CLIMATE COUNCIL

ANGRY SUMMER 2016/17: CLIMATE CHANGE SUPER-CHARGING EXTREME WEATHER

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Key Findings

1

The Australian summer of 2016/17 marked the return of the *Angry Summer* with record-breaking heat especially in the east of the nation. The *Angry Summer* was characterised by intense heatwaves, hot days and bushfires in central and eastern Australia, while heavy rainfall and flooding affected the west of the country. Noteworthy records from this summer include:

- In just 90 days, more than 205 records were broken around Australia.
- The state-wide mean temperature in summer was the hottest for New South Wales since records began, with temperatures 2.57°C above average.
- Sydney had its hottest summer on record with a mean temperature 2.8°C above average.
- Brisbane had its hottest summer on record in terms of mean temperature at 26.8°C, equivalent to 1.7°C above average.
- Canberra had its hottest summer on record in terms of daytime temperatures and recorded temperatures of at least 35°C on 18 days, already far higher than what is projected for 2030 (12 days).
- Adelaide experienced its hottest Christmas day in 70 years at 41.3°C.
- Moree in regional New South Wales experienced 54 consecutive days of temperatures 35°C or above, a record for the state.
- Perth had its highest summer total rainfall on record of 192.8 mm.

2

Climate change is driving hotter, longer lasting and more frequent heatwaves.

- The 2016/17 extreme summer heat in New South Wales was at least 50 times more likely to occur due to climate change.
- Protecting Australians from the impacts of summers with relentless extreme heat requires the uptake of cheap, clean and efficient renewable energy and the phasing out fossil fuels.
- Commissioning new fossil fuel (coal, oil and gas) projects is incompatible with limiting the dangerous impacts of climate change, such as the failure of critical infrastructure.

3

Escalating extreme weather is putting Australia's ageing energy system under intense pressure.

- Australia's energy system is ageing, inefficient and polluting, and during the *Angry Summer* proved unable to cope with escalating extreme weather, like heatwaves.
- Days of extreme heat and heatwaves will become even more frequent and severe in Australia, and will increase the risks to critical infrastructure (e.g. electricity), the economy, health and ecosystems.

4

The costs of the extreme heat are clear with reduced work productivity, increasing risk of bushfires and escalating damage to the Great Barrier Reef.

- The impacts of the last *Angry Summer* of 2013/14 cost the Australian economy approximately $8 billion through absenteeism and a reduction in work productivity. The economic impact from the 2016/17 *Angry Summer* has not yet been quantified.
- Above-average sea surface temperatures this summer have triggered a new bleaching outbreak on the Great Barrier Reef. This follows the worst mass bleaching event in the reef's history in 2016.
- Extreme fire weather is increasing in Australia's southeast. During the most severe heatwave of this recent Australian summer, nearly 100 bushfires were ignited and raged through parts of inland New South Wales.

Introduction

The Australian summer of 2016/17 marked the return of the *Angry Summer* with record-breaking heat, especially in the east of the nation. The summer was characterised by intense heatwaves, hot days and bushfires in central and eastern Australia, while heavy rainfall and flooding affected the west of the country, indicative of a warming climate holding more moisture in the atmosphere. This summer follows hot on the heels of previous *Angry Summer* in 2012/13 and 2013/14, with Australians again enduring record-breaking extreme weather events driven by climate change.

2016 was the hottest year on record, with many heat records broken around the world. It was the third consecutive year in which the global average temperature record was broken. The Australian cities of Sydney and Darwin had their hottest years on record (maximum and minimum temperatures), while Brisbane and Canberra had their record hottest and equal third-hottest years (annual mean temperature), respectively (BoM 2017d). Above-average sea surface temperatures this summer offered no reprieve to our iconic reefs under threat from climate change, with a new bleaching outbreak underway in the Great Barrier Reef and elsewhere in Australia.

