DANGEROUS SUMMER:
ESCALATING BUSHFIRE, HEAT AND DROUGHT RISK

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Key Findings

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Australia is being battered by extreme weather events, made worse by climate change. The summer of 2019/20 is shaping up as another terrible trifecta of heatwaves, droughts and bushfires.

› The projections for the summer of 2019/20 are extremely concerning. The Bureau of Meteorology is forecasting above average maximum temperatures for most of Australia with eastern Australia – already plagued by drought – likely to be drier than average.

› The 2019/20 bushfire season in New South Wales and southeast Queensland began in winter. Already six lives have been lost and more than 600 homes destroyed in New South Wales, mostly in remote and rural areas and small towns. It is now only the beginning of summer, which means the hottest weather and greatest danger period may still be to come.

› The bushfires have been costly for farmers. In Cobraball, Queensland, for example, an estimated 12,000 hectares of farmland have been destroyed, including 230 hectares of high-value horticultural crops, with an estimated $20 million damage bill for farms in the region.

› Wildlife has also been badly affected by the ongoing bushfires, with reports of at least 1,000 koala deaths in important habitats in New South Wales, Queensland and South Australia and the habitats of some of the most ancient and globally iconic songbirds have either been burnt or are under threat.

2

Climate change is making many extreme weather events in Australia worse.

› Climate change is now making hot days hotter, and heatwaves longer and more frequent. This has implications for bushfire weather, with fire seasons starting earlier and lasting longer.

› Long-term heating and the reduction in cool season rainfall in mainland southern Australia are exacerbating drought conditions.

› The period from January 2017 to October 2019 has been the driest on record for the Murray-Darling Basin as a whole. Over the same period of time, new long-term records for low soil moisture have been set, with ten of the Basin's 26 river catchments recording the lowest soil moisture levels on record.

3

Worsening extreme events, such as heatwaves, drought and bushfires, are affecting the health and well-being of Australians and important sectors such as farming.

- The number of heatwave days each year has been increasing in Perth, Adelaide, Melbourne, Sydney, Canberra and Hobart, and across Australia as a whole since 1950. Heatwaves can have severe effects on human health, including both direct heat illnesses (e.g. heat exhaustion) and indirect impacts (e.g. cardiovascular failure).
- The heatwave that occurred during the summer of 2009 is estimated to have resulted in as many as 500 excess deaths in Melbourne and Adelaide (374 deaths in Melbourne and 50-150 deaths in Adelaide).
- The current prolonged drought across eastern Australia is threatening crops for the third year in a row, and national summer crop production is forecast to fall by 20 percent to 2.1 million tonnes in 2019/20.
- Bushfires also cause serious health impacts, including direct loss of life, physical injuries and mental health issues. Large populations are also at risk from the health impacts of bushfire smoke, which contains respiratory irritants and cancer-causing substances.

4

The catastrophic events that are unfolding in Australia are not "normal". Now is the time to act decisively and swiftly.

- A long-term heating trend from the burning of coal, oil and gas is supercharging extreme weather events, putting Australian lives, our economy and our environment at risk. Australia is one of the most vulnerable developed countries to climate change.
- If greenhouse gas emissions continue to rise, the unusually hot weather currently experienced will become commonplace, occurring every summer across the country. Sydney and Melbourne could experience unprecedented 50°C summer days by the end of the century.
- Australian states, territories, towns and cities are leading the way on climate action. This leadership is hugely important because the Federal Government has no credible pathway for reducing emissions.
- Australia must contribute to the global effort to deeply and rapidly reduce greenhouse gas emissions and we must prepare our fire and emergency services and communities for worsening extreme weather events.

1. Introduction

A long-term warming trend from the burning of coal, oil and gas is supercharging extreme weather events, putting Australian lives, our economy and our environment at risk.

Northern New South Wales and southern Queensland are experiencing record breaking dry conditions.

Eastern Australia is currently gripped by a prolonged and devastating drought, with no relief in sight. Parts of northern New South Wales and southern Queensland are currently experiencing their driest conditions on record over certain time periods. Some of the largest rainfall deficiencies have occurred in the Macquarie, Namoi–Peel, and Border Rivers catchments. Murrurundi in the Upper Hunter in New South Wales has run out of water and more than a dozen large New South Wales towns have dwindling water supplies.

Major regional centres such as Dubbo, Tamworth and Orange are currently facing severe water shortages. Dubbo's Burrendong Dam, fed by the Macquarie River, is currently at 3 percent of its storage capacity, and water levels are still falling (current as at 22 November 2019) (WaterNSW 2019). At current usage rates and without significant rainfall, the Burrendong Dam is likely to run out of water in May 2020, after which time the town will rely predominantly on bore water. Dubbo has just introduced Level 4 water restrictions in November and the council is investigating options such as drilling new bores, using recycled water, and stormwater harvesting.

Armidale's main water supply comes from the Malpas Dam, which is currently at 36.7 percent of storage capacity (as at 25 November 2019) (Armidale Regional Council 2019). The town may have to resort to trucking water in, if water supplies from the Malpas Dam run out (SMH 2019).

The majority of Orange's water comes from the Suma Park and Spring Creek Dams, which sit at a combined level of 26.72 percent of storage capacity (current as at 6 November 2019) (Orange City Council

2019). Other sources of water come from the Macquarie River to Orange pipeline, underground water bores and the stormwater harvesting schemes. Level 5 water restrictions have been in place since October (Orange City Council 2019). Orange has been funded to connect to the Wyangala Dam, which is 20 times bigger than Orange's own dam when full (SMH 2019). Future projections for the Central Slopes region indicate that winter rainfall is likely to decrease, and spring rainfall may also decrease, due to climate change. Severe water restrictions are in place for most mid-coast New South Wales areas and Sydney is about to go to Level 2 water restrictions due to falling water storage levels in Warragamba Dam.

Droughts also have direct and substantial impacts on agriculture with knock-on effects to livelihoods and regional employment. The current prolonged drought across eastern Australia is threatening crops for the third year in a row, and national summer crop production is forecast to fall by 20 percent to 2.1 million tonnes. The mental health of people in rural areas is also affected by droughts, from both personal distress and loss of community networks.

Unprecedented extreme and catastrophic fire danger conditions that have broken records a number of times since 6 September in both New South Wales and Queensland, and then in November in Victoria and South Australia, have been aggravated by climate change. Bushfire risk has been exacerbated by drought conditions, very dry vegetation and soils, and record-breaking heat.

The 2019/20 bushfire season in New South Wales and southeast Queensland had an early and devastating start in winter (August). More than 100 fires burned in southeast Queensland and northeast New South Wales, including in some areas of subtropical rainforest and wet eucalyptus forest that do not often experience fire. In November 2019, both New South Wales and Queensland state governments declared states of emergency. Catastrophic fire danger ratings have been experienced at locations and times of the year never before recorded.

For the first time since the catastrophic fire danger rating was introduced in 2009, the rating was forecast for Greater Sydney on 12 November 2019. It is also the first time a catastrophic bushfire danger rating has been declared over such a densely populated area – covering around six million residents across eastern New South Wales. Catastrophic fire conditions were also forecast in numerous places in South Australia on 20 November and parts of Victoria on 21 November 2019 (catastrophic conditions are known as Code Red in Victoria). Catastrophic is the highest fire

Queensland and New South Wales have both lost more homes since August 2019 than in any previous year, with the hottest months of the fire season still to come.

danger rating and was introduced after the 2009 Black Saturday fires to describe "off the (McArthur) scale" fire danger indices. Fires in catastrophic conditions cannot be fought safely, homes are not built to withstand fires in these conditions, and lives can be lost.

Tragically, the fires in New South Wales have claimed the lives of six people and burnt over 1.7 million hectares of land since November. Since August 9 in New South Wales more than 600 homes, hundreds of sheds and outbuildings, and many public buildings have been destroyed. This is more than double the previously recorded worst loss of homes in New South Wales history, in 2013. Properties affected thus far have mostly been in small towns and remote rural areas. Queensland has lost more homes since August 2019 than in any previous year and heritage buildings such as the Binna Burra Lodge have been destroyed.

Agricultural lands have also been affected by the bushfires. For example, in Cobraball in Queensland, 12,000 hectares of farmland have been destroyed, including 230 hectares of high-value horticultural crops. The damage bill for farms in this region has been estimated at $20 million.

The current bushfires have also badly affected wildlife, with estimates of 1,000 koala deaths in important habitats in New South Wales, Queensland and South Australia. There are also many rare species whose lives and habitat have been destroyed, or remain threatened, including some of the most ancient songbirds on the planet (e.g. the Albert's Lyre Bird, the Tree Creeper and the Cat Bird).

It is likely that the bushfire seasons in New South Wales and possibly also Queensland have several more months to run with the hottest weather still to come. Property losses have also already occurred in both Western Australia and South Australia with the worst fire danger months expected in early 2020.

Climate change has influenced the pre-conditions for this unprecedented fire season. The severe weather and drought conditions before the beginning of the 2019/20 summer continue the upward trend in the deadly trio of heat, drought and fire. The Australian summer of 2018/19 marked the return of the Angry Summer with record-breaking heat and other destructive extreme weather events. Last summer was characterised by prolonged, continental-scale heatwaves, hot days, drought conditions in eastern Australia and bushfires throughout the country, particularly in Queensland and Tasmania, parts of Western Australia, Victoria and New South Wales. It was the hottest summer on record by a large margin (2.14°C above the 1961-1990 baseline) with more than 206 extreme weather records broken (Figure 1). This follows previous Angry Summers in 2012/13, 2013/14 and 2016/17.

While shorter-term climate drivers such as the Indian Ocean Dipole (IOD) (one of the strongest positive Indian Ocean Dipoles on record is still going on) and the Southern Annular Mode (SAM) (which has been in an unusually long negative phase, bringing strong westerly winds over southern Australia) can influence conditions in individual summers, the underlying driver of the longer-term worsening of extreme summer weather is climate change. Australia's climate has warmed by about 1°C from 1910, with most heating occurring since 1950. The number of record hot days has doubled since 1960 and nine of the ten hottest years on record have occurred since 2005. Bushfire seasons are starting much earlier and lasting longer, there are more days with fire danger ratings of very high or above, and fires are now burning in vegetation that normally does not burn.

2018/19 ANGRY SUMMER

IN JUST 90 DAYS, OVER 206 RECORDS BROKEN, INCLUDING:

- **Record-highest summer temperature:** 87 locations
- **Record-lowest summer total rainfall:** 96 locations
- **Record highest summer total rainfall:** 15 locations
- **Record number of days 35°C or above:** 2 locations
- **National or state/territory hottest on record:** 5 states/territories and (1) Australia.

NORTHERN TERRITORY

- **Hottest summer on record** (2.67°C above average).
- **Rabbit Flat:** 34 consecutive days of 40°C or above.

