Expert Report to the NSW IPC on the Greenhouse Gas and Climate Implications of the Glencore Glendell Continued Operations Coal Project (SSD 9349 and SSD 5850 Mod 4)

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1 Preliminaries

1) This expert report (hereafter, this Report) is a response to a brief provided to me by Environmental Defenders Office (hereafter, EDO) on 2 March 2022. Said brief (hereafter the EDO Brief) is annexed to this report as Appendix A.

2) As detailed in the EDO Brief, I understand that this Report has been requested by EDO on behalf of its clients Mr Scott Franks and Mr Robert Lester in relation to the proposed Glendell Continued Operations Coal Project (SSD 9349) (hereafter, the Project) by Glencore Coal Pty Limited (hereafter, Glencore).

3) In particular, my independent expert advice is sought with regard to the greenhouse gases and any climate change impacts that would arise from the Project, to be provided in this Report and verbally at the public hearing organised in the latter half of March 2022 by the Independent Planning Commission for the Project.

4) I have reviewed Division 2 of Part 31 of the *Uniform Civil Procedure Rules 2005 (UCPR),* and the Expert Witness Code of Conduct contained in Schedule 7 of the UCPR, both of which govern the use of expert evidence in NSW Courts, and I agree to be bound by them in this Report. Specifically, I understand and agree to comply with the expectation that *``An expert witness is not an advocate for a party and has a paramount duty, overriding any duty to the party to the proceedings or other person retaining the expert witness, to assist the court impartially on matters relevant to the area of expertise of the witness.''*

5) External sources used in this Report are referenced. Unless otherwise indicated, modelling work presented in these external sources is taken at face value, as verifying the results is beyond the scope of this Report. Where relevant, underlying assumptions are noted.

6) A curriculum vitae of my relevant qualifications and experience is attached as Appendix B to this report.

2 Executive Summary

7) The primary conclusions of this Report are presented below. Sections of the Report that contain more detail are listed in brackets after each main point.

8) Greenhouse gases (GHGs) emitted by human activities are responsible for essentially all of the global warming driving climate change. [Sections 3.1 and 3.3]

9) The primary anthropogenic GHGs are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Atmospheric concentrations of all these gases have risen dramatically since the 1960s at an accelerating rate. The level of CO_2, the most important GHG driving current climate change, is now higher than at any other time humans have inhabited Earth. [Section 3.1]

10) About 90% of the CO_2 emitted by humans each year is from the burning of fossil fuels: coal, gas, and oil. [Section 3.2]

11) Unabated climate change is likely to be greatest overall threat to the environment and people of New South Wales (NSW) because it is comprehensively dangerous, global, fundamental, rapid, compounding, self-reinforcing, has delayed effects and, in some cases, is irreversible. [Section 4]

12) The current level of global warming is about 1.2 degrees Celsius (°C) above pre-industrial times. For comparison, the temperature difference between ice ages and the intervening periods is about 4°C – 6°C. [Sections 4 and 5.1]

13) Some aspects of the Earth system have already changed irreversibly. Continued warming increases the risk that some subsystems of the Earth will cross `tipping points' that would cause irreversible changes. Some subsystems already show signs of approaching these transitions, which could accelerate climate change and greatly intensify its impacts, perhaps irreversibly. [Sections 4.8 and 4.9]

14) Current effects of climate change worldwide include increased severity of storms and heat waves, species extinction, wildfires, coastal inundation from rising sea levels and increased storm surge. Changes are happening rapidly, examples include: [Section 5.1]

    a) The Earth's energy imbalance was estimated in mid-2019 to be about 2 to 3 times what it was in mid-2005.

b) The past seven years have been the hottest seven years on record.

c) Over just the last two years, precipitation, heat, and wildfire records have been broken across all areas of the globe.

15) Most years in Australia are now warmer than almost any year in the 20th Century. Long-term increases in extreme fire weather and fire-season length are seen across the country. Flash droughts now happen so quickly that farmers find it difficult to adapt. Three billion individual native vertebrates perished in the Black Summer fires. Australians are five times more likely to be displaced by a climate-fuelled disaster than someone living in Europe. The cost of extreme weather disasters in Australia has more than doubled since the 1970s, reaching $35 billion for the decade 2010-2019. Australia has been rated fourth highest in the G20 for economic losses per unit of GDP incurred from extreme weather events over the last 20 years (1999-2018). [Section 5.2]

16) NSW has borne the brunt of many of these changes. For example, 37% of the State's rainforests were fire-affected during Black Summer, including over half of the Gondwana Rainforests. In some cases, local tipping points in these forests may have already been crossed. The short-term NSW health costs associated with smoke exposure alone is estimated to be $1.07 billion, more than any other State. The human and economic costs associated with the 2022 floods are yet to be fully estimated. [Sections 5.2.1 and 5.2.2]

17) The trajectory of human emissions, particularly between now and 2030, is the most important determinant of how much more climate change is in store. Already, human choices have essentially ensured that 1.5°C of warming will happen in the next two decades. If the trend of rising emissions continues, in just 80 years global warming could be 3°C – 4°C above pre-industrial temperatures. [Section 6.1]

18) Climate impacts are hitting harder and sooner than previous scientific assessments have expected. In parts of NSW, some effects of climate change are already surpassing future 2030 projections published only two years ago for medium and high emission scenarios. [Sections 6.2 and 6.4]

19) Future impacts depend on the level of warming that is reached, some of which are detailed in Table 1 below. [Sections 5 and 6]

Table 1: Consequences of Global Warming at Different Levels

Warming above the pre-industrial epoch	Some of the Impacts
1.1 – 1.2°C	***This is the current level of warming.*** 47% of local extinctions reported across the globe during last century can be attributed to climate change. Millions of people are displaced annually because of weather/climate disasters. Peak heatwaves that occurred only once per 30 years in pre-industrial times in Australia, can now be expected every 5 years. Most years in Australia are now warmer than almost any year in the 20th century. Some NSW forests are near, or have already crossed, local tipping points that would irretrievably alter those ecosystems. Agricultural areas in NSW now experience runoff reduced by 15%, on average. The frequency of very warm days in Australia has increased approximately fivefold compared to the period 1960-1989. Black Summer wildfires occur in Australia in 2019-20. Similar fires happen in California in 2020 and 2021. Temperatures reach 38°C above the Arctic Circle and 50°C in Canada. Both poles simultaneously experience heatwaves of 30 to 40°C above their normal temperatures in March 2022.
1.5°C	***This level of warming will almost certainly be reached, as early as sometime in the 2030s.*** Peak heatwaves that occurred only once per 30 years in pre-industrial times in Australia, can be expected every 2.7 years. 6% of insects, 8% of plants, and 4% of vertebrates lose over half of their climatically-determined geographic living area. What used to be Australia's hottest year on record (2019) is now an average year. NSW has 2 – 4 more heatwave days per year than it currently experiences.
2.0°C	***This level is above the Paris Agreement goal of "holding the increase in global average temperature to well below 2°C above pre-industrial levels."*** 13% of the Earth's surface undergoes complete ecosystem transformations. 99% of the world's coral reefs, including the Great Barrier Reef, are eliminated. The number of insects, plants and vertebrates losing over half of their habitat doubles compared to losses at 1.5°C.

2.0°C (cont.)	Moderate risk of large-scale singular events leading to climatic tipping points. The world's most vulnerable people experience compounding crisis upon crisis. In Australia, considerably higher risk of impacts compared to 1.5°C with regard to: a) Water stress and drought, b) Shifts in biomes in major ecosystems, including rainforests, c) Changes in ecosystems related to the production of food, d) Deteriorating air quality, e) Declines in coastal tourism, f) Loss of coral reefs, sea grass and mangroves, g) Disruption of marine food webs, loss of fin fish, and ecology of marine species, h) Heat related mortality and morbidity, and i) Ozone-related mortality. Black Summer-like weather conditions are four times more common than in 1900. Sydney and Melbourne experience summer temperatures of 50°C. NSW has 4 – 8 more heatwave days per year than it currently experiences. Agricultural areas in NSW experience runoff reduced by 30%.
3.0°C – 4.0°C	***This level of warming could be a consequence of the world continuing with its current policy settings regarding GHG emissions.*** Most of the world's ecosystems are heavily damaged or destroyed. Extreme weather events are far more severe and frequent than today. Large areas of the world become uninhabitable, causing migration and conflict. Aggregated global impacts significantly damage the entire global economy. Peak heatwaves that occurred only once per 30 years in pre-industrial times in Australia expected annually. Megafires to occur in southeast Australia irrespective of whether drought occurs simultaneously. Many locations in Australia become uninhabitable due to water shortages. Many Australian properties and businesses are uninsurable. Severe impacts to both flora and fauna cause many of Australia's ecological systems to become unrecognisable. Sea level rise transforms Australia's coastal regions, putting the health and wellbeing of many people at severe risk. NSW has one to two more heatwave weeks per year than it currently experiences. Agricultural areas in NSW experience runoff reduced by 45-60%. Moderately high risk that a cascade of tipping points in the climate system drives the Earth system into a Hothouse Earth state not seen for millions of years, irrespective of humanity's late attempts to reduce emissions.

20) The world is emitting greenhouse gases on a trend that would lead to substantially more dangerous climate change. Nations that have committed to reducing emissions by 2030 have done so on average by only 7.5%, whereas a 30% reduction (on 2010 levels) is needed to limit warming to 2°C and a 55% reduction is needed to limit warming to 1.5°C. Australia's 2030 emissions reduction target is consistent with global warming of 4°C if all other countries followed a similar level of ambition. [Sections 7.1 and 7.4.1]

21) Based on current policies as opposed to Paris Agreement pledges, warming could go as high as 3.6°C. [Section 7.1]

22) Only about 8 years remain at current emission levels before the remaining global carbon budget to hold warming to 1.5°C with at least a 67% chance is exhausted. Australia's and NSW's notional `share' of this budget would be exhausted in 3 and 4 years, respectively. [Sections 7.2 and 7.4.2]

23) In order to have even a 50% chance of holding warming to 1.5°C, 58% of oil, 59% of fossil methane gas, and 89% of coal reserves must not be extracted. Despite this, governments are still planning to produce about 45% more fossil fuels by 2030 than would be consistent with a 2°C pathway and more than double than would be consistent with a 1.5°C pathway. [Section 7.3]

24) NSW could play a major role in limiting climate change by quickly reducing its production of fossil fuels, particularly those which are exported. The emissions caused by combusting the black coal NSW produces are three times more damaging to the NSW environment than its own direct emissions. [Section 7.5.3]

25) The Project EIS used outdated values for emission factors in calculating the Project's GHG emissions. These emissions have been recalculated in this Report using appropriate, recent emission factors from NGER regulations. [Section 8.1]

26) Scope 1 and Scope 2 emissions from the Project alone would make it 11% more difficult for Australia to meet its 2030 emissions target. The Project's Scope 1 emissions would make more than 5% more difficult for NSW to meet its 2030 target. Furthermore, the Project may continue to generate emissions after closure. [Section 8.2]

27) The Project is inconsistent with holding global warming to well below 2°C. Glencore itself concedes that `the Project is consistent with the A2 SRES emissions scenario.' [Section 8.3]

28) The cumulative effect GHGs causes climate change, and climate damages and risks to the people and environment of NSW which last for decades to millennia. It is, therefore, appropriate and necessary to consider the cumulative effect of GHGs when assessing the climate impacts of the Project. [Section 8.4]

29) Depending on the path that world emissions take, global warming will likely be 1.5°C to 2.0°C in the last years of the Project's proposed lifetime. The Proponent does not appear to have considered effects of future climate on the Project itself and its workers, or subsequent consequences for the wider community. Examples are given. [Section 9.1]

30) From a scientific perspective, all emissions, including Scope 3 emissions released when fossil fuels are combusted by any end user, must be included when considering environmental and social effects, including local environmental and social effects. To do otherwise is to assume that the fuel is never used for its intended purpose. [Section 9.2]

31) The 'Social Cost of Carbon' is the value of the net damage caused to society by adding a tonne of CO_2 into the atmosphere. It is not same as a 'price on carbon' that may be introduced by government policies or prices related to emissions trading schemes or carbon 'offsets.' These are policy instruments, not assessments of climate damage. [Section 9.2]

32) The Project economic assessment presented in the EIS drastically underestimates the cost the Project GHG emissions on the people and environment of NSW. Applying a recent median scientific value for the Social Cost of Carbon to the full (all Scopes) lifetime emissions of the Project yields at least 136 billion AUD of global damages. Apportioned to NSW on the basis of fraction of world population, this translates to a median value of 144 million AUD in damages to NSW from approval of the Project due its GHG emissions. These values do not take into account all damages, and thus are underestimates. [Section 9.2]

33) The Glencore 'Observations' paper on climate and GHG litigation makes several statements that incorrectly conflate of matters of law and matters of science, and are either irrelevant, misleading or both. In particular, these apply to a misunderstanding of the carbon budget approach, various methods of accounting or 'adding up' GHG emissions, and to an assumption of GHG 'locality.' [Section 9.3]

34) The IPC is tasked with considering the impact of the Project (including GHG impacts) on the environment and people of NSW. All GHG emissions (Scopes 1, 2 and 3) that arise from the Project's approval would influence the environment and people of NSW in precisely the same way, on a tonne per tonne basis. The manner in which signatories of the Paris Agreement report GHG emissions is irrelevant in this context. [Section 9.3.1]

35) The carbon budget approach has been endorsed as a method to evaluate the expected progress of climate change as a result of GHG emissions by every country (including Australia) that participates in the UN IPCC Reports that describe the science and impacts of climate change, including the most recent AR6 reports from Working Groups I and II. Its relevance to the Project is in placing its GHG emissions in the context of the *remaining* carbon budgets required to hold global warming to 1.5°C or 2°C. [Section 9.3.2]

36) The actual effect of Project's Scope 1 emissions on the ability of NSW to meet its 2030 emissions target is 5.3% every year through 2030, more than 17 times the measure used in the Departmental Assessment. [Section 9.4]

37) If the world's remaining global 1.5°C carbon budget were to be distributed according to population, Australia would be allotted four Project-equivalent `activities' (in a GHG emissions sense) in total until net-zero emissions were reached. [Section 9.4]

38) The recommended Conditions of Approval do not address the most important component of the Project's emissions that affect the environment of NSW: Scope 3 emissions. Further, in the case of GHG emission exceedance above the conditions, they rely on offsets, which are unlikely to significantly reduce GHGs substantially or permanently. [Section 9.4.1]

39) An argument that the Project's emissions represent a small fraction of national or global emissions is irrelevant and misleading. If individual consent authorities around the world were to accept this argument and act upon it to approve fossil fuel expansion projects, the climate change predicament would, *per force*, continue to worsen. [Section 9.5]

40) The climate change externalities of the Project, which have not been fully accounted, will be borne disproportionately by younger and future generations, with no clear recourse or path to remediation. [Sections 9.4 and 9.5]

3 Causes of Anthropogenic Climate Change

41) ***Anthropogenic* climate change is change in the Earth's climate caused by *human activities* that release additional greenhouse gases (GHGs) into the atmosphere or alter the natural land and ocean sinks for these gases**. GHGs trap energy that would otherwise escape from the Earth's upper atmosphere. The additional GHGs caused by human activity create an energy imbalance that produces global warming of the Earth's surface, which drives climate change.

3.1 Increases in greenhouse gases drive global warming

42) GHGs have kept the Earth's surface at temperatures suitable for modern human civilisation and agriculture for thousands of years. Since industrialisation, however, and in particular over the last 70 years, **human activities have upset this long-standing balance, by increasing the amount of GHGs in the atmosphere. Extra energy is returned to the Earth's surface, causing the global warming that fuels changes in the global climate.**

43) The primary GHGs driving current human-caused climate change are **carbon dioxide (CO_2)**, **methane (CH_4)**, and **nitrous oxide (N_2O)**. These gases differ in their concentration in the atmosphere, residence time in the atmosphere, and potential to cause a given amount of warming per weight. Of these, **atmospheric concentration is the only property of GHGs that can be significantly influenced by humans**.

44) Excess amounts of CH_4 and N_2O persist in the atmosphere for about 12 and 109 years, respectively.[1] The life cycle of atmospheric CO_2 is more complex. **Most of the carbon dioxide that is not absorbed quickly by ocean and land 'sinks' will remain in the atmosphere for thousands of years or longer.**[2] This is the primary reason why **most long term global warming is caused by increases in the amount of CO_2 in the atmosphere**.

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[1] Forster P., T. et al. (2021) The Earth's energy budget, climate feedbacks, and climate sensitivity, Chapter & of Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Table 7.15, accessed at: https://www.ipcc.ch/report/sixth-assessment-report-working-group-i/
[2] Lee, J.Y. et al. (2021) Future Global Climate: Scenario-Based Projections and Near-Term Information, Chapter 4 of Climate Change 2021: The Physical Science Basis. Contribution of

45) Due to their different chemical properties and residency times in the atmosphere, GHGs have different global warming potentials (GWPs), that is, they differ in the amount of heat they trap over a given period of time after they are emitted. Over a 20-year period, fossil methane[3] is 82.5 times more effective than CO_2 in trapping heat, and 29.8 times more effective over 100 years. Nitrous oxide has a global warming potential about 273 times that of CO_2 on timescales of 20 to 100 years.[4]

46) Whilst GHGs remain in the atmosphere, they continue to contribute to global warming, year after year, regardless of when they were emitted. This means that **the full effect of past GHG emissions is yet to be felt**, as the Earth continues to warm under the influence of historical emissions (particularly CO_2) as well as those emitted in the current year.

