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Type of article	**Perspective**
Title	The 2019 report of the *MJA-Lancet* Countdown on health and climate change: a turbulent year with mixed progress

Summary	
Summary word count	**321**

- The *MJA-Lancet* Countdown on health and climate change was established in 2017 and produced its first Australian national assessment in 2018. It examined 41 indicators across five broad domains: climate change impacts, exposures and vulnerability; adaptation, planning and resilience for health; mitigation actions and health co-benefits; economics and finance; and public and political engagement. It found that, overall, Australia is vulnerable to the impacts of climate change on health, and that policy inaction in this regard threatens Australian lives.

- In this report we present the 2019 update. We track progress on health and climate change in Australia across the same five broad domains and many of the same indicators as in 2018. A number of new indicators are introduced this year, including one focussed on 'wildfire exposure', and another on 'engagement in health and climate change in the corporate sector'. Several of the previously reported indicators are not included this year, either due to their discontinuation by the parent project, the *Lancet* Countdown, or because insufficient new data were available for us to meaningfully provide an update to the indicator.

- In a year marked by an Australian federal election in which climate change featured prominently, we find mixed progress on health and climate change in this country. There has been progress in renewable energy generation, including substantial employment increases in this sector. There has also been some progress at state and local government level. However, there continues to be no engagement on health and climate change in the Australian Federal Parliament, and Australia performs poorly across many of the indicators in comparison to other developed countries, for example, it is one of the world's largest net exporters of coal and its electricity generation from low carbon sources is low. We also find significantly increasing exposure of Australians to heatwaves and, in most states and territories, continuing elevated suicide rates at higher temperatures.

- We conclude that Australia remains at significant risk of declines in health due to climate change, and that substantial and sustained national action is urgently required in order to prevent this.

Text	
Text word count	**7311**

Introduction

The natural environments in which we live play a major role in our health and wellbeing, and include the important roles of weather and climate. The depth and breadth of this connection with our health in Australia continues to be the subject of new research (e.g., Austin et al.[1]; Hanigan et al.[2]). Climate change is a leading issue of our times, and Australia is especially sensitive to this change. Indeed, the CSIRO has recently reiterated that "climate change and the environment" is one of six major challenges facing the nation.[3] In September 2019 the Australian Medical Association (AMA) recognised climate change as a health emergency (AMA 2019). With the enormity of the threat to health from climate change being well-established, the challenge is to embrace the opportunity to reduce or avoid this threat through proactive adaptation and mitigation. However, there continues to be much we do not know about the potential impacts of climate change on health in Australia, and this heightens our underlying vulnerability and weakens our ability to act effectively.

The *Lancet* Countdown, a multi-institutional collaboration spearheaded by University College London, examines progress on climate change and human health at a global scale. Its first two assessments were published in 2017 and 2018 respectively[4,5] and annual assessments will continue until 2030, consistent with the near-term timeline of the Paris Agreement.

In partnership with *The Lancet*, University College London, and the *MJA*, Australia was the first and only country to produce its own national Countdown assessment report in 2018.[6-8] That report found that, overall, Australia is vulnerable to the impacts of climate change on health, and that policy inaction in this regard threatens Australian lives.[8] The current report presents our first annual update of this assessment with which we track Australia's engagement with and progress on this vitally important issue.

Methods

We track progress on health and climate change in Australia across 31 indicators divided into five broad sections: climate change impacts, exposures, and vulnerability; adaptation, planning, and resilience for health; mitigation actions and health co-benefits; finance and economics; and public and political engagement. Where possible, we adopt the methods used by the *Lancet* Countdown, including those used in its current report[9]. Where more appropriate for an Australia-focused assessment, or where it was possible to refine or improve on the original method as more precise and

comprehensive data or methods were available at the national level, the method for the Australian indicators was modified or an alternative method was employed.

Consistent with developments in the *Lancet* Countdown[5,9], a number of new indicators are introduced this year, including 1.1 Vulnerability to the heat-related risks of climate change, 1.6 Wildfire exposure, and 5.4 Engagement in health and climate change in the corporate sector. Similarly, thirteen of the previously reported[8] indicators are not included this year, either due to their discontinuation by the *Lancet* Countdown or because insufficient new data were available to provide an update to the indicator.

Details of our methods, data, and caveats are provided for each indicator in the Appendix. We also provide a brief summary of the method within the text for each indicator here. Our final list of 31 indicators is provided in Table 1, including mapping to the equivalent indicator numbers from our previous report[8].

Section 1: Climate change impacts, exposures, and vulnerability

Last year, we presented ten indicators of climate change impacts, exposures and vulnerability. We are here presenting our first updates for four of these: exposure to temperature change (previously 'health effects of temperature change'; we have changed the title of this indicator to better reflect its purpose); health effects of heatwaves; change in labour capacity; and mental health. This year, we also present two new indicators: 'vulnerability to the heat-related risks of climate change'; and 'wildfire exposure'. Finally, we present an introduction to the topic of climate change and health attribution (Text Box 1).

We are not presenting updates for six indicators this year, including 'lethality of weather-related disasters' and 'climate-sensitive infectious diseases'. Our indicator 'trends in overall burden of climate-sensitive diseases' was reported for the years 1990-2016 last year. Rather than reporting annual numbers, which vary considerably, we propose reporting this indicator every second year to allow trends to emerge. Food insecurity and malnutrition remain significant yet under-addressed problems in Australia, particularly in rural, remote and low-income locations.[11,12] However, as Australia does not collect consistent data on the prevalence of food insecurity or on malnutrition, we cannot yet include a food insecurity indicator in this report. For that reason, we do not present indicators for food insecurity and malnutrition. Finally, due to insufficient data, we do not include migration and population displacement as an indicator this year but we do discuss this important issue in Text Box 2.

1.1 Vulnerability to the heat-related risks of climate change

Adults aged more than 65 years and people with underlying cardiovascular diseases, diabetes, and chronic respiratory diseases are particularly vulnerable to heat-related morbidity and mortality.[5] The urban heat island combined with increasing temperatures resulting from climate change also puts those living in urban areas at

greater risk of heat-related disease. Australia is one of the world's most urbanised countries, with almost 90 percent of people living in urban areas. This indicator reports the Heat Exposure Vulnerability Index (HEVI), a measure of potential vulnerability of a country to heat exposure based on the proportion of the population aged more than 65 years, the prevalence of the above underlying diseases in this sub-population, and the proportion of the population living in urban areas (Appendix). The Heat Exposure Vulnerability Index for the Australian population for 1990-2017 (Figure 1) is high and shows an upward trend. The impact of this trend will be felt throughout the already stretched public health system in Australia, with numbers of heat-related hospital presentations increasing more quickly among those living with the greatest vulnerability and disadvantage than among other groups. Impacts will continue to rise because of the general rise in ambient temperatures and will be especially large during and shortly after heatwave events.

1.2 Exposure to temperature change

Summer maximum temperatures are expected to rise as a result of global warming. Figure 2 shows nationally averaged Australian summer (December-February) maximum temperature anomalies (i.e., departures from the long-term average) for the last 20 summers, 1999-2000 to 2018-19, relative to a thirty-year baseline period of 1981-2010. An ordinary least squares linear regression analysis calculated for the nationally averaged Australian summer maximum temperature anomalies over last 50 summers (1969-70 to 2018-19; blue trend line), relative to the same thirty-year baseline period, shows that summer maximum temperatures have risen by around 0.43°C over the last twenty years. The summer maximum temperature rise calculated from regression analysis over just the last twenty years is much larger (1.66°C; grey trend line). While this figure is not indicative of the longer-term trend, it suggests the rate of increase may be getting larger in more recent years. Details of the data and methods used for this indicator are provided in the Appendix.

1.3 Health effects of heatwaves

The excess heat factor (EHF) is a measure of heatwave intensity as it applies to human health impacts.[17,18] It is based on three-day-averaged daily mean temperatures. Figure 3 shows the Australia averaged accumulated heatwave-season (November to March) EHF for the last 20 heatwave seasons, 1999-2000 to 2018-19. An ordinary least squares linear regression analysis calculated over the last 50 heatwave seasons (1969-70 to 2018-19) shows that this indicator has risen by about 31 K^2 (around 33%; blue line) over the last 20 years. The reasons for using the longer period in the trend calculation are the same as those mentioned above for summer maximum temperature: the calculation over the last 20 heatwave seasons (a rise of 81 K^2 or 113%; grey line) is not indicative of the longer-term change.

1.4 Change in labour capacity

Exposure to heat during work can reduce labour capacity and result in decreased productivity. Recent Australian research investigating the relationship between self-reported heat stress and subjective well-being showed that many people thought that heat compromised their productivity.[19] Last year, we reported on the combined effects of temperature and humidity on hours of labour lost, captured in what is referred to as the Wet Bulb Globe Temperature (WBGT). This year, we calculated annual total hours of labour lost due to heat in the agriculture, industry, and service sectors in Australia from 2000 to 2018 using an indicator that also includes the impact of sunlight on work hours lost (Figure 4). In 2018, there were fewer hours of labour lost due to heat (just under 2.7 million) than in 2017 (almost 5 million). This continues the significant inter-annual variability in this indicator that we highlighted last year. However, hours of labour lost due to heat in the service sector rose to 19,687 hours in 2018 from 7,889 hours in 2017. Overall, from 2000 to 2018, annual total hours of labour lost due to heat have been increasing and this continues to be of concern.

1.5 Mental health

Last year, we presented baseline data (2007-16) showing that higher mean annual maximum temperatures predicted elevated age-adjusted suicide rates in warmer jurisdictions, while the inverse (less-hot years) predicted elevated suicide rates in cooler jurisdictions (Figure 5 and Figure A2). This finding was replicated this year and a similar pattern was observed for the available year of post-baseline data (2017).

This year, we also examined the association between mean annual minimum temperatures and suicide, finding that higher minimum temperatures (i.e., less-cold years) were associated with elevated suicide rates in warmer and cooler jurisdictions. Thus, except for less-hot years in cooler jurisdictions, higher annual mean temperatures, both hotter and less-cold, were associated with elevated suicide rates. We again found that the association between annual mean maximum temperatures and suicide was gendered. Males completed suicide more often than did females, and male suicide rates increased faster with increasing heat. Data for this indicator were obtained from the Australian Bureau of Statistics and the Australian Bureau of Meteorology. Full details of the data and methods used are provided in the Appendix.

We note that development of this indicator is ongoing, with future analysis likely to consider social determinants of mental health, such as unemployment, which vary from one jurisdiction to another and also contribute to suicide rates.

1.6 Wildfire exposure

Fires are an integral process that occurs in all vegetated landscapes. Fire regimes are shaped by many factors including weather, climate, land use, ignition sources and land management activities. Climate change is causing fire seasons to start earlier and finish later,[20,21] and anomalous meteorological conditions have been linked to a trend

towards more extreme fire events.[22] Extreme fire events are more likely to cause disasters with substantial social and economic harms from the loss of life, livelihoods, property, and infrastructure than are smaller, shorter, and less severe fire events.[22-24] Further, increases in landscape fire activity overall, including severe events, will increase air pollution, further harming health.[25] Climate change-related increases in landscape fire smoke emissions may offset health gains from reducing pollution emissions from other sources.[26,27] For example, it has been estimated that premature mortality associated with wildfire smoke will double in the US by 2100.[26] Similar projections have not been done in Australia. However, 197 deaths attributable to landscape fire smoke were estimated for Sydney from 2001-2013,[28] while five direct fire-related deaths were reported during the same period.[29] While fire disasters and serious smoke impacts in Australia appear to be escalating in line with global trends, we lack the systematic ongoing data collection and reporting needed for Australia.

