFDI, an indicator of extreme fire weather. Some regions of Australia, especially in the south and southeast have already experienced a significant increase in extreme fire weather days since the 1970s, as well as a longer fire

season (CSIRO and BoM 2016). The FFDI increased significantly at 24 of 38 weather stations across Australia between 1973 and 2010, with none of the stations recording a significant decrease (CSIRO and BoM 2015). These changes have been most marked in spring, indicating a lengthening fire season across southern Australia, with fire weather extending into October and March. The lengthening fire season means that opportunities for fuel reduction burning are decreasing (Matthews et al. 2012).

The concept of a 'normal' bushfire season is rapidly changing as bushfires continue to increase in number, burn for longer and affect larger areas of land.

Figure 7: Extreme heat can cause severe impacts to infrastructure and essential services, including disruptions to electricity.



4. Future Projections of Fire Activity in Southeast Australia

Research aimed at understanding future fire activity in NSW and the ACT has a long history (Table 1). While the detailed results of these studies vary due to the use of different global circulation models (GCMs) and different climate scenarios, their collective conclusion is clear – weather conditions conducive to fire in the southeast and southwest of the continent are becoming increasingly frequent. The IPCC (2014) projects with virtual certainty that warming in Australia will continue throughout the 21st century. In addition, there is high confidence that bushfire danger weather will increase in most of southern Australia, including NSW and the ACT (CSIRO and BoM 2015).

Future changes in the El Niño-Southern oscillation (ENSO) phenomenon are also likely to have an influence on fire activity. There is a strong positive relationship between El Niño events and fire weather conditions in southeast and central Australia (Williams and Karoly 1999; Verdon et al. 2004; Lucas 2005) and between El Niño events and actual fire activity (Harris et al. 2013). Significant changes have occurred in the nature of ENSO since the 1970s, with the phenomenon being more active and intense during the 1979-2009 period than at any other time in the past 600 years (Aiken et al. 2013). It is likely that climate change is and will continue to influence ENSO behaviour, especially extreme El-Niño events (e.g. 1982/83, 1997/98, 2015/16), which are likely to double in occurrence due to anthropogenic warming (Cai et al. 2014). Recent projections suggest increases in El Niño-driven drying in the western Pacific Ocean by mid-to-late 21st century (Power et al. 2013; Cai et al. 2014); such a change would increase the incidence of heat and drought, and potentially increase fire activity in eastern Australia.

Weather conditions conducive to fire in the southeast of Australia are occurring more frequently.

Figure 8: Severe drought in the summer of 2006 in Canberra. Recent projections show that by the mid-to-late 21st century, increases in El Niño-driven drying in the western Pacific Ocean may increase the incidence of heat and drought, potentially increasing fire activity in eastern Australia, including NSW and the ACT.



Table 1: Summary of projections from modelling studies aimed at projecting changes in fire risk in southeast Australia.

Study	Projections
Beer and Williams (1995)	Increase in FFDI with doubling of atmospheric carbon dioxide, commonly >10% across most of continent, especially in the southeast, with a few small areas showing decreases.
Williams et al. (2001)	General trend towards decreasing frequency of low and moderate fire danger rating days, but an increasing frequency of very high and in some cases extreme fire danger days.
Hennessy (2007)	Potential increase of very high and extreme FFDI days in the range of 4–25% by 2020 and 15–70% by 2050.
Lucas et al. (2007)	Increases in annual FFDI of up to 30% by 2050 over historical levels in southeast Australia and up to a trebling in the number of days per year where the uppermost values of the index are exceeded. The largest changes are projected to occur in the arid and semi-arid interior of NSW and northern Victoria.
Hasson et al. (2009)	Projected potential frequency of extreme events to increase from around 1 event every 2 years during the late 20 th century to around 1 event per year in the middle of the 21 st century, and to around 1 to 2 events per year by the end of the 21 st century.
Clarke et al. (2011)	In the southeast, FFDI is projected to increase strongly by end of the 21 st century, with the fire season extending in length and starting earlier.
Matthews et al. (2012)	A warming and drying climate is projected to produce drier, more flammable fuel, and to increase rate of fire spread.
CSIRO and BoM (2015)	Projections of warming and drying in southern and eastern Australia will lead to increases in FFDI and a greater number of days with severe fire danger. In a business as usual scenario (worst case, driest scenario), severe fire days increase by up to 160–190% by 2090.