Climate change – driven largely by rising atmospheric carbon dioxide concentrations from the burning of coal, oil and gas – is increasing temperatures and cranking up the intensity of extreme weather events globally and in Australia. The global heat record of 2016, along with the record-breaking summer of 2016/17, is part of the long-term warming trend (Figure 1). Australia has warmed by about 1°C since 1910, with the majority of warming occurring since the 1950s (CSIRO and BoM 2016). Global temperatures have already reached 1.1°C above pre-industrial levels (UK Met Office 2017), and the accumulating energy in the atmosphere is affecting all extreme weather events (Trenberth 2012). Climate change is driving global warming at a rate 170 times faster than the baseline rate over the past 7,000 years (Steffen et al. 2016).

Climate change – driven largely by the burning of coal, oil and gas – is cranking up the intensity of extreme weather events.

Climate change is worsening the impacts from heatwaves and hot weather and is putting a strain on critical infrastructure. This summer alone has shown the vulnerability of the electricity grid to heatwaves, with power outages during peak times in South Australia during a severe February heatwave, while New South Wales narrowly avoided widespread outages several days later. The hot weather, combined with very dry conditions, led to tinderbox fire conditions in New South Wales in early February prior to, and during, the most severe heatwave of the Australian summer. During the heatwave itself, nearly 100 bushfires were ignited and raged through parts of inland New South Wales.

Despite the urgent need for greenhouse emissions to be trending strongly downwards, Australia's emissions have risen 0.8% in the last year (Commonwealth of Australia 2016a), with much of the emissions coming from the electricity sector. This rise puts into serious doubt whether even Australia's very weak emissions reduction target of 26-28% by 2030 can be achieved. The only approach to slowing and eventually halting the increasing trend of heat-related extreme weather is to rapidly increase the uptake of renewable energy and to phase-out all forms of coal fired power plants, as well as phasing out other fossil fuels.