To be consistent with the approach used in the global *Lancet* Countdown report, we adopted the same data and methods as used by Watts et al.[9], this being the number of days people were exposed to wildfire during a four-year baseline period (2001-2004) compared to the most recent four years (2015-2018) (Figure 6). The indicator uses the Collection 6 active fire product from the Moderate Resolution Imaging Spectroradiometer (MODIS) aboard the NASA Terra and Aqua satellites, and population count per squared kilometre.[9] While the four year average of 191,227 was lower in the more recent period, compared with 249,394 in 2001-2004, this represents substantial adverse exposure in both periods and misses some of the worst wildfires in 2007-9. A major confounding factor in identifying trends in fire activity in Australia is the very significant inter-annual variability due to factors including the El Niño–Southern Oscillation (ENSO) cycle and other inter-annual climate drivers including the Indian Ocean Dipole and the Southern Annular Mode.[30,31]

Conclusion: climate change impacts, exposures, and vulnerability

Increases in heat continue to present as a leading source of climate change-related health risk in Australia. This trend is likely to continue and, despite uncertainties created by the large variability in daily and seasonal temperatures, there has been a striking upward trend in the rate of increase in maximum temperatures over the last two decades. Large increases in heatwave intensity are also evident over the same period, with consequent risks for health, particularly among people experiencing underlying vulnerability and disadvantage. While hours of labour lost due to heat in 2018 were far fewer than they were in 2017, hours lost in the service sector substantially increased last year. Additionally, hot years, in terms of both maximum and minimum annual temperatures, continued to be associated with higher suicide rates. We find little evidence to suggest that Australia is acting effectively to mitigate these multiple heat-related risks for physical and mental health (Table A1). This is particularly concerning in the context of a growing and ageing population.

Progress in developing our impact indicators continues to be hampered by inadequate data availability. We do not have reliable data for Australia on weather-related temporary or permanent displacement and migration; or on food insecurity or

malnutrition, though these are climate change-sensitive and already affect many Australians, particularly those living with underlying vulnerabilities.

Section 2: Adaptation, planning, and resilience for health

Most of the indicators on adaptation, planning, and resilience that were used in 2018 have been updated for this year, with the exceptions of 'Health adaptation funding from Australian climate financing mechanisms' and 'Climate-resilient health infrastructure', which have not been included this year. Two new topics have been introduced, 'Climate change adaptation to vulnerabilities from mosquito-borne diseases' and 'Inclusion of health and climate change within medical curricula' (Text Boxes 3 and 4), and these warrant more detailed exploration in future iterations of this report.

Of particular relevance to this section is that three Australian cities have recently declared a 'climate emergency' – Canberra in May 2019 and Hobart and Sydney in June 2019 – following similar declarations by cities overseas. These declarations recognise the need for urgent climate action, and both Canberra and Sydney are already at the forefront of climate adaptation action.

2.1 Australian adaptation plans for health

There are no new climate change and health adaptation plans for Australia as a whole, and Queensland is still the only state to have produced a comprehensive standalone health adaptation plan[34]. All other States and Territories, and Australia as a whole, have a broad-ranging adaptation plan or strategy in which health receives only a mention as a sector of note and requiring attention. However, some progress is being made. Tasmania is in the process of developing its health adaptation strategy, having convened an expert climate and health roundtable in April 2019. In March 2019, Western Australia announced an inquiry into the impacts of climate change on health in Western Australia, to be conducted under the *Public Health Act 2016.* A final report will be presented to the WA Minister for Health by March 2020. The Climate and Health Alliance has produced a Framework for a National Strategy on Climate, Health and Well-Being for Australia[35] based on expert and stakeholder consultation. This would be helpful, should the Australian Government choose to develop a comprehensive national plan for climate change and health.

2.2 City-level climate change risk assessments

No new climate change risk assessments were found for Australia's capital cities. Local, more grass-roots action remains the principal domain of activity in climate adaptation and mitigation, with 99 local councils now signed up to the Cities Power Partnership, a free, non-profit support and networking initiative to facilitate local renewable energy projects (Table 2). With the exception of the Australian Capital

Territory (ACT) (which only has one local government area), New South Wales (NSW) still has the highest percent of its councils participating in the Partnership, increasing from 58.5% to 66.2% of councils (Figure 7). South Australia still has the lowest participation rate, at 8%, but this has increased five-fold since 2018. Participation in the Northern Territory (NT) and Tasmania remained unchanged from 2018.

2.3 Detection, preparedness, and response to health emergencies

This indicator tracks Australia's International Health Regulations capacities relevant to climate adaptation and resilience, as reported in the World Health Organization's Global Health Observatory data repository. In 2017, the most recent year available, Australia maintained its average value of 100% for the 13 core capacity indicators. Similarly, surveillance, response, preparedness, and human resources capacities were scored at 100% (Figure 8). While this is an excellent result for Australia, we note that two of these capacities have not consistently scored at this level over the period 2010 to 2017, with Australia's surveillance capacity score being as low as 88% in 2010, and its response capacity score decreasing from 100% in 2010 and 2011 to 94% in 2012 and 2013. It is therefore important that Australia actively work to maintain its current excellent capacities in these important areas.

2.4 Climate information services for health

The Australian Bureau of Meteorology continues to provide routine forecasts to the health sector and public for ultraviolet (UV) radiation and heatwaves through its website, mobile app, and other channels. Web traffic to the heatwave website http://www.bom.gov.au/australia/heatwave was measured during the period 11 October 2018 to 17 April 2019 using Google Analytics. The heatwave site was the tenth most viewed page on the Bureau website. Unique page-views for that period were 226,911 for the main heatwave page, with people spending an average time of 2:52 minutes on the page. This was more than two-and-a-half times the number of unique page-views measured during the previous year (87,663 views during 20 October 2017 to 30 April 2018).

The pilot thunderstorm asthma early warning service led by the Bureau of Meteorology and Victorian Department of Health and Human Services provided again in 2018 daily three-day forecasts of thunderstorm asthma risk in Victoria during the grass pollen season, October-December.

2.5 National assessments of climate change impacts, vulnerability, and adaptation for health

Australia's 2008 *Garnaut Climate Change Review* remains the Federal Government's only national assessment of climate change impacts, vulnerability and adaptation, and

it was mainly focused on economic indicators with health included as a sectoral component. The crowd-funded not-for-profit Climate Council continues to produce reports of national significance in this area, including a major 2018 report, *Deluge and Drought: Water security in a changing climate*[36], which provides evidence for the impacts climate change is already having on Australia's water cycle with significant implications for human health. Other new reports of significance to health include one on extreme weather in Australia[37], and an interim report ahead of a forthcoming major report on the increasing threat of bushfires in Queensland[38]. The reports continue to recommend deep cuts to greenhouse gas emissions to avoid the worst impacts of climate change.

Conclusion: adaptation, planning, and resilience for health

In the absence of coherent, meaningful policy at national level, states, territories, cities, and local councils continue to take the lead in Australia on climate adaptation strategy and activities. While Australia's Bureau of Meteorology plays a role in disseminating information on forecasting climate-related health events (heat stress and thunderstorm asthma), this is not explicitly linked to a broader national climate change and health policy. Overall, very little has changed in Australia's adaptation space since the baseline 2018 report. An update on these indicators was included this year to highlight that inaction on climate adaptation risks serious damage to infrastructure and people's health and will be increasingly financially costly without leadership in adaptation planning an implementation.

Section 3: Mitigation actions and health co-benefits

Updated data available for 2019 show that, since last year's report, Australia has seen some slight progress in lowering the carbon intensity of the Australian energy system and in phasing out coal and shifting towards lower carbon and renewable sources (Table 3). However, Australia lags well behind other developed countries in its shift towards renewable energy.

3.1 Carbon intensity of the energy system

As for last year, we define the carbon intensity of the energy system as "the tonnes of CO_2 emitted for each unit of primary energy supplied". Data for our last report[8] were only available up to 2012. This year, new data have become available[39] up to 2016 (Figure 9) and show relatively little change since 2012: the carbon intensity of Australia's total primary energy supply continues to be the highest of the developed countries presented, with China only in recent years (2010-2016) reporting values slightly higher than Australia.

3.2 Coal phase-out

According to data provided by the International Energy Agency,[40] world coal production was in decline in 2015 and 2016. However, new reports[41] confirm a rise in 2017 and 2018 to 7,585Mt because of global economic growth and because some large developing nations (Indonesia, India) increased the share of coal in their energy mix. The latest available data for world coal production from 2016 show that coal accounted for 27% of the world total energy supply that year, second behind oil, which accounted for 32% (2017 and 2018 data not available at the time of publication).[42] However, in terms of electricity production, the share of coal was higher (38%), while renewables and natural gas respectively accounted for 25% and 23%.[42]

Together with Indonesia, Australia remains one of the world's largest net exporters of coal. Both countries together accounted for 57% of world coal exports in 2016, and Australia's share alone was 31% of world coal exports.[42] Provisional data suggest that Australia and Indonesia accounted for 60% of world coal exports in 2017. Leading countries for production of coal are China (45% of global production), India (10%), followed by US, Australia, and Indonesia. Together, these five countries account for 77% of production of coal (Figure 10).[42]

Domestically, coal and coal products continued to be used primarily for power generation. In 2016, 91% of Australia's coal consumption was devoted to power generation, while the average was 79% for OECD countries.[42]

3.3 Renewable and low-carbon emission electricity

As for last year, we define renewable energy sources as those which "produce energy from renewable sources in a sustainable manner (including bioenergy, geothermal energy, hydropower, ocean energy, solar energy and wind energy, but excluding nuclear power)", while low-carbon sources are defined as "sources that have zero-carbon or low-carbon emissions at the point of energy production (i.e., this excludes biomass, but includes nuclear and hydro)". Data for this indicator are now available for 2016.[43]

As can be seen from Figures 11 and 12, countries such as Germany and the UK that were leading the adoption of renewable and low carbon energy sources have not reported strong increases for 2016. However, recent German data show that the upward trend has continued in 2017 and 2018, with renewables contributing to 38% of energy production in Germany.[44,45] From 1990 to 2016, the share of electricity generation from renewable sources increased from 11% to 18%, and from 10% to 16% from low carbon sources in Australia. However, Australia continues to have a much smaller proportion of electricity from low carbon sources compared to leading countries.

3.4 Access to clean energy

In 2018, 21% of Australia's electricity was provided by renewable energy sources.[46] It is estimated that 35.2% of Australia's renewable energy was contributed by hydroelectric power plants in 2018, making hydro power an important contributor.[46] Australia has had a renewable energy target regulation in place, with a target of 33,000 GWh for large-scale generation by 2020 from wind and solar farms or hydroelectric power stations. About half of the renewable energy target has been achieved so far.[47] However, the Federal government elected in mid-2019 has no renewable energy target in place as of September 2019.