5. Impacts of Bushfires in NSW and the ACT

In NSW and the ACT, bushfires have had a very wide range of human and environmental impacts, including loss of life and severe health effects,

damage to property, devastation of communities and effects on water and natural ecosystems.

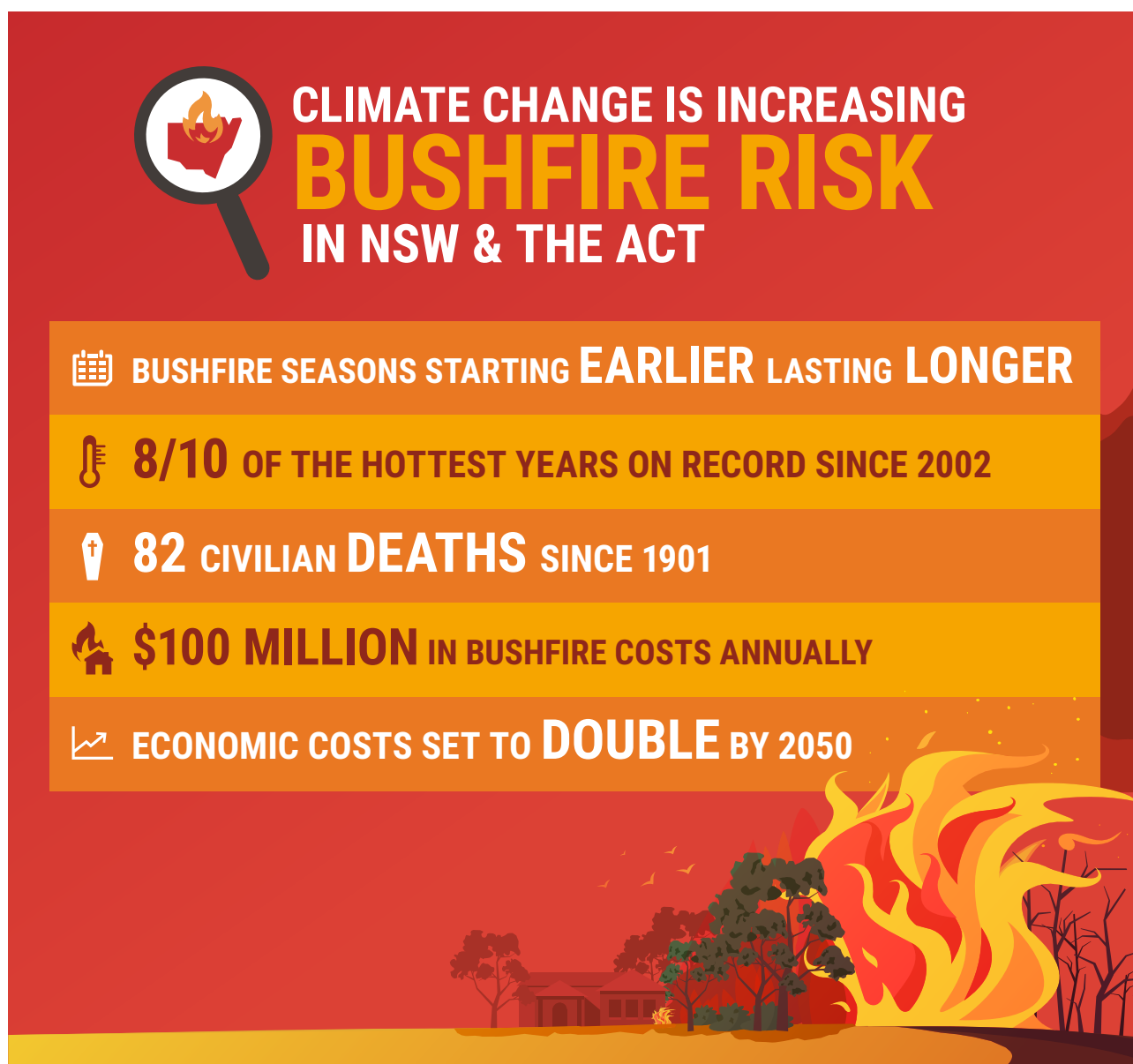


Figure 9: Climate change and bushfire impacts in NSW and the ACT.

5.1 Health Impacts

Large populations in NSW and the ACT are at risk from the health impacts of bushfires, which have contributed to physical and mental illness as well as death. Communities in NSW and the ACT are particularly vulnerable to bushfires because large populations live close to highly flammable native vegetation, such as eucalyptus trees, that are exposed to frequent severe fire weather (Chen and McAneney 2010; Handmer et al. 2012; Price and Bradstock 2013). For example, in the Blue Mountains, approximately 38,000 homes are within 200 m of bushland, and 30,000 within 100 m; with many of these homes backing directly onto bushland (McAneney 2013).

Tragically, in Australia there have been 825 known civilian and firefighter fatalities between 1901 and 2011 (Blanchi et al. 2014). Of the known civilian deaths, 82 (12%) have occurred in NSW or the ACT (Blanchi et al. 2014).

Bushfire smoke can seriously affect health. Smoke contains not only respiratory irritants, but also inflammatory and cancer-causing chemicals (Bernstein and Rice 2013). Smoke can be transported in the atmosphere for hundreds or even thousands of kilometres from the fire front, exposing large populations to its impacts (Spracklen et al. 2009; Dennekamp and Abramson 2011; Bernstein and Rice 2013). Days with severe pollution from bushfires around Sydney are associated with increases in all-cause mortality of around 5% (Johnston et al. 2011). Recently, an extreme smoke event in the Sydney Basin from fires designed to reduce fire hazard is thought to have caused the premature deaths of 14 people (Broome et al. 2016). The estimated annual health costs of bushfire smoke in Sydney are also high, at \$8.2 million per annum (2011\$) (Deloitte Access Economics 2014).