QUEENSLAND

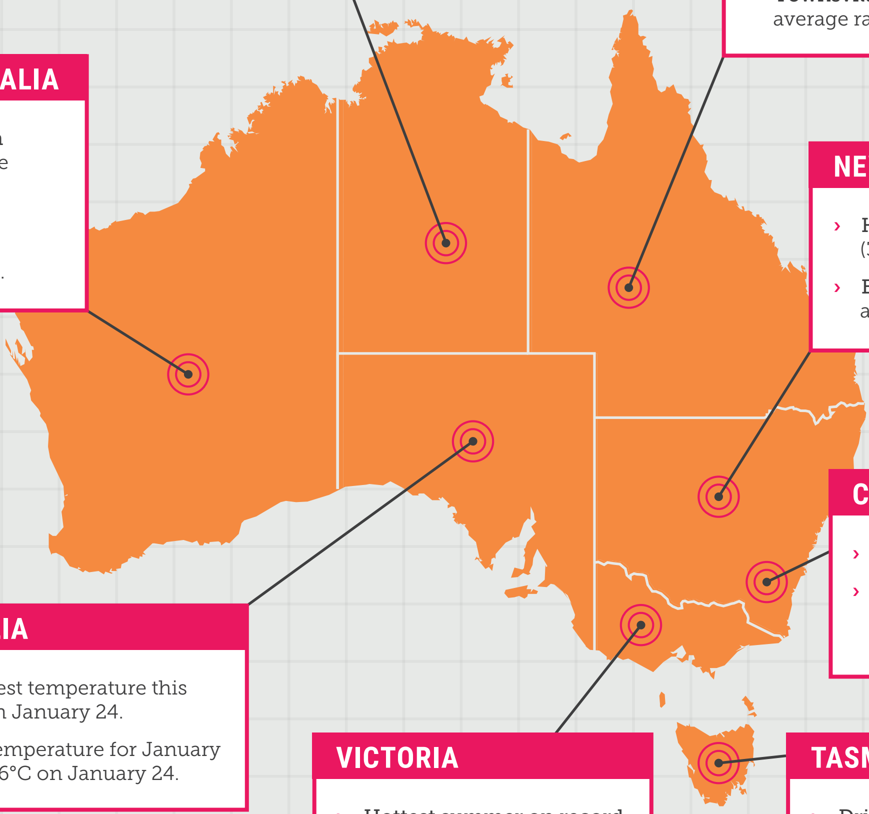
- **Cloncurry:** 43 consecutive days of 40°C or above (State record).
- **Townsville** received more than annual average rainfall in 10 days (1,257 mm).

WESTERN AUSTRALIA

- **Hottest summer on record** (1.73°C above average).
- **Marble Bar:** 45°C or higher on 32 days during the summer.

NEW SOUTH WALES

- **Hottest summer on record** (3.41°C above average).
- **Bourke:** 21 consecutive days above 40°C (State record).



CANBERRA

- **Hottest summer on record.**
- **35°C or above on 24 days,** five times the summer average.

SOUTH AUSTRALIA

- **Port Augusta:** Hottest temperature this summer - 49.5°C on January 24.
- **Adelaide:** Hottest temperature for January or any month – 46.6°C on January 24.

VICTORIA

- **Hottest summer on record** (2.54°C above average).

TASMANIA

- **Driest January on record.**
- **Bushfires burned** ~ 200,000 hectares of vegetation.

Note: For all statistics, the average is calculated over the period between 1961 and 1990. Records are for seasonal or monthly mean temperature unless otherwise specified.

Figure 1: Climate change is increasing the frequency and/or severity of extreme weather in Australia. During the 2018/19 Angry Summer over 206 extreme weather records were broken.

The rate of heating is increasing, leading to temperature records being broken in close succession. Over recent decades there has been a strong upswing in summer temperatures in Australia, with above average temperatures recorded for most summers since the late 1970s (compared to a 1961-1990 baseline).

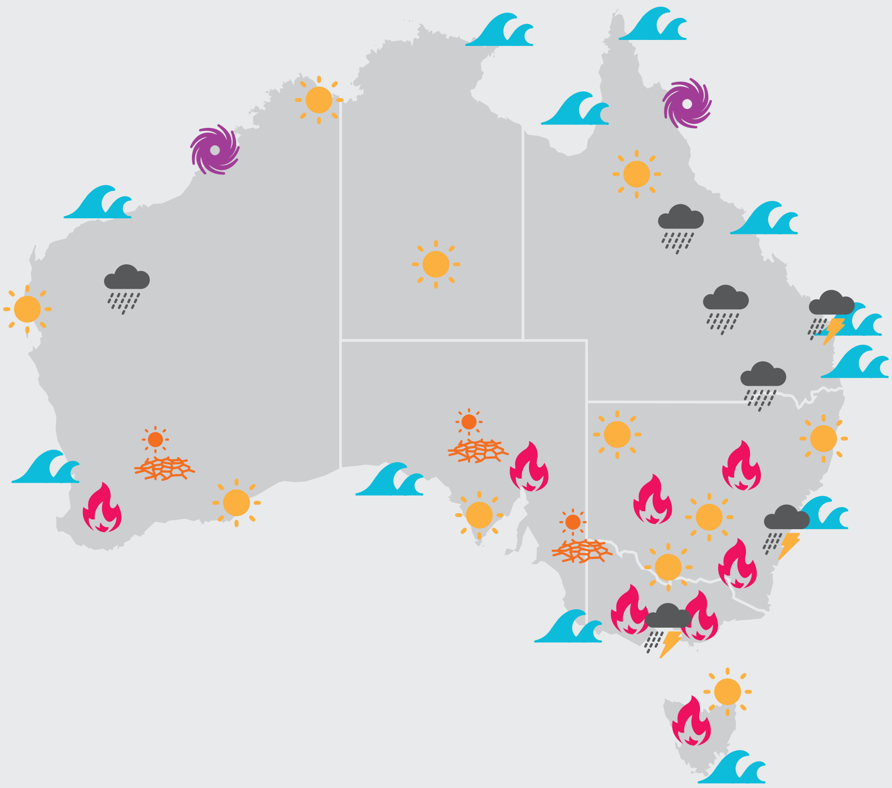
Climate change is making many types of extreme weather worse, especially heatwaves. Heatwaves are lasting longer, reaching higher maximum temperatures and are occurring more frequently over many regions of Australia. During the 2018/2019 summer, exceptional heatwaves occurred, which were notable for their continental-wide scale, as well as for breaking records for duration and individual daily extremes. During the spring just past (2019) a heatwave traversed the continent from Western Australia, across Southern Australia to the eastern states. Perth had its hottest November day on record (40.4˚C on 16 November), while Melbourne and Hobart both equalled their spring maximum temperature records (40.9˚C and 36.8˚C, respectively on 21 November).

Worsening extreme weather events are already exacting a heavy toll on the health and well-being of Australians, damaging livelihoods and economic assets, and threatening many of our most iconic ecosystems. For more details on climate impacts on ecosystems, see "This is What Climate Change Looks Like" (Climate Council 2019a), and for a more detailed account of the economic impacts of climate change, see "Compound Costs: How Climate Change is Damaging Australia's Economy" (Climate Council 2019b).

The impacts that we are experiencing now at around a 1.1°C rise in global average temperature are the forerunners of rapidly escalating risks as the temperature rises towards 2°C and beyond, compared to pre-industrial levels. All Australian states and territories are already affected by climate change in different ways (Figure 2). The severity of future extreme weather events in Australia depends on how fast and deeply greenhouse gas emissions can be reduced, here in Australia and around the world.

The impacts Australians are experiencing now at around a 1.1°C rise in global average temperature are a prelude to the rapidly growing risks as the temperature rises towards 2°C and above compared to pre-industrial levels.

HOW WILL CLIMATE CHANGE AFFECT AUSTRALIA?



Cyclones are likely to become **more intense,** but less frequent.

Heatwaves will become even **longer and hotter.**

Potential severe thunderstorm days are **expected to increase.**

Extreme rainfall events are expected to become **more intense.**

Higher sea levels will **increase flooding** in coastal cities and towns.

Droughts are likely to happen **even more often.**

Hotter and drier conditions will lead to harsher bushfire weather.

Figure 2: Impacts of climate change on extreme weather events across the Australian continent. Nowhere in Australia is immune to the impacts of climate change.

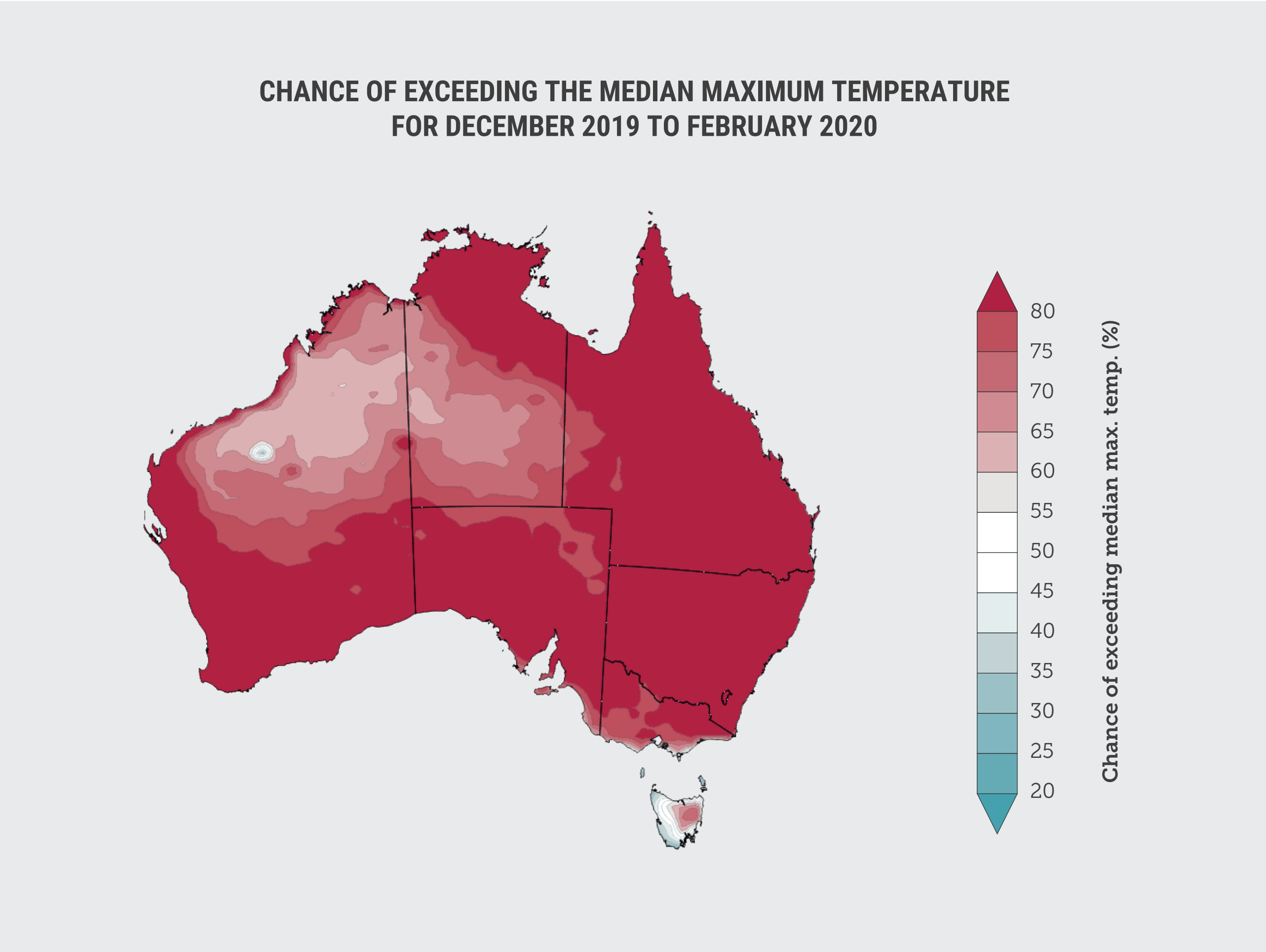


Figure 3: Most of Australia is forecast to experience above average maximum temperatures over summer 2019/20.
Source: BoM 2019a.

The projections for the rest of the summer are extremely concerning. The Bureau of Meteorology forecasts hot conditions for most of Australia (Figure 3) with eastern Australia likely to be drier than average (Figure 4).