Australia has a small-scale renewable energy scheme,[48] providing incentives for individual households or small businesses to install renewable energy systems (e.g., solar hot water or solar photovoltaic). About 220,000 solar rooftop systems were installed in 2018, a 26% increase on 2017.[49] NSW recorded the highest growth of installations in 2018, up 35% from 2017. In 2018, 20% of Australian households had rooftop solar. There are also signs that uptake is increasing, especially in Victoria where the Victorian Government's Solar Homes Rebate makes the rooftop solar installation more affordable.[46]

However, and as noted above, Australia tracks behind other countries such as Germany and the UK. Furthermore, there is limited additional evidence regarding improvements of energy supply (in particular, from renewable and low carbon sources) for Australia's remote and Indigenous communities that still lack a reliable energy supply.[50]

3.5 Exposure to ambient air pollution

This indicator provides information on the health impacts of exposure to airborne fine particulate matter, that is, particles less than 2.5 μm in diameter ($PM_{2.5}$). Fine particulate matter, once inhaled, can affect the respiratory system and the cardiovascular system. We report on two sub-indicators: 3.5.1 Exposure to air pollution in cities; and 3.5.2 Premature mortality from ambient air pollution by sector.

3.5.1 Exposure to air pollution in cities

Last year, we calculated exposure to air pollution using air pollution monitor data, reporting the average of all monitors within 50km of the centre of major cities (defined as urban areas with populations greater than 100,000 in 2016). This year's indicator uses information on annual average background concentrations of $PM_{2.5}$ in typical urban settings. Population weighted averages of $PM_{2.5}$ modelled data for all major Australian cities were calculated. In all these cities, the annual average $PM_{2.5}$ concentrations were below the World Health Organization (WHO) annual guideline of 10 mg/m^3 and the Australian advisory reporting standard of 8 mg/m^3. $PM_{2.5}$ pollution concentrations in these cities have generally remained stable over the past few years.

3.5.2 Premature mortality from ambient anthropogenic air pollution

Ambient air pollution in the form of fine particulate matter < 2.5μm ($PM_{2.5}$) causes premature mortality. Last year, we reported 2,900 deaths attributable to fine particulate matter in 2015 (the latest data available at the time of reporting). Around 2,800 deaths were attributable to anthropogenic air pollution in Australia in 2016 (equivalent to 2% of all deaths), slightly fewer than for the previous year.

3.6 Clean fuel use for transport

While the uptake of electric drive vehicles (EVs) in Australia has been slow compared to international trends, some progress has been observed, such as significant increases in EV sales and numbers of charging stations.[51] This indicator shows the proportion of new vehicle sales in Australia which were electric. The largest shares were found in South Australia and the ACT, where EVs comprised 0.22% and 0.21% of new vehicle sales respectively, while the smallest share was sold in NT, where they comprised only 0.01% of new sales (Table 4). Overall, only 0.09% of new cars sold in Australia in 2016 were EVs.

3.7 Sustainable travel infrastructure and uptake

This indicator is based on household travel data for the capital city of each Australian state and territory. The data were sourced from the Australian Bureau of Infrastructure, Transport and Regional Economics,[52] which provides research services to the Australian Government Department of Infrastructure, Regional Development and Cities. It is found that people living in Canberra recorded the highest number of kilometres travelled per capita, as well as the highest number of kilometres travelled in private modes (per capita). Hobart, however, was found to have the greatest share of passenger kilometres travelled in private modes (96.6%). Sydney, Australia's most populous city, had the lowest share of passenger kilometres associated with private transport (85.1%). Correspondingly, the share of passenger kilometres associated with public transport (bus and rail) in Australian capital cities is low, ranging from 14.6% in Sydney to 3.8% in Hobart.

3.8 Health-care sector emissions

This indicator quantifies carbon dioxide (CO_2) equivalent emissions in Australia's health-care sector, using existing data on CO_2 equivalent intensities from Malik et al.[53], coupled with updated health-care expenditure data from the Australian Institute of Health and Welfare (AIHW). Australia's health-care expenditure has increased in nominal terms over time. From 2011-12 to 2016-17, there has been a nominal 4.94% average annual increase in expenditure (Figure A4).[54] Looking at the last three reporting rounds: in 2014-15 Australia's health-care expenditure was AUD161.6 billion, leading to 35,772 kilotons of emissions;[53] expenditure increased to AUD170.5

billion in 2015-16, resulting in 37,711 kilotons; and to AUD180.7 billion in 2016-17, contributing 40,102 kilotons of emissions. While the causes of these increases in health-care sector expenditure and emissions will be complex and are beyond the scope of this analysis, we note that they do not appear to have been accompanied by corresponding increases in health care accessibility, and indeed some indicators of accessibility, such as waiting times for emergency department care have worsened over this period (AIHW 2019).

These emission estimates are derived using a national input-output table for Australia with existing data on CO_2 equivalent intensities.[53] There have been efforts directed at using a global multi-regional input-output table for quantifying the contribution of Australian and International industry sectors to Australia's health-care emissions. The results for various studies show some variation owing to differences in procedures used for the compilation of greenhouse gas emissions inventories and monetary input-output tables for different databases.[9,53,55] The supply chains of hospitals and pharmaceuticals are emissions-intensive; hence efforts need to be directed at ensuring sustainable practices are implemented in health-care sectors.[56]

Conclusion: mitigation actions and health co-benefits

Australia has seen slight progress in transitioning to clean technology and shifting towards lower carbon and renewable sources. However, overall, Australia lags well behind other developed countries, in particular in terms of clean energy uptake and coal phase-out. The uptake of sustainable transportation, as measured by the uptake of electric drive vehicles in Australia, also remains relatively slow compared to international standards. This means that Australians miss out on less-polluting sources of energy production and also on the substantial economic benefits which are associated with a transition to clean technology.[57]

Section 4: Finance and economics

This section examines the financial and economic enablers of a transition to a low-carbon economy, and the implications of inaction.[5] We consider recent developments in mitigating carbon emissions and the transition of the electricity sector to a substantial share of renewable energy generation. We also report trends in economic losses due to climate-related extreme events as well as developments on carbon pricing and the use of revenues from pricing carbon emissions.

4.1 Economic losses due to climate-related extreme events

This indicator tracks the total insured economic losses from climate-related disaster events and is based on numbers provided by the Insurance Council of Australia (ICA).

Figure 13 plots the cumulative annual insured losses arising from bushfires, cyclones, flooding, hail storms, storm flooding, and tornados. For 2018, total annual insured losses from climate-related catastrophes were estimated to be AUD1.62 billion. Approximately 80% (AUD1.30 billion) of these losses resulted from the significant hail storm event in multiple metropolitan and rural regions across NSW in December 2018. Estimated total insured losses for 2018 were lower than in 2015 and 2017, but higher than in 2016.

4.2 Investments in zero-carbon energy and energy efficiency

This indicator reports investment in renewable zero-carbon energy based on generation capacity in the Australian National Electricity Market (NEM). Investment in generation from renewable energy sources has substantially increased over the last decade. According to the most recent report by the Australian Energy Regulator[58], between 2012-13 and 2018-19, new investment in renewable plant capacity was approximately 5,100 MW. Of this additional capacity, 3,445 MW (67%) was in wind power, 1,618 MW (32%) in solar, and 70 MW in hydro. Figure 14 illustrates that most of this investment in renewable generation capacity happened between 2017 and 2019 (3,187 MW). By October 2018, more than 2,000 MW of additional committed capacity from renewable energy were expected to be commissioned in 2018-19.[58]

Further, 185 MW of battery storage have been added to the market, including the 100 MW Hornsdale Power Reserve in South Australia, the first scheduled battery in the NEM and currently the world's largest lithium ion battery. Further investment in battery storage has been commissioned, which will increase the efficiency of the NEM.

4.3 Investment in new coal capacity

This indicator reports investment in coal capacity. As reported last year,[8] since 2009-10, investment in coal capacity has decreased substantially and several major coal-fired power plants have been removed from the market. According to the most recent report by the AER[58] and information provided by the Australia Energy Market Operator[59], market participants in the NEM (including AGL, ENGIE, and Origin Energy) have signalled they have no plans to invest in new coal-fired power plants.

At the same time, investment is still flowing into improving existing generation from coal. For example, in 2018, AGL had completed AUD 70 million of work that included the installation of a new control system at the coal-fired Bayswater power station in NSW to improve plant stability, operational flexibility, and reliability.[60] Additional investment, including a AUD 200 million turbine efficiency upgrade, will be conducted over the next two years.

4.4 Employment in renewable and fossil-fuel energy industries

This indicator suggests that direct full-time equivalent (FTE) employment in renewable energy activities in Australia has increased by 3,890 (28%) from the 2016-17 financial year, following a 25% increase over the previous year. Annual direct FTE employment is now estimated at 17,740 people in 2017-18, representing the highest level since 2012-13. Figure 15 illustrates the recent substantial rise in employment numbers in renewable energy since 2015-16, after a decline between 2012 and 2016. The highest estimated growth rates in FTE employment in the sector were in Victoria (47%), followed by Queensland (44%) and NSW (27%). The boost in employment in renewable energy activities over the last 12 months has been mainly supported by increased construction activity for large-scale solar photovoltaic (PV) systems and increased installation of rooftop PV systems.[61]

The mining sector, a key representative of high-carbon industries, also exhibited some growth. FTE employment in mining operations increased by 7% to 168,000 for the 2017-18 year, after a significant drop in the previous five years from 194,000 in 2011-12 to 157,000 in 2016-17.

4.5 Funds divested from fossil fuels

We assessed funds divested from fossil fuels in Australia through two indicators. The first is the number of companies and government organisations which have partially or entirely committed to divest themselves of assets involved in extracting or generating energy from fossil fuels. While Australia continues to play a major role in the divestment movement,[62,63] we have no updated information on the actual number of organisations and committed funds this year.

The second indicator measures the withdrawal of electricity generation capacity from coal-fired power plants. Approximately 1,400 MW of generation capacity from black coal and 2,700 MW capacity from brown coal were withdrawn from the NEM between 2014 and 2017 (Figure 14). This also included Australia's most emissions-intensive power station in Hazelwood (Victoria) that supplied approximately 5% of the total output of the NEM.[58] Further retirements of coal-fired power plants are scheduled in upcoming years, including the Liddell power station (1,680 MW) in NSW in 2022.[59]

4.6 Coverage and strength of carbon pricing

Australia's carbon pricing policy is categorised as 'ETS [emissions trading system] implemented or scheduled for implementation' on the World Bank's Carbon Pricing Dashboard. However, it could be reasonably argued that the voluntary Emissions Reduction Fund (ERF), with its safeguard mechanism, is not a genuine ETS:[64,65] the ERF uses taxpayer funds to support emission reduction actions through a reverse auction process; it does not require polluters to pay for emissions reductions, which is a key FASTER* principle for successful carbon pricing.[66] Recent figures also show that less than one-fifth of the paid-for abatement has been delivered.[48] In early 2019,

amendments were made to the safeguard mechanism to soften baselines[67] and the ERF was augmented by AUD 2 billion and renamed the Climate Solutions Fund.

* Fairness, Alignment of policies and objectives, Stability and predictability, Transparency, Efficiency and cost-effectiveness, Reliability and environmental integrity

4.7 Use of carbon pricing revenues

There is no indication that any revenue obtained by the Emissions Reduction Fund (ERF) has been used for mitigation, adaptation, revenue recycling or other relevant general funds in 2018-2019. Further, the additional AUD2 billion put into the Climate Solutions Fund in 2019 will not be revenue explicitly returned to a broad portion of the population through tax cuts or rebates. Consequently, it is not included in this indicator.

Conclusion: finance and economics

This section highlights economic and finance-related efforts aimed at reducing the impacts of climate change on human health (Table 5). The indicators provide evidence of a continued trend of rising economic losses from climate-related extreme events. In recent years, there has also been a substantial increase in investment in renewable energy generation from wind and solar, and the withdrawal of generation capacity from coal-fired power plants. Between 2016 and 2018, employment in renewable energy activities increased by almost 60%, providing further evidence of progress towards a low-carbon economy in Australia. At the same time, only limited efforts towards carbon pricing are evident, while no revenue from pricing carbon emissions has been spent on climate mitigation, adaptation or health-related activities.

