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Supporting Information

This appendix was part of the submitted manuscript and has been peer reviewed. It is posted as supplied by the authors.

Appendix to: Beggs PJ, Zhang Y, Bambrick H, et al. The 2019 report of the *MJA–Lancet* Countdown on health and climate change: a turbulent year with mixed progress. *Med J Aust* 2019; doi: 10.5694/mja2.50405.

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

Introduction

This Appendix includes details of the data, methods, and caveats for each of the 31 indicators assessed in the 2019 *MJA-Lancet* Countdown. It also includes additional figures and tables that further illustrate particular indicators. Finally, it includes, for each indicator, current thoughts regarding the potential future form of the indicator. This is provided in the context of this being the second *MJA-Lancet* Countdown and the acknowledgement that its indicators, like those of the *Lancet* Countdown, will likely continue to develop in future annual assessments.

Section 1: Climate change impacts, exposures, and vulnerability

1.1 Vulnerability to the heat-related risks of climate change

Data

Institute for Health Metrics and Evaluation (IHME). Global burden of disease collaborative network study 2017 (GBD 2017) population estimates 1950-2017. Seattle: IHME, 2018. http://ghdx.healthdata.org/record/ihme-data/gbd-2017-population-estimates-1950-2017 (accessed Jul 2019).

Australian Bureau of Statistics (ABS). Australian historical population statistics, 2016 (urbanisation data in Australia). Canberra: Australian Bureau of Statistics, 2019. (Catalogue Number 3105.0.65.001) https://www.abs.gov.au/ (accessed Jul 2019).

Methods

This indicator is included for the first time in this national report, and as such, we have included prior years as well as most current data so trends can be identified.

The Heat Exposure Vulnerability Index (HEVI) was calculated using the equation below:

HEVI=100*(Pop65plus + Major non-communicative disease (NCD) prevalence + Urbanisation rate)/3.

In this equation, Pop65plus is the proportion of the population aged 65 years or above. We download this data for 1990-2017 from Global Burden of Disease Study 2017. Major non-communicative disease (NCD) prevalence of cardiovascular, diabetes and chronic respiratory diseases among population aged 65 years, or above, was used for the period 1990-2017 which was also sourced from GBD 2017 using the online tool available there. The Urbanisation rate was calculated as the proportion of people living in urban areas, as a measure of exposure to the urban heat island. Urbanisation data in Australia for 1991, 1996, 2001, 2006, 2011, and 2016 came from the Australian Bureau of Statistics. Since the urbanisation rate showed a very good linear relationship with the year, we used a linear regression model to estimate the urbanisation rate for other years during 1990-2017.

Caveats

There is no consistent and universally accepted standard for distinguishing urban from rural areas. Australia classifies urban to include: (1) Major Urban (which represents a combination of all Urban Centres with a population of 100,000 or more); and, (2) Other Urban (which represents a combination of all Urban Centres with a population between 1,000 and 99,999). This indicator does not include the existence of heat early warning systems, or prevalence of cooling devices. Neither does it include the prevalence of green areas in cities.

Future form of indicator

GBD estimates are revised annually, and Australian urbanisation revised every five years.

1.2 Exposure to temperature change

Data

The temperature dataset employed for this calculation is the Bureau of Meteorology's operational Australian Climate Observations Reference Network - Surface Air Temperature (ACORN-SAT) curated temperature network analyses.[1]

Methods

Fields of monthly maximum surface air temperature on a 0.25° latitude/longitude grid were extracted for the summer months (December-February) of the years 1969-70 to 2018-19 and time-averaged to obtain annual grids of summertime maximum temperature. The baseline grid was the 30-year average of summertime maximum temperatures during 1981-2010. Summertime anomaly grids (i.e., departures from the baseline) were area-averaged to produce a time series of nationally averaged summer maximum temperature anomalies. Ordinary least squares linear regression was calculated over the last 50 summers (1969-70 to 2018-19); and 20 summers (1999-2000 to 2018-19).

Future form of indicator

Population weighting of summer maximum temperatures will put greater emphasis on the impact of temperature changes on human health.

1.3 Health effects of heatwaves

Data

The heatwave dataset employed for this calculation is the Bureau of Meteorology's national Excess Heat Factor (EHF) heatwave analysis.[2,3]

Methods

0.25°-resolution national grids of EHF were extracted for three-day periods containing days during the heatwave season (November-March) of 1969-70 to 2018-19, with tapered down-weighting for the four three-day periods (two at each end) which are only partially within the November-March season. The data from each season were accumulated over the season to create grids of annual heat load. Only positive values of the EHF (positive values indicating the presence of heatwave, negative values its absence) are included in the accumulation. The annual grids were area-averaged to produce a time series of nationally averaged annual heat load. Ordinary least squares linear regression was calculated over the last 50 heatwave seasons (1969-70 to 2018-19); and 20 heatwave seasons (1999-2000 to 2018-19).

Future form of indicator

Population weighting of excess heat factor will put greater emphasis on the impact of temperature changes on human health.

1.4 Change in labour capacity

Data

Data for this indicator are the same as those used for "Indicator 1.1.4: Change in labour capacity" in Watts et al.[4].

Methods

Methods for this indicator are the same as those used for "Indicator 1.1.4: Change in labour capacity" in Watts et al.[4].

Caveats

Caveats for this indicator are the same as those for "Indicator 1.1.4: Change in labour capacity" in Watts et al.[4].

Future form of indicator

We intend to continue working closely with the *Lancet* Countdown on this indicator. The current assessment is only at the national (Australia) level, and future development of this indicator could include sub-national assessment (state/territory, capital cities, urban versus rural, etc.).

1.5 Mental health

Data

Data for this indicator are the same as those used for indicator 1.9, mental health, in Zhang et al.[5] and have been updated as follows. Death rates due to self-harm (suicide) data for females and males for each state and territory were taken from the Australian Bureau of Statistics standardised death rates for every year from 2006 to 2017 (latest available year at the time of writing). Standardised rates are deaths per 100,000 of estimated mid-year population adjusted for age structures (see https://www.abs.gov.au/ausstats/abs@.nsf/Lookup/by%20Subject/3303.0~2017~Main%20Features~Intentional%20self-harm,%20key%20characteristics~3). With 28 missing values, we were able to extract a total of 148 observations for eleven years from 2007 to 2017 (8 jurisdictions * 11 years * 2 sexes, less 28 missing values). We did not impute missing values primarily because death rates are highly variable across years and jurisdictions and imputation would have led to the introduction of too much error. We identified one extreme outlier in suicide rates (from the Northern Territory that for males in 2007). This outlier heavily biased initial results and was removed.

To match the death rates time series, mean annual maximum and minimum temperatures for each state and territory were calculated for every year from 2007 to 2017. Mean annual daily maximum and minimum temperature data for 2007-2017 were obtained for every climate station across Australia and were sourced from the Bureau of Meteorology (see http://www.bom.gov.au/climate/current/statement_archives.shtml). These data were loaded into ArcMap software (v 10.6) and used to calculate interpolated mean annual maximum and minimum temperature surfaces for each year (inverse distance weighted (IDW) function). The interpolated values were summarised for each state and territory using the zonal statistics function in QGIS software (v 3.4). This process yielded a mean annual maximum and minimum temperature value for each state and territory for every year from 2007 to 2017.