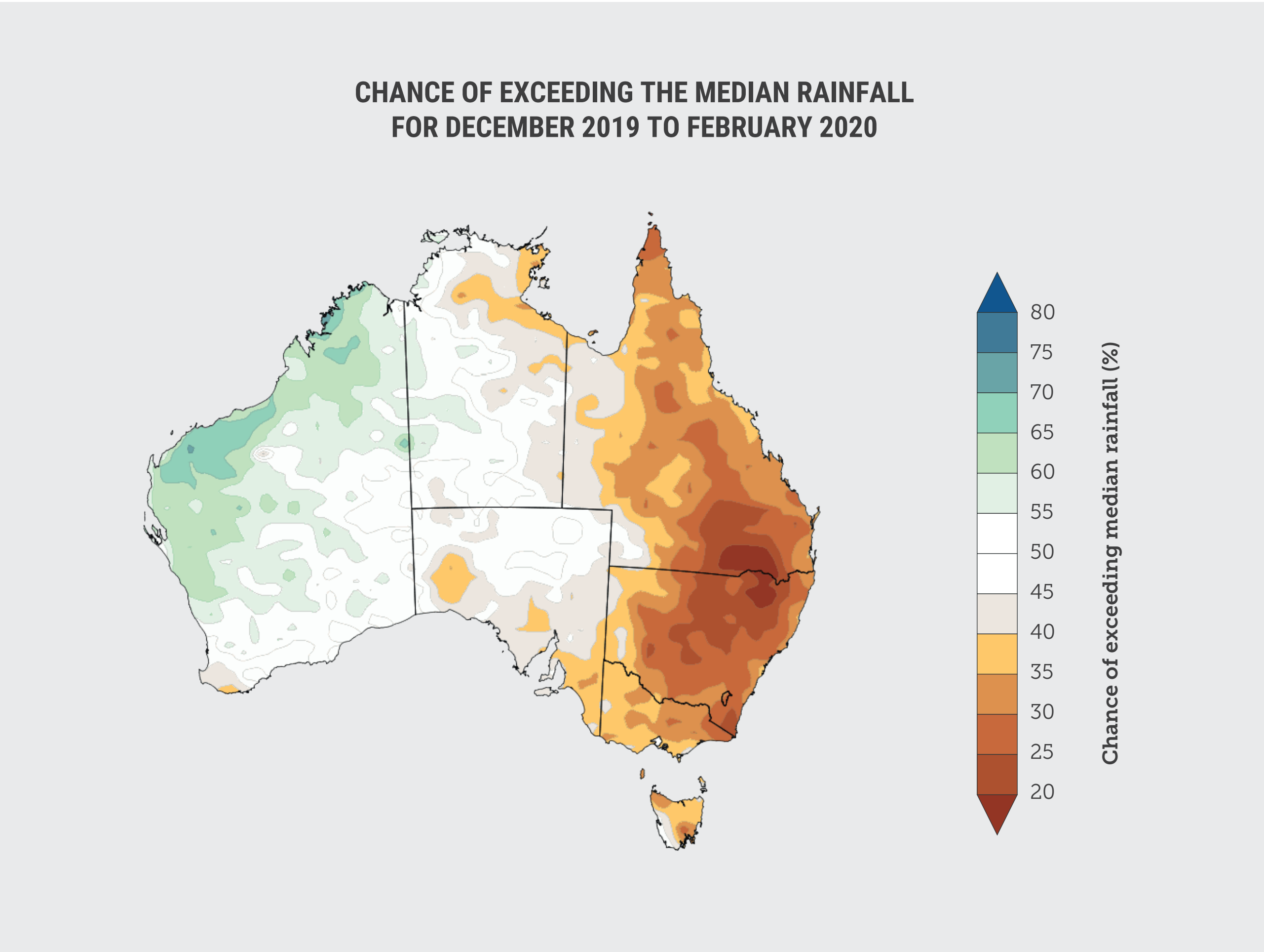


Figure 4: Dry conditions set to prevail over the summer 2019/20, particularly in eastern Australia. **Source:** BoM 2019a.

For more details, access BoM's website: http://www.bom.gov.au/climate/outlooks/#/overview/summary.

With Australia already reeling from the impacts of extreme weather and more likely to be on the way, we describe here the influence of climate change on these extreme events and their effects on human health and well-being.

2. Heatwaves

Heatwaves are one of the most serious climate-related risks for Australians, and the link between climate change and more extreme heatwaves is clear. Heatwaves are lasting longer, reaching higher maximum temperatures and are occurring more frequently over many regions of Australia (for the time period 1971-2008) (Perkins and Alexander 2013; Perkins-Kirkpatrick et al. 2016).

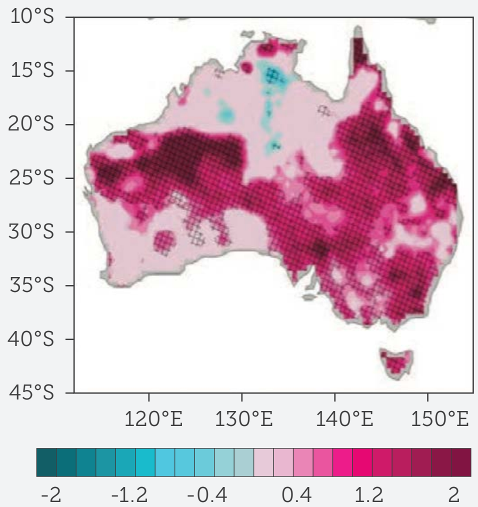
BOX 1: WHAT IS A HEATWAVE?

In Australia, a heatwave is defined operationally as a period of at least three days where the combined effect of high temperatures and excess heat is unusual within the local climate (BoM 2012; Nairn and Fawcett 2013). Two aspects of this definition are important. First, a heatwave is defined relative to the local climate. That is, a heatwave for Hobart will occur at lower temperatures than one for Alice Springs. Second, the concept of excess heat is also important. Excess heat occurs when unusually high overnight temperatures do not provide relief from daytime heat. Heatwaves have several significant characteristics. These include (i) frequency characteristics, such as the number of heatwave days and the annual number of summer heatwave events; (ii) duration characteristics, such as the length of the longest heatwave in a season; (iii) intensity characteristics, such as the average excess temperature expected during a heatwave and the hottest day of a heatwave; and (iv) timing characteristics, including the occurrence of the first heatwave event in a season (Figure 5).

As greenhouse gases continue to accumulate in the atmosphere from the burning of coal, oil and gas, more heat is trapped in the lower atmosphere. Australia's climate has warmed by just over 1°C since 1910, with most of the warming occurring since 1950. This long-term warming trend has led to an increase in the frequency of extreme heat events (CSIRO and BoM 2018). Since 1960, the annual number of record hot days across Australia has more than doubled (CSIRO and BoM 2012).

While hot weather is a pre-requisite for heatwaves, it is important to remember that heatwaves are more than just stand-alone hot days. At least three excessively hot days must occur in a row for a heatwave to form, according to the Australian definition (BoM 2012; Nairn and Fawcett 2013).

A

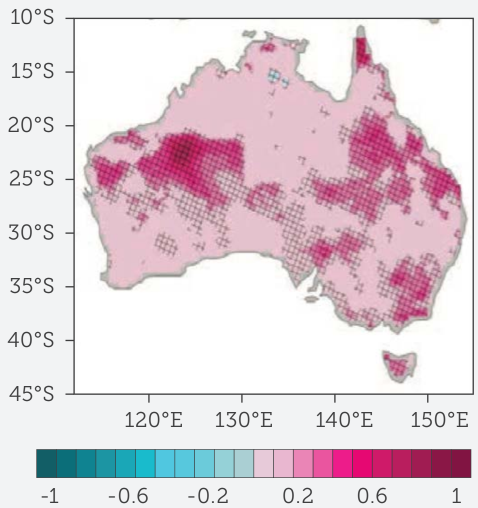


Heatwave days expressed as a percentage of all summer days per summer.

THE NUMBER OF HEATWAVE DAYS IS INCREASING

Red shows an increase in the number of heatwave days. Figure A clearly shows that the number of heatwave days has increased over much of Australia, particularly the eastern half.

B



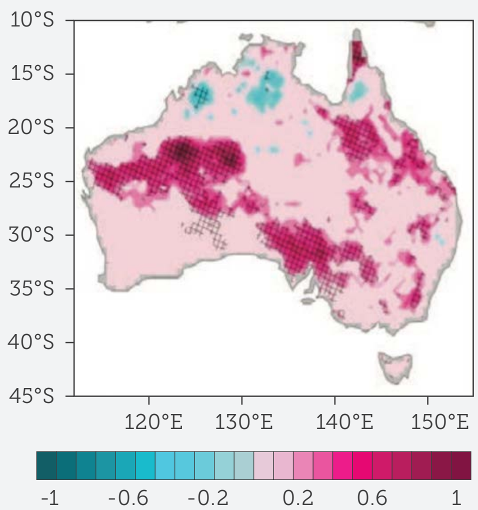
Number of heatwave events per summer.

HEATWAVES ARE OCCURING MORE FREQUENTLY

Red indicates an increase in the number of heatwave events per summer.

An increase in the number of heatwave days in turn influences the number of heatwave events and/or their duration, and although smaller, areas of increasing trends in heatwave frequency (Figure B) and duration of the longest yearly event (Figure C) are consistent with that of heatwave days. Note that changes in heatwave events and duration will generally lag behind that of heatwave days— while an increase in the number of days is required to increase the duration and frequency, both cannot occur at the same time. That is, for each extra heatwave day that is gained, the new day can only contribute to heatwave duration or frequency.

C

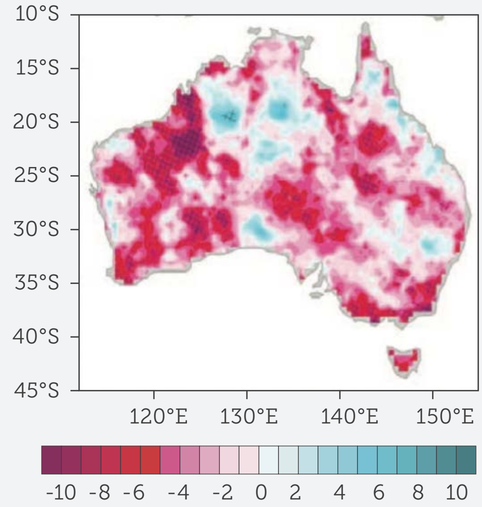


The length in days of the longest event per summer

THE DURATION OF THE LONGEST YEARLY HEATWAVE IS INCREASING

Red indicates an increase in the number of days of the longest heatwave of a summer.

D

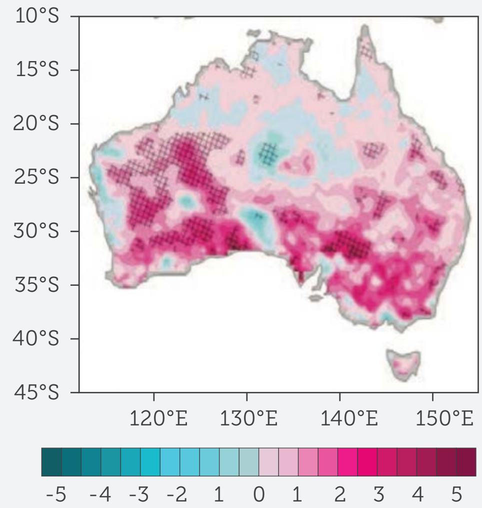


Start day of the first event per summer.

THE FIRST HEATWAVE OF THE SEASON IS OCCURING EARLIER

Red indicates a heatwave occurring earlier relative to the long- term average. Since 1950, almost all of Australia has experienced a lengthening of the heatwave season, where the first event is occurring much earlier (Figure D).

E



Extreme Heat Factor units (°C2).

THE HOTTEST DAY OF A HEATWAVE IS BECOMING HOTTER

Red shows increasing temperatures. Figure E shows that the hottest day of a heatwave, i.e. its peak, has a detectable increase for almost all of Australia below the Tropics. Such trends are consistent with, and continue on from those reported by (Perkins et al. 2012), since they include the latest complete Australian summer data.