Section 5: Public and political engagement

Public and political engagement in health and climate change is a prerequisite for action by governments, industry, and communities. The domains of engagement covered in this section are media, science, government, and corporate. The indicators track hard-copy newspaper coverage, selected online media, scientific journal articles, parliamentary records and corporate sector engagement with the UN Global Compact.

5.1 Media coverage of health and climate change

Exposure to news coverage about health and climate change in Australia has declined over the last decade. This decline contrasts with the increase in global media coverage of this topic.[5]

This indicator examined media stories in 13 national and regional high-circulation English-language newspapers from 1 January 2008 until the day before the Australian Federal election on 18 May 2019. This year, the indicator included Australian Broadcasting Cooperation online news and transcripts of programs. Overall, coverage of health and climate change in the Australian newspapers dropped 67% between 2008 and 2018, with the largest regional drop occurring in Canberra (Figure 16). ABC online coverage of health and climate change has also substantially decreased (Figure A5). Notably, in the first four-and-a-half months of 2019, the number of news stories addressing health and climate change was similar to or higher than that of the whole of 2018, especially in Melbourne, Sydney, and Hobart. The increase may be attributable to the Federal election campaign, as well as reporting of the warmest January on record for Australia.[68] Our findings indicate that the Australian public has diminishing opportunities to be engaged in health and climate change discourse via mainstream newspapers and online news media.

5.2 Coverage of health and climate change in scientific journals

Scientific publications on health and climate change in Australia increased four times between 2008 and 2014, but no further increase has since been observed (Figure 17). In total, we have identified 540 scientific publications about health and climate change from 2008 to 2018, which account for 5% of the total number of Australian climate change scientific publications over the same period.

We adopted similar search terms to those used by the *Lancet* Countdown study[5] with added geographic terms to identify Australian studies. Among the identified publications, 84% were original research and the others were reviews (10%), editorials (3%), and correspondence (3%) (Figure A6). The proportion of scientific publications reporting original research was much higher in Australia than for the world as a whole (47%), which may reflect research capacity in Australia and contribution to knowledge about health and climate change at a global level. In terms of subject areas, 34% of these scientific publications were in medicine, followed by environmental sciences (23%) and social sciences (14%) (Figure A7). With respect to health outcomes, while infectious diseases were the most common health focus (24%) at a global level, in Australia, more publications focused on total mortality/non-communicable disease related to heat, respiratory health related to bushfire, and mental health related to bushfire and other natural disasters. More studies were in Victoria and Queensland, with few studies in Tasmania, the NT, and the ACT.

5.3 Engagement in health and climate change in Australian government

We searched the Parliamentary websites of the Australian Government for legislation, programs, policy, speeches and statements on health and climate change. We also searched the website of the Federal Department of Health for policies, programs or statements on climate change. We found no engagement in health and climate change by the Australian Federal Government during the last ten years (Table A6). Given the

current and projected impacts of climate change on the health of the Australian population, and the related escalation in frequency and severity of extreme weather events, the lack of engagement by the Australian Government is of significant concern. At the State level, the Queensland Government have a health and wellbeing climate adaptation plan.[34] In March 2019, the Government of Western Australia announced a Chief Health Officer Inquiry to investigate the health implications of climate change, including the health impacts of more frequent and intense weather events. The aim of the Inquiry is to review the current planning and response capacity of the WA health system for the health impacts of climate change. The Inquiry will also make recommendations for improving climate change mitigation and public health adaptation strategies. We will formally review the engagement at State level in future assessments.

5.4 Engagement in health and climate change in Australian corporate sector

Compared to the data available for the global report[5], Australian data from the United Nations (UN) Global Compact Communication of Progress (COP), relevant to the corporate sector's engagement in health and climate change, are extremely limited. Only 170 organisations in Australia are signed up for this initiative, and of those, 150 are classified as "active" (i.e., they are reporting under the initiative). Of the 150 active organisations, 20 joined very recently in 2019, meaning that these organisations have not yet submitted a report. A further 24 organisations joined in 2018, and only 7 of those have started to submit reports (mostly existing annual or sustainability reports). Around one fifth of the organisations in the Australia database (21%) consist of academic institutions or non-government organisations (NGOs). Given the small number of corporate reports available, and the lack of comment they contained on malnutrition, communicable diseases, or malaria, a statistical analysis of corporate engagement with the intersection of health and climate change issues was not feasible. However, most ASX-listed companies have produced sustainability reports alongside their annual/financial reports. Thus, a future version of this indicator could focus on sourcing sustainability reports for a sample of Australia's ASX-listed companies and examining the intersection between both local/regional and global health outcomes.

Conclusion: public and political engagement

Progress on public and political engagement in health and climate change has been mixed, as summarised in Table 6. Media coverage about health and climate change in Australia continues to be modest by comparison with the levels of coverage in other countries. In the context of the Federal election, there was a relative increase in this coverage in the first part of 2019. The number of Australian scientific journal articles on health and climate change has risen in recent years to more than 60 per annum, returning to a level similar to the previous peak in 2014 and 2015. While there continues to be no engagement on health and climate change in the Australian Federal Parliament, the climate change and health inquiry recently commenced by the WA Government is a positive development. Corporate engagement on health and climate

change in Australia is currently difficult to assess using the UN Global Compact reporting processes because, at this time, only a limited number of Australian organisations have signed up for this initiative.

Conclusion: the *MJA-Lancet* Countdown in 2019

In a year marked by an Australian federal election in which climate change featured prominently, we find mixed progress on health and climate change in this country. There has been progress in renewable energy generation, including substantial employment increases in this sector. There has also been some progress at state and local government level. However, there continues to be no engagement on health and climate change in the Australian Federal Parliament, and Australia performs poorly across many of the indicators in comparison to other developed countries. We also find significant increasing exposure of Australians to heatwaves and, in most states and territories, greatly elevated suicide rates at higher temperatures.

The lack of Australian national policy to address threats of climate change to health – and the consequent failure to realise the enormous opportunities that doing so would afford our nation – is disappointing to say the least. This work is urgent and should be undertaken within a complex systems thinking framework (see, for example, Berry et al.[69]). As a direct result of this failure, we conclude that Australia remains at significant risk of declines in health due to climate change, and that substantial and sustained national action is urgently required in order to prevent this.

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Tables and Boxes

Table 1. Indicators assessed for the 2019 *MJA-Lancet* Countdown, including equivalent 2018 *MJA-Lancet* Countdown indicators

2019 Indicators	2018 Equivalents
Section 1: Climate change impacts, exposures, and vulnerability	
1.1 Vulnerability to the heat-related risks of climate change	New
1.2 Exposure to temperature change	1.1
1.3 Health effects of heatwaves	1.2
1.4 Change in labour capacity	1.3
1.5 Mental health	1.9
1.6 Wildfire exposure	New
Section 2: Adaptation, planning, and resilience for health	
2.1 Australian adaptation plans for health	2.1
2.2 City-level climate change risk assessments	2.2
2.3 Detection, preparedness, and response to health emergencies	2.3
2.4 Climate information services for health	2.4
2.5 National assessments of climate change impacts, vulnerability, and adaptation for health	2.5
Section 3: Mitigation actions and health co-benefits	
3.1 Carbon intensity of the energy system	3.1
3.2 Coal phase-out	3.2
3.3 Renewable and low-carbon emission electricity	3.3
3.4 Access to clean energy	3.4
3.5 Exposure to ambient air pollution	3.5
3.5.1 Exposure to air pollution in cities	3.5.1
3.5.2 Premature mortality from ambient anthropogenic air pollution	3.5.2
3.6 Clean fuel use for transport	3.6
3.7 Sustainable travel infrastructure and uptake	3.7
3.8 Health-care sector emissions	3.9
Section 4: Finance and economics	
4.1 Economic losses due to climate-related extreme events	4.4
4.2 Investments in zero-carbon energy and energy efficiency	4.1
4.3 Investment in new coal capacity	4.2
4.4 Employment in renewable and fossil-fuel energy industries	4.5
4.5 Funds divested from fossil fuels	4.3
4.6 Coverage and strength of carbon pricing	4.7
4.7 Use of carbon pricing revenues	4.8
Section 5: Public and political engagement	
5.1 Media coverage of health and climate change	5.1
5.2 Coverage of health and climate change in scientific journals	5.2
5.3 Engagement in health and climate change in Australian	5.3

government	
5.4 Engagement in health and climate change in Australian corporate sector	New

Table 2. Summary of progress on Australian climate change adaptation, planning, and resilience for health

Indicator Number	Indicator Name	Previous Value	Current Value	Change	Progress?
2.1	Australian adaptation plans for health	1	1+[a]	0	✓
2.2	City-level climate change risk assessments[b]	70	99	41%	✓
2.3	Detection, preparedness, and response to health emergencies[c]	100%	100%	0	✓
2.4	Climate information services for health	3	3	0	✓
2.5	National assessments of climate change impacts, vulnerability, and adaptation for health	1	1+[d]	0	✓

[a] While there is still only one published health adaptation plan, unchanged from 2018, Tasmania's progress towards a State plan should be acknowledged.

[b] Number of local councils (nationally) participating in the Cities Power Partnership supporting local initiatives in adaptation and mitigation.

[c] While the latest data shows Australia scoring 100% on all core capacities, previous recent years have been inconsistent.

[d] While there is still only one national impact assessment produced by the Australian Government, *The Garnaut Climate Change Review* (2008), the growing contributions to policy relevant information by the Climate Council should be acknowledged.

Table 3. Summary of progress on Australian climate change mitigation actions and health co-benefits

Indicator Number	Indicator Name	Previous Value[a]	Updated Value[b]	Change	Progress?
3.1	Carbon intensity of the energy system (total energy supply)- CO_2/MJ	71.89 (2013 data) [a] Subsequently adjusted to 72.35 (2013 data) [b]	72.23 (2016 data)	-0.12	✓
3.2	Coal phase-out (total primary coal supply in Mtoe)	42.87 (2015 data)	44.02 (2016 data)	+1.15	×
3.3	Zero-carbon emission electricity (in % of total)				
	Renewable sources	16.17% (2015 data)	17.95% (**2016** data)	+1.78%	✓
	Low carbon sources	14.66% (2015 data)	16.42% (**2016** data)	+1.76%	✓
	Renewable sources	16.17% (2015 data)	18.80% (**2017** data)	+2.63%	✓
	Low carbon sources	14.66% (2015 data)	17.41% (**2017** data)	+2.75%	✓
3.4	Access to clean energy - See description in text for details				
3.5	Exposure to ambient air pollution (3.5.2)	2900 (2015)	2800 (2016)	-3.45%	✓
3.6	Clean fuel use for transport - See description in text for details				
3.7	Sustainable travel infrastructure and uptake - See description in text for details				
3.8	Health-care sector emissions	35.8 megatonnes emissions (year: 2014-15)	40.1 megatonnes emissions (year: 2016-17)	+4.3	×

[a] As reported in Zhang et al.[8].

[b] Based on latest available data (year noted in brackets).

