CLIMATE COUNCIL

CLIMATE CHANGE AND THE VICTORIA BUSHFIRE THREAT: UPDATE 2017

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Key Findings

1

Climate change is increasing the risk of bushfires in Victoria and lengthening fire seasons.

- Extreme fire weather has increased since the 1970s in the east and south of Australia, including Victoria, with the fire season length extending from October to March.
- Climate change is now making hot days hotter, and heatwaves longer and more frequent. Drought conditions have been increasing in Australia's southeast.
- Climate change is driving an increase in dangerous fire weather, which in turn is increasing the frequency and severity of bushfires.

2

Victoria is the state in Australia that is most affected by bushfires and is on the frontline of increasing bushfire risk.

- The 2016–17 bushfire season in Victoria is expected to be 'above normal' for the majority of the state including the Melbourne hinterland.
- Severe long term rainfall deficits remain across much of western Victoria and West and South Gippsland, which may increase fire risk. Very wet winter and spring conditions has led to high levels of grass growth and above average fuel loads, particularly in the north of the state.

3

The economic cost of bushfires in Victoria is projected to more than double by 2050.

- Victoria has sustained around half of the Australian economic losses from bushfires despite comprising only 3% of the continent.
- The annual economic cost of bushfires in Victoria is approximately $180 million.
- By around the middle of the century these costs could more than double to $378 million. These projections do not incorporate increased bushfire incident rates and severity due to climate change, so the total cost is likely to be much higher.

4

Bushfires will continue to adversely affect human and environmental health.

- More than two thirds of known civilian bushfire fatalities in Australia have occurred in Victoria (more than 450 fatalities since the start of the 20th century).
- Bushfire smoke can seriously affect human health because it contains respiratory irritants, as well as inflammatory and cancer-causing chemicals. Elderly, infants and those with chronic heart or lung diseases are at higher risk.
- After the 2009 Black Saturday bushfires, some members of the community developed Post Traumatic Stress Disorder, major depressive episodes and increased alcohol use.
- Fires can affect water infrastructure. The Black Saturday fires affected about 30% of catchments supplying Melbourne's drinking water, with estimated recovery costs totalling more than $2 billion.
- Increasing fire frequency can cause rapid ecosystem change. After successive fires in 2003 and 2006–07, acacia shrublands replaced some mountain and alpine forests, putting at risk vertebrate species including the endangered Leadbeater's possum.

5

In the future, Victoria is very likely to experience an increased number of days with extreme fire danger. Communities, emergency services and health services across Victoria must keep preparing.

- Fire severity and intensity is expected to increase substantially in coming decades in Victoria. The fire season will continue to lengthen, further reducing the opportunities for safe hazard reduction burning.
- Melbourne's rural-urban fringe is among the most vulnerable in the world to bushfires. The population of Melbourne is continuing to spread, encroaching into surrounding bushland, increasing risk to life and property from bushfires.
- An increased likelihood of dangerous fire weather and a lengthening fire season will strain Victoria's existing resources for fighting and managing fires.

6

Reducing emissions is critical to protecting Australians.

- Australia must cut its emissions rapidly and deeply to join global efforts to stabilise the world's climate and to reduce the risk of even more extreme 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 Victoria have experienced the serious consequences of bushfires. Although Victoria comprises only 3% of Australia's land mass, 67% of all known civilian fatalities since the beginning of the 20th century, and around 50% of the economic losses due to bushfires have occurred in the state.

Australians have always lived with fire and its consequences, but climate change is increasing fire danger weather and thus the risks that fires pose. These risks will continue to increase in coming decades.

This report provides an update to the previous Climate Council report on bushfire risk and Victoria (https://www.climatecouncil.org.au/be-prepared-climate-change-and-the-victorian-bushfire-threat). We first describe the background context of fire and its history in Victoria. We then outline the link between bushfires and climate change, before considering how bushfire danger weather is increasing in Victoria 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 influence of climate change on bushfires, and the implications for Victorian 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, between 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.

Victoria has been affected by bushfires throughout its history. A study by Blanchi et al. (2014) reveals that there have been a total of 825 known civilian and firefighter fatalities in Australia from 1901 to 2011. Of the known civilian deaths, more than two thirds have occurred in Victoria (454/674) (Blanchi et al. 2014). Extreme fires have also destroyed and damaged property more frequently in Victoria than in any other state (Haynes et al. 2010). Significant bushfires in Victoria's recent history that have damaged property and resulted in loss of life include the Ash Wednesday and Black Saturday fires. Ash Wednesday occurred in February 1983 in Victoria and South Australia. The fires claimed a total of 75 lives (47 in Victoria, 28 in South Australia) and over 2,300 homes were destroyed (BoM 2011). The Black Saturday bushfires occurred in February 2009, killing 173 people and destroying more than 2,000 homes (CFA 2012).