47) **Atmospheric concentrations of CO_2, CH_4 and N_2O have risen since the industrial revolution, with dramatic upward increases of CO_2 beginning around 1960** (Fig. 1).[5]

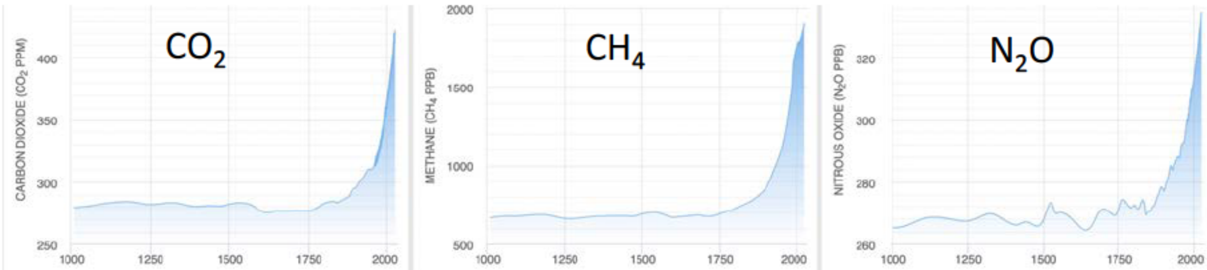

Fig. 1: The rise of GHGs in the atmosphere from 1000AD to present. Graph prepared by the Two Degree Institute, based on ice core records (CSIRO) and in situ measurements (Scripps).

48) Current levels of CO_2, CH_4 and N_2O in the atmosphere are about 147%, 256% and 123%, respectively, of their pre-industrial levels around 1750.[6]

Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, accessed at: https://www.ipcc.ch/report/sixth-assessment-report-working-group-i/

[3] Note: Fossil methane has a higher GWP than other sources of CH_4 because it results in fossil carbon added to the atmosphere, which was not previously part of the carbon cycle of the atmosphere. The GWPs for *non-fossil* CH_4 is 80.8 and 27.2 on 20 and 100-year timescales, respectively.

[4] Forster P., T. et al. (2021) The Earth's energy budget, climate feedbacks, and climate sensitivity, Chapter 7 of Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Table 7.15, accessed at: https://www.ipcc.ch/report/sixth-assessment-report-working-group-i/

[5] 2 Degrees Institute (2020) Accessed at: https://www.climatelevels.org/

[6] IPCC (2021) Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, accessed at: https://www.ipcc.ch/report/ar6/wg1/#SPM

49) **The rate at which atmospheric concentrations of the main GHGs is increasing is *itself* increasing**, as illustrated in Fig. 2 at right.[7]

50) The current level of **atmospheric CO_2 is** about 415 parts per million (ppm), **25% higher than any other time since the mid-Pliocene, about 2 million years ago,**[8] **and concentrations of CH_4 and N_2O are higher than at any time in at least 800,000 years.**[9] See Fig. 3 below.

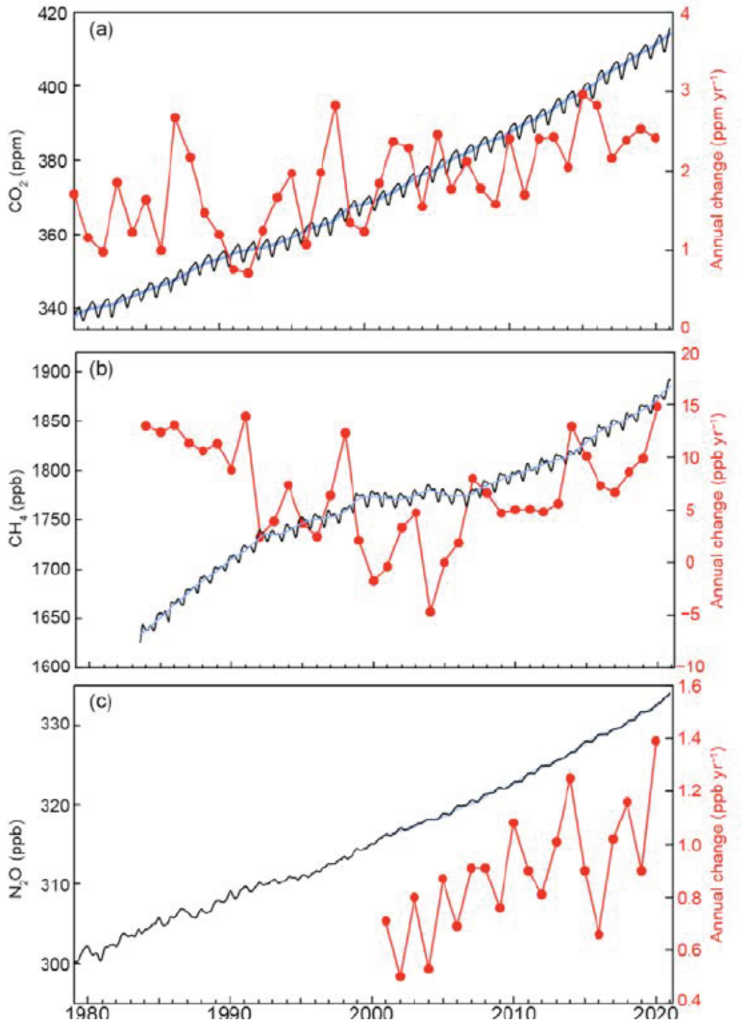

Fig.2: Dark lines: Increases in the atmospheric concentration of CO_2, CH_4 and N_2O from 1980 to 2020. Note that the vertical scales do not start at zero. Red lines: Increases in each year compared to the previous year. This figure derives from Figure 2.50 of Blunden and Boyer (2020).

[7] Blunden, J. and T. Boyer, eds. (2020) State of the Climate in 2020 in *Bull. Amer. Meteor. Soc.*, 102 (8), Si–S475, https://doi.org/10.1175/2021BAMSStateoftheClimate.1
[8] Fedorov, A.V. et al (2013) Patterns and mechanisms of early Pliocene warmth, in Nature, 496, doi:10.1038/nature12003.
[9] IPCC (2021) Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, accessed at: https://www.ipcc.ch/report/ar6/wg1/#SPM

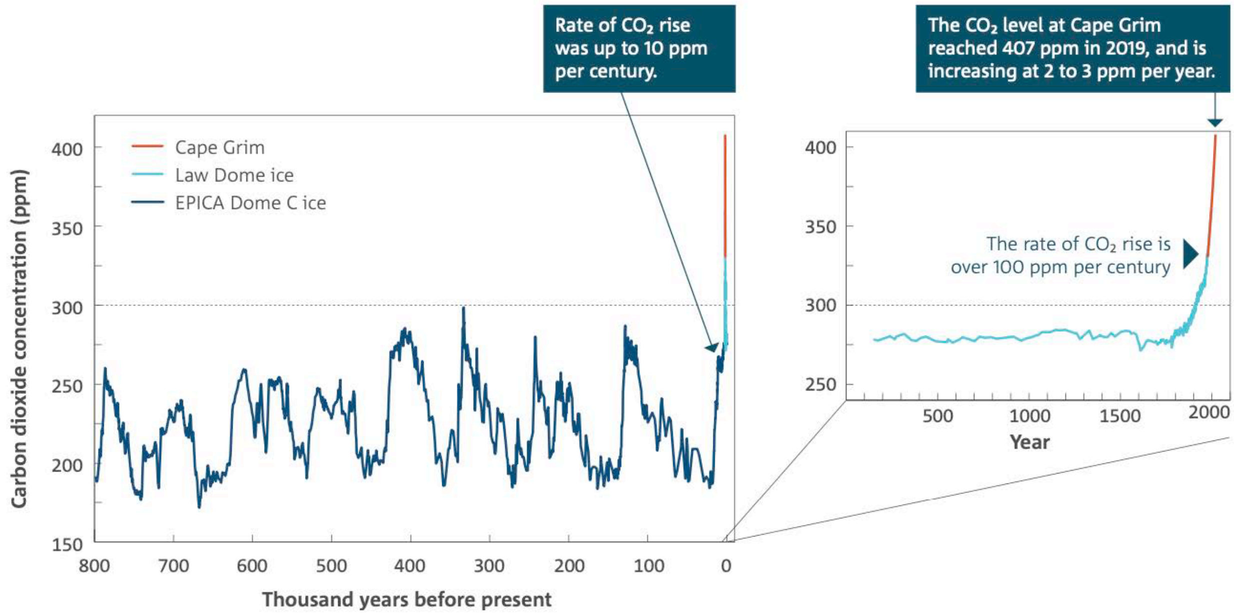

Fig. 3: Current increases in atmospheric CO_2 compared to last 800,000 years. Figure from CSIRO/BOM (2020).

51) For perspective, the species *Homo sapiens* (modern human) is thought to have arisen only 300,000 to 600,000 years ago. In other words, **carbon dioxide levels are higher now than at any other time our species has inhabited the Earth**. (See Fig. 3 above.)[10]

52) **Since 1970, the global average surface temperature has been rising at a rate** of 2.0°C per century,[11,12] **about 200 times faster than the average rate of change** of about 0.01°C per century **for the last 7,000 years**.[13]

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[10] CSIRO/BOM (2020), State of the Climate 2020, Commonwealth of Australia. http://www.bom.gov.au/state-of-the-climate

[11] NOAA (2016) State of the Climate: Global Analysis for Annual 2015. National Centers for Environmental Information, available at http://www.ncdc.noaa.gov/sotc/global/201513

[12] IPCC SR1.5 (2018) Intergovernmental Panel on Climate Change Special Report on Global Warming of 1.5°C. Accessed at: http://ipcc.ch/report/sr15/

[13] Marcott SA, Shakun JD, Clark PU, Mix A (2013) A reconstruction of regional and global temperature for the past 11,300 years. *Science* 339:1198-1201

3.2 Human greenhouse gas emissions come primarily from fossil fuels

53) **At present, about 90% of the additional CO_2 emitted per year is from the burning of coal, gas, and oil,**[14] with most of the remainder due to land use changes (e.g., deforestation which removes a natural sink for CO_2).

54) **Human CO_2 emissions from fossil fuel use continue to rise,** although at a smaller rate than in the first decade of this century.[15] (See Fig. 4.)[16]

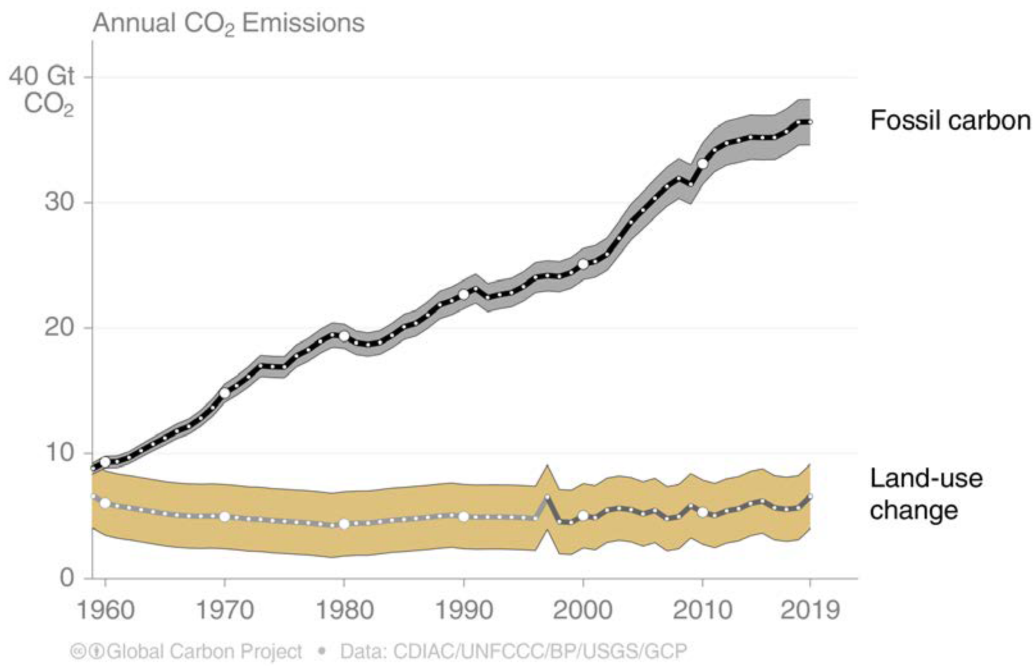

Fig. 4: Global human emissions from fossil sources continue to grow, whilst those from land-use changes (primarily deforestation) have remained relatively constant. Combined, humans emitted about 42 billion tonnes (Gt) of CO_2 into the atmosphere in 2019. Data from Friedlingstein et al (2020).

55) The growing trend in emissions continues: **year-on-year CO_2 emissions from fossil fuels are now more than 300% of 1960s levels.**[17]

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[14] Friedlingstein, P et al. (2021) Global Carbon Budget 2021, Earth Syst. Sci. Data. See their Table 6, https://essd.copernicus.org/preprints/essd-2021-386/

[15] Friedlingstein, P et al. (2020) Global Carbon Budget 2020, Earth Syst. Sci. Data, 12, 3269-3340. https://doi.org/10.5194/essd-12-3269-2020

[16] Figure is from the Global Carbon Project (2020), Accessed at : https://www.globalcarbonproject.org/carbonbudget/20/presentation.htm

[17] Friedlingstein, P et al. (2019) Global Carbon Budget 2019, Earth Syst. Sci. Data, 11, 1783–1838, See their Table 6, https://doi.org/10.5194/essd-11-1783-2019

56) The production, delivery and combustion of **fossil fuels is also associated with the release of CH_4**.[18] **A recent surge in atmospheric methane over the past decade is attributed in equal parts to agriculture (particularly livestock) and fossil fuels**.[19]

57) Restrictions imposed in response to **COVID-19** are responsible for annual human GHG emissions decreasing by about 7% in 2020,[20] a result that **will have negligible impacts in terms of climate change.**[21] It is estimated that Australian GHG emissions will be 4.5% lower in 2020 than in 2018, but will likely rebound in 2021 to the trend observed prior to 2018.[22] After the Global Financial Crisis of 2008-2009, global CO_2 emissions from fossil-fuel combustion and cement production grew 5.9% in 2010, more than offsetting the 1.4% decrease in 2009.[23]

3.3 Humans are the cause of essentially all currently observed global warming

58) **Nearly all of the warming experienced in past 160 years is due to human activities**, with natural forces (volcanos, changes in solar radiation, etc) playing a negligible role.[24]

59) According to most assessment report from Working Group I (AR6 WGI)[25] of the United Nations' Intergovernmental Panel on Climate Change (IPCC) (my emphasis):

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[18] WMO 2019, United in Science, Report prepared for the UN Climate Action Summit 2019, https://wedocs.unep.org/bitstream/handle/20.500.11822/30023/climsci.pdf

[19] Jackson, RB et al. (2020) Increasing anthropogenic methane emissions arise equally from agricultural and fossil fuel sources, Environ. Res. Lett., 15, 071002, https://doi.org/10.1088/1748-9326/ab9ed2

[20] Friedlingstein, P et al. (2020) Global Carbon Budget 2019, Earth Syst. Sci. Data, 12, 3269-3340, https://doi.org/10.5194/essd-12-3269-2020

[21] CSIRO/BOM (2020), State of the Climate 2020, Commonwealth of Australia. http://www.bom.gov.au/state-of-the-climate

[22] Sadler, H. (2021) National Energy Emissions Audit, The Australia Institute, Accessed at: https://australiainstitute.org.au/report/national-energy-emissions-audit-january-2021/

[23] Peters et al. (2012) Rapid growth in CO_2 emissions after the 2008–2009 global financial crisis, Nature Climate Change, 2, 2-4.

[24] Gillett, N.P. et al. (2021) Constraining human contributions to observed warming since the pre-industrial period, in Nature Climate Change, https://doi.org/10.1038/s41558-020-00965-9

[25] IPCC (2021) Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, accessed at: https://www.ipcc.ch/report/ar6/wg1/#SPM

a) "It is **unequivocal that human influence has warmed the atmosphere, ocean and land**" and

b) "**Human influence has warmed the climate at a rate that is unprecedented in at least the last 2000 years**" and

c) "**Observed warming is driven by emissions from human activities**, with greenhouse gas warming partly masked by aerosol cooling."

60) **Reducing net anthropogenic GHG emissions to zero and maintaining them at that level is the only way that humans can stabilise the climate. The primary determinant of future climate change, beyond that which is already locked in by emissions to date, is the future trajectory of world emissions, especially the path between now and 2030**.[26] The more quickly emissions are brought and held to zero, the lower the peak global warming temperature will be.

[26] WMO (2019) United in Science, Report prepared for the UN Climate Action Summit 2019, https://wedocs.unep.org/bitstream/handle/20.500.11822/30023/climsci.pdf

4 Why Climate Change is Different to other Threats

61) **Scientists describe the amount of global warming by comparing the average global surface temperature of the Earth now to that in pre-industrial times** (often taken to mean prior to about 1850). An enormous amount of energy (heat) is required to raise the average surface temperature of the entire Earth by even a small amount. It is this large energy increase that drives the major changes in climate being experienced now, by 'super-charging' the Earth's physical systems.