Table 4. Share of new vehicles in each Australian state and territory in 2016 which are electric (or hybrid)

State/Territory	Share of new vehicles which are EVs (or hybrid) (%)
South Australia	0.22
Australian Capital Territory	0.21
New South Wales	0.10
Victoria	0.10
Western Australia	0.08
Queensland	0.06
Tasmania	0.03
Northern Territory	0.01
Australia	0.09

Table 5. Summary of progress on Australian climate change finance and economics

Indicator Number	Indicator Name	Previous Value	Current Value	Change	Progress?
4.1	Economic losses due to climate-related extreme events	AUD2.75 billion (2017)	AUD1.62 billion (2018)	-41%	✓
4.2	Investments in zero-carbon energy and energy efficiency	Renewables Coal withdrawal		+ 0	✓ x
4.3	Investment in new coal capacity	See indicator text			✓
4.4	Employment in renewable and fossil-fuel energy industries	Renewable ~15,000 Fossil-fuel 157,000 (2016-17)	17,740 168,000 (2017-18)	+28% +7%	✓ x
4.5	Funds divested from fossil fuels	Withdrawal of coal 0 (2017-18)	0 (2018-19)	0	x
4.6	Coverage and strength of carbon pricing	See indicator text			x
4.7	Use of carbon pricing revenues	See indicator text			x

Table 6. Summary of progress on Australian climate change public and political engagement

Indicator Number	Indicator Name	Previous Value[a]	Current Value[a]	Change	Progress?
5.1	Media coverage of health and climate change	103	65	-36%	x
5.2	Coverage of health and climate change in scientific journals	56	66	+18%	✓
5.3	Engagement in health and climate change in Australian government	0	0	0	x
5.4	Engagement in health and climate change in Australian corporate sector	106[b]	130[b]	+23%	✓

[a] Previous value is 2017 and current value is 2018 unless otherwise indicated.

[b] Previous value is the number of active organisations in 2017 and current value is the number of active organisations in 2018.

Text Box 1. Climate change and health attribution

In climate science, 'extreme event attribution' refers to estimating the change in likelihood of a severe weather-related event due to underlying specific mechanisms, including anthropogenic climate change. Recently, extreme event attribution studies have begun to calculate the anthropogenic climate change-related health impacts of certain weather events ([10], Ebi et al. 2017). For example, in the 2003 European heatwaves, anthropogenic climate change increased the risk of heat-related mortality in Central Paris by ~70% and by ~20% in London .[10]

Being able to quantify the extent to which anthropogenic climate change contributes to conspicuous impacts means that scientists can more fully demonstrate the range of climate change and related costs to health, society and the economy (Ebi et al. 2017). Because this field is still in its infancy, many technical questions remain unresolved, such as reliable long-term datasets, which physical climate models to employ, how to measure impacts, and how to suitably merge these respective fields in standardized approaches for effective attribution of climate change impacts (Stone et al. 2013; Ebi et al. 2017). Moreover, some events and their impacts are more amenable to attribution calculations than are others, which is not always clear until analyses are underway. There are thus numerous questions to answer before important uncertainties can be resolved. Nevertheless, attribution assessments show great potential in helping demonstrate the many ways in which anthropogenic climate change has influenced extreme events and their health impacts (Ebi et al. 2017).

Text Box 2. Migration and population displacement

While climate change is unquestionably altering Australia's landscape and affecting resource availability (e.g., causing severe drought and more frequent and severe bushfires, and affecting agriculture), there are no published quantitative data for Australia on migration related to climate change. However, since the publication of the first *MJA-Lancet* Countdown report last year, anecdotal evidence has been reported for evacuation or temporary displacement (though not for permanent migration) made necessary by climate change-sensitive weather-related disasters. For example, severe fire events have occurred in New South Wales (NSW), Queensland, Tasmania, Victoria, and Western Australia requiring community evacuations due to the fire threat, or advice that vulnerable individuals relocate away from hazardous air pollution.[13,14] Australian Indigenous peoples face particularly severe threats due to their unique circumstances and to the vulnerability of some of their lands, for example, in the Torres Strait.[15] Disruption to traditional relationships to land resulting from weather-related disasters, such as the loss of meeting places on rivers during the millennium drought, profoundly affect social and emotional wellbeing.[16]

Text Box 3. Climate change adaptation to vulnerabilities from mosquito-borne diseases

Several mosquito-borne diseases are currently transmitted within Australia, causing about 9,000 infections annually.[32] Dengue virus (about 700 cases notified per year) is not endemic but circulates locally each year after it is introduced by an overseas visitor or a resident returning from an endemic country. Most of these cases occur in Queensland. Ross River virus and Barmah Forest virus are endemic to a number of regions in Australia, including in the south, and affect around 5,500 and 1,400 people each year respectively.[32] Murray Valley Encephalitis, Japanese Encephalitis, and Kunjin virus occur only rarely. Malaria has not been transmitted on the mainland for several decades but occasional cases occur in the Torres Strait. Other mosquito-borne diseases that are not currently transmitted in Australia but occur in the region and could potentially take hold are zika virus, chikungunya, and yellow fever.

While there are many factors at play in the transmission of mosquito-borne disease, climate sets the parameters under which mosquitoes and the pathogen occur and disease can be transmitted. Mosquitoes favour warm, wet environments, and generally speaking will proliferate under these conditions and feed more frequently, which provides more opportunities to transmit disease. The relationship between virus transmission and temperature is, however, not linear, characterised by optimal transmission temperatures and bounded by thresholds, below and above which transmission does not occur, and these temperature effects vary by both mosquito species and pathogen (Mordecai et al. 2019). To an upper threshold, virus replication is sped up under warmer ambient temperatures, also enhancing transmission potential. Temperature effects on mosquito abundance are also moderated by humidity and rainfall. Humid environments generally enhance mosquito survival, while rainfall can contribute to breeding habitat. With the increased likelihood of more intense rainfall events over much of Australia even as overall rainfall declines (as is expected in the south-east and south-west of the country), there is potential for increased mosquito breeding habitat available through localised flooding but the effect on disease may be season and location dependent (Tall and Gatton, 2019). The changes to climate in Australia overall are likely to lead to more favourable habitats for mosquitoes and greater transmission potential for the diseases they carry, in some regions. The transmission ecology of certain pathogens that can involve multiple host species, such as Ross River virus (Flies et al. 2018), further increase the complexity of predicting the effects of climate change on disease incidence. A focused adaptation response to this increasing threat of disease from climate change is required, and how Australia is tracking on adaptation to mosquito-borne disease will be included as an indicator in subsequent versions of this report.

Text Box 4. Inclusion of health and climate change within medical curricula

From 2020, the *MJA-Lancet* Countdown will track an indicator of the actions of Australia's 21 medical schools in preparing medical graduates to deal with the health consequences of climate change and to work in an environmentally sustainable healthcare system. To date, there has been a limited response in medical training to developing the capacity of future doctors to respond to the current and future challenges posed by climate change and other environmental threats in Australia and internationally.

Consequently, the Medical Deans of Australia and New Zealand (MDANZ), the peak body for professional medical education in Australia and New Zealand, has formed a working group to develop learning resources and to support medical schools to work collegially to implement change.[33] The working group has developed graduate outcome statements and learning objectives, and MDANZ has distributed these to all medical schools. The introduction of the *MJA-Lancet* Countdown indicator provides an opportunity to track engagement with these resources and create a baseline in this area of learning against which developments can be monitored.

This approach potentially presents a model that can be adapted by other regulated health professions in Australia.

Photographs, graphs and illustrations

Figure 1. The Heat Exposure Vulnerability Index for the Australian population, 1990-2017.

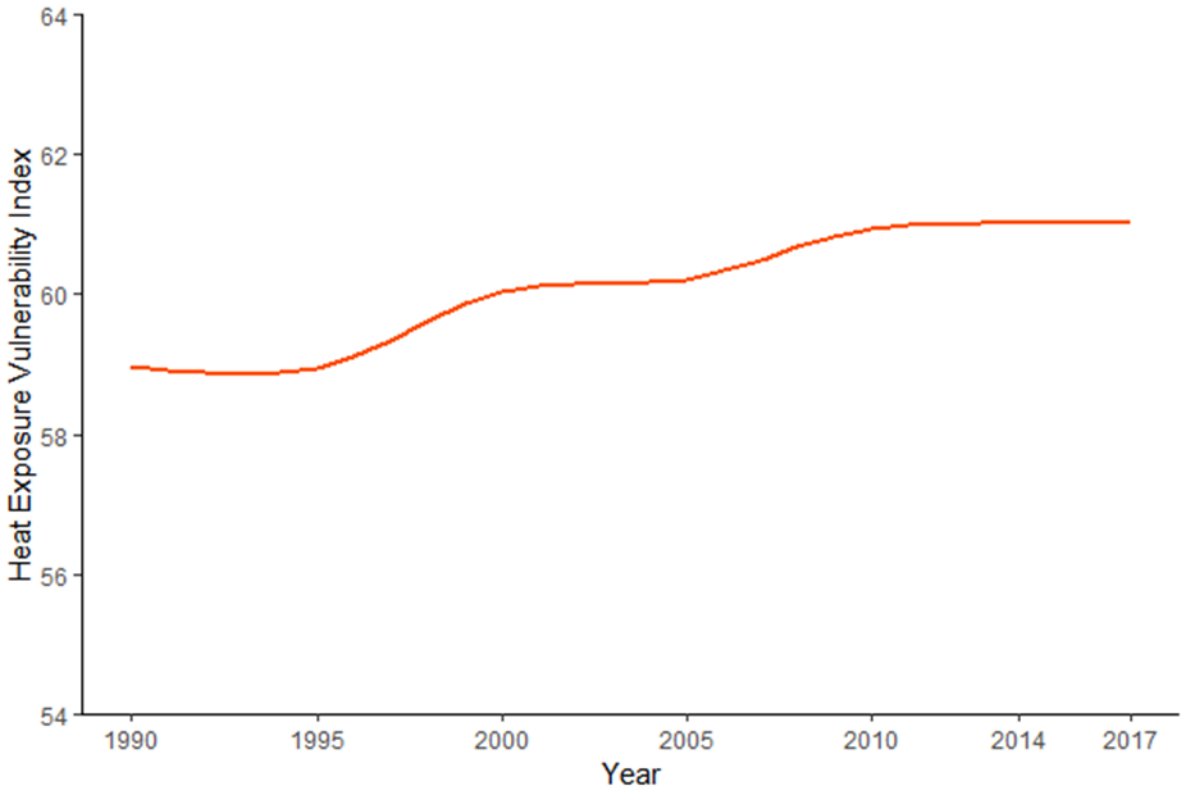


Figure 2. Nationally averaged Australian summer (December-February) maximum temperature anomalies (in °C) for the last 20 summers (1999-2000 to 2018-19). The base period for the anomalies is 1981-2010. The grey trend line is calculated over the last 50 summers (1969-70 to 2018-19), while the blue trend line is calculated over the last 20 summers