More than two-thirds of bushfire fatalities in Australia have occurred in Victoria.

Figure 1: Trees burn in Bullumwaal, Victoria. After the unprecedented ferocity of the 2009 Black Saturday bushfires, a new 'catastrophic' category was added to the FFDI scale.

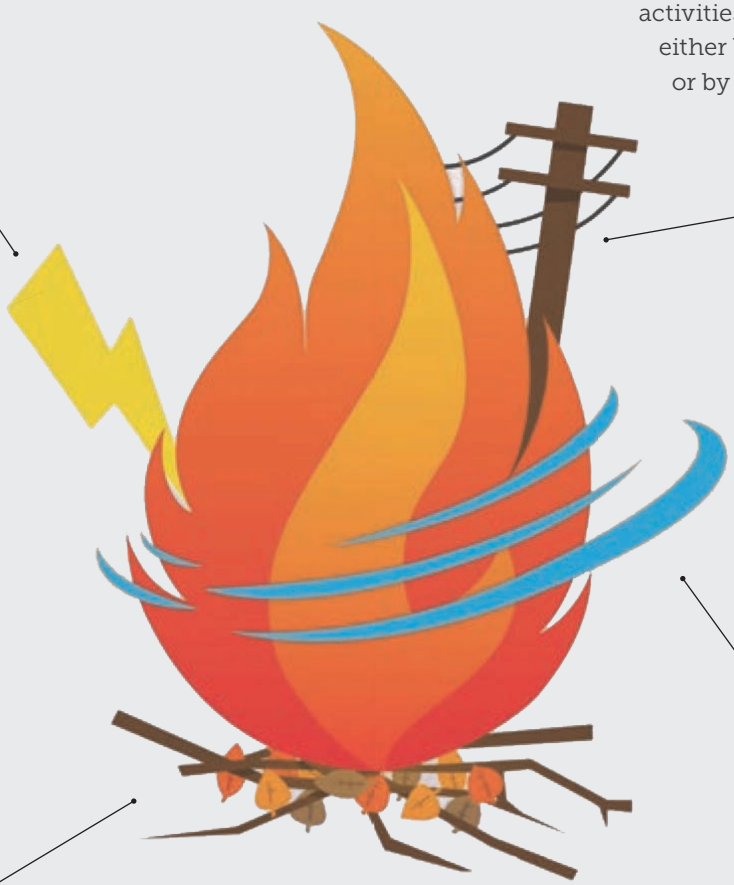
Fire is a complex process that is very variable in space and time. A fire needs to be started (ignition), it needs something to burn (fuel) and it needs conditions that are conducive to its spread (weather and topography) (see Figure 2). Fire activity is strongly influenced by weather, fuel, terrain, 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. 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 can also be associated with a higher incidence of lightning activity (Jayaratne and Kuleshov, 2006), increasing the risk of ignition. In many regions, local weather conditions are the most important influence on fire activity (Climate Council 2014a).

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: Main factors affecting bushfires: ignition, fuel, people and weather.

The most important aspects of weather that affect fire and fuels are temperature, precipitation, wind and humidity.

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, such as the mountain ash forests in Victoria (Clarke et al. 2011; Bradstock et al. 2012).

People are also 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 (Climate Council 2014a).

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

Climate change can affect ignition, fuel and fire weather 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 about 25% of the ignitions in Victoria (Attiwill and Adams 2011) and the incidence of lightning is sensitive to weather conditions, including temperature (Jayaratne and Kuleshov 2006). Climate change can also affect fuel.

Figure 3: An example from Kinglake in Victoria of the disturbing impacts of bushfires in Australia. The unprecedented ferocity of the Black Saturday bushfires in Victoria claimed 173 lives.

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 (Climate Council 2014a).

Very hot, dry and windy days create very high bushfire risk. 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 2012; 2013), and is driving up the likelihood of extreme fire danger weather (Box 1). 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, including Victoria (CSIRO and BoM 2016).

While there have been relatively few 'attribution' studies on bushfires – these refer to studies that quantify the probability that an extreme event such as a bushfire was made more likely as a result 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

Climate change is increasing the number of days with very high and extreme fire weather, particularly in southern Australia.

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. Yoon et al. (2014) demonstrated that the risk of such bushfires in California has increased due to human-induced climate change. Most recently, in May 2016, an extreme wildfire (Figure 4) 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 4: A severe fire burns at Fort McMurray, Alberta, Canada in May 2016.