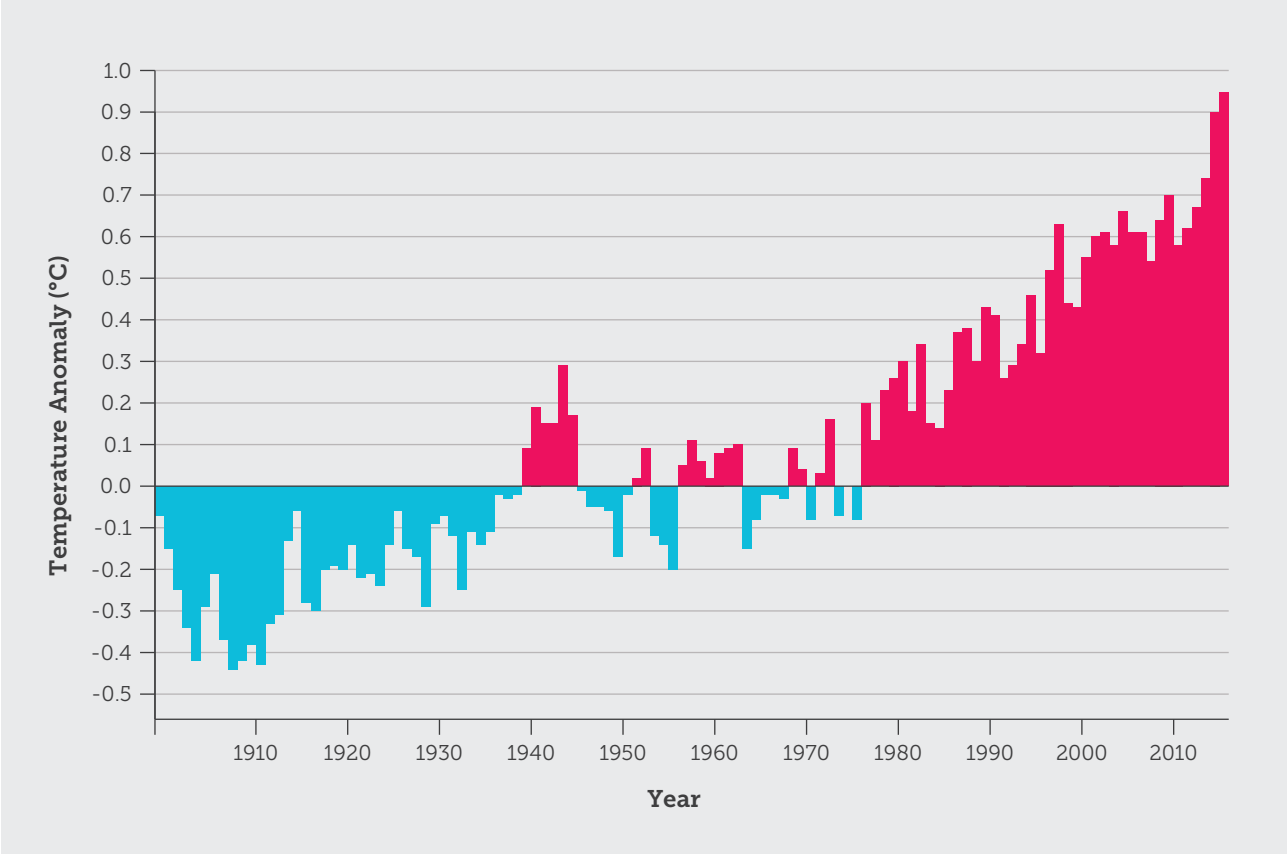

Figure 1: Column graph of the annual global temperature anomalies through to 2016, relative to the global annual average temperature for the 20th century (1901-2000). Data from the US National Oceanic and Atmospheric Administration (NOAA).

1. Temperature Records Tumble, Yet Again: Summer of 2016/17

In just 90 days, more than 205 records were broken around Australia. Heatwaves and hot days scorched the major population centres of Adelaide, Brisbane (Figure 2), Canberra, Melbourne and Sydney, as well as the rural and regional heartlands of eastern Australia.

The most severe heatwave of this *Angry Summer* began around January 31 and continued until February 12, with the highest temperatures recorded from February 9-12 (BoM 2017u). This heatwave was made twice as likely to occur because of climate change (Perkins-Kirkpatrick et al. 2017), while the extreme heat in New South Wales over the entire summer season was at least 50 times as likely to occur because of climate change (King et al. 2017). The hot weather, combined with very dry conditions, led to tinderbox fire conditions in New South Wales in early February and resulted in nearly 100 bushfires raging across the state (BBC 2017).

This summer a number of long-standing temperature records were broken. This section highlights some of these records for both a number of Australian capital cities and for the states of Queensland and New South Wales, where the heat had its biggest impact. At least 19 sites across those two states, with 40 or more years of data, set new records for the number of summer days with maximum temperatures of at least 40°C (BoM 2017u). Figure 3 summarises some of the extreme events to hit Australia during the *Angry Summer* of 2016/17.

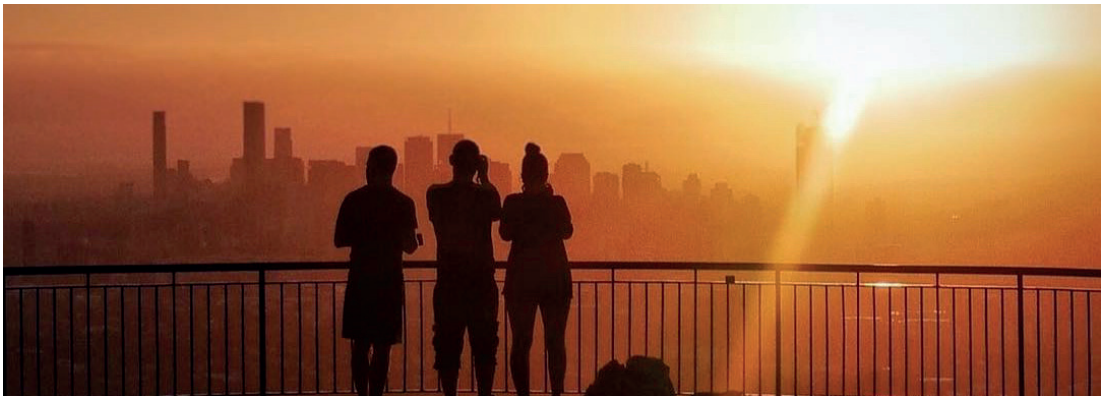

Figure 2: The hot Brisbane sun – Brisbane had its hottest (mean temperature) summer on record in 2016/17.