Large populations in NSW and the ACT are at risk from the health impacts of bushfires, which have contributed to physical and mental illness as well as deaths.



Figure 10: Bushfire smoke from the Blue Mountains blankets Sydney in 2013.

During the Blue Mountains bushfires in October 2013, air quality levels in the Sydney region were measured at 50 times worse than normal. NSW Health recorded that 228 people attended hospital with breathing difficulties; 778 other individuals were treated by ambulance staff and there was a 124% increase in patients with asthma conditions seeking hospital treatment (AEM 2013). A study of hospital admissions from 1994–2007 has found that hospital admissions for respiratory illness increased by 12% on days with bushfire smoke in Sydney (Martin et al. 2007). The health impacts of bushfire smoke are by no means confined to Sydney, with cities such as Newcastle and Wollongong also experiencing increases in hospital admissions due to respiratory conditions (Martin et al. 2007). The impacts of bushfire smoke in the community are also uneven, with the elderly, infants and those with chronic heart or lung diseases at higher risk (Morgan et al. 2010).

In addition to physical health impacts, the trauma and stress of experiencing a bushfire can also increase depression, anxiety, and other mental health issues, both in the immediate aftermath of the trauma and for months or years afterwards (McFarlane and Raphael 1984; Sim 2002; Whittaker et al. 2012). Following the 2013 Blue Mountains bushfires, mental health charity 'Beyond Blue' collaborated with the Australian Red Cross to develop resources to assist bushfire victims experiencing increases in depression and anxiety (Beyond Blue 2013a; 2013b) and over 100 households requested wellbeing assistance from Red Cross volunteers (Red Cross 2013). Post-traumatic stress, major depression, anxiety and suicide can also manifest among firefighters, sometimes only becoming evident many months after an extreme event (McFarlane 1988; Cook and Mitchell 2013).