BOX 1: EXTREME HEAT

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

While hot weather has always occurred in Australia's southeast, it has become more common and severe over the past few decades. There has been significant warming during the last 50 years (Timbal and Drosdowsky 2012). In Victoria, 7/10 of the hottest years ever recorded have occurred since 2000 (BoM 2017; see Figure 6). The recent 2015–16 summer was Victoria's third hottest on record (+1.73°C above average; BoM 2016a), while 2014 was the second hottest year on record (BoM 2015). During the summer of 2013–14 Melbourne set a record for four consecutive days at 41°C and above, and two nights in a row at 27°C or above (BoM 2014; Climate Council 2014b).

Heatwaves in Victoria are increasing in frequency, intensity and duration. For example, in Melbourne from 1951–2011, the average intensity of heatwaves has increased by 1.5°C and the average intensity of the peak day during a heatwave has increased by 2°C (Perkins and Alexander 2013; Climate Council 2014c). This has implications for bushfire danger weather. For example, the 2009 Black Saturday fires in Victoria were preceded by a decade-long drought with a string of record hot years, coupled with a severe heatwave in the preceding week. The weather conditions on February 7 broke temperature records, with maximum temperatures up to 23°C above the February average in Victoria and record high temperatures for February set in over 87% of the state (BoM 2009a; BoM 2009b). Over this period, the FFDI ranged from 120 to 190, the highest values ever recorded (Karoly 2009).

Figure 5: Heatwaves are increasing in frequency, intensity and duration in Victoria, increasing the risk of bushfire danger weather.

3. Observations of Changing Bushfire Danger Weather in Victoria

Increasing hot days, heatwaves and rainfall deficiencies in Victoria are driving up the likelihood of very high fire danger 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