62) Consequently, **climate change impacts can be large even for rather small changes in the global surface temperature. The global average temperature difference between glacials (ice ages) and the periods in between (interglacials) is about 4 – 6°C** (Fig. 5).[27]

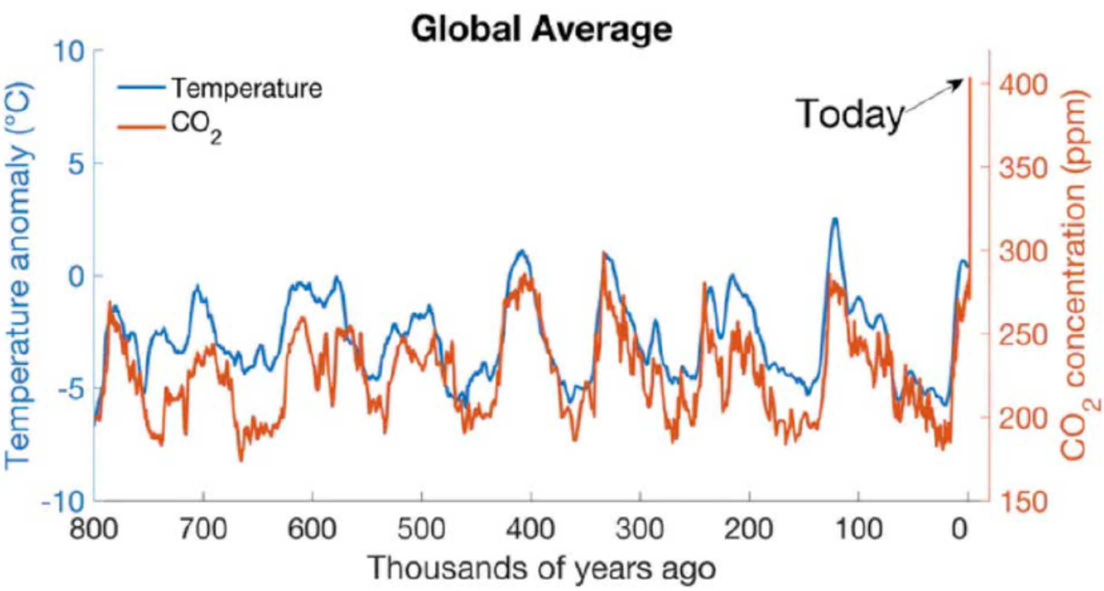

Fig. 5: Global average temperature difference (blue) and atmospheric concentration of CO_2 (orange) over the last 800,000 years. Low periods are ice ages, whilst high periods are interglacials; Only about 5°C separates the two. Plot from Henley and Abram (2017).

[27] Henley, B. and Abram, N. (2017) https://theconversation.com/the-three-minute-story-of-800-000-years-of-climate-change-with-a-sting-in-the-tail-73368, and data sources and references therein

63) Unabated climate change poses an enormous threat to the environment and peoples of the world, Australia and NSW for several reasons that, when taken together, are unique to climate change. Unabated anthropogenic climate change is:

a) **Fundamental** – affecting basic aspects of the physical Earth system, and the ecosystems that depend on it,

b) **Global** – greenhouse gases emitted anywhere in the world affect the whole globe,

c) **Comprehensively Dangerous** – with the potential to disrupt or destroy nearly every ecosystem,

d) **Rapid** – occurring at a speed that precludes many organisms and even whole ecosystems from adapting,

e) **Inertial** – with a delayed response to emissions that `locks in' some measure of climate change greater than that currently experienced,

f) **Compounding** – the effects of climate change do not occur independently, but can occur simultaneously, greatly increasing the negative consequences of extreme events,

g) **Self-reinforcing** – many elements of the Earth System react to warming by releasing greenhouse gases, further accelerating climate change (positive feedback),

h) **Irreversible** – feedbacks may cause the crossing of tipping points, with the potential to irreversibly change ecosystems and processes in the Earth system, including the possibility of cascading to an unimaginably hostile world.

4.1 Climate change is fundamental to the environment

64) Over the last million or so years, the Earth system has travelled on bounded **pathways that connect glacial periods to warmer interglacial periods.** These pathways are not identical, but cycle about every 100,000 years.[28] (See Fig. 6 below.)

[28] Steffen W et al. (2018) Trajectories of the Earth System in the Anthropocene. Proc. Natl. Acad. Sci. (USA) doi:10.1073/pnas.1810141115 and references therein https://www.pnas.org/content/pnas/115/33/8252.full.pdf

65) **The climate changes profoundly during each transition, reshaping the Earth's physical system and the life it supports.** Sea levels can change by 100 m, the fraction of the Earth's surface covered with ice dramatically changes, and different species dominate the biosphere, on land and in the ocean. Yet these **hugely different versions of Earth are separated by only 4 – 6°C of average global temperature.**

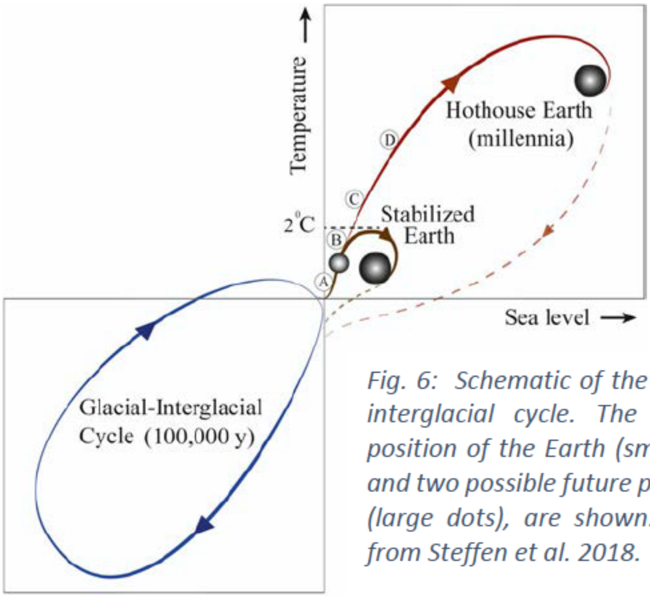

Fig. 6: Schematic of the glacial-interglacial cycle. The current position of the Earth (small dot) and two possible future positions (large dots), are shown. Figure from Steffen et al. 2018.

66) **Anthropogenic GHG emissions are now pushing the Earth System rapidly away from the glacial-interglacial cycle of stability** (see Fig. 6) **toward new, hotter climatic conditions and a profoundly different biosphere.**

4.2 Climate change is global

67) Due to the interconnectivity of the Earth's systems, **GHGs emitted anywhere are distributed throughout the atmosphere, where they contribute to the warming of the planet as a whole.** Thus, **the location, or the identity of the emitter, is of no consequence to the ultimate warming effect**. Australian emissions contribute to climate change impacts everywhere on Earth, and emissions from any location on Earth influence the effects that Australia experiences from climate change. **Humans bear collective responsibility for anthropogenic climate change.**

68) A very large number of small, individual human sources of greenhouse gases combine to form the collective global risk of climate change. **If every source of emissions that is a 'small fraction of the whole' were to be ignored, the problem would persist.**

4.3 Anthropogenic change is comprehensively dangerous

69) **Current levels of greenhouse gases are already dangerous**: ecosystems are degrading and catastrophes due to extreme weather are occurring that can be directly attributed to anthropogenic climate change. Recent IPCC reports[29,30,31] outline the comprehensive nature of the damage already being done by climate change across the whole of Earth's environmental systems, as well as that likely to occur in future if greenhouse gas emissions remain unchecked. Some of these effects are detailed in Sections 5 and 6 of this Report. **Nearly every environmental system on Earth will be affected if global warming increases to 3°C – 4°C**.

4.4 Anthropogenic climate change is rapid

70) The dramatic changes that accompany the switch from a glacial to an interglacial period occur over tens of thousands of years with total temperature changes of about 5°C. **Yet in just 200 years humans have raised the average global temperature to more than 20% of this glacial-interglacial gap**, so that the Earth is now nearing the upper envelope of interglacial conditions over the past 1.2 million years.[32]

71) The speed of this change makes it difficult, or in some cases impossible, for species and ecosystems to adapt. A study of 105,000 species found that even at 1.5°C of warming, 6% of insects, 8% of plants, and 4% of vertebrates are likely to lose over half of their climatically determined geographical area; the percentages *double* for 2°C of warming.[33]

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[29] IPCC SR1.5 (2018) Intergovernmental Panel on Climate Change Special Report on Global Warming of 1.5°C. Accessed at: http://ipcc.ch/report/sr15/

[30] IPCC (2014): Summary for policymakers. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Field et al. (eds.) Cambridge University Press, pp. 1-32.

[31] IPCC (2022) Climate Change 2022: Impacts, Adaptation and Vulnerability, Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, accessed at: https://www.ipcc.ch/report/ar6/wg2/

[32] Steffen W et al. (2018) Trajectories of the Earth System in the Anthropocene. *Proc. Natl. Acad. Sci. (USA)* doi:10.1073/pnas.1810141115 and references therein https://www.pnas.org/content/pnas/115/33/8252.full.pdf

[33] Warren, R., J. Price, E. Graham, N. Forstenhaeusler, and J. VanDerWal (2018): The projected effect on insects, vertebrates, and plants of limiting global warming to 1.5°C rather than 2°C. Science, 360(6390), 791–795, doi:10.1126/science.aar3646.

4.5 Climate change has delayed effects

72) **The full climatic effects of greenhouse gases (especially CO_2) are not felt until long after the time of emission.** This means that a few tenths of a degree of additional warming above the present 1.1°C – 1.2°C are already locked as inertia in the Earth system responds to greenhouse gases that have already emitted.[34]

73) This, together with natural variability, means that **even with rapid reductions of about 5% per year (relative to the year previous) beginning in 2021, a drop in global average temperatures may not be reliably measured until about 2050**.[35] This is an example of how global emission decisions made in the period 1990 to 2020 have a delayed effect.

74) The amount of climate change expected in the next decade is similar under all plausible global emissions scenarios. However, by the mid-21st century, higher ongoing emissions of greenhouse gases will lead to greater warming and associated impacts, while reducing emissions will lead to less warming and fewer impacts.[36] **The lag between the full effects of emissions and the global warming they cause means that what we do this year has consequences for every year hereafter into the foreseeable future**.

4.6 Climate change is compounding

75) **The effects of climate change often compound one another**, acting to amplify deleterious effects. This includes instances where **multiple destructive events or elements occur at the same time or in close succession, exacerbating one another such that the overall impact is worse than if each had occurred in isolation.**[37,38]

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[34] IPCC SR1.5 (2018) Intergovernmental Panel on Climate Change Special Report on Global Warming of 1.5°C. See their Fig. 1.5. Accessed at: http://ipcc.ch/report/sr15/

[35] Samset, BH, Fuglestvedt, JS and Lund, MT (2020) Delayed emergence of a global temperature response after emission mitigation. *Nature Communications,* 11, 3261, https://doi.org/10.1038/s41467-020-17001-1 (and references therein)

[36] CSIRO/BOM (2020) State of the Climate 2020. http://www.bom.gov.au/state-of-the-climate/

[37] Steffen, W. and Bradshaw, S. (2021) Hitting Home: The Compounding Costs of Climate Inaction, and references cited therein. Climate Council of Australia Ltd. Accessed at: https://www.climatecouncil.org.au/resources/hitting-home-compounding-costs-climate-inaction

[38] IPCC (2022) Summary for Policy Makers, in Climate Change 2022: Impacts, Adaptation and Vulnerability, Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, accessed at: https://www.ipcc.ch/report/ar6/wg2/

76) For example, tropical storms are damaging not only due to high winds, but also due to accompanying storm surge caused by rising sea levels and a warming, wetter atmosphere. This can then cause coastal erosion and flooding with different and longer lasting consequences.

77) Another example is the drivers of interannual climate variability over southeast Australia, which do not operate independently of each other. This increases the chance of compounding effects on fire risk.[39] Further, pre-existing drought conditions and heatwaves often occur simultaneously with high fire danger days. This 'triple whammy' effect has severe implications not only for the landscape and the ecosystems it supports, but also for humans working outside, on the land, and combating fires.

4.7 Climate change can be self-reinforcing

78) In some cases, the response of an Earth subsystem can enhance (or diminish) the effect of global warming itself. The physical, chemical and biological processes that cause these effects are called *feedbacks*.

79) ***Negative feedbacks* are those that act in the opposite sense of warming to restore Earth back to its original stability**. Examples include: the physics of (black body) radiation that increases the amount of outgoing radiation into space as the Earth warms, and the larger uptake of carbon by land forests and oceans as the Earth warms. Detailed climate models include these effects. Some negative feedback processes, such as the uptake of carbon by forests, are losing strength, increasing the **risk that self-reinforcing mechanisms will counter efforts to mitigate further climate change, and instead accelerate it**.[40,41]

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[39] Abram, N.J., et al. (2021) Connections of climate change and variability to large and extreme forest fires in southeast Australia, Communications Earth & Environment 2:8, https://doi.org/10.1038/s43247-020-00065-8

[40] Raupach MR, et al. (2014) The declining uptake rate of atmospheric CO2 by land and ocean sinks. Biogeosciences 11:3453–3475.

[41] WMO 2019, United in Science, Report prepared for the UN Climate Action Summit 2019, https://wedocs.unep.org/bitstream/handle/20.500.11822/30023/climsci.pdf

80) ***Positive feedbacks* are self-reinforcing mechanisms that act to enhance warming to push Earth away from its previous (cooler) stability state.** A few examples that are already underway include:[42]

   a) dieback of the Amazon and Boreal forests due to global warming, which decreases their ability to act as carbon sinks, and releases their stored CO_2 into the atmosphere,

   b) thawing of frozen permafrost soil due to warming, which releases CO_2 and/or CH_4, depending on local conditions,

   c) reduced spring snow cover in the Northern Hemisphere and loss of summer sea-ice in the Antarctic and Arctic, and long-term loss of polar ice sheets, which reduces the amount of sunlight reflected back into space, as well as allowing land ice to more easily escape to the sea, increasing sea levels.

81) The combined effect of all climate feedback processes is net positive, that is, acting to amplify the climate response.[43]

4.8 Some climate changes are irreversible

82) According to the AR6 WGI, "**Many changes due to past and future greenhouse gas emissions are irreversible for centuries to millennia, especially changes in the ocean, ice sheets and global sea level.**"[44] Specifically, the AR6 WGI lists the following:

   a) Changes in global ocean temperature (*very high confidence*), deep ocean acidification (*very high confidence*) and deoxygenation (*medium confidence*) are irreversible on centennial to millennial time scales.

   b) Mountain and polar glaciers are committed to continue melting for decades or centuries (*very high confidence*).

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[42] Steffen W et al. (2018) Trajectories of the Earth System in the Anthropocene. Proc. Natl. Acad. Sci. (USA) doi:10.1073/pnas.1810141115 and associated Appendix https://www.pnas.org/content/pnas/115/33/8252.full.pdf

[43] Arias, PA et al. (2021) Technical Summary Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, accessed at: https://www.ipcc.ch/report/ar6/wg1/#FullReport

[44] IPCC (2021) Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, accessed at: https://www.ipcc.ch/report/ar6/wg1/#SPM

c) Loss of permafrost carbon following permafrost thaw is irreversible at centennial timescales (*high confidence*).

d) It is *virtually certain* that global mean sea level will continue to rise over the 21st Century. In the longer term, sea level is committed to rise for centuries to millennia due to continuing deep ocean warming and ice sheet melt, and will remain elevated for thousands of years (*high confidence*).

83) Culminating years of work, Working Group II of the IPCC has also released its assessment report (hereafter, AR6 WGII), which among other points, indicates **these irreversible in Earth's physical systems are already having irreversible impacts on Earth's biological, environmental and human systems, with more irreversible impacts expected, depending on the amount of further global warming.** Specifically, ARC WGII states that: [45]

a) Climate change has caused substantial damages, and increasingly irreversible losses, in terrestrial, freshwater and coastal and open ocean marine ecosystems (*high confidence*).

b) The extent and magnitude of climate change impacts are larger than estimated in previous assessments (*high confidence*).

c) Widespread deterioration of ecosystem structure and function, resilience and natural adaptive capacity, as well as shifts in seasonal timing have occurred due to climate change (*high confidence*), with adverse socioeconomic consequences (*high confidence*).

d) Approximately half of the species assessed globally have shifted polewards or, on land, also to higher elevations (*very high confidence*).

e) Hundreds of local losses of species have been driven by increases in the magnitude of heat extremes (*high confidence*), as well as mass mortality events on land and in the ocean (*very high confidence*) and loss of kelp forests (*high confidence*).

[45] IPCC (2022) Summary for Policy Makers, in Climate Change 2022: Impacts, Adaptation and Vulnerability, Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, accessed at: https://www.ipcc.ch/report/ar6/wg2/

f) Some losses are already irreversible, such as the first species extinctions driven by climate change (*medium confidence*). Other impacts are approaching irreversibility, such as the impacts of hydrological changes resulting from the retreat of glaciers, or the changes in some mountain (*medium confidence*) and Arctic ecosystems driven by permafrost thaw (*high confidence*).

4.9 Crossing climate tipping points could lead to a cascade to a `Hothouse Earth'

84) The **most devastating risk of continued global warming is that some of Earth's subsystems** (e.g., Arctic sea ice, ocean circulation, the Amazon rainforest, or coral reefs, for example) **will become unstable and `tip' irreversibly into new states that accelerate the effects of climate change**. Some of these subsystems are already showing signs of becoming unstable, with 'tipping points' that could lie on our current trajectory of global warming rising to 2°C, 3°C or 4°C above pre-industrial temperatures.[46,47]

85) *Tipping points*[48] in the Earth System refer to thresholds that, if crossed, would lead to far-reaching, and in some cases, abrupt and/or irreversible changes in subsystems (called tipping elements). **The nature of tipping points is that they are irreversible on timescales associated with natural variability in the Earth System**.

86) **Recent research indicates that tipping point risks are now much higher than earlier estimates**. Over **half of previously identified**[49] **tipping elements are now 'active,'** that is, they are moving in the direction that could cause irreversible change (see Fig. 7 below).[50]

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[46] Steffen W et al. (2018) Trajectories of the Earth System in the Anthropocene. Proc. Natl. Acad. Sci. (USA) doi:10.1073/pnas.1810141115 and associated Appendix, accessed at: https://www.pnas.org/content/pnas/115/33/8252.full.pdf

[47] Lenton, T. M., Rockström, J., Gaffney, O., Rahmstorf, S., Richardson, K, Steffen, W. & Schellnhuber, H.J. (2019) Nature, vol 575, pp 592 – 595.