We did not impute missing temperature values but used the available data from the weather stations in that district and all the other districts to calculate mean scores for that state/territory for that year.

Methods

Methods for this indicator are the same as those used for indicator 1.9, mental health, in Zhang et al.[5] except that we used geospatial modelling to calculate maximum and minimum mean annual temperatures (see Data section).

Caveats

Caveats for this year’s mental health indicator remain the same as they were for the mental health indicator (1.9) last year.[5] Last year, we noted the need to analyse the temperature-suicide relationship separately by sex. Analysis of the standardised residuals from regression modelling again confirmed the need to take the same approach this year (Figure A1). Inspection of scatterplots confirmed this (Figure A2).

Last year, we also noted that using mean maximum annual temperature is a crude measure of exposure to unusually hot or cool weather, especially in states and territories with substantial climate variation. As an initial test of this, we computed a count of the number of climate zones in each jurisdiction and found that this count indicator was positively correlated with suicide rates for men (r=.27, p-value=.01) but not for women (r=.12, p-value=.37, n.s.). That is, for men, the greater the number of climate zones within the jurisdiction, the higher the suicide rate. While little substantive meaning can be inferred from this statistic, it adds weight to the conclusion that it is essential to analyse the temperature-suicide relationship at the sub-jurisdictional level and by sex.

We note the following improvements: (i) the use of geospatial modelling to calculate temperature data; (ii) including minimum as well as maximum mean annual temperatures in the indicator; and (iii) improved sensitivity testing of our results. We ran all analyses three times, once to re-calculate the baseline using the improved temperature data (it produced the near-identical results); once for the baseline data plus the additional year of now available data (2017); and finally, for the additional year of now available data on its own. All analyses supported the conclusions presented in the main report. Last year, we noted that population size, characteristics and dispersion vary greatly among jurisdictions. As a preliminary analysis of this, we investigated (by excluding them from the analysis one-by-one) whether jurisdictions with unusually high rates of suicide (NT) or limited suicide data (Australian Capital Territory (ACT)) would affect the overall obtained patterns of results. They did not.

Future form of indicator

In our 2018 report,[5] we noted that mean suicide rates and mean maximum annual temperatures differed significantly by jurisdiction, indicating that each state and territory had its own unique heat and suicide profile for the decade 2007-16. This year, we observed possible within-jurisdiction variance in the relationship between suicide and mean annual maximum and minimum temperatures (Figure A3), further underlining the need to analyse at sub-jurisdictional level and by underlying climate. To support the development of this indicator, a scientific background project has been commenced. We are building a database linking geospatially calculated annual and monthly temperature data, geocoded confidentialised suicide unit record files, underlying climate zones and socio-demographic data that we can analyse at the sub-jurisdictional level, both within and across Australian climate zones, as well as at more fine-grained levels. This will enable us to calculate a more refined indicator for next year's report, and to expand our analyses beyond suicide as a primary outcome measure to examine other climate-sensitive mental health outcome domains in future.

1.6 Wildfire exposure

Data

Data for this indicator are the same as those used for "Indicator 1.2.1: Wildfires" in Watts et al.[4].

Methods

Methods for this indicator are the same as those used for "Indicator 1.2.1: Wildfires" in Watts et al.[4].

Caveats

Caveats for this indicator are the same as those for "Indicator 1.2.1: Wildfires" in Watts et al.[4]. In addition, the extremely high interannual variation in landscape fire activity in Australia, means that data from two recent periods of time cannot be taken to represent long-term trends. Further, it should be noted that the Collection 6 active fire product from the Moderate Resolution Imaging Spectroradiometer (MODIS) aboard the NASA Terra and Aqua satellites, on which this indicator is based, includes all fires (both natural and human-made) and will therefore include fires in Australia that were conducted as part of fire mitigation strategies (e.g., hazard reduction burns) and those that were illegally lit by humans.

Future form of indicator

The future form of this indicator is the same as that for "Indicator 1.2.1: Wildfires" in Watts et al.[4].

Section 2: Adaptation, planning, and resilience for health

2.1 Australian adaptation plans for health

Data

Data for this indicator are largely the same as those used for Indicator 2.1 Australian adaptation plans for health in Zhang et al.[5], consisting of adaptation plans obtained through various internet searches, and other related documents, as well as information from direct personal communication with policy makers.

Methods

Methods for this indicator are the same as those used for Indicator 2.1 Australian adaptation plans for health in Zhang et al.[5], exploring the status of adaptation planning for health in Australia for each State and Territory. Documents were sourced using search term combinations of "adaptation", "plan", "health" and the names of each State and Territory.

Caveats

Caveats for this indicator are the same as those for Indicator 2.1 Australian adaptation plans for health in Zhang et al.[5].

Future form of indicator

This indicator could continue in its current form. It may be of value in the future for the indicator to be expanded to include other countries in the Asia-Pacific region, enabling comparison of preparedness with Australia's near neighbours.

2.2 City-level climate change risk assessments

Data

Data for this indicator are the same as those used for Indicator 2.2 City-level climate change risk assessments in Zhang et al.[5], including:

1. publicly available risk assessments from all state and territory governments, and from the local council for each capital city; and

2. Cities Power Partnership, member councils.[6]

Methods

Methods for this indicator are the same as those used for Indicator 2.2 City-level climate change risk assessments in Zhang et al.[5]. The local councils participating in the Cities Power Partnership were as listed at 4 May 2019.

Caveats

Caveats for this indicator are the same as those for Indicator 2.2 City-level climate change risk assessments in Zhang et al.[5].

Future form of indicator

The future form of this indicator could consider comprehensive adaptation strategies for all capital cities and regional population centres that include a focus on health and wellbeing; the linking of health to other sectors (e.g., water, housing, urban planning, energy, infrastructure); and links between greenhouse gas mitigation and adaptation, including co-benefits.

2.3 Detection, preparedness, and response to health emergencies

Data

Data for this indicator are the same as those used for "Indicator 2.3: detection, preparedness, and response to health emergencies" in Watts et al.[4].

Methods

Methods for this indicator are the same as those used for "Indicator 2.3: detection, preparedness, and response to health emergencies" in Watts et al.[4].

Caveats

Caveats for this indicator are the same as those for "Indicator 2.3: detection, preparedness, and response to health emergencies" in Watts et al.[4].

Future form of indicator

This indicator could evolve to also examine surveillance, response, preparedness, and human resources capacities at a state and territory level in Australia.

2.4 Climate information services for health

Data

Data for this indicator are the same as those used for "Indicator 2.4 Climate information services for health" in Zhang et al.[5].

Data on visits to the Bureau of Meteorology's heatwave website are from Google Analytics.

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

Data

Data for this indicator are the same as those used for Indicator 2.5 National assessment of vulnerability, impacts, and adaptation for health in Zhang et al.[5], with the addition of several new major reports published by the Climate Council.

Methods

Methods for this indicator are the same as those used for Indicator 2.5 National assessment of vulnerability, impacts, and adaptation for health in Zhang et al.[5].

Caveats

Caveats for this indicator are the same as those for Indicator 2.5 National assessment of vulnerability, impacts, and adaptation for health in Zhang et al.[5].