Figure 5: A through E depict changes in five heatwave characteristics across the continent from 1950–2013. All heatwave metrics are calculated relative to a 1961–1990 base period, using the heatwave definition from the Australian Bureau of Meteorology (Nairn and Fawcett 2013). **Source:** Climate Council 2014, modified from Perkins and Alexander (2013) using AWAP (Australian Water Availability Project) data from the Bureau of Meteorology.

Heatwaves have been worsening in Australia's cities. The number of heatwave days each year has been increasing in Perth, Adelaide, Melbourne, Sydney, Canberra and Hobart, and across Australia as a whole since 1950. Heatwaves now start earlier – by 19 days in Sydney and by 17 days in Melbourne during the period 1981-2011 compared to 1950-1980 (see Table 1). The intensity of the hottest day in a heatwave has increased in all cities. Most dramatically, the peak day in Adelaide is, on average, now 4.3°C higher in 1981-2011 than it was in 1950–1980.

City	Number of heatwave days		Number of heatwave (events)		Length of longest event		Changes in average intensity of the heatwave (°C)	Changes in average intensity of the peak day (°C)	Changes in timing of first event (days)
	1950-1980	1981-2011	1950-1980	1981-2011	1950-1980	1981-2011			
Sydney	6	9	1-2	2-3	4	5	1.5	1.5	-19
Melbourne	5	6	1-2	1-2	4	4	1.5	2	-17
Brisbane	10	10	2-3	2-3	6	6	1	1.5	-8
Perth	6	9	1-2	2-3	4	5	1.5	1.5	+3
Adelaide	5	9	1-2	1-2	4	6	2.5	4.3	-2
Hobart	4	5	1	1-2	4	4	-1.5	1.7	-12
Darwin	3	7	1	1-2	4	5	0	1	-7
Canberra	6	13	1-2	2-3	5	7	0	1.5	-3

Table 1: The average number of heatwave days, number of events, length of the longest event, average heatwave intensity, average intensity of the peak heatwave day, and change in the timing of the first summer heatwave for Australia's capital cities (Perkins and Alexander 2013). Statistics were calculated from the high-quality ACORN-SAT temperature dataset for the period 1951-2011 (Trewin 2013), using the Excess Heat Factor heatwave definition (Nairn and Fawcett 2013; Perkins and Alexander 2013). All statistics are rounded to the nearest integer. The first column for each characteristic is for the 1950–1980 period and the second is for the 1981–2011 period. Changes in average intensity and peak intensity are calculated by comparing the respective averages for the periods 1950–1980 and 1981–2011. Changes in timing are calculated by subtracting the average start date during 1981–2011 from that of 1950–1980. **Source:** Climate Council 2014.

Climate change has increased the risk of severe heatwaves by two- and three-fold in terms of their frequency and intensity respectively (Perkins et al. 2014), a trend that is reflected in recent observations of individual heatwave events. Over the past decade a remarkably large number of record-breaking and devastating heatwaves have occurred in Australia and in many other parts of the world (Coumou and Rahmstorf 2012). During the 2018/19 summer in Australia, exceptionally severe heatwaves occurred, notable for their continental-wide scale as well as for breaking records for both duration and individual daily extremes (BoM 2019b). The widespread heatwave conditions occurred throughout most of December and January but peaked in late December and in mid-January. The latter heatwave was the most significant heatwave on record at the national scale (Figure 6).

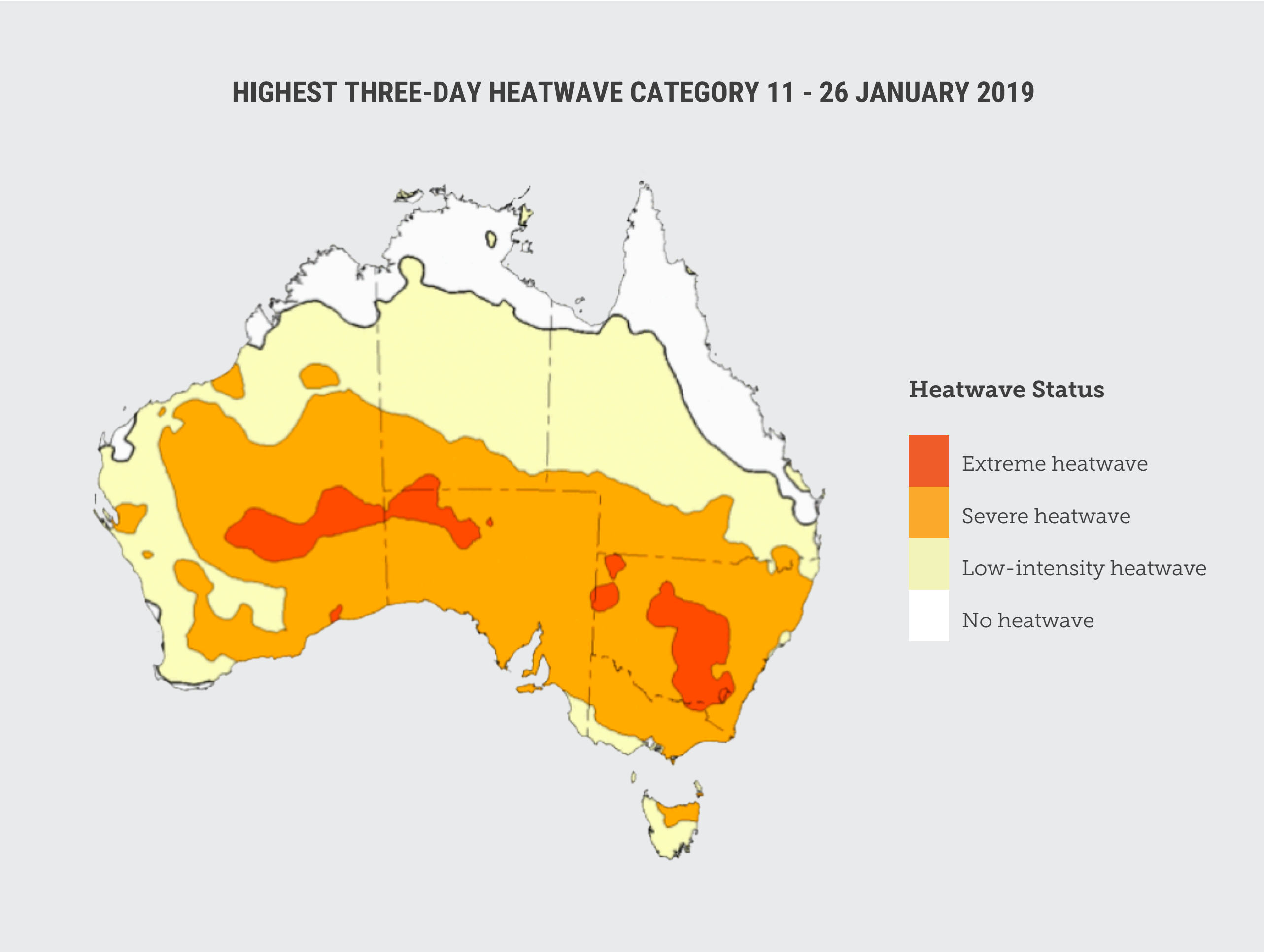


Figure 6: Highest three-day heatwave category reached in different areas between January 11 - 26 2019. Large areas of Western Australia, South Australia, New South Wales and Victoria were affected by either severe or locally extreme heatwaves during this period. **Source:** BoM 2019b.

Climate change is making heatwaves worse. The 2018/19 summer heatwaves were unprecedented.

If greenhouse gas emissions continue to rise, the unusually hot weather currently experienced will become commonplace, occurring every summer across the country. Sydney and Melbourne could experience unprecedented 50°C summer days by the end of the century — even if global warming is limited to 2°C above pre-industrial levels (Lewis et al. 2017).

3. Drought

RAINFALL

Rainfall is the main variable that influences droughts. How climate change is influencing droughts around the world largely depends on how it is affecting total rainfall and rainfall patterns. In Australia, rainfall is highly variable and is significantly influenced by climate drivers such as the El Niño Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD) phenomena, especially in eastern Australia. This natural climate variability can make it more difficult to extract and identify the climate change signal in changes to rainfall. Despite this variability, some trends in rainfall have emerged in recent decades.

Northern Australia has become wetter, particularly in the northwest. Rainfall across most of northern Australia has been very much above average in the northern wet season (the monsoon). In northwest Western Australia, rainfall has also been above average in the dry season (CSIRO and BoM 2015; CSIRO and BoM 2018).

At the same time, rainfall in the mainland southeast and southwest corners of the continent has been declining during the cool season (April – October) in recent decades (CSIRO and BoM 2018). The cool months of the year also coincide with the typical growing season in these regions.

Southwest Western Australia has experienced a pronounced decline in cool season rainfall, with particularly strong drying from May through July when rainfall has reduced by around 20 percent since 1970 (CSIRO and BoM 2018). Since the mid-1990s, mainland southeast Australia has experienced an 11 percent reduction in April-October rainfall (CSIRO and BoM 2018). This decline has been most apparent in April and May (see Figure 7) (CSIRO and BoM 2016; CSIRO and BoM 2018).

The reduction in cool season rainfall in these regions is having significant impacts, as the majority of annual rainfall in these regions typically falls during the cool season. Over the past 200 years or so, cool season rainfall in this region has been relatively stable, supporting some of the nation's most productive agricultural areas. Major cities such as Perth, Adelaide and Melbourne have also traditionally been dependent on cool season rainfall to fill dams.

Although changes to several influences on annual (seasonal) and interannual rainfall variability seemingly play a role in the observed rainfall declines, climate change has likely exacerbated certain aspects of these declines through links to the poleward shift in storm tracks, positive trends in the Southern Annular Mode, an increase in pressure in the sub-tropics and the expansion of the Hadley Cell (CSIRO and BoM 2015).

In recent decades, the subtropical ridge that extends across the southern part of the continent has intensified, blocking more cool-season rain bearing systems from reaching southern Australia. The increased intensity of the subtropical ridge, related to the rising global average temperature, is able to explain up to two thirds of the decline in rainfall across mainland southeast Australia between 1997 and 2009 (associated with the Millennium Drought) (Timbal and Drosdowsky 2013). The World War II drought is the first dry decade of the 20th century in southeast Australia that