[48] Schellnhuber HJ, Rahmstorf S, Winkelmann R (2016) Why the right climate target was agreed in Paris. *Nature Climate Change*, 6:649-653

[49] Lenton, T.M. et al. (2008) Tipping elements in the Earth's climate system. In PNAS, 105(6), p1786-1793. Accessed from: https://www.pnas.org/content/105/6/1786

[50] Lenton, T.M. et al. (2019) Climate tipping points — too risky to bet against. Nature, 2019; 575 (7784): 592. Accessed at: https://www.nature.com/articles/d41586-019-03595-0

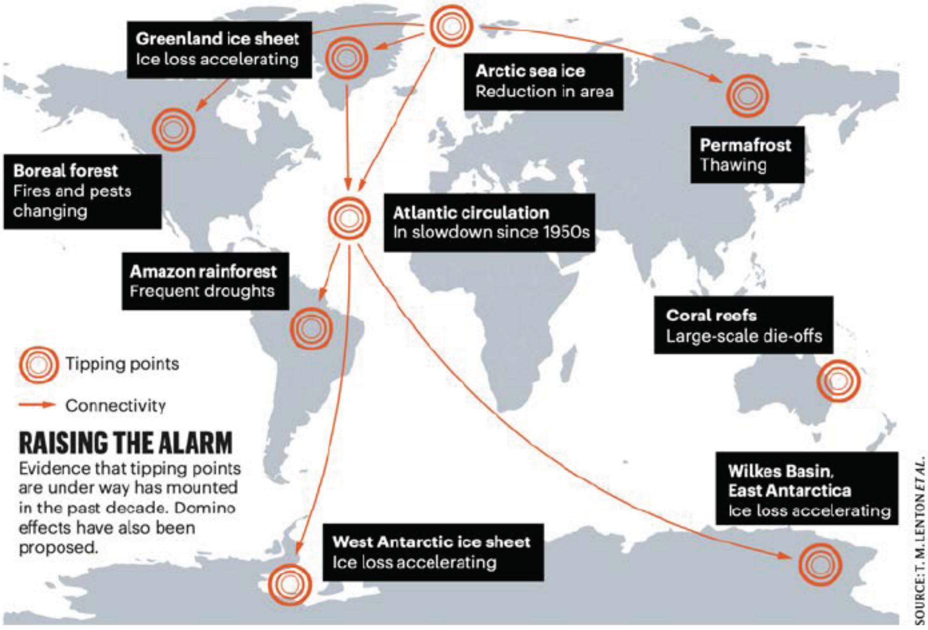

Fig. 7: Tipping elements that are currently changing, and their interactions with one another. (Figure from Lenton et al. 2019).

87) The recent AR6 WGI Report states: "**Abrupt responses and tipping points of the climate system, such as strongly increased Antarctic ice sheet melt and forest dieback, cannot be ruled out (*high confidence*).**"[51]

88) **The Amazon rainforest**, historically a substantial carbon sink, is observed to have lost resilience to changes in climate and deforestation for the past 20 years, and **may now be headed toward a tipping point of permanent dieback that would accelerate warming.**[52]

89) **Permafrost peatlands in Europe and Western Siberia are very close to a (melting) tipping point that they will soon cross unless rapid and strong action is taken to reduce GHG emissions.**[53]

90) **One of the most significant tipping elements is the Atlantic Meridional Overturning Circulation (AMOC),**[54] a complex of deep and surface currents in the Atlantic Ocean that

[51] IPCC (2021) Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, accessed at: https://www.ipcc.ch/report/ar6/wg1/#SPM

[52] Boulton, C.A., Lenton, T.M. & Boers, T. (2022) Pronounced loss of Amazon rainforest resilience since the early 2000s, in Nature Climate Change, https://doi.org/10.1038/s41558-022-01287-8

[53] Fewster, R.E. et al. (2022) Imminent loss of climate space for permafrost peatlands in Europe and Western Siberia, in Nature Climate Change, https://www.nature.com/articles/s41558-022-01296-7

[54] NB: The Gulf Stream is part of AMOC.

is responsible for considerable heat exchange between the oceans and the atmosphere. **The AMOC appears to be at its weakest point (that is, the circulation and heat exchange responses are at their slowest) in the past 1000 years**.[55]

91) **Whilst there is *medium confidence* that there will not be an abrupt AMOC collapse before 2100, if such a collapse were to occur, it would *very likely* cause abrupt shifts in regional weather patterns and water cycle**, such as a southward shift in the tropical rain belt, weakening of the African and Asian monsoons and strengthening of Southern Hemisphere monsoons, and drying in Europe.[56]

92) **Continued warming increases the risk** that crossing tipping points will cause subsystems of the Earth to rapidly collapse, one initiating another, to create **a cascade of transformations that result in what has been dubbed a 'Hothouse Earth'.** [57] In this future, **average temperatures would rise to match those not seen since the beginning of the Stone Age, millions of years ago, with devastating consequences**. If such a cascade in a domino effect were to occur, the result would be an unrecognisable landscape for current ecosystems and human civilisation.

93) It is **uncertain precisely where this 'Hothouse' threshold may lie, but it could be as close as a few decades away, that is, at or just beyond 2°C of warming.**[58]

94) On the basis of the foregoing, it is reasonable to state that unabated climate change is the greatest threat to the environment and people of NSW.

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[55] Caesar, L., et al. (2021) Current Atlantic Meridional Overturning Circulation weakest in last millennium. Nat. Geosci. 14**,** 118–120 https://doi.org/10.1038/s41561-021-00699-z

[56] IPCC (2021) Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, accessed at: https://www.ipcc.ch/report/ar6/wg1/#SPM

[57] Steffen W et al. (2018) Trajectories of the Earth System in the Anthropocene. Proc. Natl. Acad. Sci. (USA) doi:10.1073/pnas.1810141115 and associated Appendix https://www.pnas.org/content/pnas/115/33/8252.full.pdf

[58] Steffen W et al. (2018) Trajectories of the Earth System in the Anthropocene. Proc. Natl. Acad. Sci. (USA) doi:10.1073/pnas.1810141115 and associated Appendix https://www.pnas.org/content/pnas/115/33/8252.full.pdf

5 Current Impacts of Anthropogenic Climate Change

95) This section describes some of the impacts of climate change that are already occurring. Impacts that can be expected in future, depending on human GHG emissions emitted in the next decades, are discussed in Section 6.

5.1 The Global Context

96) Growing GHG concentrations in the atmosphere cause an imbalance in the amount of energy absorbed by the Earth and the amount emitted into space. This imbalance has been growing rapidly. **The Earth's energy imbalance is estimated in mid-2019 to be about 2 to 3 times what it was in mid-2005**.[59]

97) Since the 1980s, each successive decade has been warmer than any preceding decade since 1850.[60] Since 1978, no year has had a global mean temperature below the 1961–1990 average;[61] thus, **no one under the age of 44 has ever experienced a year in which global temperatures were 'below normal' by last century's standards.**

98) At the time of writing, the hottest year on record is 2020, at nearly the same temperature as 2016. Despite 2021 being slightly cooler to previous years due to the cooling effect of La Niña, it is still one of the hottest seven years on record.[62] **In fact, the past seven years have been the hottest seven years on record**.[63]

99) Global surface temperature was 1.09°C higher averaged over the period 2011–2020 than in the period 1850–1900, with larger increases over land (1.59°C) than over the ocean

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[59] Loeb, N. G., Johnson, G. C., Thorsen, T. J., Lyman, J. M., Rose, F. G., & Kato, S. (2021). Satellite and ocean data reveal marked increase in Earth's heating rate. *Geophysical Research Letters*, *48*, e2021GL093047. Accessed at: https://doi.org/10.1029/2021GL093047

[60] IPCC (2021) Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, accessed at: https://www.ipcc.ch/report/ar6/wg1/#SPM

[61] BOM (2020), Annual Climate Statement 2019, accessed at: http://www.bom.gov.au/climate/current/annual/aus/2019/

[62] WMO (2022) Press Release. https://public.wmo.int/en/media/press-release/2021-one-of-seven-warmest-years-record-wmo-consolidated-data-shows

[63] WMO (2021) State of Global Climate 2021, WMO Provisional Report, accessed at: https://library.wmo.int/index.php?lvl=notice_display&id=21982

(0.88°C).[64] Given that the rate of global warming averages about 0.2°C per decade,[65] **underlying trends in global warming place the world at about 1.2°C above pre-industrial periods in 2022**, with year-to-year fluctuations.

100) **Current effects of climate change worldwide include**:[66] **increased severity of storms and heat waves, species extinction, wildfires, coastal inundation from rising sea levels and increased storm surge, and an increasing risk of crossing so-called 'tipping points' that would accelerate climate change** and greatly intensify its impacts[67], **perhaps irreversibly.**

101) Global effects of climate change are already substantial and costly: [68,69]

a) **Accelerating sea-level rise**, with the observed global rate increasing 25% over the last decade, from 3.04 millimetres per year (mm/yr) during the period 1997–2006 to approximately 4 mm/yr in 2007–2016, driven in part by accelerating land ice melt from Greenland and West Antarctica.

b) **Heat waves,** which were **the deadliest meteorological hazard in the last five years**, affect all continents. Between 2000 and 2016, the number of people exposed to heat waves is estimated to have increased by 125 million.

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[64] IPCC (2021) Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, accessed at: https://www.ipcc.ch/report/ar6/wg1/#SPM

[65] IPCC SR1.5 (2018) Intergovernmental Panel on Climate Change Special Report on Global Warming of 1.5°C. Accessed at: http://ipcc.ch/report/sr15/

[66] IPCC (2014): Summary for policymakers. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Field et al. (eds.) Cambridge University Press, pp. 1-32.

[67] Schellnhuber HJ, Rahmstorf S, Winkelmann R (2016) Why the right climate target was agreed in Paris. *Nature Climate Change*, 6:649-653

[68] WMO (2019) United in Science, Report prepared for the UN Climate Action Summit 2019, https://wedocs.unep.org/bitstream/handle/20.500.11822/30023/climsci.pdf

[69] IPCC, SPM (2013) Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis, Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, edited by Stocker TF, et al. Cambridge and New York, Cambridge University Press, pp 3-29. https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_SPM_FINAL.pdf

c) **More extreme wildfires,** including the unprecedented wildfires in 2019 in the Arctic and in the Amazon rainforest, in 2020 and 2021 in California, in 2021 in Canada, and in 2019/20 in Australia.

d) **Hotter days and warmer nights** over most land areas. Globally, July 2019 had been listed as the hottest month on record, with July 2020 taking second place.[70] That first-place record has now been eclipsed by July 2021.[71]

e) **Intensification of the hydrological cycle**: increases in the frequency, intensity and amount of heavy precipitation in many areas, and increases in the intensity and duration of drought in other regions.

f) **Ocean acidification**, threatening sea life and destroying entire ecosystems.

g) **Increases in coastal flooding**, caused by more, and more extreme, high sea level events.

102) AR6 WGII describes the current consequences of anthropogenic climate change in clear and stark terms, stating: "**The rise in weather and climate extremes has led to some irreversible impacts as natural and human systems are pushed beyond their ability to adapt**." Specifically, according AR6 WGII[72], climate change has:

a) "caused substantial damages, and increasingly irreversible losses, in terrestrial, freshwater and coastal and open ocean marine ecosystems,"

b) "reduced food and water security,"

c) "adversely affected physical health of people globally," and

d) contributed to "humanitarian crises where climate hazards interact with high vulnerability."

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[70] NOAA (2020), July 2020 was record hot for N. Hemisphere, 2nd hottest for planet**,** https://www.noaa.gov/news/july-2020-was-record-hot-for-n-hemisphere-2nd-hottest-for-planet
[71] NOAA (2021) https://www.noaa.gov/news/its-official-july-2021-was-earths-hottest-month-on-record
[72] IPCC (2022) Summary for Policy Makers, in Climate Change 2022: Impacts, Adaptation and Vulnerability, Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, accessed at: https://www.ipcc.ch/report/ar6/wg2/

103) **In 2020 and 2021 alone** the following extraordinary climate events were recorded,[73,74,75,76] among many others:

a) In both 2020 and 2021, Death Valley in the United States of America (US) reported a temperature of 54.4°C, possibly the **highest temperature ever reliably recorded on Earth**.

b) In South America, **record fires burnt over a quarter of the Pantanal, the world's largest tropical wetlands**, in 2020.

c) **Europe had its warmest year on record**, with 17 countries reporting record average temperatures for 2020.

d) The **highest temperature**, 18.3°C, was **recorded in Antarctica in 2020**.

e) In 2021, it rained – rather than snowed – for the first time on record at the peak of the Greenland ice sheet.

f) **A heatwave in Canada** and adjacent parts of the US **pushed temperatures to 49.6°C in 2021 in a village in British Columbia, breaking the previous Canadian national record by 4.6°C**; the town was devastated by fire the next day.

g) In 2020, **Cyclone Gati**, the strongest landfalling cyclone recorded in Somalia, **brought over a year's worth of rain in 24 hours to its city of Bosaso**.

h) In 2020, **wildfires in California displaced 100,000 people from their hom**es. The area burnt in California in 2021 is larger than that burnt in 2020,[77] which itself set records for the state.

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[73] Steffen, W. and Bradshaw, S. (2021) Hitting Home: The Compounding Costs of Climate Inaction, and references cited therein. Climate Council of Australia Ltd. Accessed at: https://www.climatecouncil.org.au/resources/hitting-home-compounding-costs-climate-inaction
[74] Blunden, J. and T. Boyer, eds. (2020) State of the Climate in 2020 in *Bull. Amer. Meteor. Soc.*, 102 (8), Si–S475, https://doi.org/10.1175/2021BAMSStateoftheClimate.1
[75] WMO (2021) State of the Global Climate 2020, Accessed at: https://library.wmo.int/index.php?lvl=notice_display&id=21880#.YOwDJOgzbIV
[76] WMO (2021) State of the Global Climate 2021, WMO Provisional report. Accessed at: https://reliefweb.int/report/world/wmo-provisional-report-state-global-climate-2021
[77] https://www.fire.ca.gov/stats-events/

i) **Super Typhoon Goni was the strongest tropical cyclone to make landfall in the historical record and led to the evacuation of almost 1 million people in the Philippines.**

j) In Siberia, an intense, persistent and widespread heat wave broke temperature records, fuelled large fires, and thawed permafrost. The Russian town of Verkhoyansk recorded **a temperature of 38°C in June 2020, likely the highest temperature ever recorded in the Arctic**.

k) Extreme rainfall hit Henan Province of China in 2021. On 20 July, **the city of Zhengzhou received 201.9mm of rainfall in one hour (a Chinese national record)**, 382mm in 6 hours, and 720 mm for the event as a whole, more than its annual average.

l) The on-going megadrought in southwestern North America has been shown to be the driest 22-year period in that area in more than 1200 years.[78]

104) **The most dramatic – and previously unthinkable – heatwave ever recorded occurred in March 2022 at both of Earth's poles simultaneously. In the East Antarctic, temperatures were about 40°C warmer than average, whilst parts of the Arctic were nearly 30°C warmer than average**.[79]

5.2 Australia

105) Australia is witnessing serious climate-related impacts now. According to the recently released AR6 WGI, all areas of Australia have been assessed at high confidence to already be experiencing an increase in heat extremes due to human-caused climate change.[80]

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[78] Park Williams, A., Cook, B. I., and Smerdon, J. E. (2022) Rapid Intensification of the emerging southwestern North American megadrought in 2000-2021, in Nature Climate Change, Accessed at: https://www.nature.com/articles/s41558-022-01290-z

[79] https://www.yahoo.com/news/eastern-antarctica-registers-temperatures-70-173500030.html and sources therein.

[80] IPCC (2021) Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, accessed at: https://www.ipcc.ch/report/ar6/wg1/#SPM

106) Specifically, the Australian Bureau of Meteorology (BOM) and the CSIRO[81,82,83] report that recent climate trends include:

a) Australia has warmed by 1.44 ± 0.24°C since national recording keeping began in 1910. The seven years 2013 – 2019 all rank in the top nine warmest years on record. **Most years in Australia are now warmer than almost any year in the 20th century (2021 was an exception). Australia's hottest year and driest year on record was 2019**.

b) Increased warming, both daytime and night-time, is observed across Australia in all months, sharply increasing the number of extremely warm days. **There were 43 extremely warm days in 2019, more than triple than in any year prior to 2000**.

c) National daily average maximum temperatures have increased dramatically: **33 days exceeded 39°C in 2019, more than the number observed from 1960 to 2018 combined**, which totalled 24 days.

d) **Very warm day- and night-time temperatures** that occurred only 2% of the time in the past (1960-1989) **now occur five to six times more frequently** (2005-2019). As a result, the frequency of extreme heat events is increasing. (See Fig. 8 below.)[84]

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[81] BOM (2020), Annual Climate Statement 2020, accessed at: http://www.bom.gov.au/climate/current/annual/aus/

[82] CSIRO/BOM (2020), State of the Climate 2020, Commonwealth of Australia. http://www.bom.gov.au/state-of-the-climate

[83] CSIRO/BOM (2021), State of the Climate 2020, Commonwealth of Australia. http://www.bom.gov.au/state-of-the-climate

[84] CSIRO/BOM (2020), State of the Climate 2020, Commonwealth of Australia. http://www.bom.gov.au/state-of-the-climate

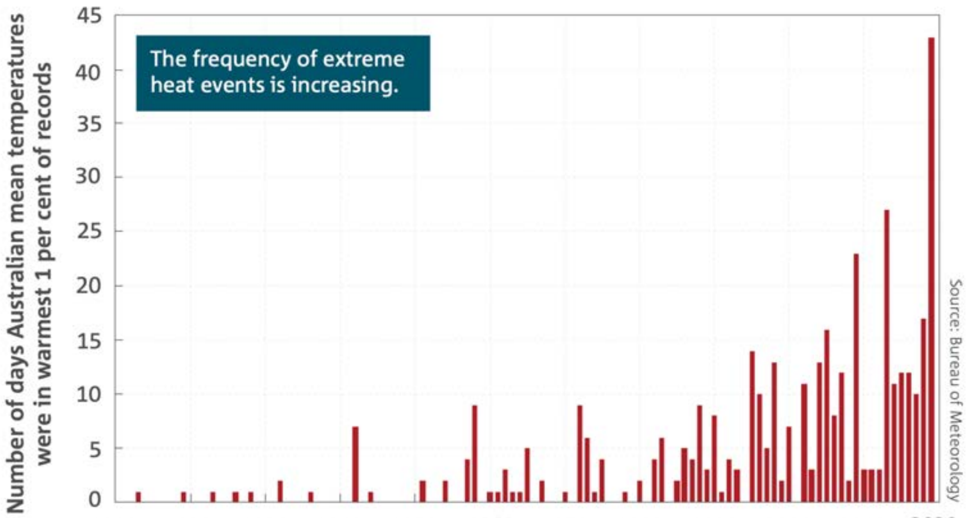

Fig. 8: Number of extreme (top 1%) heat days from 1910 to 2019. Figure from BOM.

e) In December 2019, there were 11 days for which the *national area-averaged* maximum temperature was 40 °C or above[85] (see Fig. 9 below). Only 11 other such days have been recorded since 1910, seven of which occurred in the summer of 2018–19.