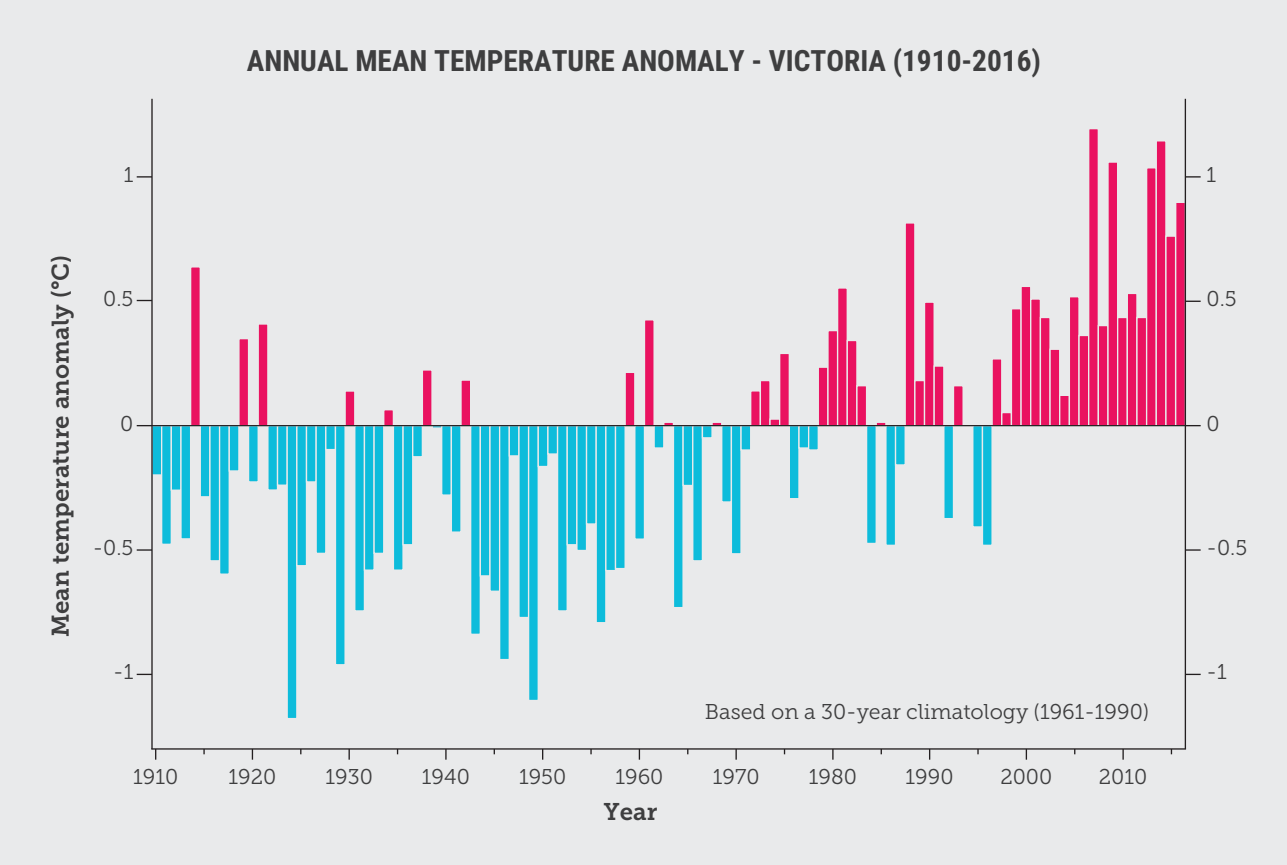


Figure 6: Annual mean temperature anomalies for Victoria, with increasing heat in recent years. Blue bars indicate years where annual temperatures were below average, and red bars indicate years of above average temperatures (relative to 1961–1990 climate) (BoM 2017).

increasing temperatures (BoM 2013; Climate Commission 2013). Since the mid-1990s, southeast Australia has experienced an 11% decline in rainfall during the April–October growing season (CSIRO and BoM 2016). It is very likely that an increased incidence of drought in the southeast, coupled with consecutive hot and dry days will in turn result in longer fire seasons and an ever larger number of days with extreme fire danger in coming decades (e.g. Clarke et al. 2011; 2013).

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 (Bushfire and Natural Hazards CRC 2016). The influence of hotter, drier weather conditions on the likelihood of bushfire spread in Victoria is captured by changes in the FFDI. 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 beginning in October and extending into March. The lengthening fire season means that opportunities for fuel reduction burning are decreasing (Matthews et al. 2012).

Bushfires continue to increase in number, burn for longer and affect larger areas of land.

The Australia Seasonal Bushfire Outlook for 2016–17 released by the Bushfire and Natural Hazards CRC (2016) anticipates the severity of the bushfire season in different states. Victoria's 2016–17 bushfire season outlook is for above normal fire potential in most regions, including the Melbourne hinterland.

Severe long term rainfall deficits remain across much of western Victoria and West and South Gippsland, which may increase fire risk. In addition, very wet winter and spring conditions, including the second wettest September on record (BoM 2016b), has led to high levels of grass growth and above average fuel loads, particularly in the north of the state (Bushfire and Natural Hazards CRC 2016). Already this fire season, Victoria has been affected. For example, a grassfire in Swan Hill in northwest Victoria required assistance from New South Wales (NSW) firefighting crews, including the use of two NSW water bombers (ABC 2016).