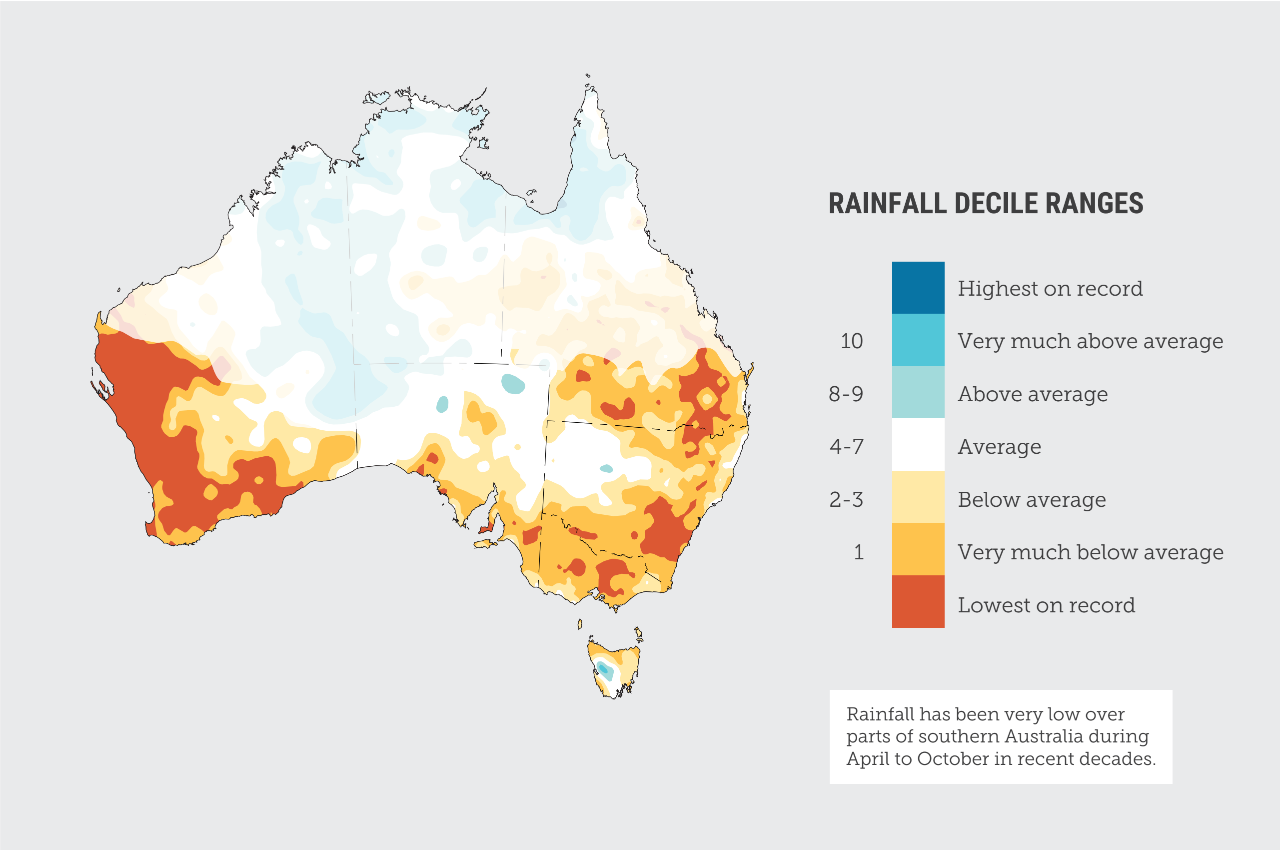


Figure 7: Cool season (April – October) rainfall has been below average across Australia over the past 20 years compared to the entire rainfall record from 1900. **Source**: CSIRO and BoM (2018).

may have been influenced by climate change through the intensification of the subtropical ridge (Drosdowsky 2005; Timbal and Drosdowsky 2013; Gergis 2018, p.102).

Some studies have also suggested that climate change may increase the occurrence of positive phases of the IOD, which are associated with decreased rainfall in the southeast during the cool season (on interannual timescales) (Cai et al. 2009a; Ummenhofer et al. 2009; Ummenhofer et al. 2011).

The behaviour of the Southern Annular Mode (SAM) also appears to have changed in recent decades, but the extent to which climate change is responsible is equivocal. During the summer and autumn months (December through to May), the SAM shows an increasing tendency to remain in a positive phase, with westerly winds contracting towards the south pole. Paleoclimatic evidence indicates that the SAM index is now at its highest level (indicating increased occurrence of positive phases) for at least the past 1,000 years (Abram et al. 2014; Dätwyler et al. 2018). The SAM may also be affected by the expansion of the Hadley Cell as the climate warms and the tropics expand, 'pushing' temperate regions poleward. The expansion of the Hadley Cell is effectively a change in the position and strength of the temperature gradient between the equatorial regions and the polar regions. As the temperature gradient influences mid-latitude storms, the change in position of this gradient also leads to a change in the mean position of mid-latitude storms.

TEMPERATURES AND EVAPORATION

Droughts are usually accompanied by an increase in temperature. This is because evaporation tends to be limited by the total water availability during droughts, so rainfall deficiencies are generally associated with reduced evaporative cooling, which raises local temperatures (Lockart et al., 2009).

As well as the natural increases in local temperature that occur during drought periods, there has also been a greenhouse-induced rise in global and regional temperatures. For example, the average temperature across Australia has risen by about 1˚C since 1910, leading to an increase in extreme heat events (see Section 2) (CSIRO and BoM 2018). This means that when local temperature rises in association with drought conditions, it occurs on top of a warmer baseline.

Increased temperatures have the effect of increasing evaporative demand (the extent to which the environment is 'trying' to evaporate water – actual evaporation depends on the supply of water as well as evaporative demand). Other variables that increase evaporative demand include more sunlight, more wind, and lower atmospheric humidity. These latter factors have a relatively larger influence than temperature. Nevertheless, sustained increases in temperature can further reduce the amount of water available during droughts, for example, for plant growth or runoff to rivers by contributing to increased evaporative demand, assuming other factors are stable. For example, if the temperature increases by 1˚C, daily evaporation should increase by roughly 0.08 mm per day, or 1 mm over 12 days (ARC COE for Climate Extremes 2019). Changes to other variables can either strengthen or weaken this influence.

The extent to which higher temperatures due to climate change worsen droughts is still an active area of research (Kiem et al. 2016). Nevertheless, some studies have found that the severity of the Millennium Drought was exacerbated by increased temperatures due to climate change (Cai et al. 2009b; Ummenhofer et al. 2009). Research has also found that the influence of rising temperatures due to climate change reduced streamflow during the Millennium Drought (Cai and Cowan 2008). A 1˚C rise in annual average temperature was found to lead to a 15 percent reduction in annual streamflow over the southern MDB in winter and spring (Cai and Cowan 2008).

Increased temperatures have also been found to worsen the impacts of droughts. For example, higher air temperatures, combined with lower streamflow, can enhance the production of toxic cyanobacterial blooms, leading to lower dissolved oxygen concentrations in lakes and streams (Mosley 2015). Observed tree die-off events across Australia have also been found to increase when water deficits coincide with high maximum temperatures. Higher temperatures are also associated with increased demand for water by humans and animals.

CURRENT DROUGHT CONDITIONS

The Murray-Darling Basin (MDB) has been one of the most severely affected regions in the current drought (BoM 2019c). Rainfall deficiencies have affected most of the New South Wales, Queensland and South Australian parts of the MDB since the start of 2017. In New South Wales, long-term rainfall deficiencies have also extended towards the coast in the Illawarra and Hunter districts, and have affected most of the eastern half of South Australia. Long-term rainfall deficiencies are also affecting Gippsland in eastern Victoria and the east coast of Tasmania, as well as the northern half of New South Wales and southern Queensland. (BoM 2019c).

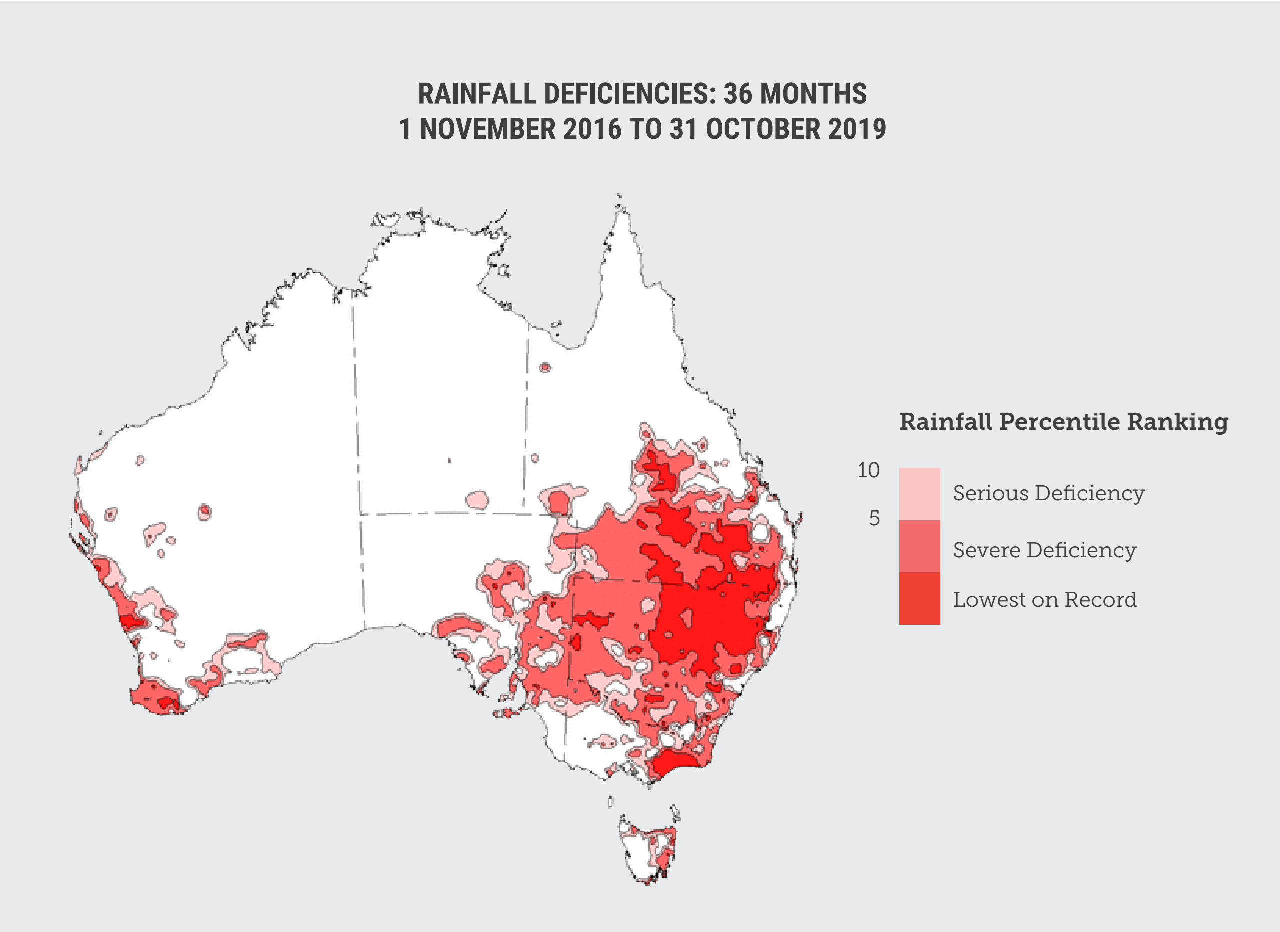


Figure 8: For the past three years rainfall across most of New South Wales, the southern half of Queensland, the eastern half of South Australia, parts of Victoria and southwest Western Australia has been either seriously deficient (above the lowest 5 percent of observations but below the lowest 10 percent of observations), severely deficient (below the lowest 5 percent of observations) or the lowest on record. **Source:** BoM 2019c.

Northern New South Wales and southern Queensland are experiencing their driest conditions on record.

The 34 months from January 2017 to October 2019 have been the driest on record for the MDB as a whole, particularly in the northern MDB and for New South Wales. Both east and west Gippsland districts have also had their driest 34 months on record since January 2017 (BoM 2019c). In the MDB, new long-term records for low soil moisture have been set, with ten of the Basin's 26 river catchments recording the lowest soil moisture on record for the 34 months from January 2017 (BoM 2019c).

In each of the past three years, rainfall deficiencies have been particularly acute during the cool season. In 12 of the 30 rainfall districts in New South Wales, rainfall was at least 50 percent below average in 2017, 2018 and 2019. The cool season is particularly important for generating runoff to fill rivers, streams and reservoirs in time for the summer, which is generally when water demand increases (BoM 2019c). Figure 8 shows rainfall deciles for the three-year period commencing 1 November 2016. It shows the areas with severe and serious rainfall deficiencies, as well as the lowest rainfall on record over this period.

The impacts of the dry conditions have been exacerbated by record high temperatures. Temperatures have been particularly warm over the most drought affected regions. For example, the mean annual temperature averaged over the MDB in 2017 was the highest on record (+1.53°C above the 1961-1990 average), but this record was broken again in 2018 with a mean annual temperature +1.66°C above the 1961-1990 average. While droughts are often associated with above average temperatures as described above, these conditions are 1°C or higher than comparably dry years that occurred in the past (BoM 2019d).