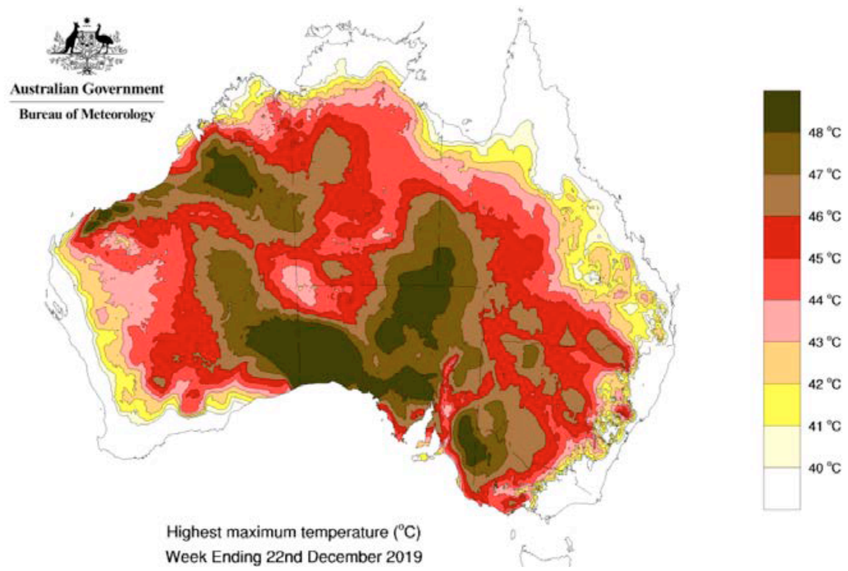

Fig. 9: Highest daily maximum temperature from 16-22 Dec 2019. Figure from BOM.

f) A long-term increase in extreme fire weather, and fire-season length, has occurred across large parts of Australia, with devastating consequences. **Much of Australia now**

[85] BOM (2019) Special Climate Statement 70b update. Accessed at: http://www.bom.gov.au/climate/current/statements/

witnesses up to 25 more days with weather conditions conducive to extreme bushfires compared to 1950-1985.[86] (See Fig. 10.)

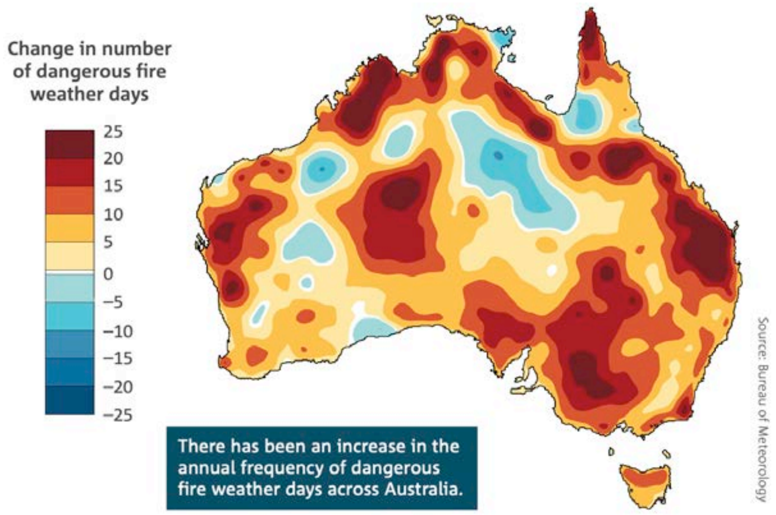

Fig. 10: Change in number of days of dangerous fire weather in 1985-2020 compared to 35 years earlier, 1950-1985.

These are days recording a Forest Fire Danger Index (FFDI) that exceeds its 90th percentile.

g) **Cool-season rainfall has declined in southeast and southwest Australia** over the past 20 years, while rainfall has increased in northern Australia. (See Fig. 11 below.)[87]

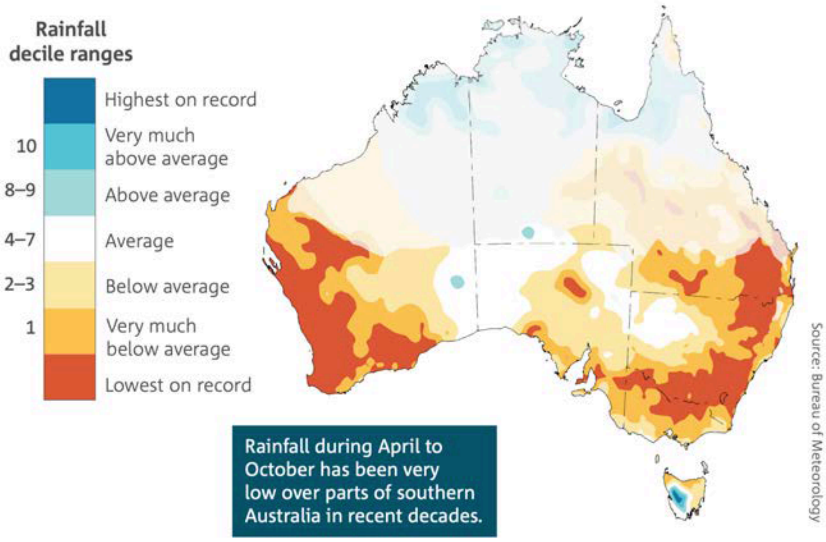

Fig. 11: April to October rainfall deciles for the last 20 years (2000 – 2019) compared to the total entire rainfall record since 1900. Figure from BOM.

h) More of the total annual rainfall in recent decades has come from heavy rain days. **Heavy rainfall events are becoming more intense**.

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[86] CSIRO/BOM (2020) State of the Climate 2020, Commonwealth of Australia. http://www.bom.gov.au/state-of-the-climate/

[87] CSIRO/BOM (2020), State of the Climate 2020, Commonwealth of Australia. http://www.bom.gov.au/state-of-the-climate

i) In part due to La Niña effects, rainfall has been above average in 2021. Major flooding occurred in multiple West Gippsland catchments after more than 200 mm of rain fell during the 24 hours in June 2021. **Daily rainfall records were set across a number of stations in Victoria and major flooding occurred in multiple catchments in 2021. It was the wettest November on record for Australia as a whole**, with flooding occurring across large areas of inland NSW and large areas of Queensland**. Now much of this has been dwarfed by the unprecedented floods in the early part of 2022.** (See subsection 5.2.2.)

j) Ocean warming, particularly around southeast Australia and in the Tasman Sea, has contributed to **longer and more frequent marine heatwaves**, depleting kelp forests and sea grasses, increasing disease and bleaching coral reefs.

k) **Increasing acidity of oceans has accelerated, to more than five times faster than that from 1900 to 1960, and 10 times faster than at any time in the past 300 million years**. The entire marine ecosystem is affected, with a **significant reduction in coral calcification and growth rates on coral reefs such as the Great Barrier Reef**. The **widespread coral bleaching of the Great Barrier Reef during 2016 was made 175 times more likely due to climate change caused by humans**.[88]

107) A new trend, called '**flash drought' is emerging in Australia**. Flash droughts occur from a very fast reduction in soil moisture, typically caused by a lack of rainfall combined with high temperatures, low humidity, and strong winds. **Flash droughts occur so quickly that adaptation by farmers is difficult**.[89]

108) The cost of extreme weather disasters in Australia has more than doubled since the 1970s, reaching $35 billion for the decade 2010-2019. **Australians are five times more likely to be displaced by a climate-fuelled disaster than someone living in Europe**.[90]

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[88] King A, Karoly D, Black M, Hoegh-Guldberg O, and Perkins-Kirkpatrick S (2016) Great Barrier Reef bleaching would be almost impossible without climate change. The Conversation, April 29, 2016.
[89] Steffen, W. and Bradshaw, S. (2021) Hitting Home: The Compounding Costs of Climate Inaction, and references cited therein. Climate Council of Australia Ltd. Accessed at: https://www.climatecouncil.org.au/resources/hitting-home-compounding-costs-climate-inaction
[90] Steffen, W. and Bradshaw, S. (2021) Hitting Home: The Compounding Costs of Climate Inaction, and references cited therein. Climate Council of Australia Ltd. Accessed at: https://www.climatecouncil.org.au/resources/hitting-home-compounding-costs-climate-inaction

109) **Australia has been rated fourth highest in the G20 for economic losses per unit of GDP incurred from extreme weather events over the last 20 years** (1999-2018).[91]

110) Changes to physical systems caused by human-induced climate change have already had detrimental effects in effects on the natural environment of Australia. AR6 WGII states: **"Climate trends and extreme events have combined with exposure and vulnerabilities to cause major impacts for many natural systems, with some experiencing or at risk of irreversible change in Australia."** [92]

111) AR6 WII continues: "The region faces an extremely challenging future. **Reducing the risks would require significant and rapid emission reductions to keep global warming to 1.5–2.0°C, as well as robust and timely adaptation. The projected warming under current global emissions reduction policies would leave many of the region's human and natural systems at very high risk and beyond adaptation limits."**

5.2.1 National Example 1: The 2019/2020 Black Summer Fires

112) **Australia is the most fire-prone continent on Earth**.[93,94] The accumulation of charcoal (fire residue) in Australia is now higher than at any other time in the last 70,000 years.[95]

113) **The Forest Fire Danger Index (FFDI) indicates the fire danger on a given day** based on daily values for temperature, humidity and wind speed, and a drought factor that represents the influence of recent temperatures and rainfall events on fuel moisture. Extremely dangerous fire weather results in high FFDI values. **An FFDI larger than 50 represents 'severe' fire risk that results in a total fire ban. Fire weather drives the chances of a fire starting, its subsequent behaviour, and the difficulty of suppressing it.**

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[91] Climate Transparency Report (2020) International Climate Transparency Partnership, accessed at: https://www.climate-transparency.org/g20-climate-performance/the-climate-transparency-report-2020

[92] IPCC (2022) Chapter 11, Australasia, in Climate Change 2022: Impacts, Adaptation and Vulnerability, Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, accessed at: https://www.ipcc.ch/report/ar6/wg2/

[93] Sharples, J. J. et al. (2016) Natural hazards in Australia: extreme bushfire. Clim. Chang. 139, 85–99

[94] Bradstock, R. A. (2010) A biogeographic model of fire regimes in Australia: current and future implications. Glob. Ecol. Biogeogr. 19, 145–158.

[95] Mooney, S. D. et al. (2011) Late Quaternary fire regimes of Australasia. Quat. Sci. Rev. 30, 28–46.

114) **In 2019, the national annual accumulated FFDI was its highest since 1950, when national records began**.[96] Accumulated FFDI reached record high values in areas of all States and Territories in Spring 2019,[97] including essentially all of NSW.

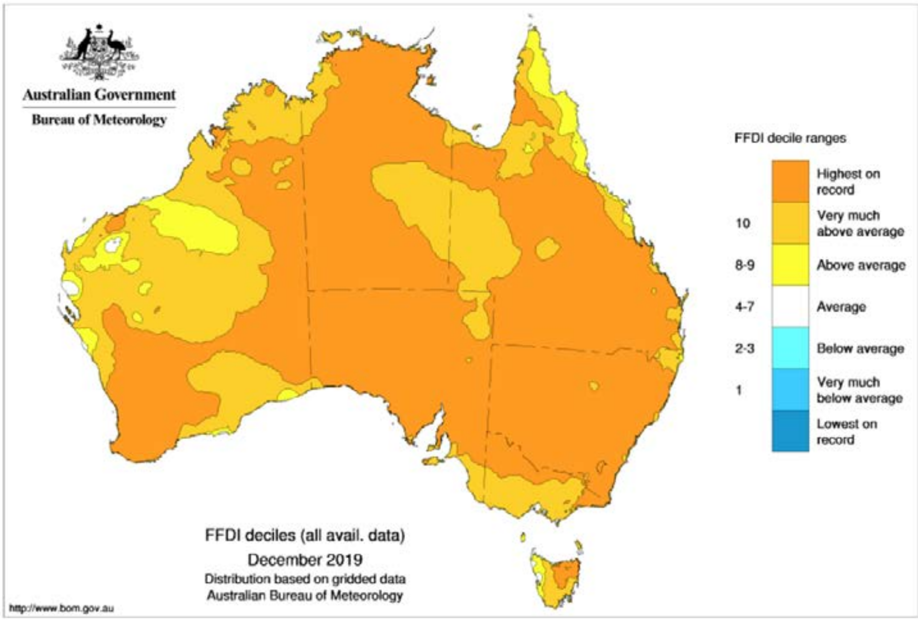

Fig. 12: FFDI deciles for December 2019, showing large areas of Australia had highest values on record for that month (dark orange colour). Figure from BOM Climate Statement 73.

115) Those dangerous fire weather conditions continued **into summer of 2019/2020, with December accumulated FFDI values the highest on record across large areas of Australia, and essentially all of NSW** (see Fig. 12 above).[98]

116) It is not surprising, therefore, that **the Australian 2019/20 bushfires were the worst on record on many measures**.[99,100]

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[96] BOM (2020) Special Climate Statement 73 update, Accessed at: http://www.bom.gov.au/climate/current/statements/
[97] BOM (2020) Special Climate Statement 73 update, Accessed at: http://www.bom.gov.au/climate/current/statements/
[98] BOM (2020) Special Climate Statement 73 update, Accessed at: http://www.bom.gov.au/climate/current/statements/
[99] Hughes, L, Steffen, W, Mullins, G, Dean, A, Weisbrot, E, and Rice, M (2020) *The Summer of Crisis.* Published by the Climate Council of Australia Ltd. Accessed at: https://www.climatecouncil.org.au/resources/summer-of-crisis/ and references cited therein.
[100] Abram, N.J., et al. (2021) Connections of climate change and variability to large and extreme forest fires in southeast Australia, Communications Earth & Environment 2:8, https://doi.org/10.1038/s43247-020-00065-8

117) **Nearly 80% of all Australians were affected directly or indirectly by the 2019-20 bushfires,**[101] **which have now come to be known as the 'Black Summer' fires.**

118) The Black Summer fires resulted in extensive social, environmental and economic impacts. The direct social impacts included the loss of 33 lives[102] and the destruction of over 3,000 houses.[103]

119) The economic costs of Black Summer go beyond the direct impact on gross domestic product (GDP). Nationally, the fire season is expected to break new records for economic costs from bushfires,[104] and **was judged to be Australia's costliest natural disaster up to 2020**.[105] It remains to be seen whether those costs will be surpassed by the 2022 floods (see Subsection 5.2.2.)

120) The tourism sector alone is likely to have lost at least $4.5 billion due to effects of the fires.[106] The Australian food system is estimated to have suffered at least $4–5 billion in economic losses due to the Black Summer fires, with only about a third of this recovered through funding for bushfire recovery. In NSW, over **600,000 hectares of pasture was burnt and nearly 90,000 linear kilometres (km) of agricultural boundary fencing damaged.** [107]

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[101] Biddle et al. (2020) Exposure and the impact on attitudes of the 2019-20 Australian Bush Fires. ANU Centre for Social Research Methods. Accessed at: https://csrm.cass.anu.edu.au/sites/default/files/docs/2020/2/Exposure_and_impact_on_attitudes_of_the_2019-20_Australian_Bushfires_publication.pdf

[102] Hughes, L, Steffen, W, Mullins, G, Dean, A, Weisbrot, E, and Rice, M (2020) *The Summer of Crisis.* Published by the Climate Council of Australia Ltd. Accessed at: https://www.climatecouncil.org.au/resources/summer-of-crisis/ and references cited therein.