Future form of indicator

Australia remains long overdue for a comprehensive, national assessment of climate change impacts and mitigation and adaptation options. A new assessment must extend beyond the impact of climate change on the economy and consider the costs to people and their communities, and the cost to the natural environment including biodiversity, the costs to people's health and to the health system. With the health impacts of climate change in Australia increasingly well understood, the focus should be on building resilience in our population in systems that support health. A focus on the co-benefits would enable more accurate costings of the short as well as longer term economic savings attributable to meaningful climate action.

Section 3: Mitigation actions and health co-benefits

3.1 Carbon intensity of the energy system

Data

This indicator measures the carbon output per unit of energy consumed. Data for this indicator are based on data provided by the International Energy Agency (IEA). Data in Zhang et al.[5] were only available until 2012. For this update, new data[7] have become available that track this indicator until 2016.

Methods

In accordance with Watts et al.[8] and Zhang et al.[5], the technical definition for this indicator is tonnes of CO_2 emitted for each unit (TJ) of primary energy supplied.

The indicator for Australia is calculated based on total CO_2 emissions from fossil fuel combustion in Australia divided by Total Primary Energy Supply (TPES), that is, the total amount of primary energy used in Australia, accounting for the flow of energy imports and exports.

Caveats

This indicator does not provide more detailed information about the energy mix within Australia (for example, the relative share of different fossil fuels, also across in different sectors), the extent to which pollution abatement measures have been put into place going forward, as well as the absolute levels of usage of fossil fuels.

Future form of indicator

Data can be updated to include more recent years.

3.2 Coal phase-out

Data

The graphic presented in the text was sourced from the International Energy Agency.

Methods

The following indicator is used here:

Total primary coal supply for Australia in million tonnes of oil equivalent (Mtoe), also in comparison with total primary coal supply by India, China, and the US.

The indicator allows assessment of changes in coal consumption across the selected countries and regions.

Caveats

The indicator provides a proxy for air pollutant emissions associated with the combustion of coal, however, it does not provide detailed information about how the combustion of different coal types translates into different air pollutants.

Future form of indicator

The indicator can be improved in the future to convert coal use by sector and type into emissions of different air pollutants.

3.3 Renewable and low carbon emission electricity

Data

Data for this indicator are now available for 2016.[9]

Methods

In accordance with Watts et al.[8] and Zhang et al.[5], several different metrics are used to determine the installed power and generation of renewables:

- Electricity generation (gross electricity) from low carbon sources (terawatt hour (TWh));
- Share of electricity generation from low carbon sources (%) (including nuclear), estimated as a % of total generation;
- Generation from renewables (gross electricity) (excluding hydro, TWh);
- Share of electricity generation from renewables (%), estimated as a % of total generation.

Caveats

Information on electricity generation from low carbon and renewables sources does not provide information regarding implications for air pollutant emissions.

Future form of indicator

Future analysis can attempt to provide further insights into implications for air pollutant emissions.

3.4 Access to clean energy

Data

Given that Australia is a developed country and essentially all of Australia's population has access to electricity (noting issues with reliable access in remote areas), this indicator was modified to draw on data from the Clean Energy Council and other sources to provide data on renewable energy uptake in Australia, as well as access to small-scale renewable energy systems.

Methods

This indicator relies on secondary data provided by the Clean Energy Council.

Future form of indicator

Data on renewable energy access in indigenous and remote communities is sparse. Diesel generators are often used in these communities, and the future form of this indicator could try and track both the use of such unsustainable energy generation as well as the uptake of renewable alternatives.

3.5 Exposure to ambient air pollution

3.5.1 Exposure to air pollution in cities

Data

We used the 2013-2016 modelled $PM_{2.5}$ data from the dataset "Surface $PM_{2.5}$ Global Estimates (V4.GL.02): Atmospheric Composition Analysis Group at Dalhousie University Data". We used the estimated data for "All Composition $PM_{2.5}$ Satellite-Derived $PM_{2.5}$, 2015, at 35% relative humidity (RH) [$\mu g/m^3$], 0.01° × 0.01° with Geographically Weighted Regression (GWR) adjustment". The methods for this modelled $PM_{2.5}$ are described in the paper by van Donkelaar et al.[10]. This dataset has grid cell sizes of 0.01 x 0.01 decimal degrees or approximately 1km x 1km. Some Mesh Blocks were not covered by any 1km x 1km grid cells due to masking of water bodies and the coastline, so the 10km x 10km grid cell data were used to fill those gaps.

Spatial boundaries were obtained from the ABS dataset “1270.0.55.001 - Australian Statistical Geography Standard (ASGS): Volume 1 - Main Structure and Greater Capital City Statistical Areas, July 2016”.

Mesh Blocks are the smallest geographic region for which Census data are available. The number of inhabitants of the Mesh Blocks were from ABS dataset “2074.0 - Census of Population and Housing: Mesh Block Counts, Australia, 2016”.

Methods

Methods for this indicator are slightly different from those used for “Indicator 3.5.1. Exposure to air pollution in cities” in Zhang et al.[5] which used air pollution monitors and reported the average of all monitors within 50km of the centre of each city with more than 100,000 population resident in 2016.

Caveats

We approached government agencies to provide updated monitored $PM_{2.5}$ data but did not receive new data for all states in time for this report so we instead used the modelled data of van Donkelaar et al.[10] 2013-2016. We assigned each mesh block the average of pixels that overlap, and then used the populations in each mesh block to calculate a population weighted average for each city (Table A2).

Therefore the 2013-2015 levels used for “Indicator 3.5.1. Exposure to air pollution in cities” in Zhang et al.[5] are the most current estimates based on air pollution monitor data, and the 2013-2016 levels used for this report represent a spatial model estimate instead.

The use of modelled data is comparable to this indicator from *Lancet* Countdown[8] which used a different model called the Data Integration Model for Air Quality (DIMAQ).[11] The model used here is higher resolution and so is likely to better represent spatial distribution of $PM_{2.5}$.

The other caveats for “Indicator 3.5.1. Exposure to air pollution in cities” in Zhang et al.[5] also apply to this indicator.

Future form of indicator

Future improvements of this indicator are the same as those described for “Indicator 3.5.2 Premature mortality from ambient air pollution by sector” in Zhang et al.[5].

3.5.2 Premature mortality from ambient anthropogenic air pollution

Data

The main data sources for this indicator are the same as those used for “Indicator 3.5.2 Premature mortality from ambient air pollution by sector” in Zhang et al.[5], but instead of calculating the 2015 results we calculated the 2016 results (Table A3; Table A4).

Methods

Methods for this indicator are the same as those used for “Indicator 3.5.2 Premature mortality from ambient air pollution by sector” in Zhang et al.[5].

Caveats

Caveats for this indicator are the same as those for “Indicator 3.5.2 Premature mortality from ambient air pollution by sector” in Zhang et al.[5].

Future form of indicator

Future improvements of this indicator are the same as those described for “Indicator 3.5.2 Premature mortality from ambient air pollution by sector” in Zhang et al.[5].

3.6 Clean fuel use for transport

Data

ClimateWorks Australia. The state of electric vehicles in Australia - second report: driving momentum in electric mobility. Melbourne: ClimateWorks Australia, 2018.