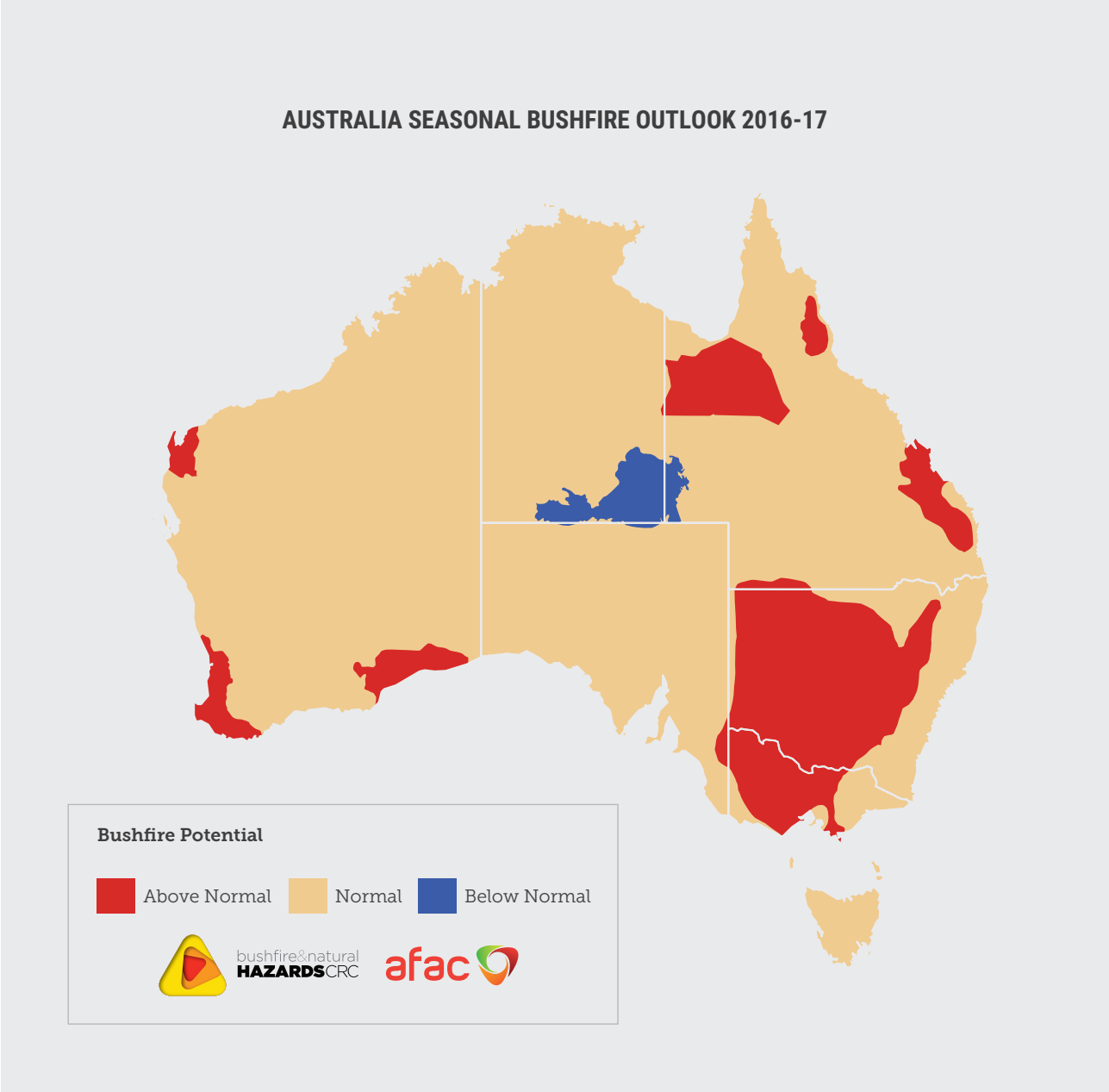


Figure 7: Australia Bushfire Outlook for the 2016–17 bushfire season (Bushfire and Natural Hazards CRC 2016).

Victoria's 2016–17 bushfire season outlook is for above normal fire potential in most regions.

4. Future Projections of Fire Activity in Southeast Australia

Research aimed at understanding future fire activity in Australia's southeast 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 emission 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) states 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 Victoria (CSIRO and BoM 2015).

Future changes in the El Niño-Southern Oscillation (ENSO) phenomenon are also likely to have an influence on fire activity. El Niño events worsen fire weather conditions and increase fire activity in southeast and central Australia (Williams and Karoly 1999; Verdon et al. 2004; Lucas 2005; 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, although the nature of this influence is still uncertain. There is some suggestion that El Niño-driven drying in the western Pacific Ocean will increase by the mid-to-late 21st century (Power et al. 2013; Cai et al. 2014). One study further suggests that particularly extreme El-Niño events (e.g. 1982/83, 1997/98, 2015/16) could double in frequency due to anthropogenic warming (Cai et al. 2014). If these projected changes in El Niño behavior eventuate, the incidence of heat and drought, as well as in fire activity, could increase in eastern and southern Australia, including Victoria.

Figure 8: Lake Hume 4% full in Victoria during a severe drought in the summer of 2007. 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.

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

Table 1: Summary of projections from modelling studies investigating 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 20th century to around 1 event per year in the middle of the 21st century, and to around 1 to 2 events per year by the end of the 21st century.
Clarke et al. (2011)	In the southeast, FFDI is projected to increase strongly by end of the 21st 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.
Jones et al. (2013)	Projected increases in FFDI for the Melbourne area.
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 Victoria

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 (Stephenson 2010).

Figure 9: Climate change and bushfire impacts in Victoria.

5.1 Health Impacts

Populations in Victoria are at risk from the health impacts of bushfires, which have contributed to physical and mental illness as well as deaths. Tragically, bushfires have accounted for 674 civilian deaths in Australia since 1901, with more than two-thirds of all bushfire fatalities having occurred in Victoria (454 deaths; Blanchi et al. 2014). The Black Saturday bushfires in Victoria in February 2009 accounted for 173 deaths, ranking as one of the world's ten deadliest recorded bushfires (Teague et al. 2010). A large proportion of the fatalities (44%) were children younger than 12 years old, people greater than 70 years and those with either chronic or acute disabilities (O'Neill and Handmer 2012).

In addition to fatalities, bushfire smoke can seriously affect human 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). For example, in Melbourne cardiac arrests increase by almost 50% on bushfire smoke-affected days (Dennekamp et al. 2011). Firefighters are also faced with higher risks to their long-term health with an elevated chance of developing a variety of cancers (Youakim 2006). The impacts of bushfire smoke in the community are uneven, with the elderly, infants and those with chronic heart or lung diseases at higher risk (Morgan et al. 2010).

The Black Saturday bushfires rank as one of the world's ten deadliest recorded bushfires.