[103] Filkov, A. I., Ngo, T., Matthews, S., Telfer, S. & Penman, T. D. (2020) Impact of Australia's catastrophic 2019/20 bushfire season on communities and environment. Retrospective analysis and current trends. J. Safe. Sci. Resil. 1, 44–56

[104] ANZ Research (2020) Australian bushfires: Impacting GDP. Accessed at: https://bluenotes.anz.com/posts/2020/01/anz-research-australian-bushfires-economic-impact-gdp

[105] Read, P. & Denniss, R. (2020) With costs approaching $100 billion, the fires are Australia's costliest natural disaster. Conversation. Accessed at: https:// theconversation.com/with-costs-approaching-100-billion-the-fires-are- australias-costliest-natural-disaster-129433

[106] AFR (Australian Financial Review) (2020) Tourism loses $4.5b to bush res as overseas visitors cancel. Accessed at: https://www.afr.com/companies/tourism/tourism-loses-4-5b-to-bushfires-as-overseas-visitors-cancel-20200116-p53s0s/

[107] Bishop, J., Bell, T., Huang, C. and Ward, M. (2021) Fire on the Farm: Assessing the Impacts of the 2019-2020 Bushfires on Food and Agriculture in Australia, WWF and University of Sydney. Accessed here: https://www.wwf.org.au/ArticleDocuments/353/WWF Report-Fire on the Farm_converted.pdf.aspx

121) **Indirect health impacts attributed to smoke exposure include an estimated 417 lives lost and 3,151 hospitalisations**.[108] The short-term health costs associated with this smoke exposure is estimated to be $1.95 billion Australia-wide, **with $1.07 billion attributed to NSW losses.**[109] The longer-term premature mortality and economic burden from cumulative effects of smoke exposure will be much higher, by factors estimated to be between two and five.[110]

122) Other long-term health impacts are difficult to quantify, but in the years following previous major fire events ongoing post-traumatic stress disorder and depression have been reported among fire-affected populations.[111] Furthermore, new research points to an under-recognised, potential health threat: microbes that thrive in pyrogenic carbon created by bushfires and can travel hundreds of kilometres once airborne, generating reduced airway conductance and inflammation.[112]

123) Overall, it is estimated that **three billion individual native vertebrates perished in the Black Summer fires**, comprising: 143 million mammals, 2.46 billion reptiles, 180 million birds and 51 million frogs.[113]

124) **In NSW, 37% of the state's rainforests were fire-affected during Black Summer, including over half of the Gondwana Rainforests, an Australia World Heritage Area.**[114]

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108 Borchers Arriagada, N. et al. (2020) Unprecedented smoke-related health burden associated with the 2019–20 bushfires in eastern Australia. Med. J. Aust. 213, 282–283.

109 Johnston, F.H. et al. (2021) Unprecedented health costs of smoke-related PM2.5 from the 2019-20 Australian megafires, Nature Sustainability, 4, 42-47.https://doi.org/10.1038/s41893-020-00610-5

110 Johnston, F.H. et al. (2021) Unprecedented health costs of smoke-related PM2.5 from the 2019-20 Australian megafires, Nature Sustainability, 4, 42-47, and Extended Data Fig. 3. https://doi.org/10.1038/s41893-020-00610-5

111 Bryant, R. A. et al. (2014) Psychological outcomes following the Victorian Black Saturday bushfires. Aust. N. Z. J. Psychiatry 48, 634–643.

112 Kobziar, L. & Thompson, G.R. (2020) Wildfire smoke, a potential infectious agent: Bacteria and fungi are transported in wildland fire smoke emissions , Science, 18 December 2020, 370, 6523, p 1408-1410. Accessed at: https://science.sciencemag.org/content/370/6523/1408

113 Van Eeden, L. et al. (2020) Australia's 2019-2020 Bushfires: The Wildlife Toll Interim Report, WWF Australia. Accessed from: https://www.wwf.org.au/news/news/2020/3-billion-animals-impacted-by-australia-bushfire-crisis

114 State of NSW Department of Planning Industry and Environment (2020) NSW Fire and the Environment 2019-20 Summary: Biodiversity and landscape data and analyses to understand the effects of fire events. 20pp. (NSW Government, 2020).

These ecosystems are not considered to be resilient to fire.[115,116] Even in ecological communities that are resilient to fire, such as resprouting eucalypt forests, severe drought had already stressed ecosystems ahead of the Black Summer fires.[117] Recurrent fire damage in some areas may impair the ability of ecosystems to recover.[118]

125) **Temperate broadleaf and mixed (TBLM)** forests in eastern Australia cover about 27 million hectares (Mha); **about half of that forest area lies in NSW**. **In Australia, typically less than 2% of temperate broadleaf forest areas burn annually**, even in extreme fire seasons. The average annual area burnt for most continents is well below 5%, except for Africa and Asia, which have average annual areas burnt of 8-9% for some biomes.[119]

126) Research substantiates that the **Black Summer fires burned a globally unprecedented percentage of any continental forest biome: at least 21% of the TBLM forest biome was burnt in a single season** (Fig. 13).[120]

127) Although the **forest areas lost in Black Summer could, in principle, be recovered by regrowth and replanting**, this will only **take place when the new trees reach full maturity in roughly 100 years**,[121,122] which is **longer than the time left to reach net zero emissions, for even a 2°C global warming** threshold. Moreover, it is not clear that these forests can fully recover in a climate that continues to warm and dry as a result of climate change.[123]

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[115] Bowman, D. M. J. S. (2000) Australian Rainforests: Islands of Green in a Land of Fire. (Cambridge University Press, 2000).
[116] Dr Patrick Norman (22 January 2021) as quoted in https://inqld.com.au/statewide/2021/01/22/forests-under-fire-black-summer-recovery-still-in-the-wilderness-reports-show/
[117] De Kauwe, M. G. et al. (2020) Identifying areas at risk of drought-induced tree mortality across South-Eastern Australia. Glob. Chang. Biol. 26, 5716–5733.
[118] Lindenmayer, D. B. & Taylor, C. (2020) New spatial analyses of Australian wildfires highlight the need for new fire, resource, and conservation policies. Proc. Natl Acad. Sci. USA 117, 12481.
[119] Boer MM, Resco de Dios V, & Bradstock RA (2020) Unprecedented burn area of Australian mega forest fires, Nature Climate Change.
[120] M. M. Boer, V. Resco de Dios, R. A. Bradstock, (2020) Unprecedented burn area of Australian mega forest fires. Nat. Clim. Chang. 10, 171–172. doi: 10.1038/s41558- 020-0716-1
[121] Ngugi MR, Doley D, Cant M & Botkin DB (2015) Growth rates of Eucalyptus and other Australian native tree species derived from seven decades of growth monitoring. Journal of *Forestry Research*, 26 (4) and references therein.
[122] Land for Wildlife. How to Age Trees. Accessed at: https://www.lfwseq.org.au/how-to-age-trees/
[123] Science News Magazine (2020) Will Australia's forests bounce back after devastating fires? Posted 11 February 2020. Accessed at: https://www.sciencenews.org/article/australia-forest-ecosystem-bounce-back-after-devastating-fires

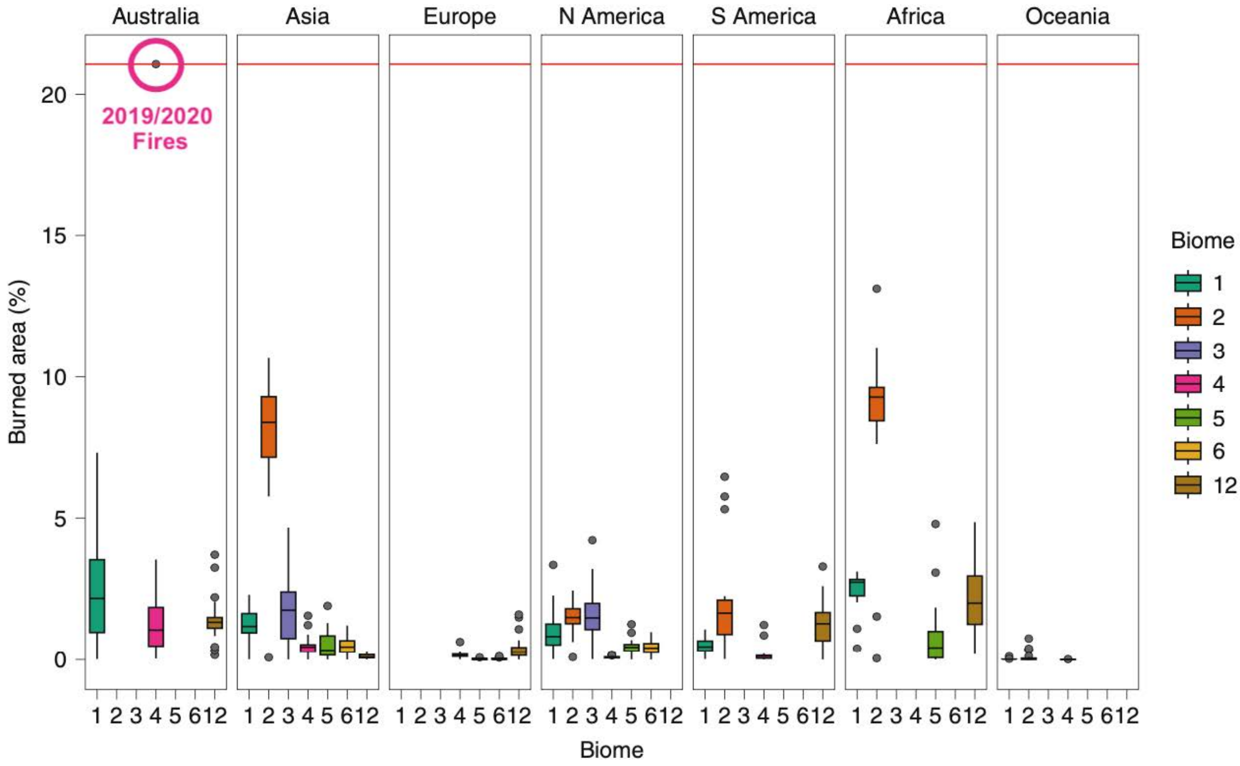

Fig. 13: Annual areas burned for different continental forest types (biomes). Boxplots show the median for each continent. The red horizontal line indicates the observed burned area of 21% for the Australian TBLM forests (biome 4, magenta) in Black Summer, far above typical forest areas burnt on any continent. Figure from Boer et al. 2020.

128) Consequently, **local tipping points in some Australian forests may have already been crossed.**[124] The future of these forests will be unlike their historical past, with a **danger that large portions may not be able to regenerate fully due to increased climate change and/or before the next catastrophic wildfire**.

129) Although unprecedented, Australia's Black Summer is consistent with previous scientific assessments dating back at least 30 years that human-caused climate warming

[124] Steffen, W. and Bradshaw, S. (2021) Hitting Home: The Compounding Costs of Climate Inaction, and references cited therein. Climate Council of Australia Ltd. Accessed at: https://www.climatecouncil.org.au/resources/hitting-home-compounding-costs-climate-inaction

will increase the duration, frequency and intensity of forest fires in southeast Australia.[125,126,127]

130) **Since the mid-twentieth century, the clear trend is towards more dangerous forest fire weather in Australia, and increasingly long fire seasons that start earlier**.[128,129,130] These trends are strengthening. **Key climate change drivers of fire risk,** particularly in southeast Australia, **are becoming stronger**.[131,132]

131) A recent study, using satellite observations with other constraints, shows that the **Black Summer** fires released 715 million tonnes (Mt) of carbon dioxide (range 517 – 867 Mt) into the atmosphere in the three months between November 2019 and January 2020.[133] This is about twice the amount of CO_2 released by Australia in 2019 from other sources.[134] Because not all of these forests are expected to obtain full regrowth before the next large scale fire, not all of this CO_2 is likely to be re-sequestered; some will

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125 Beer, T., Gill, A. M. & Moore, P. H. R. (1988) in Greenhouse: Planning for Climatic Change (ed. Pearman, G. I.) 421–427 (CSIRO Publishing)
126 Reisinger, A. et al. (2014) in Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. (eds V. R. Barros et al.) Ch. 25, 1371–1438 (Cambridge University Press, 2014).
127 Hennessy, K. et al. (2007) Australia and New Zealand in Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (eds Parry, M. L. et al.) 507–540 (Cambridge University Press, 2007).
128 Harris, S. & Lucas, C. (2019) Understanding the variability of Australian fire weather between 1973 and 2017. PLoS ONE 14, e0222328.
129 Dowdy, A. J. (2018) Climatological variability of fire weather in Australia. J. Appl. Meteorol. Climatol. 57, 221–234.
130 Abram, N.J., et al. (2021) Connections of climate change and variability to large and extreme forest fires in southeast Australia, Communications Earth & Environment 2:8, https://doi.org/10.1038/s43247-020-00065-8
131 Matthews, S., Sullivan, A. L., Watson, P., & Williams, R. J. (2012) Climate change, fuel and fire behaviour in a eucalypt forest. Global Change Biology, 18(10), 3212-3223. doi:10.1111/j.1365-2486.2012.02768.x
132 Pitman, A. J., Narisma, G. T., & McAneney, J. (2007) The impact of climate change on the risk of forest and grassland fires in Australia. Climatic Change, 84(3), 383-401. doi:10.1007/s10584-007-9243-6
133 Van der Velde, I.R. et al. (2021) Vast CO2 relrease from Australian fires in 2019-2020 constrained by satellite. Nature, 597 (7876): 366-369. doi:10.1038/s41586-021-03712-y
134 National Greenhouse Gas Inventory, maintained by the Australian Government's Department of the Industry, Science, Energy and Resources. Accessed at http://ageis.climatechange.gov.au/

permanently contribute to growing atmospheric CO_2 concentrations.[135] This is an example of how climate change can be self-reinforcing, through what is known scientifically as 'carbon feedback'.

132) **As the risk of severe bushfires grows as the climate warms, wildfire smoke may deplete the ozone layer**. By studying the effects of the Black Summer fires, research has shown[136] that large wildfires inject smoke and biomass-burning products into the mid-latitude stratosphere, where they destroy ozone, which protects us from ultraviolet radiation.

5.2.2 National Example 2: The 2022 Australian Floods

133) In three years, eastern Australia has gone from unprecedented extremes in drought, heat and bushfire, to unprecedented extremes in rainfall and flooding, sometimes in the same geographical areas. **The 2022 Australian Floods have therefore placed an additional burden, particularly in NSW and Queensland, on communities and environments not yet fully recovered climate extremes experienced just a two to three years ago**.

134) Climate change is associated with extremes in the hydrological cycle (see Sections 5.1, 5.2, 5.3, 6.2, 6.3, and 6.4). One fundamental reason for this is that a warmer atmosphere is capable of holding more water (before it precipitates out as rain or snow). According to AR6 WG1, on the global scale, extreme daily precipitation events are projected to intensify by about 7% for each 1°C of global warming (*high confidence*). Their frequency is also expected to increase, doubling with each degree of global temperature rise.[137] Increasingly extreme rainfall events and flooding due to global warming have been predicted for Australia and NSW, in particular (see e.g., paragraphs 106), 182), and 197)).

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[135] Van der Velde, I.R. et al. (2021) Vast CO2 release from Australian fires in 2019-2020 constrained by satellite. Nature, 597 (7876): 366-369. doi:10.1038/s41586-021-03712-y
[136] Bernath, P., Boone, C. & Crouse, J. (2022) Wildfire smoke destroys stratospheric ozone, in Science 375 (6586). Accessed at: https://www.science.org/doi/10.1126/science.abm5611
[137] Climate Council (2022) A Supercharged Climate: Rain Bombs, Flash Flooding and Destruction. Accessed at: https://www.climatecouncil.org.au/resources/supercharged-climate-rain-bombs-flash-flooding-destruction/

135) Although not enough time has elapsed for a scientific attribution study on this particular anomaly, **the 2022 Australia floods are entirely consistent with expectations for climate change**, with the Climate Council stating that: "*Climate change is firmly embedded in the 2022 flooding emergency that swept through southeast Queensland and New South Wales with some regions experiencing rainfall that was simply off the charts*." Examples include:[138]

a) Brisbane and southeast Queensland were hit with around 60 percent of the region's annual rainfall within three days, as a `rain bomb' lingered over the region.

b) The Wilsons River in the Northern Rivers district of New South Wales, which peaked at 14.37 metres in Lismore, broke the previous flood level record by more than 2 metres.

c) Downstream at Woodburn, the river topped 7.18 metres, nearly 50% higher than its previous record of 4.92 metres.

136) **As of 9 March 2022, at least 22 people have been reported to have died from the 2022 Australian Floods**,[139] b**ut the number of people affected are in the tens of thousands**. According to the Climate Council:[140]

a) More than 20,000 homes in Brisbane were flooded in the disaster. Preliminary assessments indicate that more than 4,200 homes were destroyed, 1,778 severely damaged and 2,430 moderately damaged.

b) On 3 March in Sydney, a total of half a million people were under evacuation orders or evacuation warnings, and over 250 schools were closed.

c) In a 24-hour period (28 Feb – 1 March 2022), rising waters led to record numbers of New South Wales SES flood rescues – over 932.

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[138] Climate Council (2022) A Supercharged Climate: Rain Bombs, Flash Flooding and Destruction. Accessed at: https://www.climatecouncil.org.au/resources/supercharged-climate-rain-bombs-flash-flooding-destruction/

[139] SkyNews (9 March 2022) Australia floods: National emergency to be declared as 'major catastrophe' claims 22 lives. Accessed at: https://news.sky.com/story/australia-floods-national-emergency-to-be-declared-as-major-catastrophe-claims-22-lives-12561501

[140] Climate Council (2022) A Supercharged Climate: Rain Bombs, Flash Flooding and Destruction, and references cited therein. Accessed at: https://www.climatecouncil.org.au/resources/supercharged-climate-rain-bombs-flash-flooding-destruction/

137) **The full human, environmental and economic damage of the 2022 Australia Floods is yet to be tallied**, but the Queensland (QLD) Treasurer indicates that provisional estimates of 2022 flood damages to QLD alone (as of 7 March 2022) stand at 2.5 billion AUD.[141]

138) Projected increases in direct flood damages are higher by 1.4 to 2 times at 2°C and 2.5 to 3.9 times at 3°C compared to 1.5°C of global warming without adaptation.[142] **This is another example large the consequences are in allowing global warming to rise to 2°C or higher.**

5.3 New South Wales and the Upper Hunter Valley

139) This section outlines some of the current effects of human-caused climate change on New South Wales (NSW) and the Upper Hunter Valley, where the proposed Project would be located, in particular.