Methods

Methods for this indicator are the same as those used for “Indicator 3.6 Clean fuel use for transport” in Zhang et al.[5].

Caveats

- Data only available for point 1: Share of new vehicles in a particular geography that are electric drive rather than combustion engine. Unable to find data for point 2: Share of electric drive vehicles for the light-duty fleet in a particular year.
- Exact data given is the Electric Vehicle Sales per 10,000 vehicles by State or Territory.
- Data collected is for 2018.
- Geographic area is whole state/territory, not just GCCSA (Greater Capital City Statistical Area).

Future form of indicator

As the electric vehicle fleet begins to grow, with rapidly increasing uptake predicted over the next decade, there is potential to stratify this indicator further – i.e., by examining proportions of hybrid vehicles, full electric vehicles, and vehicles using alternative fuel sources (e.g., biofuels). Other valuable data could include details of trip characteristics specific to electric vehicles (e.g., average km travelled per trip, total km per year, share of total km driven, etc.).

3.7 Sustainable travel infrastructure and uptake

Data

Household travel survey data for Australian capital cities (statistical area: Australian Bureau of Statistics GCCSA) – (i) total terrestrial passenger km travelled, (ii) km per capita, (iii & iv) total km by mode type (private, public), (v & vi) km by mode type per capita, (vii & viii) km share by mode type.

Data source: Bureau of Infrastructure, Transport and Regional Economics (BITRE), 2018, Yearbook 2018: Australian Infrastructure Statistics, Statistical Report, BITRE, Canberra ACT.

Methods

Methods for this indicator are the same as those used for "Indicator 3.7 Sustainable travel infrastructure and uptake" in Zhang et al.[5].

Caveats

- Data collected is for 2016-17.
- Geographic area is the GCCSA for each State/Territory. These differ markedly in population, area, and configuration.

Future form of indicator

This indicator could be developed to incorporate emerging modes of travel, such as ride sharing, electric vehicles and autonomous vehicles, and other innovations, such as community car shares, that blur the divide between private and public transport modes.

3.8 Health-care sector emissions

Data

This indicator is based on information from the supply chain model developed by Malik et al.[12], and updated data from the Australian Institute of Health and Welfare[13].

Methods

The methods for this indicator are described in detail under Indicator 3.9 Health-care sector emissions in Zhang et al.[5]. In particular, the indicator is based on 2016-17 expenditure data published by the Australian Institute of Health and Welfare for a range of health-care categories including public hospitals, private hospitals, public health and others.[13] These data were coupled with data on direct and indirect carbon dioxide equivalent emissions intensities from the customised input-output table constructed by Malik et al.[12] to undertake footprint calculations for quantifying the carbon footprint of Australia nationally, and across eight Australian states/territories.

Caveats

Caveats for this indicator are the same as those for Indicator 3.9 Health-care sector emissions in Zhang et al.[5].

Future form of indicator

The future form of this indicator could include a more comprehensive suite of greenhouse gases, and a detailed time-series assessment of trends in Australia's health-care sector emissions using sub-national multi-regional input-output tables.

Section 4: Finance and economics

4.1 Economic losses due to climate-related extreme events

Data

Reported data is based on figures on total insured economic losses from disaster events provided in the Historical Catastrophe Database 1967 - Present Day of the Insurance Council of Australia.[14] The database includes recorded data from the ICA on disaster events that have occurred over the last 50 years in the Australian market.

Cumulative annual insured losses arising from bushfires, cyclones, flooding, hail storms, storm flooding, tornados and other climate-related extreme events are considered. Extreme events related to earthquakes, arson, gas disruptions, etc. (that are also reported in the ICA database) have been excluded. Note that original loss values and not normalised loss values are used.

Methods

Methods for this indicator are the same as those used for "4.4. Economic losses due to climate-related extreme events" in Zhang et al.[5].

Caveats

Caveats for this indicator are the same as those for "4.4. Economic losses due to climate-related extreme events" in Zhang et al.[5].

Future form of indicator

An ideal form of this indicator would allow attribution of economic losses to events induced by climate change. However, such attribution is unlikely to be feasible (see Box 2 for further discussion of attribution). As such, it is not envisaged that this indicator will significantly alter in the future.

4.2 Investments in zero-carbon energy and energy efficiency

Data

The data for this indicator are sourced from the annual State of the Energy Market reports by the Australian Energy Regulator[15] and the Australian Energy Market Operator[16] Generation Information Page. Numbers are reported as installed capacity and not as investment in AUD. The investment is attributed to the year in which a new plant or the upgrade of an existing one became operational. Other areas of expenditure, including operation and maintenance, research and development, financing costs, mergers and acquisitions or public markets transactions, are not included.

Methods

Methods for this indicator are the same as those used for "4.1 Investments in zero-carbon energy and energy efficiency" in Zhang et al.[5].

Caveats

Caveats for this indicator are the same as those for "4.1 Investments in zero-carbon energy and energy efficiency" in Zhang et al.[5].

Future form of indicator

It is not envisaged that the form of this indicator will change over time. However, actual figures for investment into energy efficiency or small-scale photovoltaic installation for private households or companies can be added.

4.3 Investment in new coal capacity

Data

The data for this indicator are sourced from the annual State of the Energy Market reports by the Australian Energy Regulator[15] and the Australian Energy Market Operator[16] Generation Information Page. Numbers are reported as generation of MW capacity and not as investment in AUD.

Methods

Methods for this indicator are the same as those used for "4.2 Investment in coal capacity" in Zhang et al.[5].

Caveats

Caveats for this indicator are the same as those for "4.2 Investment in coal capacity" in Zhang et al.[5].

Future form of indicator

It is not envisaged that the form of this indicator will change over time.

4.4 Employment in renewable and fossil-fuel energy industries

Data

Data for this indicator are provided by the Australian Bureau of Statistics (ABS).

Data for full-time equivalent (FTE) employment in renewable energy activities are sourced from http://www.abs.gov.au/ausstats/abs@.nsf/mf/4631.0. As pointed out by the ABS, the estimates should be regarded as experimental as improvements continue to be made to the estimation methods and as new data sources continue to be identified.

FTE employment in mining operations is taken as a proxy for employment in high-carbon industries. The data for FTE employment in mining operations are sourced from https://www.abs.gov.au/ausstats/abs@.nsf/mf/8155.0.

This indicator includes the sub-categories 06 Coal mining, 07 Oil and gas extraction, 08 Metal ore mining, 09 Non-metallic mineral mining and quarrying, 10 Exploration and other mining support.

Methods

Methods for this indicator are the same as those used for "Indicator 4.5 Employment in low-carbon and high-carbon industries" in Zhang et al.[5].

Caveats

Caveats for this indicator are the same as those for "Indicator 4.5 Employment in low-carbon and high-carbon industries" in Zhang et al.[5].

Future form of indicator

An ideal future form of this indicator would track both direct and indirect employment from renewables and fossil fuel extraction industries.

4.5 Funds divested from fossil fuels

Data

The data for the first indicator are collected from 350.org and https://gofossilfree.org.au[17]. Organisations are committed to divestment if they fall into any of the following five categories:

Fossil Free: An institution or corporation that does not have any investments (direct ownership, shares, commingled mutual funds containing shares, corporate bonds) in fossil fuel companies (coal, oil, natural gas) and committed to avoid any fossil fuel investments in the future.