5.2 Economic Costs

The economic cost of bushfires – including loss of life, livelihoods, property damage and emergency services responses – is very high. The total economic cost of bushfires in Australia, a measure that includes insured losses as well as broader social costs, is estimated to be approximately \$375 million per year (2011\$), a figure that is expected to reach \$800 million by 2050 (Deloitte Access Economics 2014). The annual economic costs of bushfires in NSW and the ACT are estimated to average \$45 million and \$56 million per annum, respectively (2011\$). By about mid-century these costs could increase by more than double, potentially reaching \$232 million combined (Deloitte Access Economics 2014). These estimates take into account increases in the number of households, growth in the value of housing

stock, population growth and increasing infrastructure density. However, they do not incorporate increased bushfire incident rates due to climate change and could therefore be significantly higher.

NSW has already experienced a significant increase in extreme fire weather since the 1970s, and bushfires occurring in NSW from 1970-2013 have contributed to at least 40 deaths, the destruction of nearly 800 properties and have affected over 14 million hectares of land (Table 2). Indirect costs, such as impacts on local tourism industries can also be significant. For example, a month after the 2013 Blue Mountains bushfires, tourism operators estimated losses of nearly \$30 million due to declines in visitors and cancellations alone (ABC 2013).

The total economic costs of NSW and ACT bushfires are estimated to be approximately \$100 million. By about mid-century these costs could increase by more than double, potentially reaching \$232 million.

Table 2: Damage and loss estimates in ten significant bushfire events in NSW and the ACT since the mid-1970s.
Data sourced from Stephenson et al. 2013; NSW PRS 2014; ICA 2012; and Climate Council 2014d.

Date	Location	Losses (including residential property, stock)	Deaths	Significant Insured Losses (normalised to 2011 values ¹)
1974–75	Far west, Cobar, Balranald & Moolah-Corinya	4,500,000 ha. 50,000 stock	6 deaths	n/a
1977–78	Blue Mountains	54,000 ha. 49 buildings destroyed	3 deaths	n/a
1979–80	Duffys Forest, Lucas Heights, Terry Hills, Ingleside, Belrose, Elanora Heights, Lithgow, Mt Wilson, Mt Tomah & Grose Valley	> 1,000,000 ha. 28 houses destroyed. 20 houses damaged	13 deaths	n/a
1984–85	Western Division	3,500,000 ha. 40,000 stock	5 deaths	\$179m
1993–94	North Coast, Hunter, South Coast, Blue Mountains & Sydney	> 800,000 ha. 206 houses destroyed	4 deaths	\$215m
1997–98	Burraborang, Pilliga, Hawkesbury, Hunter, Shoalhaven, Central Coast & Menai	> 500,000 ha. 10 houses destroyed	4 deaths	\$8m
2001–02	44 LGAs in greater Sydney, Hunter, north Coast, mid north Coast, northern Tablelands & Central Tablelands	744,000 ha. 109 houses destroyed. 40 houses damaged 6,000 stock	0 deaths	\$131m
2002–03	81 LGAs in greater Sydney, Hunter, north Coast, northern Tablelands, northern rivers, north-west slopes, north-west plains, Central Tablelands, Southern Tablelands, Illawarra & South Coast	1,464,000 ha. 86 houses destroyed. 11 houses damaged 3,400 stock	3 deaths	\$43m (October 2002 fires)
2003	Canberra and Alpine bushfires	500 properties and 300 agricultural buildings destroyed. 17,000 stock	0 deaths	\$660m
October 2013	Blue Mountains, Port Stephens, Lake Munmorah, Hunter, Hawkesbury, Central Coast & Southern Highlands	118,000 ha. 222 houses destroyed, 168 houses damaged	2 deaths	>\$183m



Figure 11: The 2003 bushfires in Canberra caused significant damage; 500 properties were destroyed and insured losses were \$660 million.