Figure 10: Bushfire smoke blankets Melbourne in 2006.

As well as 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). For example, a study conducted 3–4 years after the Black Saturday bushfires found that some members of the affected community developed Post Traumatic Stress Disorder (PTSD), major depressive episodes and increased alcohol use (Bryant et al. 2014). A study of over 1,500 people who experienced losses in the 1983 Ash Wednesday bushfires found that after 12 months, 42% were suffering a decline in mental health ('psychiatric morbidity') (McFarlane et al. 1997). PTSD, 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

At present, 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 expected to reach $800 million by around 2050 (Deloitte Access Economics 2014). Even though Victoria comprises only 3% of the country's landmass, it has sustained around 50% of the economic damage from bushfires (Buxton et al. 2011). The total annual economic costs of bushfires in Victoria is estimated to be approximately $180 million (2011$). By about mid-century these costs could more than double to $378 million (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. These estimates do not, however, include the potential for climate change to increase bushfire frequency or intensity or the impacts to the forestry and agriculture sectors, so they should be considered very conservative.

Even though Victoria comprises only 3% of the country's landmass, it has sustained around 50% of the economic damage from bushfires.

Bushfires can cause direct damage to properties; for example, the Black Saturday bushfires destroyed over 2,000 homes (Table 2). Infrastructure such as powerlines and roads can also be damaged. In the 2003 Alpine fires in Victoria, about 4,500 km of roads were damaged and local businesses reported a 50–100% economic downturn in the fire aftermath (Stephenson 2010).

Bushfires have significant impacts in farming areas. For example, livestock losses were estimated at 13,000 in the 2003 Alpine fires, 65,000 in the 2005–06 Grampians fire and more than 11,000 in the Black Saturday fires (Stephenson 2010; Teague et al. 2010). 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). Over 8,000 km of fences were lost in the Black Saturday fires.

Figure 11: Firefighters on their way to the Kinglake fires in February 2009.

Table 2: Recorded losses from major bushfire events in Victoria since 1939.

Date	Fire Event	Location	Losses (including residential property, stock)	Deaths	Significant Insured Losses (normalised to 2011 values[1])
1939	Black Friday	Widespread across Victoria including; Warburton, Erica, Rubicon, Dromana, Manfield, the Otway ranges and the Grampian Ranges	>1,000+ homes (ABS 2004; AIC 2004)	71 (AIC 2004; Reuters 2009)	n/a
1977		Victoria, Western Districts	>100 homes (CFA 2012)	4 (CFA 2012)	$ 100 million (ICA 2013)
1983	Ash Wednesday	Victoria and South Australia including; Dandenong Ranges east of Melbourne, Macedon areas northwest of Melbourne	>2,300 homes (Ramsay et al. 1996; AIC 2004; McAeney et al 2009) >200,000 stock (Ramsay et al. 1996; AIC 2004)	75 (AIC 2004; Reuters 2009)	$1.8 billion (ICA 2013)
2003	Gippsland Fires	Victoria, North East and Gippsland	>41 homes >10,000 livestock (CFA 2012)	0 (CFA 2012)	$24 million (ICA 2013)
2006	Grampians Fires	Victoria, Grampian ranges	> 40 homes >65,000 stock (CFA 2012)	2 (CFA 2012)	$28 million (ICA 2013)
2009	Black Saturday	Churchill, Kilmore and Murrundindi, Vectis (Horsham), Coleraine, Weerite, Redesdale, Harkaway, Upper Ferntree Gully, Maiden Gully / Eaglehawk, Lynbrook / Narre Warren, Beechworth	>2,000 houses (CFA 2012; Stephenson et al. 2013) >8,000–11,800 stock (Teague et al 2010; Stephenson et al. 2013)	173 (Teague et al. 2010; Stephenson et al 2013)	$ 1.3 billion (ICA 2013)
2015	Great Ocean Road fire	Separation Creek and Wye River	>116 homes (EMV 2016)	0 (ABC 2015)	$ 86 million[2] (ICA 2016)

[1] Insured losses shown have been normalized to 2011 values (taking inflation and wealth changes into account).

[2] Loss given as 2015$ value.

Figure 12: A firefighter observes the wreckage of a home in Kinglake, Victoria.

A study by Keating and Handmer (2013) provides one of the few full economic assessments of bushfire impacts on primary industry in Victoria. These are costs over and above the present day economic costs reported by Deloitte Access Economics (2014) of about $180 million. Keating and Handmer (2013) conservatively estimated that bushfires directly cost the Victorian agricultural industry around $42 million per year. When business disruption was included more broadly, the costs to the entire Victorian economy were estimated to be $92 million per year. A similar analysis estimated direct costs at $185 million per annum for the Victorian forestry industry (Keating and Handmer 2013).