Full: An institution or corporation that made a binding commitment to divest (direct ownership, shares, commingled mutual funds containing shares, corporate bonds) from any fossil fuel company (coal, oil, natural gas).

Partial: An institution or corporation that made a binding commitment to divest across asset classes from some fossil fuel companies (coal, oil, natural gas), or to divest from all fossil fuel companies (coal, oil, natural gas), but only in specific asset classes (e.g., direct investments, domestic equity).

Coal and Tar Sands: An institution or corporation that made a binding commitment to divest (direct ownership, shares, commingled mutual funds containing shares, corporate bonds) from any coal and tar sands companies.

Coal only: An institution or corporation that made a binding commitment to divest (direct ownership, shares, commingled mutual funds containing shares, corporate bonds) from any coal companies.

More details on the list of organisations, including banks, pension funds, local governments, universities, and corporations are available from the following website: https://gofossilfree.org.au/

Data for the second indicator are sourced from the annual State of the Energy Market reports by the Australian Energy Regulator[15] and the Australian Energy Market Operator[16] Generation Information Page. Numbers are reported in MW of generation that have been retired, placed into cold storage or mothballed.

Methods

Methods for this indicator are the same as those used for "4.3 Funds divested from fossil fuels" in Zhang et al.[5].

Caveats

Caveats for this indicator are the same as those for "4.3 Funds divested from fossil fuels" in Zhang et al.[5].

Future form of indicator

Future forms of this indicator should report the actual value of funds divested from fossil fuels by the organisations. The ideal future form of this indicator would have two elements. The first element would track the value of institutional investments in fossil fuels assets, both in absolute terms and as a proportion of their total portfolios. This would also allow for tracking of associated funds that are moved out of fossil fuels, but are not explicitly advertised as ‘divesting’. However, such data is unlikely to be available. The second element of this indicator would more explicitly track the value of funds divested from fossil fuels by healthcare institutions.

It is not envisaged that the form of the second indicator (historical and announced withdrawals of coal- and gas-fired power plants) will change over time.

4.6 Coverage and strength of carbon pricing

Data

Data for this indicator are the same as those used for “Indicator 4.7 Coverage and strength of carbon pricing” in Zhang et al.[5].

Methods

Narrative revision and analysis from existing documentation of emissions trading schemes and equivalents at state and national level for the years 2018-2019 (including any scheme that occurred during any part of this time).

4.7 Use of carbon pricing revenues

Data

Australian Policy and Budget documents.

Methods

Analysis from existing documentation of national climate policies for the years 2018-2019 (including any scheme that occurred during any part of this time).

Future form of indicator

A transparent method to identify any government sources of revenue from emissions trading or carbon tax would still be of value.

Section 5: Public and political engagement

5.1 Media coverage of health and climate change

Data

Factiva (Dow Jones) global news database was used as we did in our 2018 report.[5] Thirteen national or regional newspapers were included as sources, including The Australian, The Sydney Morning Herald, The Australian Financial Review, The Age (Melbourne), Herald Sun (Melbourne), Sun Herald (Sydney), The Daily Telegraph (Sydney), Canberra Times, The Courier Mail (Brisbane), The West Australian (Perth), Adelaide Advertiser, Hobart Mercury, and Northern Territory News (Darwin).

Methods

The search methods for the major newspapers in Australia were the same as we did last year except adding the data from 1 January 2018 to 17 May 2019 (with an intention to capture the media engagement before the Australian Federal election).

Temporal trends were identified in coverage in thirteen selected newspaper sources across Australia and major cities on health and climate change, from 1 January 2008 through 17 May 2019. The data were collected by accessing the Factiva databases via The University of Sydney library. These newspapers were selected based on four factors considered by the *Lancet* Countdown report on health and climate change but modified with Australian contexts, including: (1) geographical diversity (covering all major cities), (2) circulation (higher circulating newspapers), (3) national and regional sources, and (4) reliable access to archives over time in Factiva.

The following keywords were used for searching in 'headline and lead paragraph' and English publications only. The narrower searching strategy would enable us to select articles that are most relevant. The keywords were based on the *Lancet* Countdown global report but with the use of search operators to include more relevant articles: AND - search for both terms; OR - search for either term; * Truncation - locate variant endings of a word; nearN - search terms on either side of this operator must appear within up to the specified number of words of each other.

> (malaria or dengue or diarrhoea or infecti* or disease or sars or measles or pneumonia or epidemic or pandemic or public health or (health near5 care) or epidemiology or health or mortality or morbidity or nutrition or illness or disease or NCD or non-communicable disease or communicable disease or air pollut* or nutrition or malnutrition or mental or disorder or stunting) AND ((climate near5 change) or global warming or temperature* or extreme weather or global environmental change or climate variability or greenhouse or low carbon or greenhouse gas emission* or renewable energy or carbon emission* or co2 emission* or climate pollut*)

An update in this year's analysis is the inclusion of Australian Broadcasting Corporation (ABC) online News and transcripts of ABC online programs. The same searching strategies and database were used.

Caveats

No online media was included in the analyses.

Future form of indicator

The indicator may include coverage in online news and social medias, e.g., Facebook, in future analysis.

5.2 Coverage of health and climate change in scientific journals

Data

Climate-related terms and their co-occurrence with health terms and studies in Australia, using a bibliometric search in Scopus databases.

Methods

Climate-related terms and their co-occurrence with health terms and Australia were searched using a bibliometric search in Scopus® (Elsevier B.V.). The search terms in Table A5, which mirrored those that were used in the *Lancet* Countdown 2018 report, plus the Australian location terms (all states, territories and major cities) were searched in the "Article title, Abstract, Keywords" field of the database, limited by year (1 January 2008 - 31 December 2018), human, journal articles and English only. Search results were screened and analysed by Scopus.

Caveats

The search terms used followed the *Lancet* Countdown 2018 report, which may exclude some relevant studies in Australia.

Future form of indicator

Review of identified individual studies could be more specific, e.g., subpopulations or adaptations, to provide more contents of the studies covered.

5.3 Engagement in health and climate change in Australian government

Data

The datasets of the Parliament of Australia public website for statements were searched (https://www.aph.gov.au/Parliamentary_Business) for records from 1 January 2008 to 17 May 2019 (the day before the Australian Federal Election). The documents search included Bills and Legislation, Chamber documents, Committee documents and inquiries.

Methods

The key search terms firstly for (a) climate change, and then searching in results with terms for (b) health, are listed below. In addition to the climate change terms used by the *Lancet* Countdown 2018 report, we added terms for extreme weather events that are significant to Australian population, including drought, flood, bushfire and heat.

(a) climate change:

“climate_change”, “global_warming”, “temperature”, “extreme_weather”, “global_environmental_change”, “climate_variability”, “greenhouse”, “low_carbon”, “ghge”, “renewable_energy”, “carbon_emission”, “co2_emission”, “climate_pollutant”, “drought”, “flood”, “bushfire”, “heat”.