The 2003 Canberra and Alpine bushfires caused significant economic damage; 500 properties were destroyed and insured losses were \$660 million (2011\$) (ICA 2012; Climate Council 2014d). A substantial proportion of these costs were borne by home owners as 27-81% of households affected by the fires were either uninsured or underinsured (by an average of 40% of replacement value) (ASIC 2005).

Bushfires can cause significant losses in farming areas. In the 2003 Canberra and Alpine bushfires, 13,000 sheep and nearly 4,000 cattle were killed, and more than 300 agricultural buildings were destroyed (Stephenson et al. 2013). Stock that survives the initial bushfires can face starvation in the post-fire period, as well as threats from predators due to the destruction of fences around properties (Stephenson 2010). In

The Canberra and Alpine bushfires in 2003 caused \$1.5 billion worth of losses to the timber industry, the death of 13,000 sheep and 4,000 cattle, as well as destroying 4,000 km of fencing.



Figure 12: Burnt landscape in the wake of the Blue Mountains bushfires in October 2013. Tourism operators lost an estimated \$30 million due to declines in visitors and cancellations alone.

2003, the bushfires destroyed nearly 4,000 km of fencing and \$1.5 billion worth of timber was lost (Stephenson et al. 2013). Smoke damage can also taint fruit and vegetable crops, with wine grapes particularly susceptible (Stephenson 2010). For example, bushfires in 2003 significantly tainted grapes in NSW with smoky, burnt, ash aromas, making them unusable (Jiranek 2011).

It is important to note that these economic losses shown in Table 2 do not account for the full range of costs associated with bushfires – few attempts have been made to account for loss of life, social disruption and trauma, opportunity costs for volunteer fire fighters, fixed costs for bushfire fighting services, government contributions for rebuilding and compensation, impacts on health, and ecosystem services (King et al. 2013).

5.3 Environmental Impacts

Fire can affect the quality and quantity of water in catchments and have significant impacts on ecosystems. Large-scale high intensity fires that remove vegetation expose topsoils to erosion and increased runoff after subsequent rainfall (Shakesby et al. 2007). This can increase sediment and nutrient concentrations in nearby waterways, potentially making water supplies unfit for human consumption (Smith et al. 2011; IPCC 2014). For example, bushfires in January 2003 devastated almost all of the Cotter catchment in the ACT, causing unprecedented levels of turbidity, iron and manganese and significantly disrupting water supply (White et al. 2006). Fires can also affect water infrastructure. Fires in the Sydney region in 2002 affected the Woronora pumping station and water filtration plants, resulting in a community alert to boil drinking water (WRF 2013).

Fire is a regular occurrence in many Australian ecosystems, and many species have evolved strategies over millions of years to not only withstand fire, but to benefit from it (Crisp et al. 2011; Bowman et al. 2012). Particular fire regimes (especially specific combinations of fire frequency and intensity) can favour some species and disadvantage others. If fires are too frequent, plant species can become vulnerable to local extinction as the supply of seeds in the soil declines. Conversely, if the interval between fires is too long, plant species that rely on fire for reproduction may be eliminated from an ecological community.

Animals are also affected by bushfires, for example if they are restricted to localised habitats and cannot move quickly, and/or reproduce slowly, they may be at risk from intense large-scale fires that occur at short intervals (Yates et al. 2008). Deliberate fuel reduction burning can also destroy habitats if not managed properly. For example, in the Shoalhaven region of NSW, the threatened eastern bristlebird and the glossy black cockatoo face the potential destruction of their habitats which overlap with areas of bushland that are being targeted in hazard reduction burning (Whelan et al. 2009).



Figure 13: A glossy black cockatoo in NSW. This threatened bird species, as well as the threatened eastern bristlebird, face potential destruction of their habitats because their habitats overlap with areas of bushland targeted for hazard reduction burning.

6. Implications of Increasing Fire Activity

The population of NSW is expected to grow from 7.7 million people (as of March 2016) up to 12.6 million people by 2061 (ABS 2013a; 2013b), while the population of the ACT is expected to grow from 395,000 people (as of March 2016) up to 740,000 people by 2061 (ABS 2013c).