140) Most of the **climate change impacts experienced by Australia are being felt in NSW**.[143,144,145,146] What follows are just some of the consequences for NSW over the past three years alone, which has seen a swing from record-breaking drought to record-breaking floods, with a record-breaking fire season in between:

a) **NSW had its hottest and driest year in 2019, with a mean temperature 1.95°C above average and 0.27°C warmer than the previous warmest year, 2018**. Days were

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[141] 7News (7 March 2022) Queensland flood damage bill set to top $2.5 billion, according to early estimates. Accessed at: https://7news.com.au/news/qld/queensland-flood-damage-bill-set-to-top-25-billion-according-to-early-estimates-c-5957460

[142] IPCC (2022) Summary for Policymakers, in Climate Change 2022: Impacts, Adaptation and Vulnerability, Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, accessed at: https://www.ipcc.ch/report/ar6/wg2/

[143] BOM (2019), Annual Climate Statement 2019, NSW, accessed at: http://www.bom.gov.au/climate/current/annual/nsw/archive/2019.summary.shtml

[144] BOM (2020), Annual Climate Statement 2020, NSW, accessed at: http://www.bom.gov.au/climate/current/annual/nsw/archive/2020.summary.shtml

[145] BOM (2020) Special Climate Statement 73 update, Accessed at: http://www.bom.gov.au/climate/current/statements/

[146] BOM (2021) Annual Climate Statement 2021, NSW, accessed at: http://www.bom.gov.au/climate/current/annual/nsw/archive/2021.summary.shtml

especially warm in 2019, with the NSW mean maximum temperature at a record high of 2.44°C above average.

b) **Penrith Lakes recorded 48.9°C on 4 January 2020, the highest temperature ever recorded in the Sydney basin**. Many sites in metropolitan Sydney exceeded 47°C. Such temperatures are dangerously hot, and place extreme thermal stress on humans and the environment. Fig. 14 shows how **extreme and widespread high temperatures** have been **in NSW over the past 20 years**.

c) NSW not only experienced extreme heat in December 2019 and January 2020, but also increased bushfire activity and poor air quality in Sydney. **NSW had its highest accumulated FFDI for December in 2019**. FFDI records date back to 1950. The extreme heat, drought and high FFDI conditions set the scene for the Black Summer Fires. (See subsection 5.2.1).

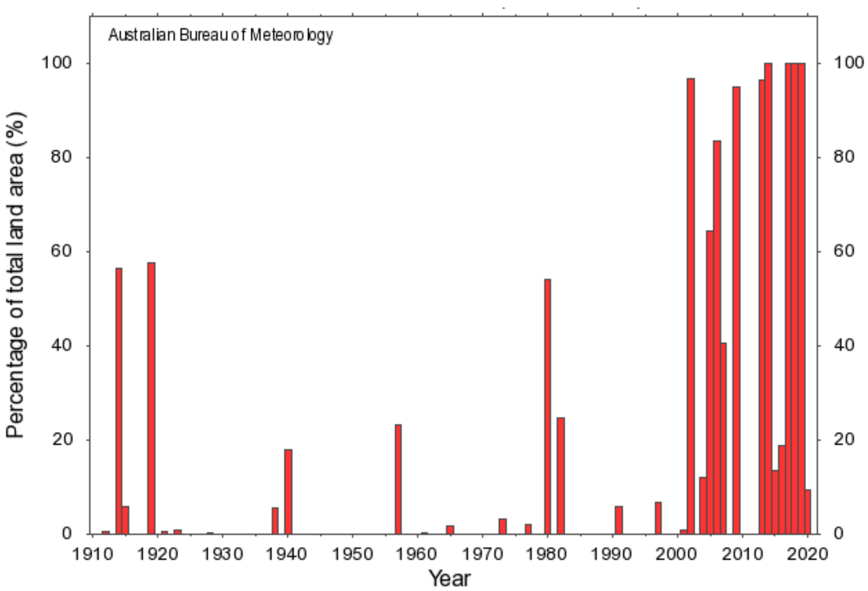

Fig. 14: The percentage of NSW area (from 0 to 100%) that experienced a maximum annual temperature in the top 10% of all records. These data from BOM cover years 1910 through 2021.

d) **Total rainfall for NSW was the lowest on record in 2019 at 55% below average; well below the previous driest year of 1944**. This **record low rainfall included most of the Upper Hunter Region.**

e) The **unprecedented conditions of inland NSW in mid-2019 correspond to what meteorologists are now calling a 'flash drought',** conditions that were similar to those along the east coast in the months bridging 2017 and 2018.[147]

f) **Switching abruptly from record low rainfall in 2019 to heavy rain records in 2020**, many **NSW sites experienced their highest annual rainfall on record or their highest for at least 20 years**. In early 2020, coastal regions had especially heavy rain, when many sites had their highest daily rainfall on record.

g) Assisted by La Niña conditions, **heavy rainfall continued into 2021**, as coastal NSW, including Sydney, experienced multiple days of heavy rainfall. **The week ending 24 March 2021 was the wettest week for the region since national daily records began in 1900**.[148]

h) While **the March 2021 rainfall** allowed some recovery of groundwater levels in the northern Murray-Darling Basin, it **came at the expense of flooding, and was followed by more flooding in November 2021, which was NSW's wettest November on record. Some areas experienced their worst flooding in 30 years**. **Muswellbrook, just 24 km to the northwest of the proposed Project, broke its annual rainfall record,** previously set in 1988.[149] **It remains to be seen how many NSW rainfall and flood records will fall in 2022** (see subsection 5.2.2).

141) Over the past 30 years **the Hunter region, in which the Project would be located**, has experienced less rainfall in most months and an increase in hot days.[150] In Fig. 15, I have graphed the number of days over 38°C and over 40°C for Lostock Dam, a weather station about 40 kilometres (km) from the proposed Project site with a relatively long recording

[147] Steffen, W. and Bradshaw, S. (2021) Hitting Home: The Compounding Costs of Climate Inaction, and references cited therein. Climate Council of Australia Ltd. Accessed at: https://www.climatecouncil.org.au/resources/hitting-home-compounding-costs-climate-inaction
[148] BOM (2021) Special Climate Statement 74, Accessed at: http://www.bom.gov.au/climate/current/statements/
[149] BOM (2021) Annual Climate Statement 2021, NSW, accessed at: http://www.bom.gov.au/climate/current/annual/nsw/archive/2021.sumary.shtml
[150] BOM and CSIRO (2019) Hunter NSW Weather and Climate Guide, accessed at: http://www.bom.gov.au/climate/climate-guides/

period. The **sharp rise in extremely hot days** over the second half of the 50-year period is evident.

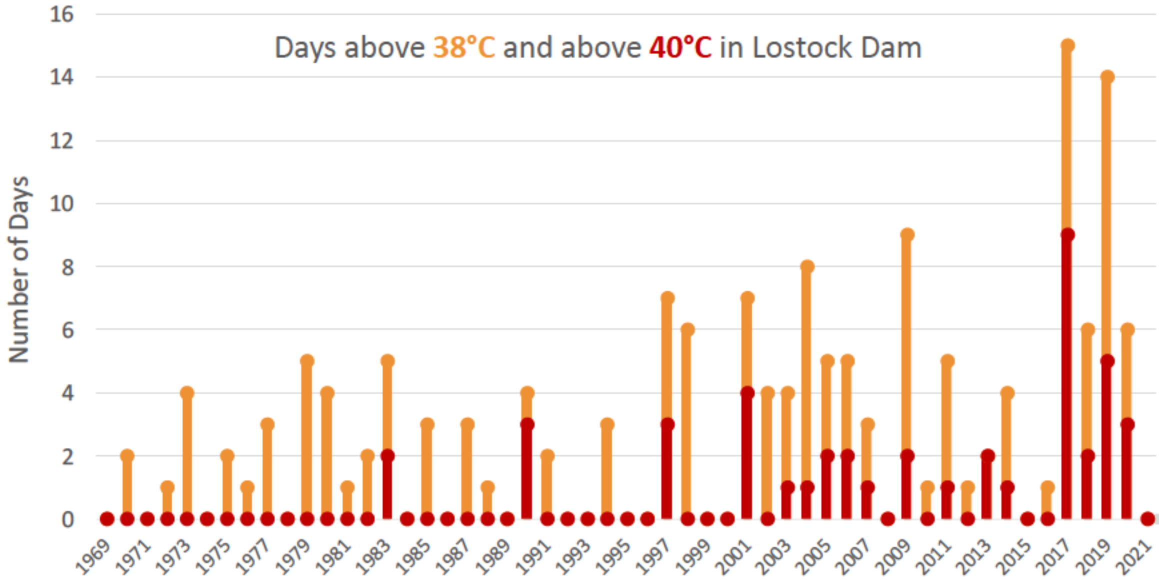

Fig. 15: The number of days each year above 38°C (orange) and 40°C (red) registered at the Lostock Dam weather station from 1969 to 2021. The trend of increasing extreme heat days due to climate change is evident. Data are from BoM.

142) **Temperatures of 38°C or more – above the internal core body temperature of humans – are particularly dangerous for human health.** The chart of 'heat index' (or 'apparent temperature') shown in Fig. 16 shows that the index rises sharply as air temperature and relative humidity climb, as does the danger to human health, as indicated by the colour coding and the associated text.[151]

[151]Figure after that published by the US National Weather Service, NOAA, What is the heat index? Accessed at: https://www.weather.gov/ama/heatindex

Temperature (°C)

Relative Humidity (%)	26.7	27.8	28.9	30.0	31.1	32.2	33.3	34.4	35.6	36.7	37.8	38.9	40.0	41.1	42.2	43.3
40	26.7	27.2	28.3	29.4	31.1	32.8	34.4	36.1	38.3	40.6	42.8	45.6	48.3	51.1	54.4	57.8
45	26.7	27.8	28.9	30.6	31.7	33.9	35.6	37.8	40.0	42.8	45.6	48.3	51.1	54.4	58.3	
50	27.2	28.3	29.4	31.1	32.8	35.0	37.2	39.4	42.2	45.0	47.8	51.1	55.0	58.3		
55	27.2	28.9	30.0	31.7	33.9	36.1	38.3	41.1	44.4	47.2	51.1	54.4	58.3			
60	27.8	28.9	31.1	32.8	35.0	37.8	40.6	43.3	46.7	50.6	54.4	58.3				
65	27.8	29.4	31.7	33.9	36.7	39.4	42.2	45.6	49.4	53.3	57.8					
70	28.3	30.0	32.2	35.0	37.8	40.6	44.4	48.3	52.2	56.7						
75	28.9	31.1	33.3	36.1	39.4	42.8	46.7	51.1	55.6							
80	28.9	31.7	34.4	37.8	41.1	45.0	49.4	53.9								
85	29.4	32.2	35.6	38.9	43.3	47.2	52.2	57.2								
90	30.0	32.8	36.7	40.6	45.0	50.0	55.0									
95	30.0	33.9	37.8	42.2	47.2	52.8										
100	30.6	35.0	39.4	44.4	49.4	55.6										

Classification	Effect on the Body
Caution:	Fatigue possible with prolonged exposure and/or physical activity
Extreme Caution:	Heat stroke, heat cramps, or heat exhaustion possible with prolonged exposure and/or physical activity
Danger:	Heat cramps or heat exhaustion likely, and heat stroke possible with prolonged exposure and/or physical activity
Extreme Danger:	Heat stroke highly likely

Fig. 16: Heat index for different temperatures and relative humidity. The table values are for shaded areas. If one is exposed to direct sunlight, the heat index value can be increased by up to 8°C.

143) NSW Health Department information on heat-related illnesses,[152] including dehydration, heat rash, heat exhaustion, heat cramps and heat stroke, states: "When the air is hotter than around 35°C, the body can only lose heat through sweating [which] can be impaired by humidity . . ." **Heat stroke occurs when the core temperature of the human body rises, and can cause shock, arrhythmia, altered mental state, convulsions, unconsciousness, and possible death.**

144) **With continued global warming, Sydney is considered the most vulnerable of all the six capital Australian cities, as it currently experiences at least 6.4 additional deaths on days with temperatures in excess of (only) 30°C.**[153]

[152] https://www.health.nsw.gov.au/environment/beattheheat/Pages/information-for-health-professionals.aspx

[153] Herold, N. (2018) Australian climate extremes in the 21st century according to a regional climate model ensemble: Implications for health and agriculture, Weather and Climate Extremes, 20, 54–68, https://doi.org/10.1016/j.wace.2018.01.001

5.4 Attribution: Is this particular consequence made more likely by climate change?

145) All extreme weather events, in fact, **all weather events are affected by climate change**, because the environment in which they occur is warmer, moister and contains more energy than used to be the case.[154] The field of **attribution science is now allowing scientists to quantity the effect of climate change on many extreme events and the consequences of anthropogenic climate change more generally**. Just a few examples are listed below.

146) Of the 131 studies investigating whether climate change is influencing extreme weather published in the Bulletin of the American Meteorological Society between 2011 and 2016, **65 percent found that the probability of the event occurring was increased due to anthropogenic climate change**. **In the case of some extreme high temperatures, the probability increased by a factor of ten or more.**[155]

147) **The widespread coral bleaching of the Great Barrier Reef during 2016 was made 175 times more likely due to climate change.**[156]

148) **Hurricane Harvey** caused deaths, extreme rainfall, catastrophic flooding and economic losses estimated at 215 billion in 2017 USD. Attribution studies have found that the amount of **rainfall** associated with the hurricane system **was increased three-fold by human-induced climate change**.[157]

149) According to the United Kingdom (UK) Met Office,[158] **human-induced climate change has made the 2018 record-breaking UK summer temperatures about 30 times more likely** than they would naturally occur.

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[154] Trenberth, K. E. (2012), Framing the way to relate climate extremes to climate change, Climate Change, 115(2), 283–290, doi:10.1007/s10584-012-0441-5

[155] WMO (2018) July sees extreme weather with high impacts. Accessed at: https://public.wmo.int/en/media/news/july-sees-extreme-weather-high-impacts

[156] King A, Karoly D, Black M, Hoegh-Guldberg O, and Perkins-Kirkpatrick S (2016) Great Barrier Reef bleaching would be almost impossible without climate change. The Conversation, April 29, 2016.

[157] IPCC (2022) Chapter 4, Water, in Climate Change 2022: Impacts, Adaptation and Vulnerability, Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, accessed at: https://www.ipcc.ch/report/ar6/wg2/

[158] UK Met Office (2018) 2018 UK summer heatwave made thirty times more likely due to climate change. Accessed at https://www.metoffice.gov.uk/about-us/press-office/news/weather-and-climate/2018/2018-uk-summer-heatwave

150) The **2020 Siberian heatwave would have been "almost impossible" without human-induced climate change**, as it was made at least 600 times more likely as a result of human-induced climate change.[159]

151) **The 2019-2020 Australian bushfires were made 30 – 80% more likely due to anthropogenic climate change**.[160]

152) A recent meta-analysis[161] of 27 studies concerning a total of 976 species found that **47% of local extinctions reported across the globe during last century could be attributed to climate change**.

153) **Of more than 4,000 species** examined in studies that assessed attribution, about **half had shifted their geographical locations** poleward or to higher altitude **due to human-induced climate change.**[162]

154) In the period 1991–2018, **37% of warm-season, heat-related human deaths has been attributed to anthropogenic climate change.**[163]

155) Based on observations and modelling, the **heatwave in the Pacific Northwest of Canada and the US** has been found to be **"virtually impossible" without human-caused climate change**; climate change made the event about 150 times more likely.[164]

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[159] Ciavarella, A. et al. (2020) Prolonged Siberian Heat of 2020. *World Weather Attribution.* https://www.worldweatherattribution.org/siberian-heatwave-of-2020-almost-impossible-without-climate-change

[160] Oldenborgh, G.J. et al. (2021) Attribution of the Australian bushfire risk to anthropogenic climate change*,* Natural Hazards and Earth System Sciences, 21, 941. Accessed at: https://doi.org/10.5194/nhess-21-941-2021

[161] Wiens, J.J., 2016: Climate-Related Local Extinctions Are Already Widespread among Plant and Animal Species. PLOS Biology, 14(12), e2001104, doi:10.1371/journal.pbio.2001104.

[162] IPCC (2022) Chapter 2, Terrestrial and Freshwater Ecosystems and their Services, in Climate Change 2022: Impacts, Adaptation and Vulnerability, Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, accessed at: https://www.ipcc.ch/report/ar6/wg2/

[163] Vicedo-Cabrera, A.M. et al. (2021) The burden of heat-related mortality attributable to recent human-induced climate change. Nature Climate Change, 11, 492-500. Accessed at: https://www.nature.com/articles/s41558-021-01058-x

[164] Phillip, S.Y. et al. (2021) Rapid attribution analysis of the extraordinary heatwave on the Pacific Coast of the US and Canada June 2021, Earth System Dynamics, Accessed at: https://esd.copernicus.org/preprints/esd-2021-90/

6 Future Impacts of Climate Change

156) At its simplest level, **future climate change can be projected on the basis of different scenarios for future human GHG emission trajectories**.

157) Other drivers of future climate change include **the speed with which the planet responds to feedbacks in the Earth System**, and how these interact with one another, possibly cascading to create a planetary tipping point. (These are discussed in subsections 4.7, 4.8 and 4.9 of this Report.)