(b) health:

“malaria”, “dengue”, “diarrhoea”, “infection”, “disease”, “pneumonia”, “epidemic”, “pandemic”, “public_health”, “health_care”, “epidemiology”, “healthcare”, “health”, “mortality”, “morbidity”, “nutrition”, “illness”, “infectious”, “ncd”, “non-communicable_disease”, “noncommunicable_disease”, “communicable_disease”, “air_pollution”, “nutrition”, “malnutrition”, “mental_disorder”, “mental_health”, “depression”, “suicide”.

Caveats

We have only focused on Federal Government.

Future form of indicator

Could include State parliament records to show the differences across the nation.

5.4 Engagement in health and climate change in Australian corporate sector

Data

Watts et al.[8] constructed Indicator 5.4 “Engagement in health and climate change in the corporate sector” based on an analysis of 33,631 United Nations (UN) Global Compact Communication of Progress (COP) reports that are publicly available via the UN Global Compact website (https://www.unglobalcompact.org). Our indicator focusses on the 170 organisations in Australia that are signed up for this initiative.

Methods

Methods for this indicator are similar to those used for “Indicator 5.4 Engagement in health and climate change in the corporate sector” in Watts et al.[8]. See main text for further details.

Caveats

Caveats for this indicator are similar to those for "Indicator 5.4 Engagement in health and climate change in the corporate sector" in Watts et al.[8]. We manually inspected reports to see if companies were reporting on malnutrition, communicable diseases or malaria, but given that many companies only operate within Australian boundaries, it is perhaps not surprising that many Australian companies do not report on these global health issues, especially in conjunction with global climate change. See main text for further details.

Future form of indicator

A future version of this indicator could focus on sourcing sustainability reports for a sample of Australia's ASX-listed companies, and examine the intersection between both local/regional and global health outcomes. Most of the ASX-listed companies have produced sustainability reports alongside their annual/financial reports.

Contributions: PJB and YZ Co-Chair the *MJA-Lancet* Countdown. HLB led Section 1; HB led Section 2; MKL led Section 3; ST led Section 4; and AGC led Section 5. Author contributions of indicators were as follows: PJB, 1.4, 1.6, 2.3; YZ, 5.1, 5.2, 5.3; HB, 2.1, 2.2, 2.5; HLB, 1.5; MKL, 3.1, 3.2, 3.3, 3.4, 5.4; ST, 4.1, 4.2, 4.3, 4.4, 4.5; DG, 1.1, 4.6, 4.7; YG, 1.1; ICH, 3.5, 3.5.1, 3.5.2; FHJ, 1.6; AM, 3.8; GGM, 3.5, 3.5.1, 3.5.2; LR, 5.3; and MS, 3.6, 3.7. Author contributions of text boxes were as follows: HB, 2, 3; DG, 2; DLM, 4; and SP-K, 1. PJB drafted the manuscript and all authors contributed to revising it critically for important intellectual content. All authors provided final approval of the version to be published and agreement to be accountable for all aspects of the work. PJB, YZ, NW, and AGC made substantial contributions to the overall conception and design of the work.

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Tables and Figures

Table A1. Summary of progress on Australian climate change and health impacts, exposures, and vulnerability

Indicator Number	Indicator Name	Previous Value	Current Value	Change	Progress?
1.1	Vulnerability to the heat-related risks of climate change	See Box 4			Worse
1.2	Exposure to temperature change	1.06	2.39	+125%	Much worse
1.3	Health effects of heatwaves	141.54	258.28	+82%	Much worse
1.4	Change in labour capacity	Hours lost overall: 3.3 million In service sector: 5,579 hours	Hours lost overall: 1.4 million In service sector: 15,409 hours	Hours lost overall: Down by 60% In service sector: Up by 176%	Overall improvement, but worse in service sector
1.5	Mental health	See indicator text			No improvement
1.6	Wildfire exposure	249,397	266,744	+7%	Worse

Table A2. The population weighted annual average $PM_{2.5}$ in Australian urban centres for the years 2013-2016 based on modelled data from van Donkelaar et al.[10]. Note these numbers are different to the monitor based estimates for 2013-2015 from last year's report[5] because these are population weighted averages

Urban Centre	**Population**	**$PM_{2.5}$**			
		2013	**2014**	**2015**	**2016**
Adelaide	1156671	4.4	4.9	4.5	4.5
Brisbane	2041661	6.3	6.2	6.0	6.1
Cairns	143950	6.4	6.3	6.0	5.7
Canberra	393570	2.4	2.7	2.7	2.4
Central Coast	305164	4.5	4.4	4.5	4.7
Darwin	117337	9.5	9.7	8.3	8.5
Geelong	156071	4.3	4.8	5.0	5.0
Gold Coast	537798	6.7	6.6	6.2	6.4
Hobart	176613	3.5	3.6	3.7	3.7
Melbourne	4159173	4.6	4.9	5.3	4.9
Newcastle	319216	5.3	5.0	5.1	5.3
Perth	1862772	8.0	8.2	8.4	8.1
Sunshine Coast	242279	4.5	4.5	4.1	4.5
Sydney	4286827	6.2	6.1	6.4	6.4
Toowoomba	99409	2.6	2.8	2.2	2.4
Townsville	167977	7.2	7.2	7.3	7.4
Tweed Heads	58787	3.7	3.7	3.2	3.4
Wollongong	259820	5.7	5.5	5.9	5.9

Table A3. The estimated attributable number of premature deaths due to anthropogenic $PM_{2.5}$ in Australian regions in 2016

Region	**Attributable number**	**Population (total aged over 30 years)**	**Premature deaths (per 1,000,000 population)**	**$PM_{2.5}$ (anthropogenic) population weighted mean for regions**	**$PM_{2.5}$ (all source) population weighted mean for regions**
Australian Capital Territory	1.6	234052	6.9	0.1	2.4
Greater Sydney	781.5	2912994	268.3	4.4	6.2
Rest of NSW	272.4	1707077	159.6	2.0	3.8
Greater Darwin	13.0	78620	165.7	3.5	8.4
Rest of NT	4.6	46392	99.6	2.1	7.0
Greater Brisbane	297.7	1338423	222.5	3.8	5.8
Rest of Queensland	260.8	1509302	172.8	2.6	4.6
Greater Adelaide	130.7	812921	160.8	2.1	4.4
Rest of SA	24.3	252685	96.3	1.3	3.6
Greater Hobart	14.6	140445	104.2	1.2	3.5
Rest of Tasmania	15.0	188906	79.3	0.9	3.2
Greater Melbourne	435.4	2700495	161.2	2.6	4.8
Rest of Victoria	82.8	928828	89.1	1.2	3.4
Greater Perth	443.3	1169450	379.1	6.1	8.0
Rest of WA	47.5	328400	144.8	2.9	4.8
TOTAL	2825.5	14348990			

Table A4. The level of anthropogenic $PM_{2.5}$ assumed in 2016 in Australian states and territories by taking the lowest concentration per state/territory as representative of the non-anthropogenic emissions

State/Territory	**$PM_{2.5}$ minimum**
Australian Capital Territory	2.3
New South Wales	1.8
Northern Territory	4.9
Queensland	2.0
South Australia	2.3
Tasmania	2.3
Victoria	2.2
Western Australia	1.9