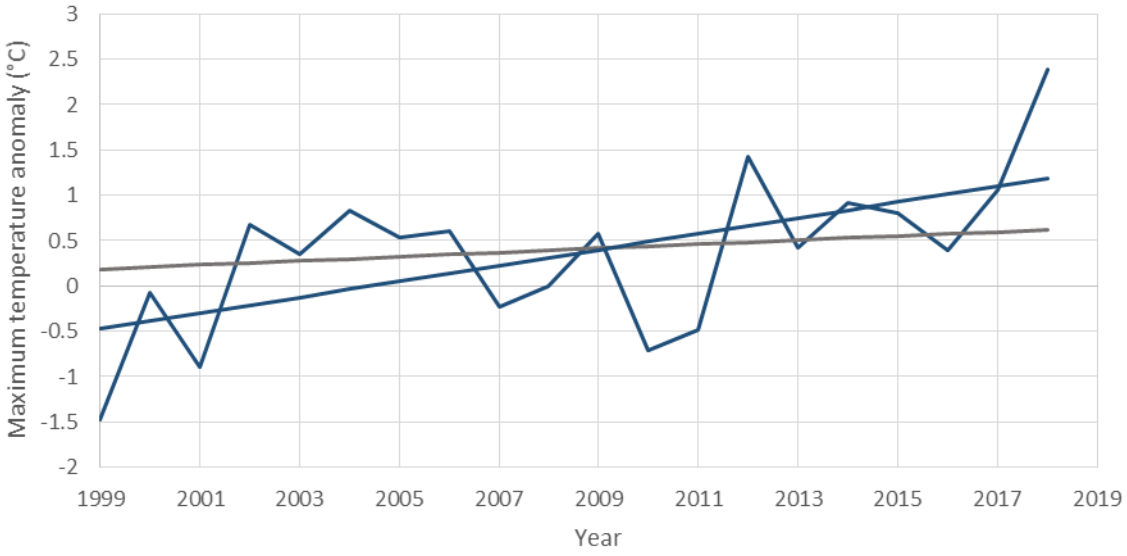


Figure 3. Nationally averaged Australian heatwave-season (November-March) accumulated excess heat factor (EHF, in K^2) for the last 20 heatwave seasons (1999-2000 to 2018-19). The grey trend line is calculated over the last 50 heatwave seasons (1969-70 to 2018-19), while the blue trend line is calculated over the last 20 heatwave seasons

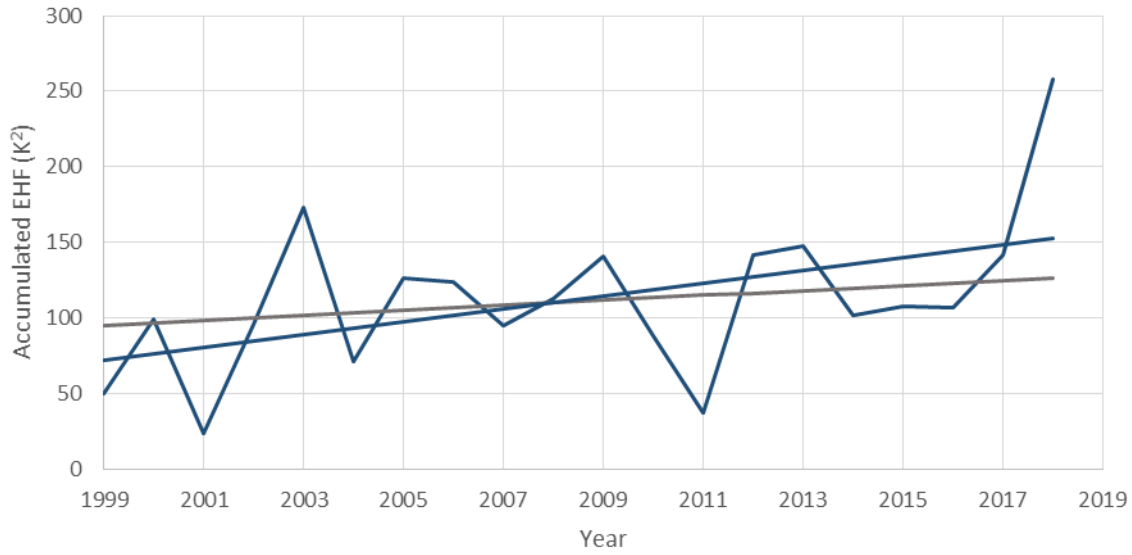
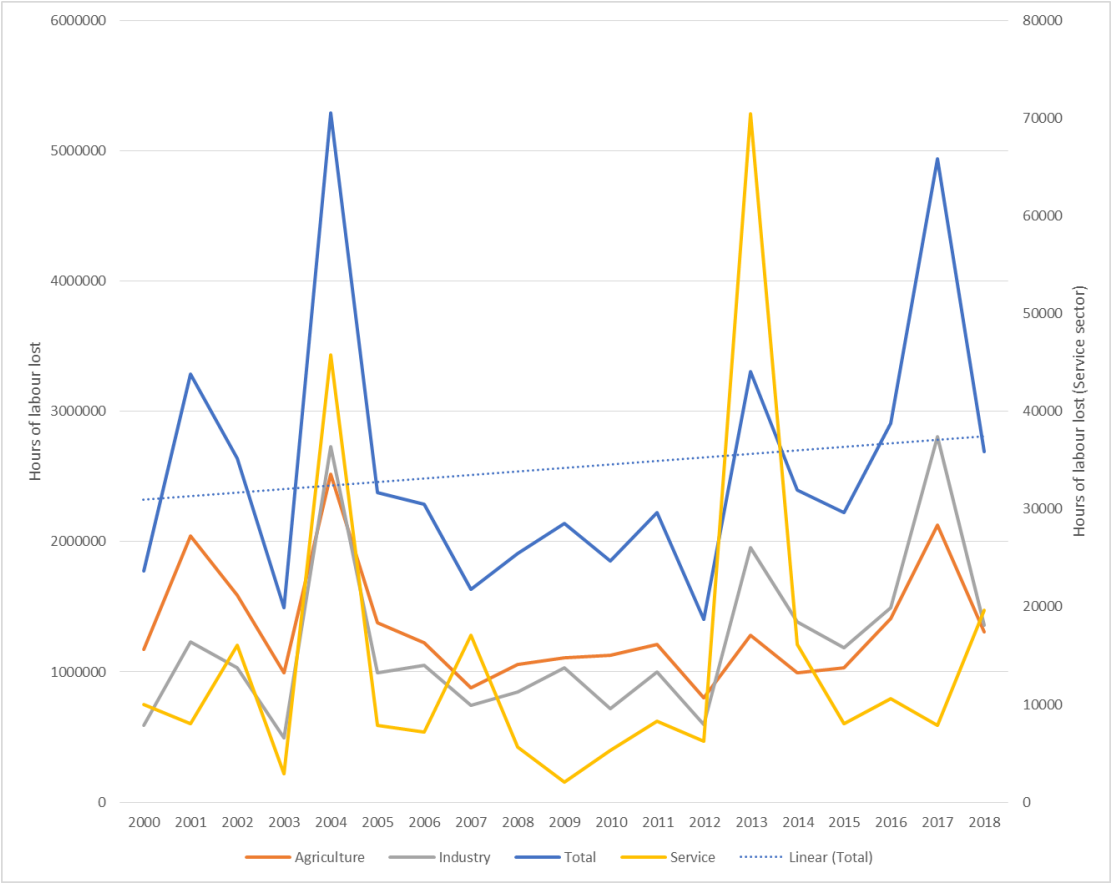


Figure 4. Total hours of labour lost due to heat, by sector in Australia, 2000-2018.



Only the Service sector is plotted against the right hand y axis. A linear trend line is included for just the total hours of labour lost.

Figure 5. Relationship between mean maximum and mean minimum annual temperature and age-standardised suicide rates by warm compared to cool jurisdictions in Australia and by sex, for baseline (2007-16), baseline plus one year (2007-17) and for latest year of available data (2017). ‘Cool’ jurisdictions are Tasmania and the Australian Capital Territory. All other jurisdictions are classified as ‘warm’. Males are blue markers, females are green

(please see document named Figure 5.docx)

Figure 6. Annual person days exposed to wildfires between 2001-2004 and 2015-2018 in Australia

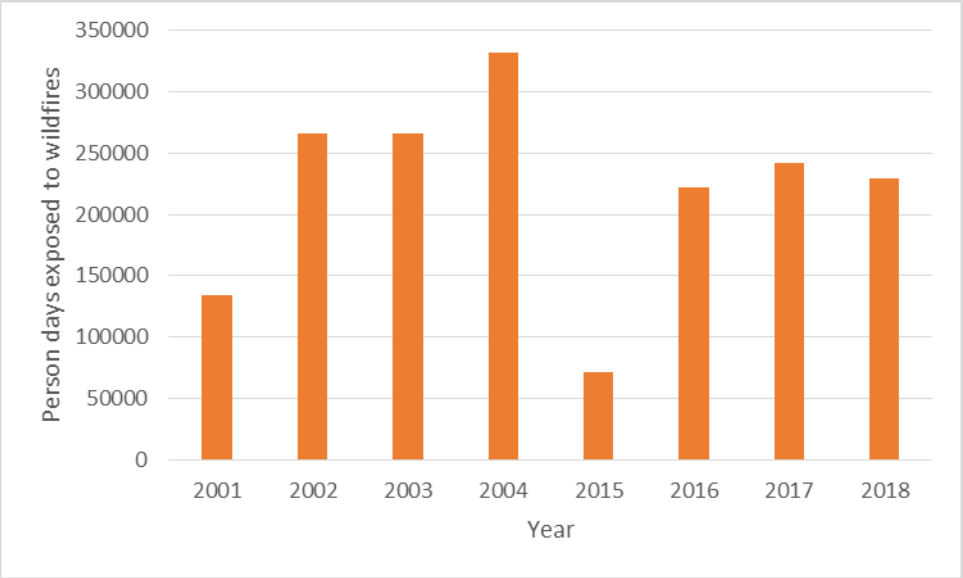


Figure 7. Percent of councils in each Australian State and Territory participating in the Cities Power Partnership in 2018 and 2019. NB the ACT has only one local government area

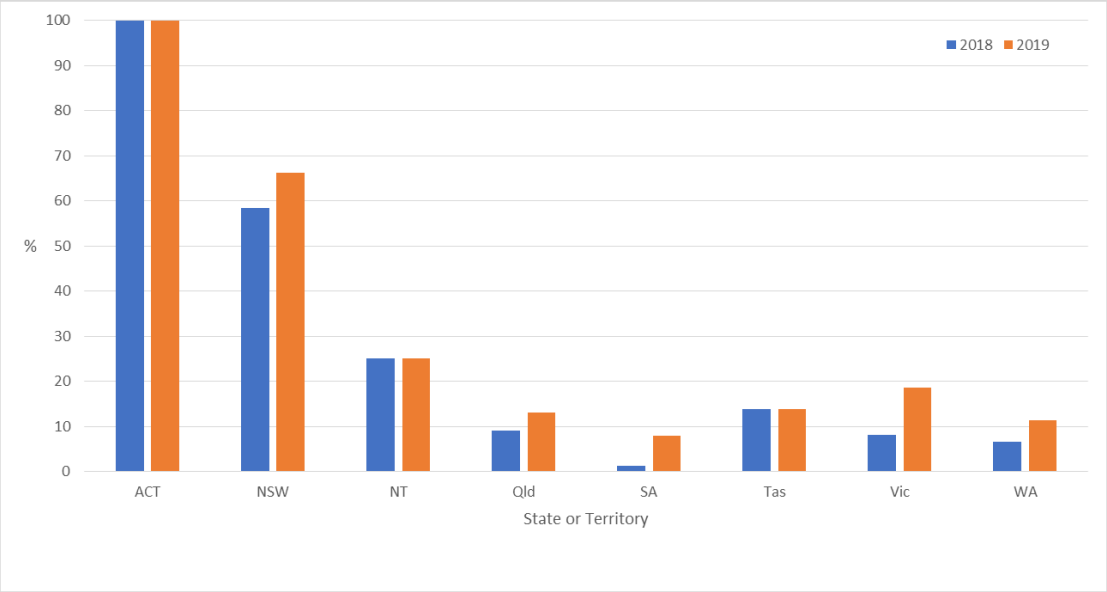


Figure 8. International Health Regulations (2005) monitoring framework capacity scores for Australia for surveillance, response, preparedness, and human resources, 2010-2017