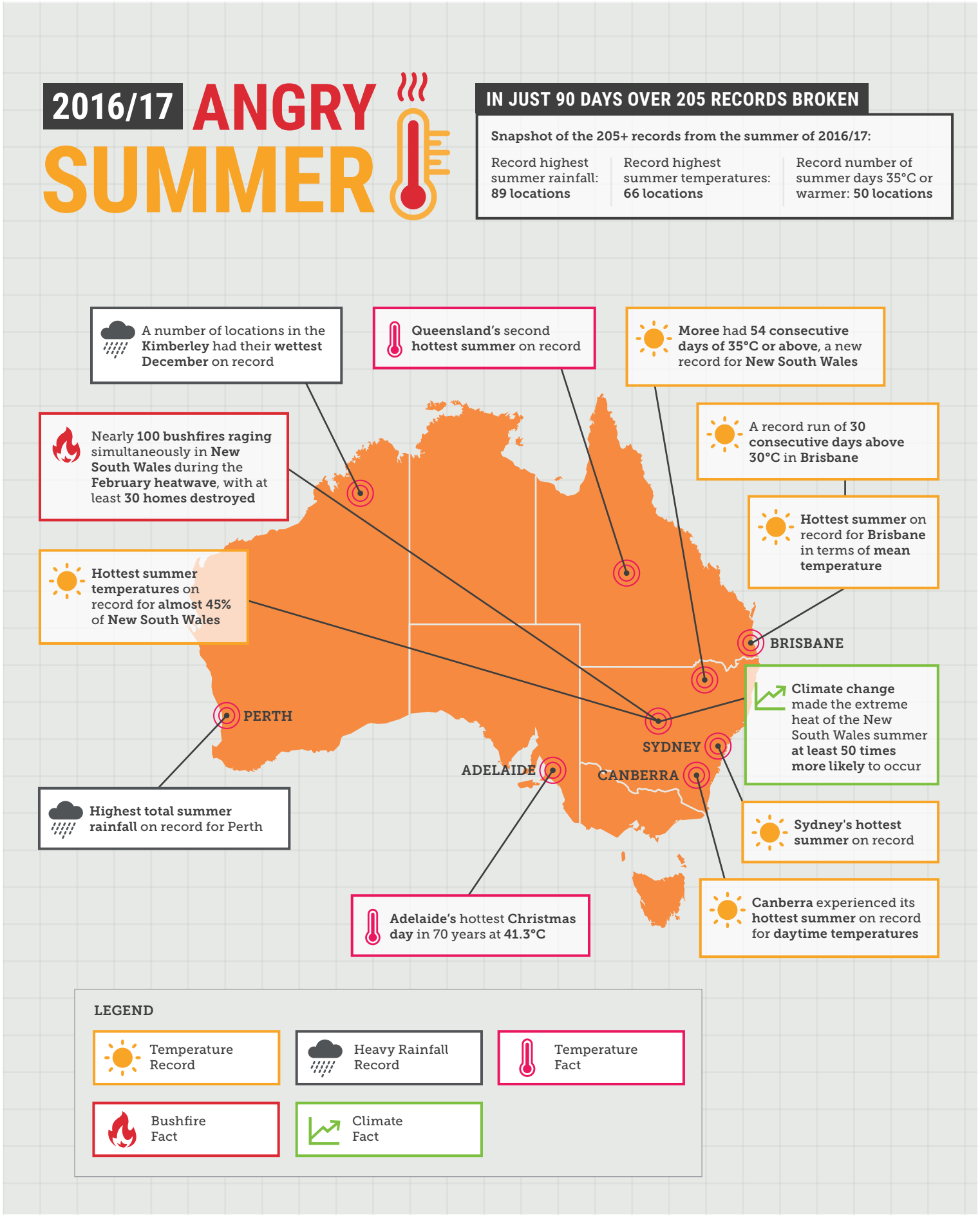

Figure 3: Some of the records broken in Australia during the *Angry Summer* of 2016/17. **Sources:** ABC 2016, BBC 2017, BoM 2017a,f,h,n,p,s,u,x,y, King et al. 2017.

1.1 Capital Cities

ADELAIDE

- Adelaide[1] had its **hottest Christmas day in 70 years** with a maximum temperature of 41.3°C (ABC 2016; BoM 2017a).
- **Adelaide[2] had its third wettest summer on record**, while six sites in the Adelaide area observed their **highest summer total rainfall on record** (BoM 2017b).

BRISBANE

- **Brisbane had its hottest summer on record** in terms of mean temperature at 26.8°C, equivalent to 1.7°C above average (BoM 2017f).
- The **hottest January night on record** was observed in Brisbane with a temperature of 28.0°C on the 21st (BoM 2017e).
- A **record run of 30 consecutive days above 30°C** between 28 January and 26 February beat the previous record from 2002 of 19 days (BoM 2017f).

CANBERRA

- **Canberra[3] experienced its hottest summer on record** for daytime temperatures, and the equal-hottest mean summer temperatures on record with the summer of 2005/06 (BoM 2017h).
- In January Canberra recorded temperatures of at least **30°C on 23 days, while reaching 35°C on 12 days, the highest number** on record for both cases (BoM 2017g).

MELBOURNE

- Both Moorabbin and Laverton (outer suburbs in Melbourne) experienced their **hottest January night** on record on the 8th (BoM 2017k).
- Essendon Airport, Latrobe University and Coldstream recorded their **highest December daily minimum temperatures** late in the month (BoM 2017j).

PERTH

- Perth[4] had its **second hottest December day** on record at 42.4°C on the 21st (BoM 2017o).
- The **second highest daily rainfall total** of 114.4 mm occurred on February 10 in Perth (BoM 2017t), while 192.8 mm total rainfall occurred over summer, which is the **highest rainfall total on record** (BoM 2017p).

SYDNEY