Table A5. Search terms used in Scopus® (Elsevier B.V.) to find Australian health and climate change articles in scientific journals

Climate & climatic effect terms	**Health-related terms**	**Australian location terms**
Climat* chang*	Health	Australia
Global warming	Disease	Australian Capital Territory
Climate variability	Non-Communicable, NCD, Communicable	New South Wales
Greenhouse effect	Epidemiology	Northern Territory
Greenhouse gas emission*	Lifestyle	Queensland
Drought	Co-Benefits	South Australia
Bushfire	Mortality	Tasmania
Tropical cyclone	Morbidity	Victoria
Heatwave	Nutrition	Western Australia
	Malnutrition	Adelaide
	Dehydration	Brisbane
	Migration	Canberra
	Mental disorders	Darwin
		Hobart
		Melbourne
		Perth
		Sydney

Table A6. Search results of health and climate change in Parliament of Australia records, 1 January 2008 - 17 May 2019*

Document type	**Number of documents identified**
Chamber	Nil (Over 1300 bills relevant to climate change, covering carbon emission, flood/bushfire/drought recovery, and biodiversity, but not related to population health).
Bills	Nil (Over 130 bills relevant to climate change authority, greenhouse gas, ozone, carbon pollution reduction, clean energy, carbon credits, and extreme weather events, but not related to health).
Committees & Inquiries (all Committees)	Over 70 in total relevant to climate change, mainly including Inquires into the current and future impacts of climate change on houses, building and infrastructure, impacts of climate change on marine fisheries and biodiversity, and implications of climate change for Australia's national security. Only one Inquiry addressed both climate change and health: "Recent trends in and preparedness for extreme weather events. Final Report" released in 2013 – "Health impacts of extreme weather events" in Chapter 3: Cost and impacts of extreme weather events, and "The health sector" in Chapter 4: Preparing for extreme weather events.
Committees & Inquiries (Environment and Communication)	In total, 172 completed inquiries from this Committee. None of them addressed climate change and health.

* There was a Standing Committee on Climate Change, Water, Environment and the Arts from 2008 until 2014.

Figure A1. Standardised residuals for regression of annual mean maximum temperature on age-standardised suicide rates controlling for sex, for Australian states and territories, 2007-2017

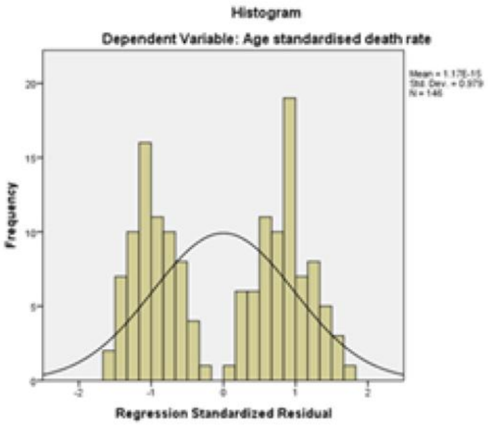


Figure A2. Relationship between mean maximum (left column) and mean minimum (right column) annual temperature and age-standardised suicide rates by sex, for baseline (2007-16), baseline plus one year (2007-17) and for latest year (2017), in Australian states and territories. Males are blue markers, females are green

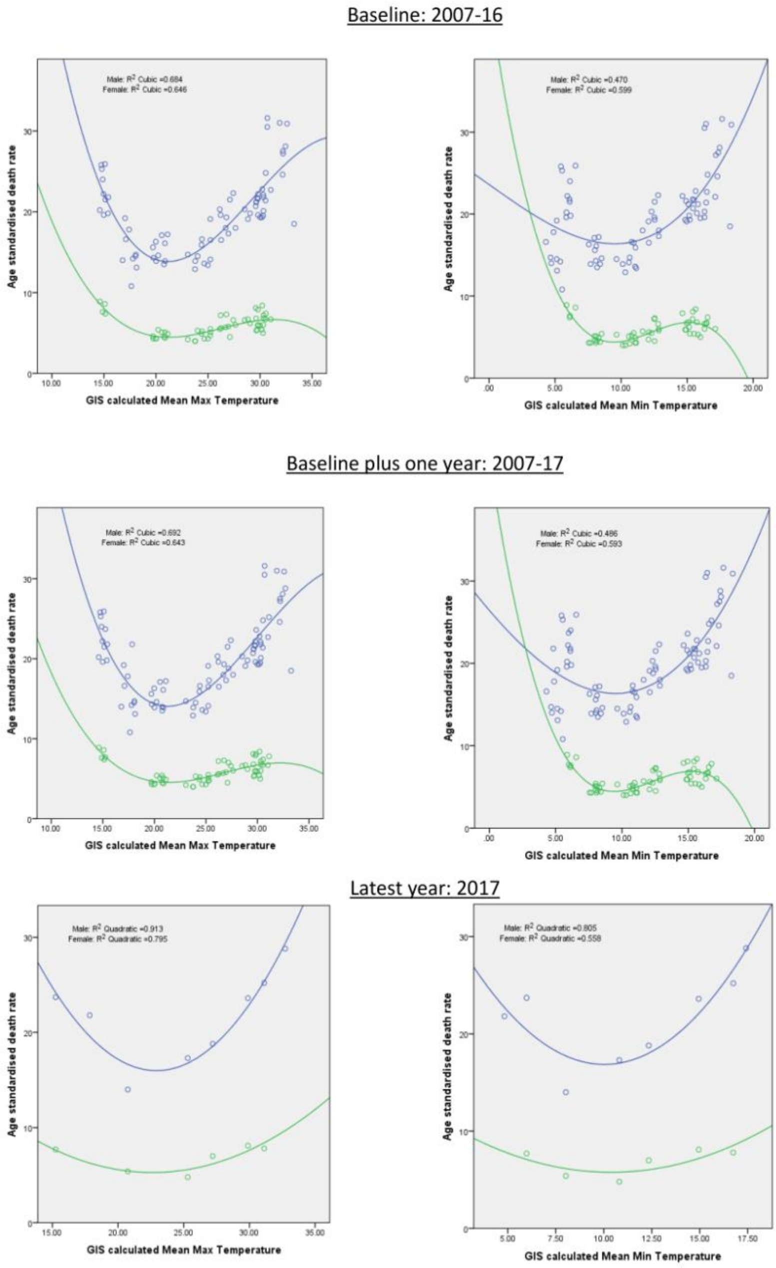
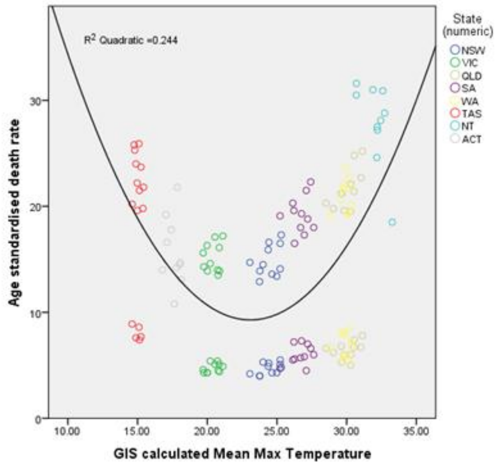