In the future, with no adaptive response to climate change, increased bushfire damage to the agricultural industry in Victoria by 2050 could add $1.4 billion (or $46.6 million per year) to the existing costs of $92 million per year (Keating and Handmer 2013). Similarly, the cost of bushfires to the Victorian timber industry could increase by an estimated $2.85 billion by 2050 ($96 million per year).

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

Bushfires directly cost $42 million and $185 million each year to the Victorian agriculture and forestry industries, respectively.

5.3 Environmental Impacts

Fire can affect the quality and quantity of water in catchments and have significant impacts on ecosystems.

5.3.1 Impact on water quality and quantity

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). During the Black Saturday fires 10 billion litres of Melbourne's drinking water were pumped to safer storage locations because of fears it would be contaminated (Johnston 2009).

Fire also has longer-term effects on water flow in forested catchments. Immediately after the fire there may be an increase in water flow. But as the forests regenerate, the new growth usually uses more water than the mature trees they have replaced (Langford 1976; Feikema et al. 2013). Seven years after the 2003 fires in the mountain ash forests of Victoria, the regrowth was still using twice the water of adjacent mature forest (Buckley et al. 2012). This pattern, known as the 'Kuczera effect', can last for several decades after a fire, with water yields from forested catchments being reduced by up to 50% (Kuczera 1985; Brookhouse et al. 2013). Fires can also affect water infrastructure; the Black Saturday bushfires in 2009 affected about 30% of the catchments that supply Melbourne's drinking water. Melbourne Water estimated the post-fire recovery costs, including water-monitoring programs, to be more than $2 billion (WRF 2013).

5.3.2 Impacts on ecosystems

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 time intervals (Yates et al. 2008).

Figure 13: Bushfire smoke at the Upper Yarra Dam, Victoria.

Ecosystems in which the natural fire interval is very long (>100 years) can undergo substantial change if the fire frequency increases. After successive fires in 2003 and 2006–07 in Victoria, Acacia shrublands have replaced some mountain and alpine ash forests because there was insufficient time between fires for the ash trees to become reproductively mature (Bowman et al. 2013; Lindenmayer et al. 2013). This change in vegetation has important flow-on effects for other species, especially the ~40 vertebrate species that rely on the hollows of 120–150 year old mountain ash trees for habitat, such as the endangered Leadbeater's possum. An estimated 42% of the possum's habitat was burned in the 2009 bushfires (Lindenmayer et al. 2013) (Figure 14).

Figure 14: The Black Saturday 2009 bushfires affected much of the habitat of the already endangered Leadbeater's possum.

6. Implications of Increasing Fire Activity

The risk that bushfires pose to people are particularly acute in southern Australia, where large populations live close to highly flammable native vegetation that is exposed to frequent severe fire weather.

The population of Victoria could potentially grow from 6 million in 2016 (ABS 2016) to 10 million by 2051, with 2.2 million in Victoria's regions and 7.8 million in Greater Melbourne (Victorian Government 2014). Melbourne's rural-urban fringe is among the most vulnerable in the world to the bushfire hazard (Buxton et al. 2011). The population of Melbourne is continuing to spread, encroaching into surrounding bushland, increasing risk to life and property from bushfires. For example, many of the homes destroyed in Marysville and Kinglake, two communities devastated by the 2009 Victorian bushfires, were either surrounded by or located less than ten metres from bushland (Chen and McAneney 2010; Crompton et al. 2010).

The increasing population and built assets, coupled with increasing fire danger weather, present significant and growing challenges for the state. Already fire prone regions are becoming more fire prone and risks to lives and property continue to increase in parts of Victoria. Hard decisions will have to be made about the ongoing livability of those regions, as they become increasingly dangerous to live in.

There is increasing interest in how adaptation to an increasingly bushfire-prone world may reduce vulnerability. Current initiatives centre on planning and regulations, building designs to reduce flammability, burying powerlines in high risk areas, retro-fitting 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).

Melbourne's rural-urban fringe is among the most vulnerable in the world to bushfires.

Figure 15: The rural-urban fringe of Melbourne is particularly vulnerable to bushfires.

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. 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). In the wake of the Black Saturday bushfires, the Royal Commission recommended treating at least 5% of Victorian public land per year (and up to 8%) by prescribed burning (Teague et al. 2010). The '5% solution' is being imported to some other states, even though fire ecologists stress that the frequency and amount of prescribed burning required to reduce risk varies greatly between different landscapes (Penman et al. 2011; Williams and Bowman 2012).

The prospect of increasing fire risk as the climate warms brings the prescribed burning issue into even sharper focus. The increasing length of the fire season will reduce the window of opportunity for hazard reduction at the same time as 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: The Victorian Country Fire Authority on patrol.