- **Summer in 2016/17 was the hottest on record** for Sydney[5] with a mean temperature 2.8°C above average (BOM 2017x).
- Sydney recorded its **hottest December night** since 1868 at 27.1°C (BoM 2017l).
- **All Sydney stations observed their highest January** mean temperature on record (BoM 2017w).
- A record-breaking **26 days of 30°C or higher and 11 days of 35°C or higher** were experienced (BOM 2017x).
- Sydney experienced a **record number of January nights with minimum temperatures above 20°C**, with 25 days, beating the previous 2013 record (BoM 2017m).
- Three sites in the Sydney region observed their **record highest summer temperature** on February 11: Richmond (47°C), Badgerys Creek (46.4°C) and Penrith Lakes (46.9°C) (BOM 2017x).

1 Adelaide rainfall observations from North Adelaide site
2 Adelaide temperature observations from Kent Town site
3 Canberra observations from Canberra Airport site
4 Perth observations from Perth Metro site
5 Sydney observations from Observatory Hill site.

1.2 Regional Australia

QUEENSLAND

- The **summer of 2016/17 was the second hottest on record** (BoM 2017s).
- The State experienced **heatwave conditions several times** during the summer, with day and night temperatures much warmer than normal (BoM 2017s).
- The peak of the heat occurred on 11 and 12 February, when **eight locations had their highest summer temperature on record** including Weipa (38.8°C), Dalby (43.0°C), Warwick (42.2°C), Applethorpe (39.7°C) and the University of Queensland - Gatton (45.7°C) (BoM 2017s).
- Maryborough recorded its **highest ever January temperature** of 39.6°C on the 21st (BoM 2017r) and had a record 23 summer days of 35°C or warmer (BoM 2017s).
- Gold Coast Seaway and Yeppoon coastal stations experienced **record overnight minimum temperatures** of 24.9°C and 26.7°C, respectively, on New Years Eve (BoM 2017q).
- 18 sites across Queensland had their **lowest summer total rainfall on record** (BoM 2017s).