The summer of 2018/19 was the hottest on record for Australia at +2.14°C above the 1961-1990 average. Daytime temperatures were +2.6°C above the long-term average (BoM 2019e). January 2019 was the hottest on record for every state and territory except South Australia and Western Australia. Conditions were particularly extreme in New South Wales, where monthly mean temperatures were 5.86 °C above average, breaking the state's hottest month on record by more than 2°C (BoM 2019d). March was also the warmest on record over Australia (BoM 2019e). Overall, the year to date has been the second-warmest January–October on record for Australia (spanning 110 years), with rainfall the second lowest on record for Australia as a whole (spanning 120 years) (BoM 2019f).

The New South Wales and Queensland Governments produce their own drought maps (NSW: https://edis.dpi.nsw.gov.au and Queensland: https://www.longpaddock.qld.gov.au/drought/archive/). The New South Wales government measures drought using a combined drought indicator, which accounts for rainfall, soil moisture and pasture/crop growth indices. An area is declared in drought if at least one indicator (rainfall, soil water, plant growth) falls below 5 percent when compared to historical records. Intense drought is recorded when all three indicators fall below 5 percent when compared to historical records, and an area is recorded as drought affected if any one of these indices falls below 30 percent when compared to historical records. By this measure, more than 99 percent of New South Wales is currently either drought declared, in intense drought or drought affected. Only 0.2 percent of New South Wales is not in drought, while 0.2 percent of the state is recovering (up to date as at 20 November 2019).

The Queensland Government has its own classification system. The responsibility for declaring or revoking a regional council, shire or property as drought affected rests with the Minister for Agricultural Development and Fisheries, who makes this decision based on advice from Local Drought Committees, and information about the previous twelve months of rainfall compared to historical records (which must meet the definition of experiencing a one in ten-to-fifteen-year rainfall deficiency) (Queensland Government 2019). According to this classification system, more than 66 percent of the land area of Queensland is currently in drought, covering 33 local government areas and partially covering a further four local government areas. There are also an additional 23 Individual Drought Affected Properties across an additional eight Local Government Areas (up to date as at 1 September 2019).

4. Bushfires

Climate change is escalating the bushfire risk, with an increase across southeast Australia in the number of days of Very High fire danger and above over the last 30 years. Bushfire seasons are starting earlier and lasting longer. For example, in New South Wales the statutory bushfire danger period established in the Rural Fires Act runs from 1 October to 31 March. In 2018, after homes were destroyed at Tathra on the New South Wales South Coast in March, a major fire threatened hundreds of homes from Holsworthy to Sutherland in Sydney's south in April. Fires continued in July, then homes were lost to fires on the South Coast with major fires breaking out in several areas including Port Stephens on 15 August.

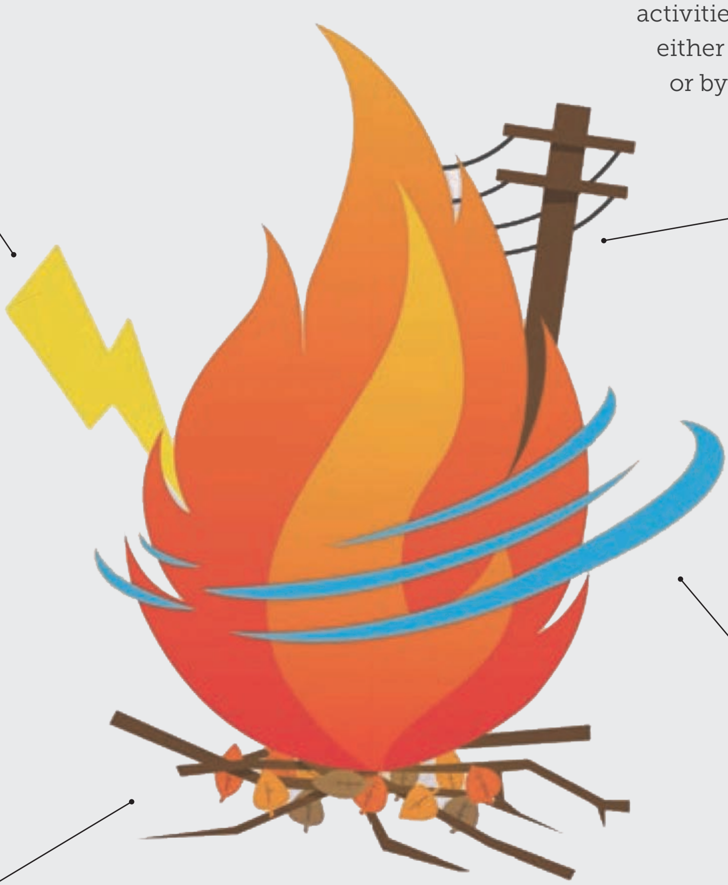
In 2019 there was an early start to the bushfire season when many major fires broke out under Very High fire danger conditions on 9 August through the Clarence and Richmond Valleys in northern New South Wales. With the absence of rain most of these fires continued to escalate and by 24 November 2019 more than 600 homes and public buildings had been destroyed in New South Wales. This is notable as apart from the October 2013 Blue Mountains and Central Coast bushfires, all previous significant property losses due to fires in New South Wales had occurred from late November through to February. It is also notable as the losses thus far have occurred in remote rural areas and small towns, not urban / bushland interface areas where most previous significant losses have occurred. Both New South Wales and Queensland have exceeded the previous record for property losses in a fire season, with perhaps months of serious fire weather still to come.

A fire needs to be started (ignition), it needs something to burn (fuel), and it needs conditions that are conducive to its spread (suitable weather) (Figure 9). Climate change, primarily driven by the burning of fossil fuels – coal, oil and gas – can affect all of these factors in both straightforward and more complex ways. The actions of people, both positive (hazard reduction, firefighting), and negative (arson) can also affect where and when a fire is started, and how it is controlled.

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

Figure 10: 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.

HOT DAYS AND HEATWAVES

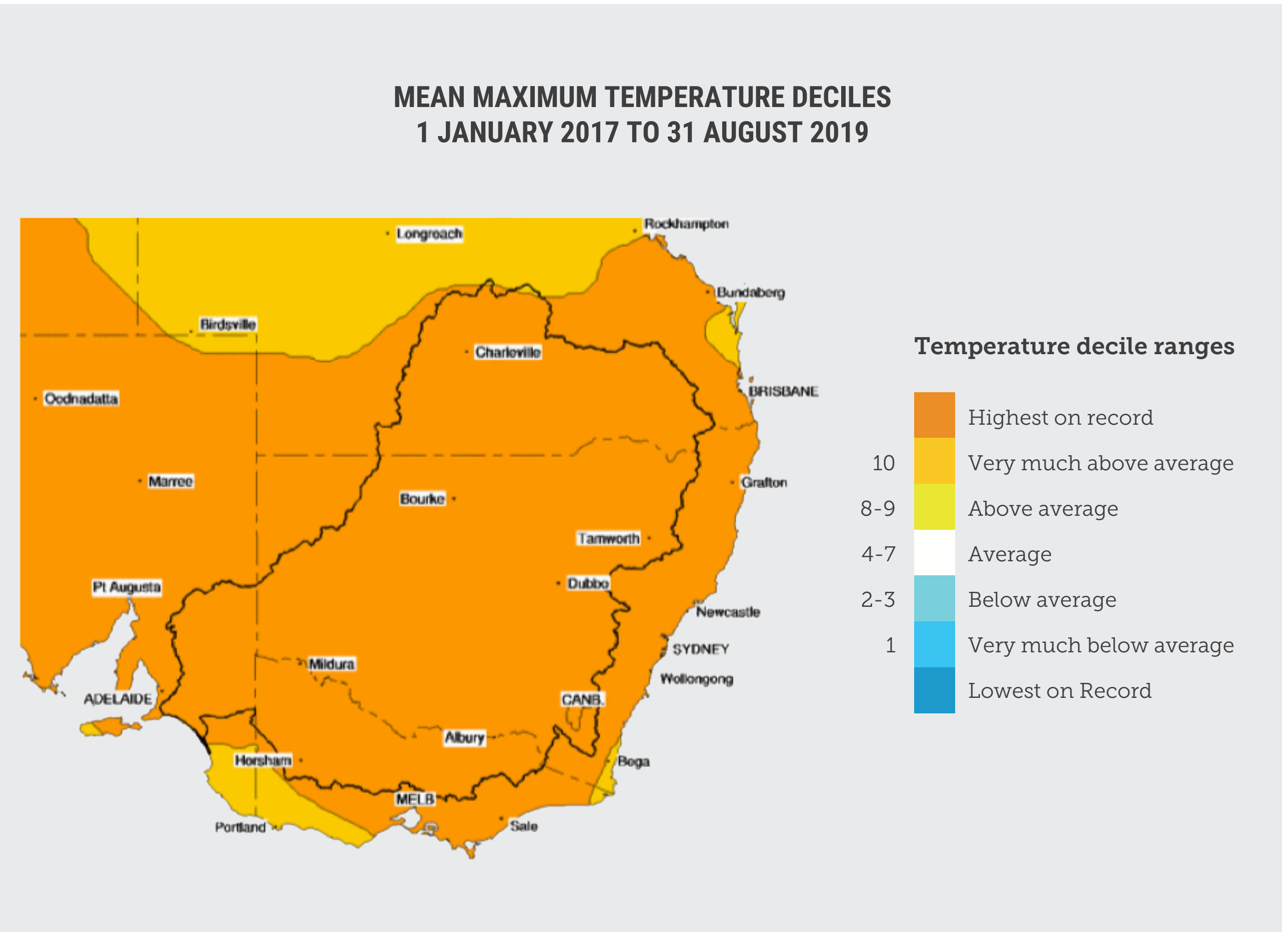
The most direct link between bushfires and climate change comes from the long-term trend towards a hotter climate. Climate change is now making hot days hotter, and heatwaves longer and more frequent (Section 2). This has implications for bushfire weather. For example, the 2009 Black Saturday fires in Victoria (Figure 10) 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 7 February 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 percent of the state (BoM 2009a; BoM 2009b). Over this period, the Forest Fire Danger Index (FFDI) ranged from 120 to 190, the highest values ever recorded (Karoly 2009).

In Australia, the Forest Fire Danger Index (FFDI) and Grass Fire Danger Index (GFDI) are used to measure the degree of risk of bush and grass fires (Luke and Macarthur 1978). The Bureau of Meteorology (BoM) and fire management agencies use the indices to assess fire risk and issue warnings. The FFDI was originally designed on a scale from 0 to 100, with 50 to 100 being categorised as Extreme. After the unprecedented ferocity of the 2009 Black Saturday bushfires in Victoria and “off the scale” readings, the ratings were revised to Severe (50-75), Extreme (75-100), and a new category for conditions exceeding the existing scale: Catastrophic (100 +) (known as Code Red in Victoria). Fire authorities now warn that on Catastrophic days, even well-prepared homes may not be saveable, and people can lose their lives.

In 2019, New South Wales and Queensland had an early and devastating start to the bushfire season with hot temperatures throughout the year making many districts primed for serious bushfire risk. In 2019, New South Wales had its warmest January to August period on record with an overall mean temperature 1.85°C above average. Australia as a whole had its warmest such period on record for maximum (daytime) temperature (1.71°C above average) and was second-warmest for mean temperature (1.30°C above average, behind 2016). Maximum temperatures on the 5th and 6th September were more than 10°C above average in some areas (BoM 2019g). The serious fire danger weather in September 2019 included northern areas of the Murray–Darling Basin; for the Basin as a whole, the four overall warmest January to August periods on record since 1910, in order, have been in 2019, 2016, 2018, and 2017.

Maximum temperature deciles for the January to August period from 2017 to 2019 are shown in Figure 11, with virtually the whole of the Murray–Darling Basin showing warmest on record. These high temperatures contribute to higher values of the drought factor and lower values of relative humidity, as well as directly raising FFDI, which increases with temperature (BoM 2019h).