The steady urban encroachment into bushland, along with increasing fire danger weather, present significant and growing challenges for both NSW and the ACT. This challenge is exemplified in greater Sydney, a region considered to be one of the more bush fire-prone areas in Australia. It is home to a quarter of Australia's population, and 2005 projections have found that 190,000 homes are exposed to greater bushfire risk due to their close proximity (within 80 m) to dense bushland (Chen 2005). The challenge is also exemplified in Canberra, where over 9,000 Canberra homes are located 400-700 m from bushland, exposing residents to greater bushfire risk (Risk Frontiers 2004).

The economic, social and environmental costs of increasing bushfire activity in NSW and the ACT are potentially immense. In one of the few analyses to consider projected costs of bushfires in NSW, Deloitte Access Economics (2014) calculated the potential insured losses and broader social costs, to forecast total economic costs of bushfires in selected Australia states, finding that bushfires in NSW and the ACT could cost \$232 million (2011\$) by 2050. In addition to insured and social losses, health costs from particulate matter emitted during bushfires in NSW are projected to cost \$8.2 million per annum. Attempting to mitigate these damages through practices such as prescribed burning can also be costly. For example, it is likely that NSW is burning around 0.5% of bushland in any given year, at a cost of 13.3 tonnes of carbon equivalent emissions per hectare (Deloitte Access Economics 2014). The Deloitte analysis notes that climate change will increase very high fire danger weather and associated bushfire incidents over time but their projections do not incorporate this, making them conservative economic forecasts.

190,000 homes in Sydney are exposed to greater bushfire risk due to their proximity to dense bushland.



Figure 14: Aerial view of Sydney. As the population of NSW continues to grow, steady urban encroachment into bushland is likely to continue, along with increasing fire danger weather, posing a higher risk to the city fringe to bushfires.



Figure 15: A hazard reduction burn being conducted by the NSW Rural Fire Service in Belrose, 2011. This can result in extensive smoke pollution as authorities attempt to meet burning schedules in the few safe days for burning.

There is increasing interest in how adaptation to an increasingly bushfire-prone world may reduce vulnerability. Current government initiatives centre on planning and regulations, building designs to reduce flammability, burying powerlines in high risk areas and retrofitting electricity systems, fuel management, fire detection and suppression, improved early warning systems, and community education (Preston et al. 2009; Buxton et al. 2011; O'Neill and Handmer 2012; King et al. 2013). Responses to bushfires can be controversial, particularly the practice of prescribed burning, where fires are lit in cool weather to reduce the volume of fuel. For example, during 2012-13,

the largest ever hazard reduction burn was conducted in NSW, with 330 burns carried out across 206,000 ha of national parks (NSW Government 2014). Fire managers are constantly faced with the challenge of balancing the need to reduce risk to life and property whilst simultaneously conserving biodiversity and environmental amenity, and controlling air pollution near urban areas (Penman et al. 2011; Williams and Bowman 2012; Adams 2013; Altangerel and Kull 2013). The increasing length of the fire season will reduce the window of opportunity for hazard reduction at the same time that the need for hazard reduction becomes greater.

The increasing length of the fire season will reduce the window of opportunity for hazard reduction.



Figure 16: Elvis – the Erickson Air-Crane fire bomber – dumping about 9,000 L of water to assist firefighters battling a blaze in Australia's southeast. Specialised firefighting aircraft like this are loaned for the bushfire seasons in both the Northern and Southern hemispheres each year. Such aircraft are expensive to operate.

Australia's fire and emergency services agencies have recognised the implications of climate change for bushfire risk and firefighting resources for some time (AFAC 2010). For a number of years, the US and Australia have participated in a resource-sharing arrangement that enables states in either country to request additional firefighting personnel at short notice (NIFC 2002). As fire seasons in the two hemispheres increasingly overlap, such arrangements may become increasingly impractical (Handmer et al. 2012). For example, longer fire seasons have implications for the availability and costs of firefighting equipment that is leased from agencies in the Northern Hemisphere, such as the Elvis fire bomber (Figure 16).