NEW SOUTH WALES

- The **state-wide mean temperature in summer was the hottest** for New South Wales since records began in 1910 (BoM 2017n).
- Summer temperatures were the **hottest on record across almost 45% of New South Wales** (BoM 2017n).
- The extreme summer heat in New South Wales was at least **50 times more likely to occur due to climate change** (King et al. 2017).
- Record maximum temperatures from February 2017 now contribute **8 of the 10 of the highest February temperatures** for New South Wales (BoM 2017u).
- Heatwaves brought extreme heat to the state. The severe heat experienced on February 11 saw the state-wide average maximum temperature reach 44.0°C, **the hottest February day on record** (BoM 2017n).
- 55 locations across the state had their **highest summer temperature on record,** while 29 locations had their **highest summer minimum temperature** on record (BoM **2017n**).
- 33 locations in New South Wales had a **record number of days of 40°C or above** (BoM 2017n).
- Moree, a large town in northern New South Wales, reached **35°C or above for 54 consecutive days** between 27 December and 18 February, a record for the state (BoM 2017u).
- Mungindi, on the New South Wales/ Queensland border, had **49 consecutive nights of 20°C or above**, smashing the previous record of 27 nights (BoM 2017u).

2. Impacts of Extreme Heat

Burning fossil fuels (coal, oil and gas) is worsening the impacts of extreme heat-related events in Australia, by affecting our health, energy systems, ecosystems and is increasing dangerous bushfire weather.

2.1 Health

Major heatwaves are a silent killer and have caused an estimated 2,900 deaths in Australia in the 1890-2013 period, which is more deaths than bushfires, tropical cyclones, earthquakes, floods and severe storms combined (DIT 2013). Extreme heat events – hot days, hot nights, and prolonged heatwaves – result in an increased use of health services (Kjellstrom and McMichael 2013). This summer, paramedics have responded to numerous heat-related incidents, particularly across Queensland, Victoria and New South Wales (e.g. ABC 2017d; News Limited 2017a; NSW Government 2017). Children, the elderly, people with existing health issues, and workers with heat-exposed jobs (e.g. farmers and construction workers) are typically the most vulnerable to extreme heat (Figure 4).

Heatwaves in Australia during the 2013/14 *Angry Summer* cost approximately $8 billion through absenteeism and a reduction in work productivity (Zander et al. 2015). Zander et al. (2015) found that 70% of about 1,700 survey respondents were less productive because of heat stress. Additional impacts of hot weather include higher work accident frequency because of concentration lapses, and poor decision-making ability due to time perception change and higher levels of fatigue (Morabito et al. 2006; Tawatsupa et al. 2013; Tamm et al. 2014). The potential for extreme heat events to affect people's health and well-being indirectly was highlighted by the failure of the South Australia energy system to cope with demand during the early February heatwave, which led to power cuts to 40,000 homes (Section 2.2).

Figure 4: Children are amongst those who are most vulnerable to extreme heat – other groups include the elderly, people with existing health issues, and workers with heat-exposed jobs (e.g. farmers and construction workers).

2.2 Energy Systems

A severe heatwave in early February across much of Australia's south, east and interior caused issues for the South Australian and New South Wales energy systems. In South Australia, 40,000 people were left without power for about half an hour in the early evening while temperatures were over 40°C. The highest temperature in South Australia recorded on February 8 was at Moomba where the daytime maximum reached 46.6°C at Moomba Airport, while Adelaide reached a high of 42.4°C (BoM 2017c,i). This extreme summer heat placed the energy system under great pressure (despite energy supply being available). This is the second time in six months that South Australia's energy system failed to deliver continuous power to the state due to extreme weather events. A major storm in September 2016 battered the state, downing 23 transmission towers cutting power to over 900,000 households.