Figure 11: Map of the Murray–Darling Basin (black outline) showing the mean maximum temperature deciles for the period January to August in 2017, 2018, and 2019 (based on all years since 1910). **Source:** BoM 2019h.



LOW RAINFALL

Declining cool season rainfall has had a significant impact on increasing bushfire risk. Since the mid-1990s, mainland southeast Australia has experienced a 15 percent decline in late autumn and early winter rainfall and a 25 percent decline in average rainfall in April and May. Climate change is influencing this drying trend.

The 2019/20 bushfire season in New South Wales and southeast Queensland had an early and devastating start in August 2019. From 9 August, bushfire risk in parts of northeast New South Wales and southeast Queensland was exacerbated by below-average rainfall on a range of timescales from months to years, leading to a prolonged, severe drought and very high dryness factors for fuels. Rainfall for January to August 2019 was lowest on record in the Southern Downs (Queensland) and Northern Tablelands (New South Wales). For example, Tenterfield and Stanthorpe were each more than 20 percent below their previous record low January–August rainfall, and 77 percent below the long-term average. (BoM 2019h).

The soils were also very dry. The top 100 cm of the soil profile was below average to driest on record for the first week of September 2019 over most of southeast Queensland and northeast New South Wales. The low soil moisture is symptomatic of both the recent intense dry conditions, as well as longer-term below average rainfall since 2017. Low soil moisture means high stress in vegetation and fuels that might not normally burn, making them more prone to bushfires (BoM 2019h).

Fuelled by a long and deepening drought, more than 100 fires burned in forest and bush areas in southeast Queensland and northeast New South Wales, including some areas of subtropical rainforest and wet eucalyptus forests that do not often experience fire, let alone intense fire (NASA 2019; Figure 12). The drought makes vegetation more flammable, and therefore more likely to support extreme fire behaviour. It also makes vegetation more susceptible to spot fires ahead of the main fires when weather conditions deteriorate (high temperatures, low relative humidity, strong winds).

Figure 12: Drought exacerbates New South Wales bushfires in September 2019. Strong winds fanned the flames and carried smoke more than 100 kilometres. **Source:** NASA 2019.

INCREASED IGNITION SOURCES

It is likely that the potential for lightning-ignited bushfires will increase in the future, as lightning is expected to occur more frequently under warmer conditions (Williams, 2005; Romps et al. 2014; Abatzoglou et al., 2016). There is a strong positive association between temperatures and fire occurrence in the southern hemisphere, with a tight coupling between lightning-ignited fire occurrences and the upward trend in the Southern Annular Mode (Mariani et al. 2018).

Fires ignited by lightning can be difficult to suppress as they often occur in inaccessible remote areas. Lightning storms also often result in multiple simultaneous ignitions. In 2016, thousands of dry lightning strikes caused multiple intense bushfires in Tasmania, burning over 120,000 hectares, including nearly 20,000 hectares in the Tasmanian Wilderness World Heritage Area (Styger et al 2018; Earl et al 2019).

The likelihood of sustained ignition of vegetation following a lightning strike is largely dependent on fuel moisture content (Dowdy, 2015). Continuing rainfall deficiencies, hotter temperatures, increased evaporation and drought all increase the likelihood of drier fuels and the likelihood of increased lightning ignitions.

LENGTHENING SEASONS

Since the 1970s, there has been an increase in extreme fire weather and a lengthening of fire seasons across large parts of Australia, particularly in southern and eastern regions, due to increases in extreme hot days and to the cool season drying trend. The lengthening seasons are reducing opportunities for fuel reduction burning (Matthews et al. 2012; Ximenes et al. 2017) and increasing the resource needs of firefighting services.

Resource sharing arrangements are becoming increasingly challenging as climate change causes the overlap of fire seasons in states and territories within Australia, and in the northern and southern hemispheres. As a result, governments are becoming constrained in their ability to share resources and deal with larger, more destructive bushfires.

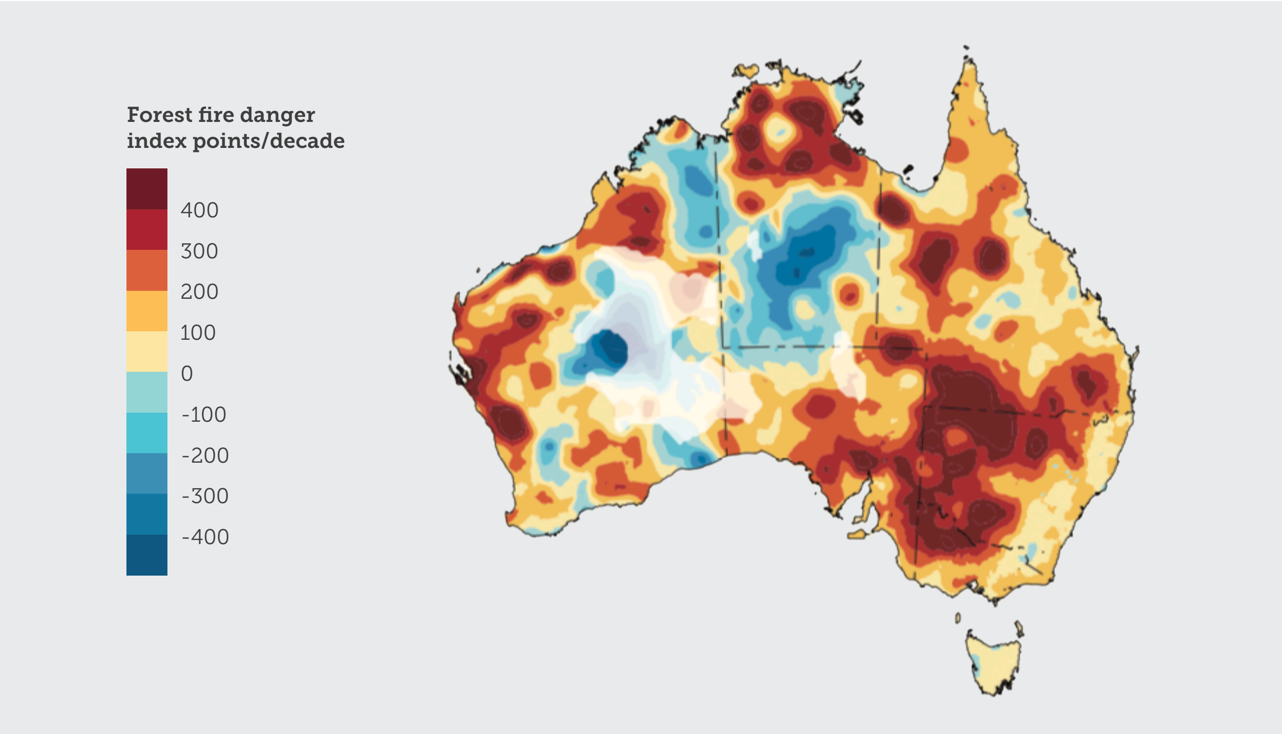


Figure 13: Trends from 1978 to 2017 in the annual (July to June) sum of the daily Forest Fire Danger Index—an indicator of the severity of fire weather conditions. Positive trends, shown in the yellow to red colours, are indicative of an increasing length and intensity of the fire weather season. A trend of 300 FFDI points per decade is equivalent to an average trend of 30 FFDI points per year. Areas where there are sparse data coverage such as central parts of Western Australia are faded.
Source: BoM 2019b.

WORSENING FIRE WEATHER CONDITIONS

Fire weather rated as very high and above has increased over the last 30 years in south and east Australia. The most extreme 10 per cent of fire weather days has increased in recent decades across many regions of Australia, especially in southern and eastern Australia (CSIRO and BoM 2018; Figure 13).

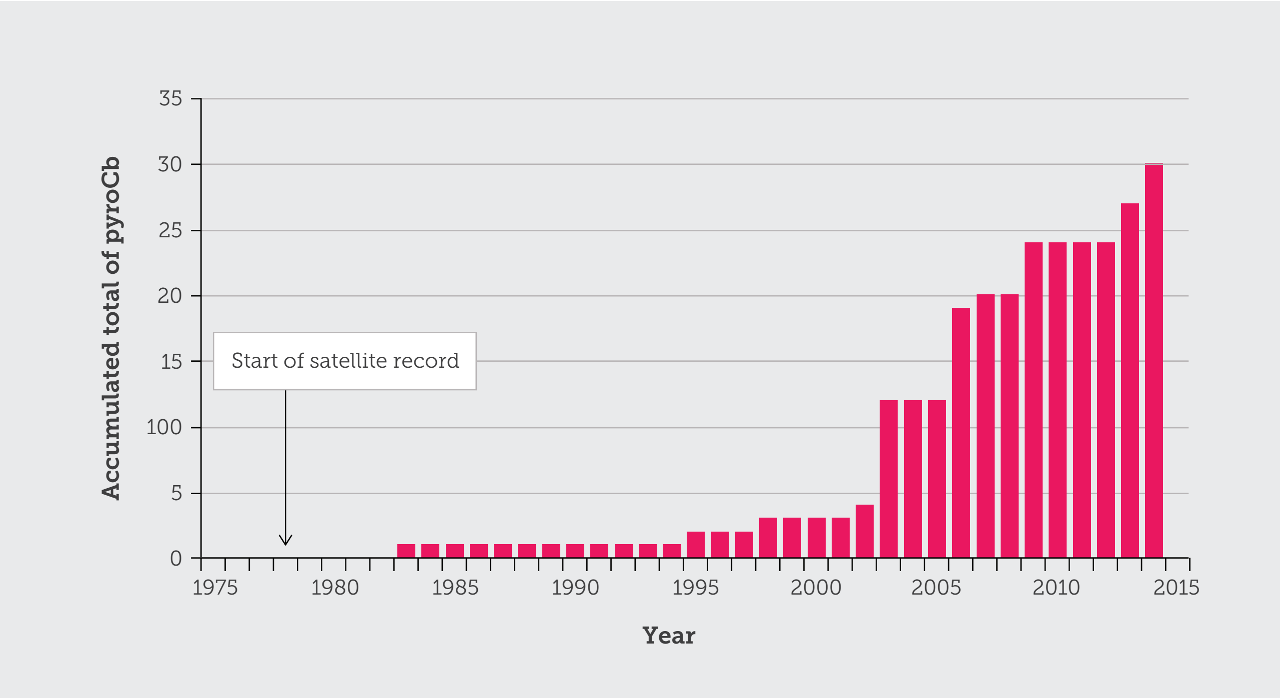


Figure 14: The accumulated occurrence of pyroCbs over southeastern Australia since 1978, when the satellite record began. The most notable feature of this record is the abrupt increase in occurrence of pyroCb events in recent years. Pre-1998 pyroCb occurrence data should be considered tentative. **Source:** Adapted from Sharples et al. (2016).

INCREASED OCCURRENCE OF EXTREME BUSHFIRES OR FIRE STORMS

Climate change could drive an increase in the development of extreme bushfires. An extreme bushfire is defined as one that:

> *… exhibits deep or widespread flaming in an atmospheric environment conducive to the development of violent pyroconvection, which manifests as towering pyrocumulus (pyroCu) or pyrocumulonimbus (pyroCb) storms (Sharples et al. 2016, p. 86).*

Extreme bushfires have a high level of energy, and exhibit chaotic and unpredictable behaviour, with lightning and strong winds that can spread fire in multiple directions and start new fires, making them impossible to suppress.

Increasing risk of extreme fire weather events under the influence of climate change may lead to increased incidence of pyro-convective fire behaviour (Dowdy and Pepler 2018). Records support the idea that the frequency of extreme bushfires has increased in south eastern Australia since around the 1980s (Figure 14) (Sharples et al. 2016). The potential for fires to transform into extreme bushfires is also projected to increase in the future, with an average projected increase of approximately 30 percent by 2070 (Sharples et al. 2016).

On 8 November 2019, despite the atmosphere being relatively stable across northern New South Wales fire grounds, the NSW Rural Fire Service issued public alerts that several fires were exhibiting pyroconvective behaviour.