During the past decade, state fire agencies have increasingly needed to share suppression resources domestically during peak demand periods. As climate change increases the severity of bushfire danger weather in NSW and the ACT and increases the fire season length, 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 NSW and the ACT. Substantially increased resources for fire suppression and control will be required. Most importantly, a significant increase in the number of career and volunteer firefighters will be needed.

7. Tackling Climate Change is Critical for Protecting Australians

The impacts of climate change are already being observed. Sea levels are rising, oceans are becoming more acidic, and heatwaves have become longer and hotter. For NSW and the ACT, these impacts include increased fire danger weather and longer bushfire seasons. Greenhouse gases from human activities, particularly the burning of fossil fuels, is the primary cause for the changes in climate over the past half-century (IPCC 2013; 2014).

The long-term trend of increasing global emissions must be slowed and halted in the next few years. Emissions must be trending sharply downwards by 2020 at the latest if we are to reduce the escalating risks of climate change and meet the goal of limiting global temperature rise to less than 2°C above pre-industrial levels. Investments in and installations of renewable energy such as wind turbines and solar must therefore increase rapidly.

Australia must do its fair share of meeting the global emissions reduction challenge. Australia's very weak target of a 26-28% reduction in emissions by 2030 compared to 2005 levels – and we are on track to miss even this target – leaves Australia lagging well behind other OECD (Organisation for Economic Co-operation and Development) countries. At present, Australia is ranked by Climate Transparency (2016) as the worst of all G20 nations on climate change action and is the only country to receive a rating of 'very poor' in a majority of categories. This lack of action is not consistent with effective action to tackle climate change.

This is the critical decade to get on with the job of protecting Australians from the dangerous impacts of climate change. We are now well into the second half of the decade, and Australia is falling further behind in the level of action required to meet the climate change challenge. The window in which we can act to avoid the most damaging effects of climate change is almost closed. Australia urgently needs a plan to close our ageing and polluting coal-fired power plants and replace them with modern, clean renewables and to become a leader, not a laggard, in the worldwide effort to tackle climate change.

The only approach to keeping the risks from bushfires manageable is rapid and deep reductions in emissions.



Figure 17: Solar panels on a roof in Sydney. Nearly 15% of Australian households have solar panels on their rooftops (Bruce and MacGill 2016). More solar and renewable energy installations are required in Australia to move towards meeting the emissions reduction challenge.

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Preparing for a Bushfire in NSW and the ACT

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

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What can I do to prepare for a bushfire?



INFORM YOURSELF

The NSW and ACT Rural Fire Service has 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 the Victorian Country Fire Service are available to assist you to assess your level of risk from bushfire. Take advantage of them. Visit: <http://www.rfs.nsw.gov.au/plan-and-prepare/know-your-risk> (NSW), esa.act.gov.au/community-information/bushfires/in-the-suburbs (ACT suburbs), esa.act.gov.au/community-information/bushfires/in-the-rural-areas (ACT rural).



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. Access the bushfire ready self assessment tool: www.rfs.nsw.gov.au/plan-and-prepare



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. An important consideration is retrofitting older houses to bring them in alignment with current building codes for fire risk and assessing the ammability of your garden. Use the Victorian Country Fire Service Fire Ready Kit to help recognise exactly what you need to prepare your property: www.rfs.nsw.gov.au/plan-and-prepare



PREPARE YOURSELF AND YOUR FAMILY

Preparation is not only about the physical steps you take to prepare – e.g., preparing your house and making a bushfire survival plan. Preparing yourself and your family also 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.

Key Links

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

ACT RFS
esa.act.gov.au/actrfs
(02) 6207 8609

Bushfire Survival Plan App:
www.rfs.nsw.gov.au/plan-and-prepare/bush-fire-survival-plan
(Available for iOS and Android)

Fire Watch Map
myfirewatch.landgate.wa.gov.au


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