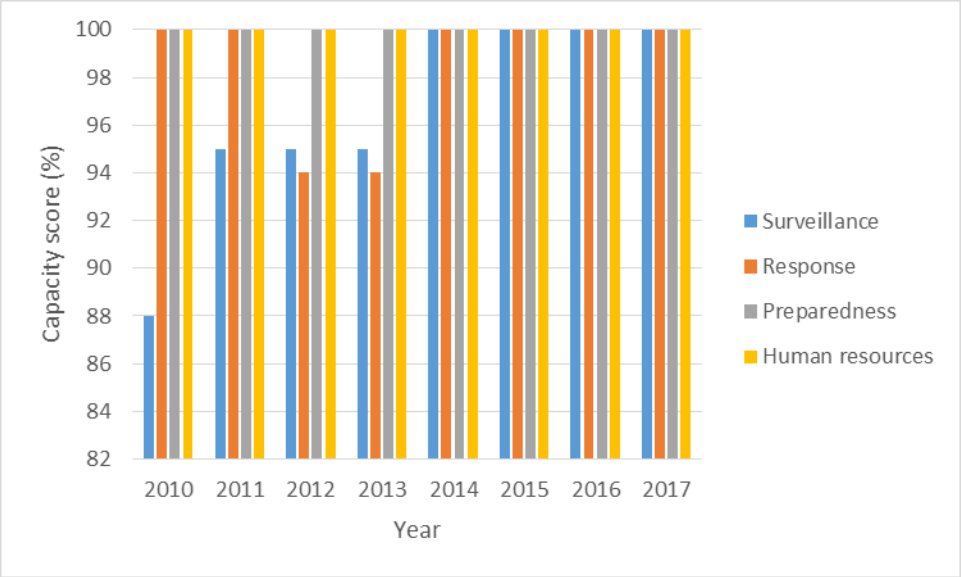


Figure 9. Carbon intensity of total primary energy supply for Australia, selected countries, and the world, and corresponding total carbon dioxide (CO_2) emissions, 1971-2016

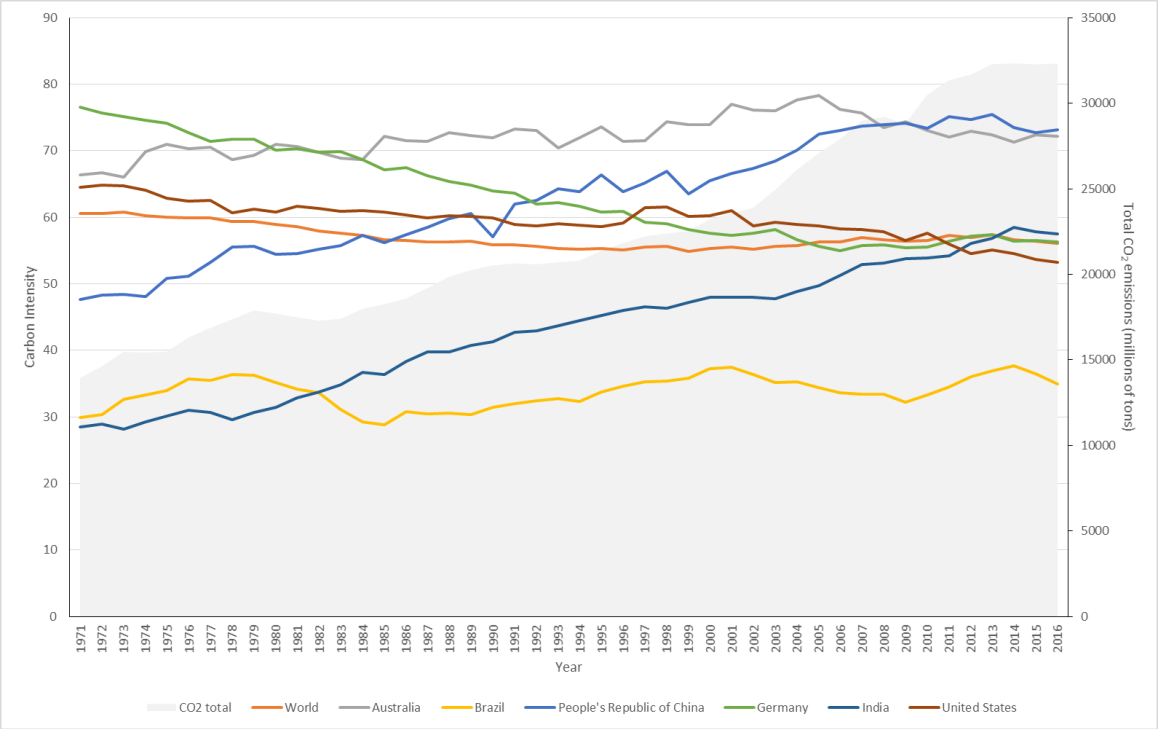


Figure 10. Total primary coal supply in Australia, China, India, and the US, 1973-2016 (Source: International Energy Agency)

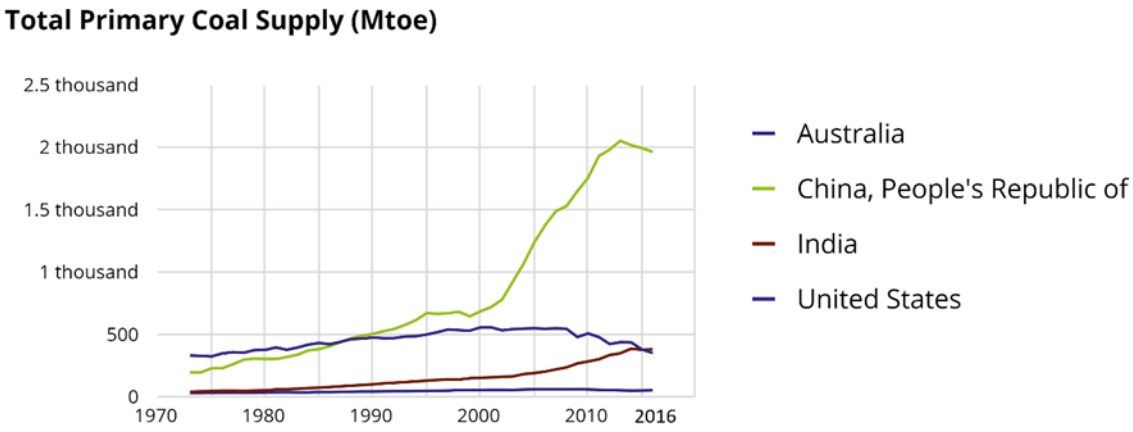


Figure A4. Total primary coal supply in Australia, China, India, and the US, 1973-2016 (Source: International Energy Agency)

Figure 11. Share of electricity generation from renewable sources in Australia, Germany, the United Kingdom and the United States, and the Organisation for Economic Co-operation and Development (OECD) total, 1990-2016

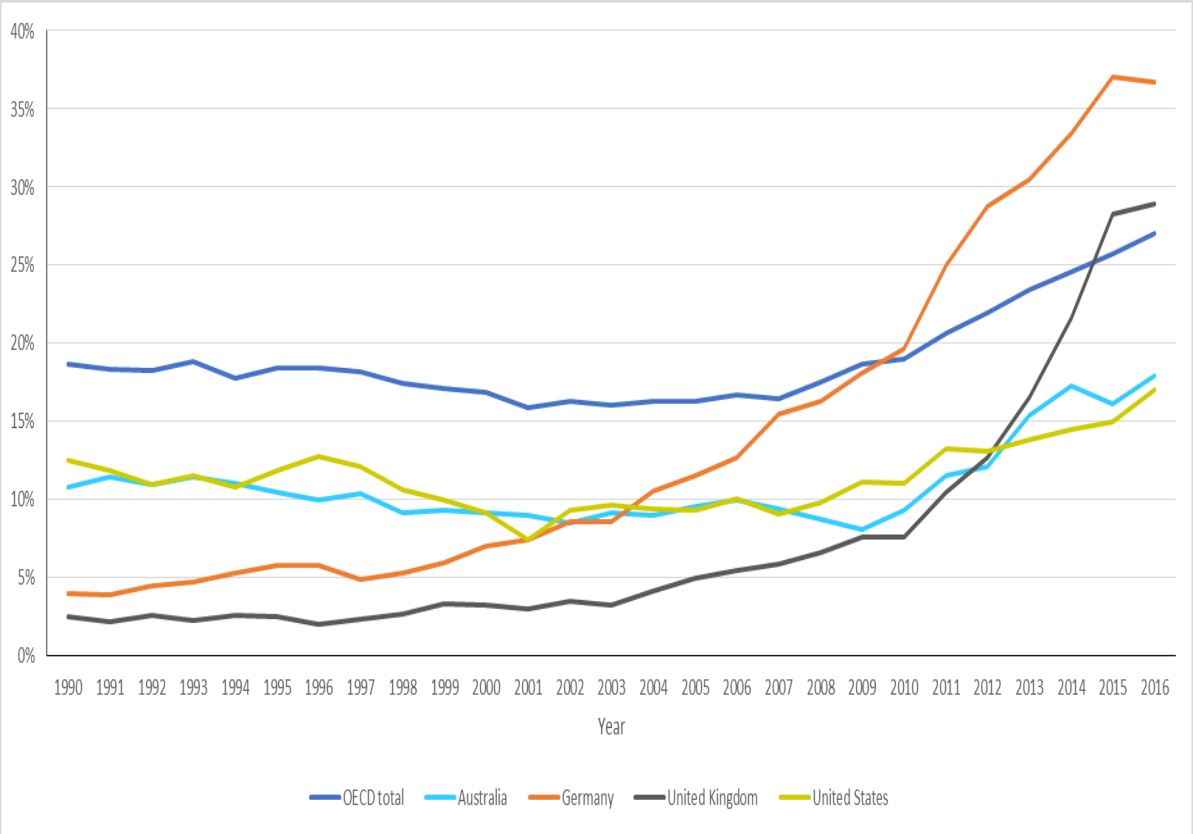


Figure 12. Share of electricity generation from low carbon sources in Australia, Germany, the United Kingdom and the United States, and the Organisation for Economic Co-operation and Development (OECD) total, 1990-2016