5. Climate Change is Adversely Affecting People

Worsening extreme events, such as heatwaves, drought and bushfires, are already exacting a large toll on the health and well-being of Australians and these extreme events are badly affecting important sectors such as farming.

HEATWAVES

Extreme heat events – particularly prolonged heatwaves – can have severe effects on human health, including both direct heat effects (e.g. heat exhaustion) and indirect impacts on health, especially where there is an underlying chronic condition (e.g. diabetes or cardiovascular disease). As extreme heat events worsen due to climate change, the risk of adverse human health impacts grows, and health and emergency services are under ever greater demand (AAS 2015).

Figure 15: Heatwaves in Australia can cause medical emergencies, resulting in an increase in emergency department presentations and excess deaths.

Heatwaves are associated with an increase in mortality (Bi et al. 2011; Tong et al. 2015; Watts et al. 2015). An estimated 2,900 Australians have died from extreme heat from 1890 to 2013, more than the deaths from bushfires, tropical cyclones, earthquakes, floods and severe storms combined (DIT 2013). Australia's mortality data indicate that over the past four decades there has been a steady increase in the number of deaths in summer compared to those in winter, suggesting that climate change may already be affecting mortality rates (Bennett et al. 2013). The heatwave during the summer of 2009 sharply increased heat-related deaths in vulnerable groups. As many as 500 excess deaths were recorded in Melbourne and Adelaide (374 deaths in Melbourne and 50-150 deaths in Adelaide) (QUT 2010). In addition, there were more than 3,000 reports of heat-related illness (QUT 2010). Emergency services such as ambulance and paramedics, emergency treatment and mortuary capacity were under severe strain in both Melbourne and Adelaide (QUT 2010).

Extreme heat increases the risk of illness and death especially among people with pre-existing conditions such as heart and kidney disease. Young children (Figure 16), older people, people living with disabilities, and outdoor workers are among those most at risk (AAS 2015; Watts et al. 2015). Heatwaves have been shown to dramatically increase emergency health care demand. During the heatwave in southeast Australia in January and February 2009, emergency call-outs jumped by 46 percent; cases involving heat-related illness jumped 34-fold; and cardiac arrests almost tripled in Victoria. The 374 excess deaths that were recorded in Melbourne represented a 62 percent increase on the same period of the previous year (DHS 2009).

People who work outdoors or in enclosed indoor spaces without adequate ventilation, even if young, fit and healthy, are highly vulnerable during extreme heat events. This vulnerability extends across a broad range of occupations including farmers, laborers, military personnel, athletes, emergency and

Figure 16: Young children are more susceptible to heat stress for a range of reasons, e.g. they are dependent upon carers to keep their environment at a safe temperature and to ensure that they are well hydrated.

essential service workers, and those working outside in the mining industry (Singh et al. 2013). Hot weather also increases the frequency of workplace accidents because of lapses in concentration and can lead to poor decision-making and greater fatigue (Morabito et al. 2006; Tawatsupa et al. 2013; Tamm et al. 2014).

Heatwaves affect health and well-being in many other ways. For example, absenteeism and reduction in worker productivity during the extreme heat of the 2013/14 summer resulted in losses of about $8 billion to the Australian economy (Kjellstrom et al. 2009).

Heatwaves and hot days directly affect the productive capacity of grazing animals, particularly cattle. Rising temperatures lead to reduced grazing time and feed intake, and increased body temperature and respiration rate, leading to weight loss. In dairy cows, heat stress reduces milk yield, reduces milk fat and protein content, and decreases reproduction rates (Jones and Hennessy 2000). Poultry and pigs are also vulnerable to increases in temperature and resultant heat stress.

Vegetable and horticultural crops (including fruits, nuts, and flowers) have various coping ranges for temperature, depending on the climate in which they have developed. The viticulture industry is particularly vulnerable to climate change, as rising temperatures contract the growing season and affect grape quality (Webb et al. 2007; Webb et al. 2008; Webb et al. 2012).

DROUGHT

Droughts are a ‘slow emergency’, and often associated with poor mental health in rural areas, arising both from personal distress, insurmountable debt, decline in local goods and services, and eventually the loss of community networks. Drought is particularly associated with increased distress among farmers, with self-reported distress highest among younger farmers living in remote areas experiencing financial hardship (Austin et al. 2018). Strong social networks that exist in rural areas can ameliorate some of the personal distress experienced by farmers, but even these networks can be eroded during prolonged periods of drought (Stain et al. 2011). With extreme droughts set to become more frequent and prolonged throughout much of continental southern Australia (CSIRO and BoM 2015), maintaining social capital and connectedness in rural areas will need to be a key adaptation strategy to strengthen community networks and reduce the higher risks of mental distress and suicide (Nicholls et al. 2006; Hanigan et al. 2012).

Droughts cause mental distress by directly affecting things that many farming families hold dear, such as the natural environment, and local community. Having to sell stock, plough in long-nurtured crops (such as fruit trees) and watch domestic and public places decline can be extremely stressful. Droughts can induce ‘solastalgia’: distress triggered by the degradation of one’s local environment (see, for example, Figure 17), especially if

Drought can cause mental health issues in rural communities, including personal distress and loss of community networks.

Figure 17: The Darling River and the Menindee Lakes are under pressure from low water flow as a result of the prolonged and ongoing drought in eastern Australia.

associated with a sense of lack of control (Albrecht et al. 2007, Sartore et al. 2008). This is exacerbated by the loss of friends and support structures as some families move away or valued businesses close (Rickards 2012).

The current prolonged drought across eastern Australia is threatening crops for a third year in a row (Reuters 2019). The area planted with winter crops in central and northern New South Wales in 2019 was well below average, reflecting the prolonged drought leading into the cropping window. Winter crop production is forecast to reach 5.1 million tonnes in 2019/20, an increase of 77 percent from the previous season but around 51 percent below the 10-year average to 2018/19 (ABARES 2019).

Australia exports the majority of its wheat crop but with increased domestic demand from the country's livestock sector due to the drought, exports from one of the world's largest exporters are set to tumble (Reuters 2019). Most crops in central and northern New South Wales will yield well below average if they survive through to harvest. The average wheat yield in 2019/20 is forecast to be below average at 1.45 tonnes per hectare. Barley production in New South Wales is forecast to be 1.1 million tonnes in 2019/20, 33 percent below the 10-year average to 2018/19. The average yield for canola is forecast to be well below average at 1 tonne per hectare as a result of drought conditions (ABARES 2019).

Area planted to summer crops is forecast to fall by 28 percent in 2019/20 to around 758,000 hectares. This reflects low levels of soil moisture and an outlook for unfavourable seasonal conditions during spring in Queensland and northern New South Wales. Summer crop production is forecast to fall by 20 percent to 2.1 million tonnes (ABARES 2019).

Figure 18: Sixty people were treated by paramedics for health complications caused by the bushfire smoke haze in Sydney on 6 November 2019.

BUSHFIRES

Large populations are at risk from the health impacts of bushfires, which have contributed to physical and mental illness as well as death (Johnston 2009). Tragically, six lives have already been lost since November 2019 in the New South Wales mega fires. In addition to fatalities, bushfires affect health through the respiratory irritants and inflammatory and cancer-causing chemicals in smoke (Bernstein and Rice 2013; Figure 18). Smoke events are associated with an increase in ambulance call-outs and emergency hospital admissions, with immediate impacts on people with respiratory conditions, and delayed impacts on people with heart conditions (Johnston et al. 2014; Haikerwal et al. 2015; Salimi et al. 2017). On 6 November 2019, at least 60 people in Sydney were treated by paramedics for health complications caused by the bushfire smoke haze (ABC 2019).

The impacts of bushfire smoke in the community are also uneven, with older people, infants and those with pre-existing heart or lung diseases at higher risk (Morgan et al. 2010; Liu et al. 2015). 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, the 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).

Beyond Blue has also studied the mental health and well-being of police and emergency service personnel across 33 agencies in every state and territory. A survey of more than 21,000 police, fire, ambulance and SES employees, volunteers and retired and former personnel found that:

- One in three police and emergency services employees experience high or very high psychological distress compared to one in eight Australian adults.
- Over one in 2.5 employees and one in three volunteers report being diagnosed with a mental health condition in their life compared to one in five Australian adults.
- Over half of the employees surveyed experienced a traumatic event during the course of their work that deeply affected them (Beyond Blue 2018).

In dealing with more intense and prolonged emergency situations, such as the recent New South Wales bushfires, it is likely that levels of psychological distress amongst emergency responders could increase as they bear witness to catastrophe, are unable to save every person and property, are placed in serious peril themselves, as the landscape is damaged and wildlife suffers, and they become mentally and physically exhausted by the demands of deployments now commonly lasting for weeks and months.

The agricultural impacts of the recent bushfires have not yet been thoroughly assessed, but it is estimated that thousands of hectares of farmland have been affected, hundreds of farm animals have perished or been injured, and farm infrastructure such as fences, sheds, water points and machinery has been damaged. Initial estimates suggest that the fire at Cobraball in Queensland had the largest impact on agriculture in recent history, burning through 12,000 hectares including 230 hectares of high-value horticultural crops. The damage bill for farms in this region has been estimated at $20 million (ABC 2019).

6. Conclusion

Against a long-term heating trend from the burning of coal, oil and gas and rising greenhouse gas emissions, many extreme weather events are worsening, putting Australian lives at risk and threatening livelihoods and well-being. The latest Bureau of Meteorology Outlook for Summer 2019/20 forecasts hot conditions for most of Australia and a dry eastern Australia. We could experience a crisis summer marked by a terrible trifecta of heatwaves, drought and bushfires.

As the climate crisis intensifies, there is no Federal leadership, no vision and no effective policy.

The catastrophic events that are unfolding in Australia are not normal. Now is the time to act decisively and swiftly by deeply and rapidly reducing greenhouse gas emissions and preparing our fire and emergency services and communities for worsening extreme weather events.

There are few forces adversely affecting the Australian economy that can match the scale, persistence and systemic risk associated with climate change. Australia's financial regulators have recently made a call for action to deal with climate change, with the Reserve Bank of Australia, the Australian Prudential Regulation Authority and the Australian Securities and Investment Commission citing risks posed by climate change as a central concern for the economy and financial stability. As the Deputy Governor of the Reserve Bank of Australia noted, the risks that climate change poses to the Australian economy are "first order" and have major knock-on implications for macroeconomic policy (Debelle 2019). If climate change continues unabated, extreme weather and climate events will increasingly cause economic shocks that will cascade through the economy (Climate Council 2019b).

Nowhere is this tension between the need for urgent action and ideologically driven denialism and inaction more evident than in Australia. At the end of the Critical Decade, and after a decade of rancorous and divisive federal politics, we have no credible pathway for reducing emissions in our economy over the next two-three decades. In short, there is no leadership, no national plan, no vision, and no coherent policies.

Fortunately, there are many Australians working at the sub-national level who are showing that "the impossible" is not only achievable, it is also desirable and is happening much faster than many thought possible. Australia is a world leader in the uptake of household solar, and industrial-scale solar systems are being rolled out at an increasing rate. Wind energy is becoming a major source of electricity in Australia's populous southeast. South Australia already generates 50 percent of its electricity from renewables, and is moving forward on energy storage technologies, including the world's largest lithium-ion battery. The Australian Capital Territory is on track to achieve 100 percent renewable energy from 1 January 2020 and aims to reach net-zero emissions in its entire economy by 2045. Such action at the state and territory level shows that meeting the climate change challenge is not at all impossible, but much more is required to effectively tackle the climate crisis in the short time frame that is now required.

Decisions we make now could well determine whether or not our children and grandchildren will have a fighting chance for a bright future or will be scrambling to survive in climatic conditions that are unprecedented in the history of human existence. Their future depends on the action we take now.

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