Several days later on February 10, New South Wales experienced the same heatwave with temperatures at Sydney Airport reaching 42.9°C, its hottest February temperature on record (BoM 2017v). With near record all-time peak electricity demand, the state narrowly avoided widespread blackouts. Imports of electricity via three interconnections with Victoria and Queensland ran above design limits, contributing 12% to meeting peak demand (AEMO 2017). Around 3000MW of fossil fuel plant was not available – tripping off (400MW), unable to start (760MW), out for maintenance (1000MW) or output limited due to cooling water limits (600MW). At one stage, the Tomago aluminium smelter shed 580 MW of load. It was this, and careful use by consumers, saving 200MW, that allowed New South Wales to avoid widespread blackouts. This heatwave highlights the vulnerability of our energy systems to extreme weather. Climate change will make heatwaves longer, hotter and more frequent, increasing stresses on Australia's ageing energy infrastructure.

Figure 5: Power pylons in southeast Australia – climate change is worsening extreme weather including heatwaves and is increasing the vulnerability of energy systems to blackouts.

2.3 Ecosystems

Ecosystems suffer severe impacts from heat-related extreme weather. The Great Barrier Reef experienced its worst ever bleaching event in 2016 (Figure 6) resulting in the mortality of two-thirds of the coral in the pristine, northern sector. Warmer than average sea surface temperatures off the Queensland east coast again this summer is triggering another bleaching event, which will have further consequences for the reef's health and the livelihoods of people who rely on tourism. The Great Barrier Reef employs around 70,000 people (Deloitte Access Economics 2013) and contributes around $7 billion to the national economy annually (Jacobs 2016), so the loss in tourism as a result of coral bleaching could be dire for the region.

The severe summer heat has also affected terrestrial wildlife such as flying foxes, which are particularly susceptible to extreme heat events. Exposure to air temperatures over 40°C can lead to heat stress and death from dehydration, especially when very hot conditions are accompanied by dry weather (Climate Council 2017a). The February heatwave caused thousands of flying fox deaths across southeast Australia. The worst affected areas were in northern New South Wales, where more than 2,000 flying foxes died (ABC 2017b).

Figure 6: Bleached coral on the Great Barrier Reef 50 km offshore from Port Douglas, in the northern pristine sector of the reef, after the worst ever bleaching event in 2016.

2.4 Bushfires

Hot weather, combined with very dry conditions in New South Wales and the Australian Capital Territory, led to tinderbox fire conditions in January and February. During the February heatwave, nearly 100 bushfires were raging simultaneously in New South Wales (BBC 2017; Figure 7), and destroyed at least 30 homes (ABC 2017c). Meanwhile in Victoria, 40 fires were burning in mid-January with temperatures across much of Victoria exceeding 40°C (News Limited 2017), and at the same time in South Australia a major fire threatened a Waterloo wind farm north of Adelaide (ABC 2017a). Dangerous bushfire weather is becoming more common in the south and east of Australia (CSIRO and BoM 2016), and climate change is projected to lead to harsher fire weather in the southeast of Australia over the coming decades (CSIRO and BoM 2015).

Figure 7: Helicopter using water buckets to fight bushfires in rural New South Wales during the February 2017 heatwave. Nearly 100 fires were burning simultaneously across the state.

3. This is the Critical Decade to Reduce Emissions

We are into the latter half of the critical decade, and temperatures are continuing to increase and extreme weather events are worsening. Climate change is increasing the frequency, duration and intensity of heatwaves and warm spells (Perkins et al. 2012). Hot days and heatwaves, like those experienced in the 2016/17 *Angry Summer*, are becoming the new normal, and even more extreme heat is on the way in future unless rapid and deep reductions in greenhouse gas emissions are achieved around the world.