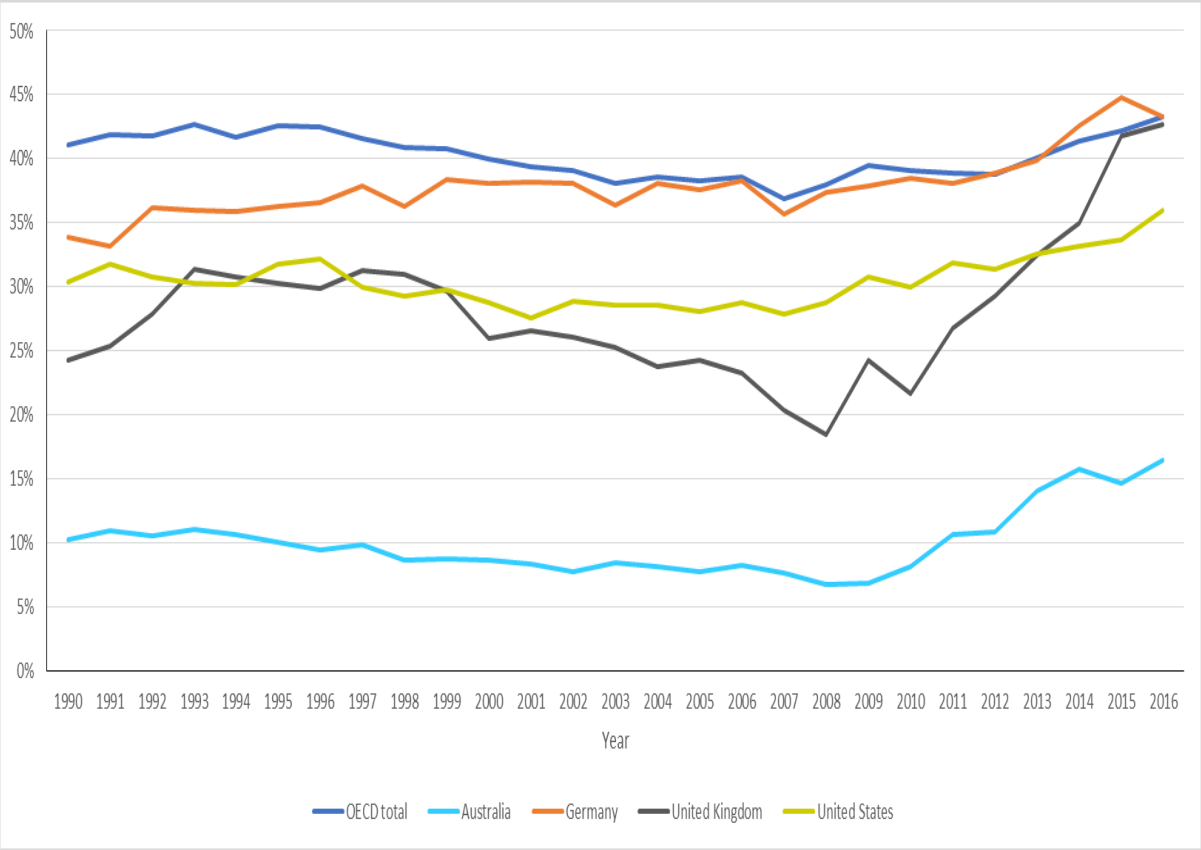


Figure 13. Annual total insured economic losses in Australia from bushfires, cyclones, flooding, hailstorms, storm flooding, and tornados for the period 2000 – 2018 based on the Historical Catastrophe Database of the Insurance Council of Australia (ICA)

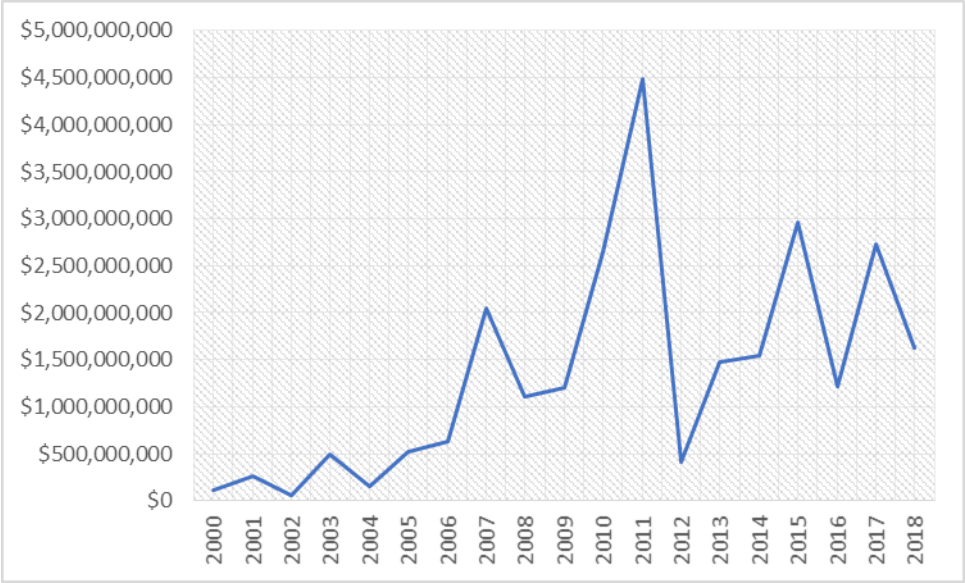


Figure 14. New investment and capacity withdrawal in the Australian National Electricity Market (NEM) for different fuel sources (black coal, brown coal, gas, hydro, wind, solar, and battery) for the financial years 2012-13 to 2018-19. Note: 2018–19 data is to 31 October 2018 only. An additional 2,076 MW of committed capacity (1,178 MW of wind, 873 MW of solar, 24 MW of biomass and 2 MW of battery storage) was expected to be commissioned in 2018–19 (Source: AER[58])

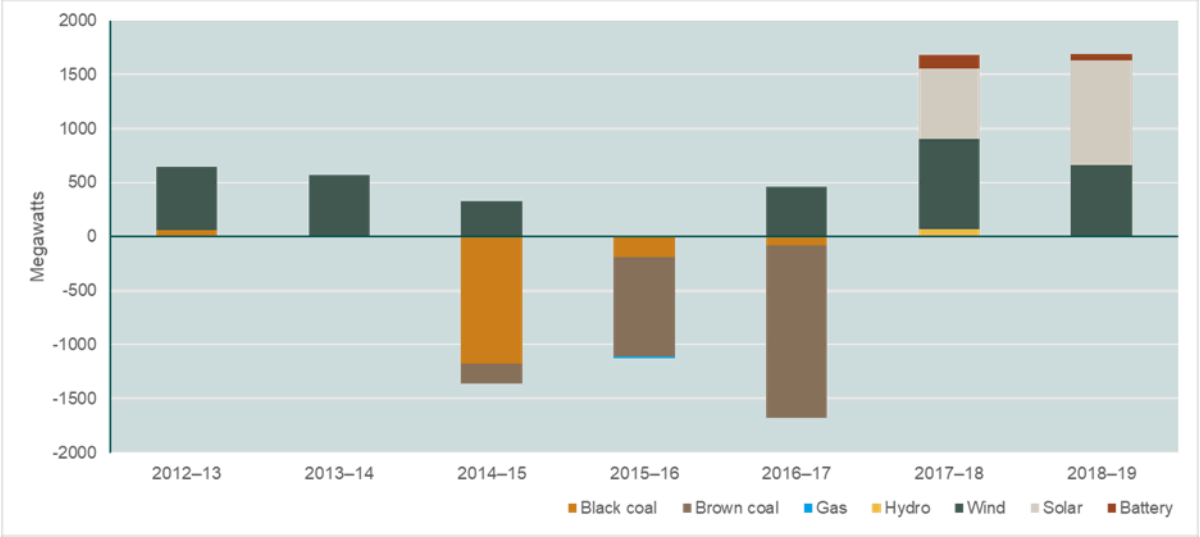


Figure 15. Annual direct full-time equivalent (FTE) employment in renewable energy activities for Australia, NSW, QLD, SA, and VIC, 2009-10 to 2017-18. (Source: Australian Bureau of Statistics)

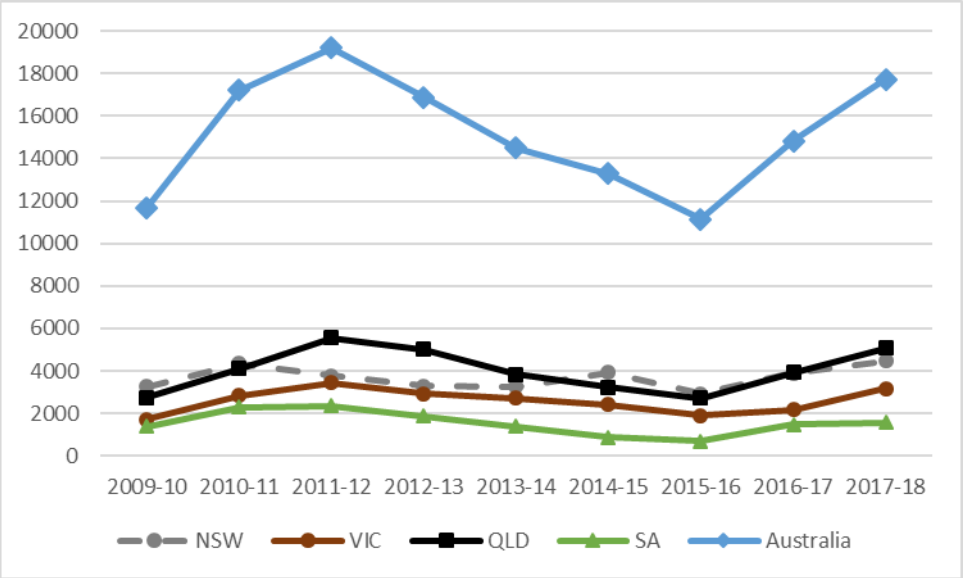


Figure 16. Annual number of newspaper articles reporting on health and climate change by regions in Australia, 2008 to 2019. Note: 2019 is part year, to 17 May

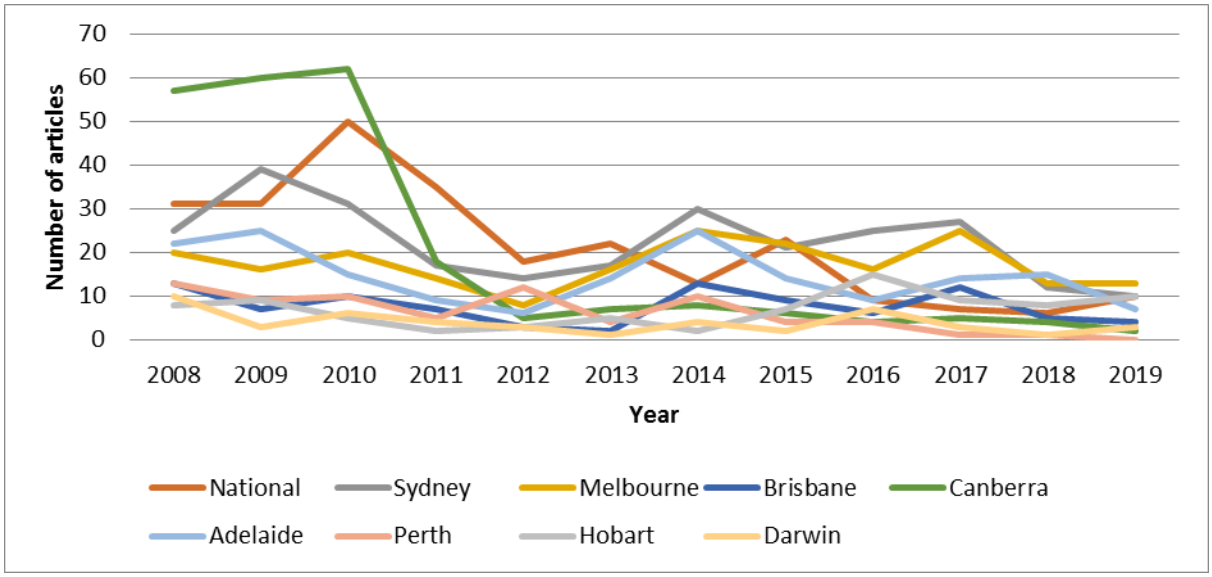


Figure 17. Number of journal articles on health and climate change in Australia, 2008-2018