Figure A3. Relationship between mean maximum (a) and minimum (b) annual temperature and age-standardised suicide rates by Australian jurisdiction, 2007-17

(a)



(b)

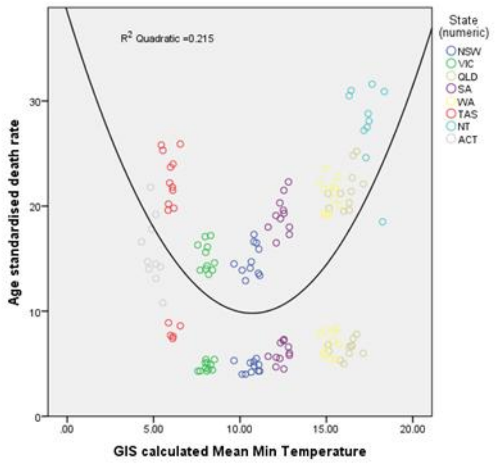


Figure A4. Australia's health-care expenditure (in current prices) from 2011-12 to 2016-17 (figure produced using data from AIHW[13]). Note that the y-axis starts at AUD100 billion

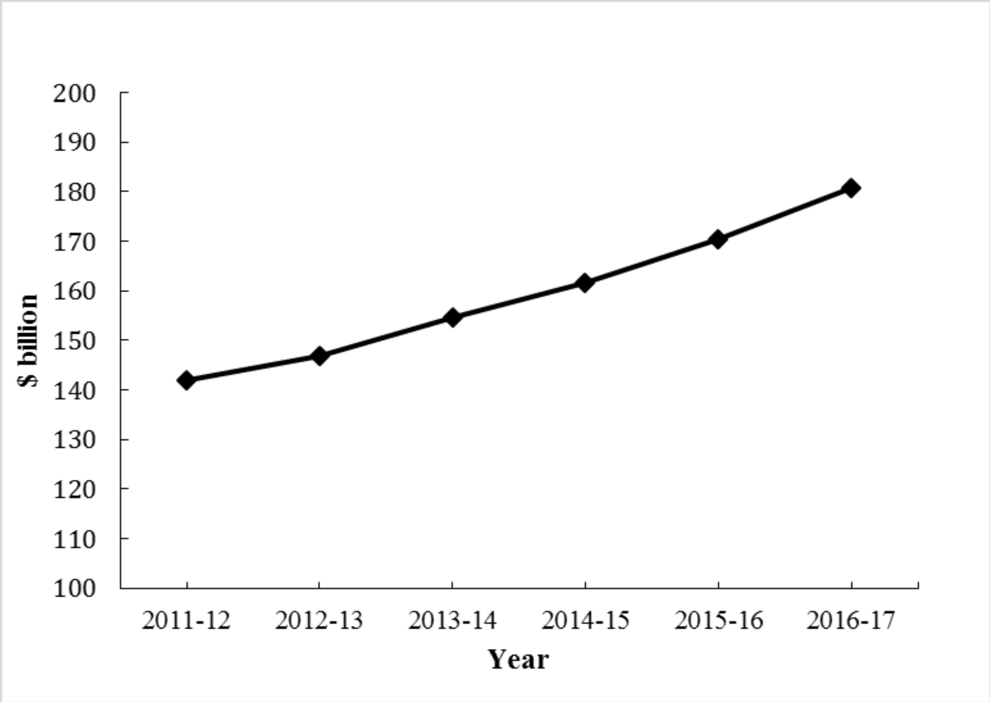


Figure A5. Number of Australian Broadcasting Corporation (ABC) online news and transcripts of online programs that cover health and climate change, 1 January 2008 – 17 May 2019

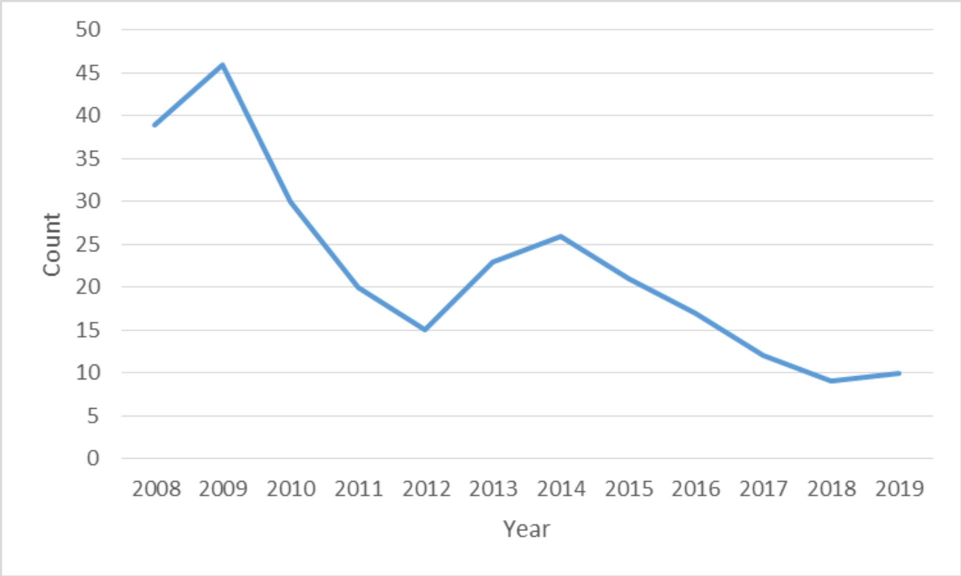


Figure A6. Number of journal articles on health and climate change in Australia by publication type, 2008-2018

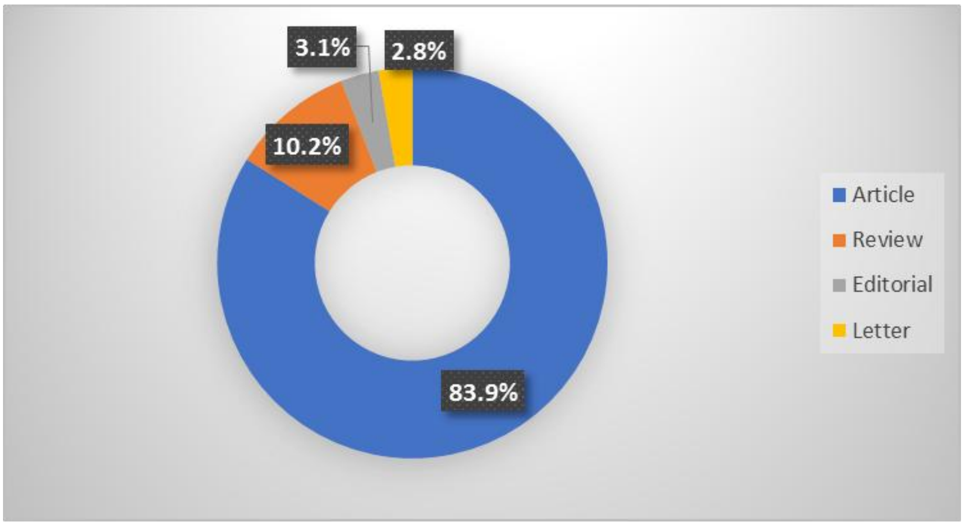


Figure A7. Number of journal articles on health and climate change in Australia by subject area, 2008-2018