Australia will continue to warm substantially during the 21st century (CSIRO and BoM 2015) and the impacts will also become more severe. CSIRO and BoM (2015) project with very high confidence that mean, daily minimum and daily maximum temperatures will continue to increase for all regions in Australia over the next two decades or so. However, whether or not extreme heat becomes even worse during the second half of the century depends on whether the world, including Australia as one of the 15 largest emitters, can rapidly and deeply reduce greenhouse gas emissions and transition to a carbon-neutral global economy by mid-century.

A high-end emissions scenario (RCP8.5), equivalent to 'business as usual' greenhouse gas emissions, would result in a temperature increase above present of 2.8-5.1°C by 2090. This would likely make large areas of Australia, especially those in the interior, uninhabitable. Even if the temperature rise was only 2°C from pre-industrial levels, a current 1 in 50 year extreme heat event in New South Wales would occur every 5 years (King et al. 2017). However, if greenhouse gas emissions are cut very rapidly and deeply, as required for a global temperature rise of 1.5°C above pre-industrial (RCP 2.6), Australian temperatures are projected to increase by only 0.6-1.7°C by 2090. Regardless of the ultimate level of temperature rise, major Australian cities will be affected significantly over the next two decades at least, with Brisbane, Canberra and Darwin set for the biggest proportional increases in the number of days with maximum temperatures 35°C and above (Table 1). In this year's *Angry Summer*, Canberra recorded temperatures of at least 35°C on 18 days, already far higher than the 12 days projected for 2030 (Table 1).

Table 1: Average number of days per year with the maximum temperature above 35°C for Australian capital cities. 2030 and 2090 figures are from median CMIP5 projected warming of maximum temperatures under different RCP (representative concentration pathway) scenarios; the 1995 figures are averages of observations for the 1981-2010 period.

Capital Cities	1995	2030	2090	
		RCP4.5	RCP2.6	RCP8.5
Adelaide	20	26	32	47
Brisbane	12	18	27	55
Canberra	7.1	12	13	29
Darwin	11	43	52	265
Hobart	1.6	2.0	2.0	4.2
Melbourne	11	13	14	24
Perth	28	36	37	63
Sydney	3.1	4.3	4.5	11

Source: CSIRO and BoM 2015.

Australia joined the rest of the world in Paris at the 21st United Nations Conference of the Parties (COP21) meeting in December 2015 to increase the level of commitment to limit climate change. While carbon emissions flat-lined in China last year and declined in the United States (Le Quéré et al. 2016), Australia's emissions rose by 0.8% (Commonwealth of Australia 2016a). This rise puts into serious doubt whether even Australia's very weak emissions reductions target of 26-28% by 2030 can be achieved.

With Australia's emissions continuing to rise, it is clear that the Federal Government's current climate policy is failing. Australia needs to transition rapidly to cheap, clean, renewable energy to reduce our emissions as opposed to "clean coal" plants. "Clean coal" plants emit significant greenhouse gases. For example, a new high-efficiency coal plant run on black coal would produce about 80% of the emissions of an equivalent old plant (Commonwealth of Australia 2016b), while renewables (e.g. wind and solar) have zero emissions. Further, it makes no economic sense to build new coal plants. New wind and solar plants both in Australia and overseas are more cost competitive than new coal (Jotzo 2017).

The *Angry Summer* of 2016/2017 is indicative of a super-charged extreme weather fuelled primarily by the burning of coal, oil and gas. We are at a critical juncture. The only viable option to protect Australians is to join the global effort in transitioning to renewables, improving energy efficiency and ramping up other zero-emission climate solutions.

Australia needs to contribute to the accelerating global transition to cheap, clean, renewable energy needed to stabilise the climate and protect Australia from worsening extreme weather.

Figure 8: Large-scale solar farm at Broken Hill, regional New South Wales. Uptake of renewable energy such as solar and wind is affordable and imperative for achieving reductions in emissions.

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