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 United States 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 Southern and Northern 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 17).

During the past decade, state fire agencies have increasingly needed to share suppression resources domestically during peak demand periods (Bushfire and Natural Hazards CRC 2012). As climate change increases the severity of bushfire danger weather in Victoria 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 Victoria. Substantially increased resources for fire suppression and control will be required. Most importantly, a significant increase in the number of both career and volunteer firefighters will be needed.

A significant increase in the number of both career and volunteer firefighters will be needed to deal with increasing bushfire risk.

Figure 17: Elvis – the Erickson Air-Crane fire bomber – dumping about 9,000 litres of water to assist firefighters at Falls Creek, Victoria. 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.

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 Victoria, 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 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.

The only approach to keeping the risks from bushfires manageable is to reduce our emissions deeply and rapidly.

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.

Figure 18: Turbines at the Macarthur Wind Farm, Victoria, the largest windfarm in Australia and the Southern Hemisphere. Phasing out dirty coal power plants and replacing them with clean, renewable energy such as wind power, is vital to reducing Australia's greenhouse gas emissions.

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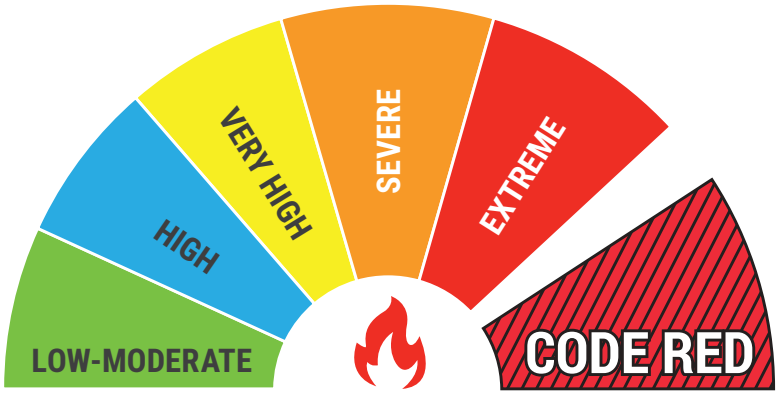
Fire Danger Rating



FIRE DANGER RATING	ACTION
CATASTROPHIC (CODE RED) Fires in these conditions are uncontrollable, unpredictable, and fast moving. People in the path of fire will very likely be killed, and it is highly likely that a very great number of properties will be damaged.	**LEAVE EARLY—DO NOT STAY** Keep up to date with the situation.
EXTREME Fires in these conditions are uncontrollable, unpredictable, and fast moving. People in the path of the fire may die, and it is likely that many properties will be destroyed.	**LEAVE EARLY.** Only stay and defend if your house has been built specifically to withstand bushfires, and if you are physically able, and your property has been prepared to the very highest level. Keep up to date with the situation.
SEVERE Fires in these conditions will be uncontrollable and will move quickly. There is a chance that lives will be lost, and that property will be destroyed.	**IF YOU PLAN TO LEAVE, LEAVE EARLY.** If you plan to stay and defend property, only do so if your property is well prepared and you are able. Keep up to date with the situation.
VERY HIGH Conditions in which fires are likely to be difficult to control. Property may be damaged or destroyed but it is unlikely that there will be any loss of life.	Monitor the situation, and be prepared to implement your bushfire survival plan.
HIGH Conditions in which fires can most likely be controlled, with loss of life unlikely and damage to property to be limited.	Know your bushfire survival plan, and monitor the situation.
LOW TO MODERATE Fires in these conditions can most likely be easily controlled, with little risk to life or property.	Ensure you have a bushfire survival plan, know where to access up-to-date information.

Source: Country Fire Authority (2013) About Fire Danger Ratings.
Accessed at: http://www.cfa.vic.gov.au/warnings-restrictions/about-fire-danger-ratings/

Preparing for a Bushfire

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 Victorian Country 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.cfa.vic.gov.au/plan-prepare/am-I-at-risk/

MAKE A BUSHFIRE SURVIVAL PLAN

Even if your household is not at high risk from bush re (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.cfa.vic.gov.au/plan-prepare/fire-ready-kit/

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.cfa.vic.gov.au/plan-prepare/fire-ready-kit/

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

VIC CFS
www.cfa.vic.gov.au
1800 240 667

Fire Ready Kit
www.cfa.vic.gov.au/plan-prepare/fire-ready-kit/

Fire Watch Map
http://myfirewatch.landgate.wa.gov.au/

CLIMATE COUNCIL

NB: Information correct as of 22/11/16

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