158) A brief overview of possible emission trajectories and their consequences for global warming levels is presented in subsection 6.1, making comparisons with the warming target of the UNFCCC **Paris Agreement,**[165] which **commits signatories to "holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C."** Australia is a signatory to the Paris Agreement. Current emissions trajectories for the world, Australia and New South Wales are discussed in more detail in Section 202).

159) Possible climate futures for the world, Australia and NSW are sketched below in subsections 6.2, 6.3, and 6.4, respectively. Which of these futures is realised depends on the trajectory of human GHG emissions.

6.1 Why emissions trajectories matter

160) Projections of how the climate will evolve into the future depend on the direction and speed with which global emissions evolve. **If the trend of rising emissions is continued**, the world will be on a pathway similar to the scenarios[166] labelled RCP6.0 and RCP8.5 by the fifth Assessment Report (AR5) of the IPCC,[167] based on extrapolation of observed

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[165] UN (2015), Paris Agreement, Accessed from https://unfccc.int/sites/default/files/english_paris_agreement.pdf

[166] NB: "RCP" is Representative Concentration Pathway, which is a scenario for the concentration of greenhouse gases in the atmosphere. The numbers refer to the 'radiative forcing' for a scenario, in Watts per square metre.

[167] Collins, M. et al. (2013) Long-term climate change: Projections, commitments and irreversibility, in Climate Change 2013: The Physical Science Basis, Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, edited by Stocker et al. Cambridge University Press, pp. 1029-1136.

emissions trends,[168] and consistent with recent analyses.[169] In this case, **global warming could be 3—4°C above pre-industrial times in just 80 years.**

161) AR6 WGI,[170] expands this older work, **using improved climate modelling constrained by previous climate responses to consider five illustrative scenarios for how human emissions may proceed from now until the year 2100.** Those scenarios are labelled: SSP1-1.9, SSP1-2.6, SSP2-4.5, SSP3-7.0 and SSP5-8.5, in order of lowest to highest emissions.[171] They are similar to, but not identical to the RCP-labelled scenarios of the fifth IPCC assessment. The global warming consequences of each of these five emissions scenarios are shown in Fig. 17 below.

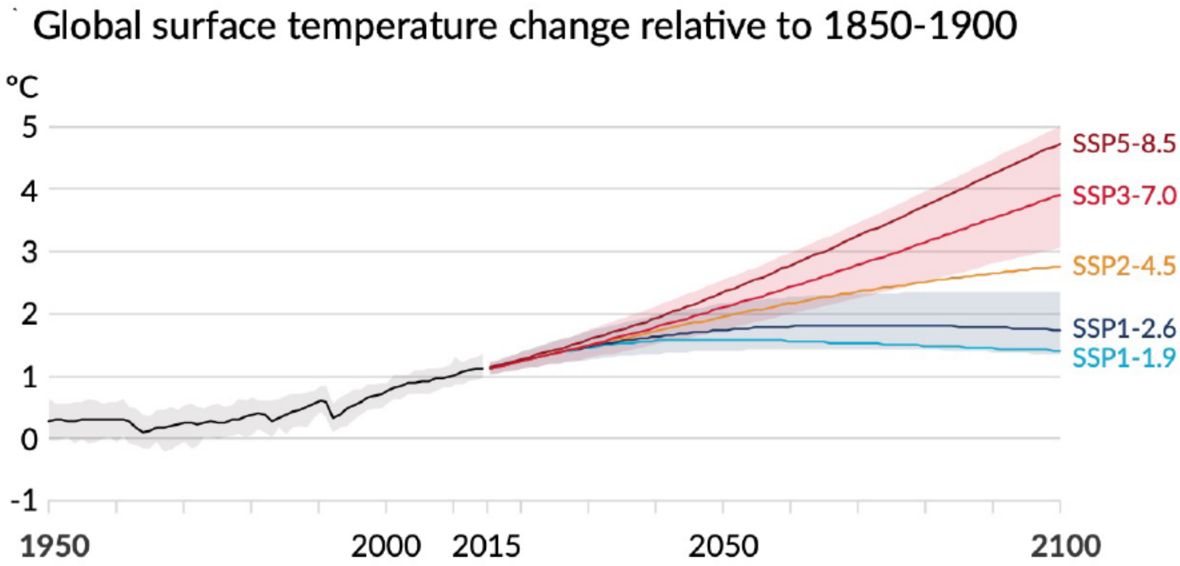

Fig 17: Projections for each of the five AR6 emission scenarios are shown in colour. The black curve indicates past warming. Shaded regions show the `very likely' ranges for the SSP1-2.6 and the SSP3-7.0 scenarios. Figure reproduced from the IPCC ARC WGI Summary for Policymakers, Fig. SPM.8.

162) ***All* scenarios considered in AR6 WGI, including the lowest emission trajectory (SSP1–1.9), are more likely than not to reach or exceed 1.5°C of warming this century.** The best estimate for the lowest emission scenario (SSP1-1.9) is that 1.5°C will be reached before

[168] Le Quéré, C et al. (2018) Global Carbon Budget 2018, Earth Syst. Sci. Data, 10, 2141–2194, https://doi.org/10.5194/essd-10-2141-2018
[169] Climate Action Tracker (2020) https://climateactiontracker.org/global/cat-thermometer/
[170] https://www.ipcc.ch/report/ar6/wg1/#FullReport
[171] IPCC (2021) Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, accessed at: https://www.ipcc.ch/report/ar6/wg1/#SPM

2040, likely peaking at 1.6°C around mid-century, and that warming will then drop slightly to 1.4°C at century's end.[172] **This means that humanity has likely lost the chance to hold warming strictly below 1.5C, the lowest of the Paris Agreement targets, but may still have the possibility of returning global temperatures to that value in 80 years' time.**

163) Indeed, due to natural fluctuations, the world may soon experience years in which the global average temperature exceeds 1.5°C of warming. Work led by the UK Met Office shows **there is a 40% chance that the world will see global average 1.5°C warming (at least temporarily) sometime before 2025.**[173]

164) **In order to hold global warming well-below 2°C, the upper of the Paris Agreement targets**, human emissions trajectories must be more closely aligned with the SSP1-1.9 or SSP1-2.6 scenarios than the other three scenarios, requiring "**deep reductions in CO_2 and other greenhouse gas emissions occur in the coming decades**,"[174] according to the AR6 WGI report.

165) The **higher emission scenarios SSP2-4.5, SSP3-7.0 and SSP5-8.5 all carry a significant of risk of global warming of at least 3°C by 2100, with SSP3-7.0 and SSP5-8.5 very likely to reach 3°C to 4°C by then, and continue to rise thereafter**.

166) The subsections that follow describe possible climate futures in a world experiencing different levels of global warming, including 1.5°C (which is now essentially inevitable), 2°C, 3°C and higher above pre-industrial times. **What separates these possible futures is the trajectory of human GHG emissions, particularly in the next decade**.

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[172] IPCC (2021) Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Table SPM.1, accessed at: https://www.ipcc.ch/report/ar6/wg1/#SPM
[173] WMO 2020, Global Annual to Decadal Climate Update: Target years 2021, and 2021-2025. Accessed at: https://hadleyserver.metoffice.gov.uk/wmolc/ on 17 December 2021.
[174] IPCC (2021) Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, accessed at: https://www.ipcc.ch/report/ar6/wg1/#SPM

6.2 Possible World Futures at Different Levels of Global Warming

167) **Climate impacts are hitting harder and sooner than previous scientific assessments have expected.** Over two decades, the IPCC has published a series of science-based risk assessments for people, ecosystems and economies worldwide. **A comparison of these "Reasons for Concern"** (see Fig. 18 below based on the WMO 2019 report)[175] **shows that the level of risk has increased with each subsequent analysis from 2001 to 2022** More recent IPCC reports indicate higher risks (redder colours) than did previous reports for the same average global warming.

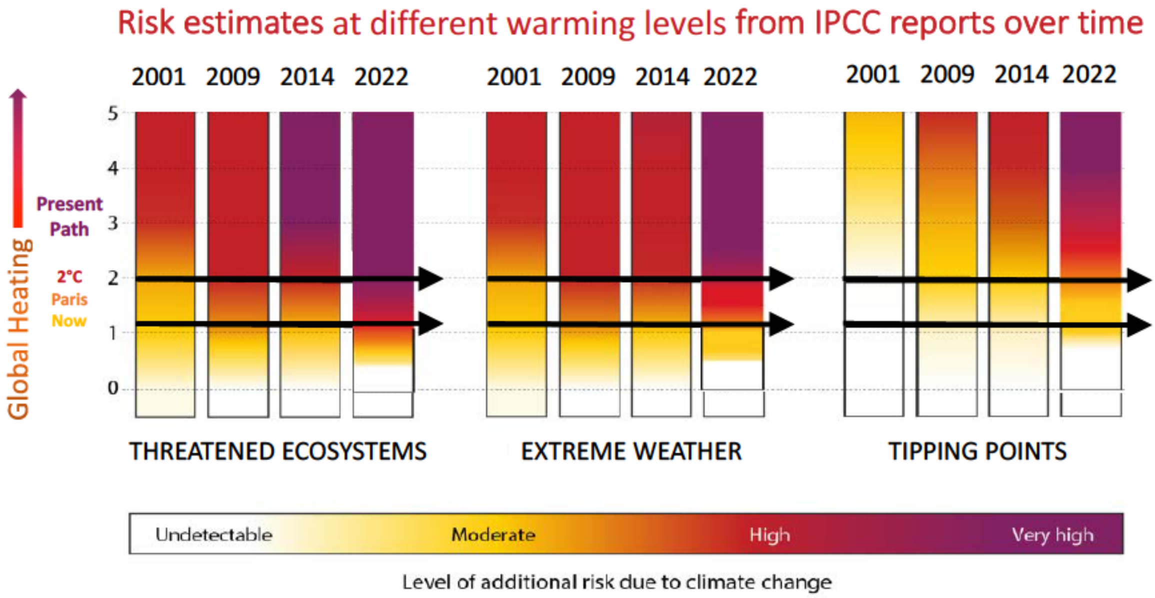

Fig. 18: As temperature (above pre-industrial time) climbs upward, climate risks increase (shown by deeper, dark colours). Indicated are the present (marked as "now"), the Paris Agreement Range, a 2°C scenario, and the present path trajectory leading to 3°C to 4°C of global heating. Results from more recent IPCC reports (arrows moving left to right) indicate higher risks than did earlier reports at the same temperature.

168) The conclusion is clear**: the more we know, the more we realise how dangerous even a small amount of warming can be.**

169) We now know that the Earth will experience 1.5°C of warming (see paragraph 162), and so it is clear that the world faces still greater risks from climate change.

[175] WMO 2019, United in Science, Report prepared for the UN Climate Action Summit 2019, https://wedocs.unep.org/bitstream/handle/20.500.11822/30023/climsci.pdf

170) **The Paris Agreement range of 1.5°C to well below 2.0°C is not 'safe' (though it is much safer than higher temperatures).** Within this range of warming, ecosystems are at high to very high risk, there is a high risk of extreme global weather events, and a moderate risk of large-scale singular events that could lead to climatic tipping points, as Fig. 18 shows.

171) According to AR6 WGI: "**With every additional increment of global warming, changes in extremes continue to become larger**. For example, every additional 0.5°C of global warming causes clearly discernible increases in the intensity and frequency of hot extremes, including heatwaves (*very likely*), and heavy precipitation (*high confidence*), as well as agricultural and ecological droughts in some regions (*high confidence*)."[176]

172) Recent research indicates that **even under 1.5°C of warming, thousands of global locations will experience what are now considered 'once-in-100-years extreme-sea-level events' *at least once a year* by 2100**.[177]

173) **Very high extinction risk for endemic species in biodiversity hotspots is projected to at least double from 2% between 1.5°C and 2°C global warming levels and to increase at least tenfold if warming rises from 1.5°C to 3°C**.[178]

174) **At 2°C warming, 99% of the world's coral reefs, including the Great Barrier Reef, are very likely to be eliminated**, and **crisis upon crisis will compound for the world's most vulnerable people.**[179]

175) Specifically, **if emissions do not come down drastically before 2030, the world will be on a path to 2°C of warming or more**, and **by 2040 some 3.9 billion people are likely to experience major heatwaves, 12 times more than the historic average.** By the 2030s, 400 million people globally each year are likely to be exposed to temperatures exceeding

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[176] IPCC (2021) Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Table SPM.1, accessed at: https://www.ipcc.ch/report/ar6/wg1/#SPM
[177] Tebaldi, C. et al. (2021) Extreme sea levels at different global warming levels. In Nature Climate Change, 11, 746-751, https://doi.org/10.1038/s41558-021-01127-1
[178] IPCC (2022) Summary for Policy Makers, in Climate Change 2022: Impacts, Adaptation and Vulnerability, Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, accessed at: https://www.ipcc.ch/report/ar6/wg2/
[179] IPCC SR1.5 (2018) Intergovernmental Panel on Climate Change Special Report on Global Warming of 1.5°C. Accessed at: http://ipcc.ch/report/sr15/

the workability threshold. Also, **by the 2030s, the number of people on the planet exposed to heat stress exceeding the survivability threshold is likely to surpass 10 million a year.**[180]

176) Although agriculture will need to produce almost 50% more food by 2050, yields could decline by 30% and **by 2040, the average proportion of global cropland affected by severe drought will likely rise to 32% a year, more than three times the historic average**.[181]

177) In a world of **2°C of warming**, the **extraordinary heatwave in the 2021 Pacific Northwest of the US and Canada would be hotter, and occur once every 5 to 10 years**.[182]

178) **At 2°C of warming, which current policies and actions would ensure** (see subsection 7.1), **13% of the Earth's surface will undergo complete ecosystem transformations.**[183]

179) **At 3°C–4°C of warming** above pre-industrial temperatures (a possible consequence of continuing on our current path), today's world would be nearly unrecognisable, with high to very high risk that:[184]

a) **Most of the world's ecosystems are heavily damaged or destroyed**;

b) **Extreme weather events are far more severe and frequent** than today;

c) **Large areas of the world become uninhabitable. Migration and conflict escalate**;

d) **Aggregated global impacts significantly damage the entire global economy**; and

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[180] Quiggin, D, De Meyer, K, Hubble-Rose, L, and Froggatt, A. (2021) Climate change risk assessment 2021, Royal Institute of International Affairs, Chatham House. Accessed at: https://www.chathamhouse.org/2021/09/climate-change-risk-assessment-2021

[181] Quiggin, D, De Meyer, K, Hubble-Rose, L, and Froggatt, A. (2021) Climate change risk assessment 2021, Royal Institute of International Affairs, Chatham House. Accessed at: https://www.chathamhouse.org/2021/09/climate-change-risk-assessment-2021

[182] Phillip, S.Y. et al. (2021) Rapid attribution analysis of the extraordinary heatwave on the Pacific Coast of the US and Canada June 2021, Earth System Dynamics, Accessed at: https://esd.copernicus.org/preprints/esd-2021-90/

[183] IPCC SR1.5 (2018) Intergovernmental Panel on Climate Change Special Report on Global Warming of 1.5°C. Accessed at: http://ipcc.ch/report/sr15/

[184] IPCC (2014): Summary for policymakers. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Field et al. (eds.) Cambridge University Press, pp. 1-32.

e) A **high risk** that a cascade of tipping points in the climate system drives the **Earth system into a state not seen for millions of years**, irrespective of humanity's late attempts to reduce emissions.[185]

180) **Over the next 2000 years, global mean sea level will rise by about 2 – 3m if warming is limited to 1.5°C, 2 – 6m if limited to 2°C, and 19 – 22m with 5°C of warming, and it will continue to rise over subsequent millennia** (*low confidence*).[186]

181) **At 5°C of warming or above,** which is possible in the highest emissions scenario SSP5-8.5 by the end of the century (see Fig. 17), **it has been estimated**[187] **that a mass extinction would occur comparable to the 'big five' mass extinctions over the past 450 million years that resulted in extinction of 75% of all marine species.**

6.3 Possible Australian Futures

182) **Regardless of emission scenarios**, the CSIRO and BOM[188] report that **Australia will certainly experience more extreme climate effects**, including:

a) Further warming, with more extremely hot days and fewer extremely cool days.

b) A **decrease in cool-season rainfall** across many regions of the south and east of Australia, with more time spent in drought.

c) A longer fire season for the south and east and an **increase in the number of dangerous fire weather days**.

d) **More intense short-duration heavy rainfall events** throughout the country.

e) Fewer tropical cyclones, a greater proportion of which will be of high intensity.

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[185] Steffen W et al. (2018) Trajectories of the Earth System in the Anthropocene. *Proc. Natl. Acad. Sci. (USA)* doi:10.1073/pnas.1810141115 and associated Appendix https://www.pnas.org/content/pnas/115/33/8252.full.pdf
[186] IPCC (2021) Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, accessed at: https://www.ipcc.ch/report/ar6/wg1/#SPM
[187] Song, H., Kemp, D.B., Tian, L., Chu, D, Song, H., and Dai, X. (2021) Thresholds of temperature change for mass extinctions. Nature Communications 12: 4694, https://www.nature.com/articles/s41467-021-25019-2
[188] CSIRO/BOM (2020) State of the Climate 2020, Commonwealth of Australia. http://www.bom.gov.au/state-of-the-climate/

f) **More frequent, extensive, intense and longer-lasting marine heat waves**, increasing risk of frequent and severe bleaching of the Ningaloo and Great Barrier Reefs.

g) Oceans around Australia will continue to warm, rise and become more acidic.

h) **Ongoing sea level rise,** with recent research on ice sheet melting revealing that sea level rise could be higher than previously assessed.

Specifically, the CSIRO/BOM 2020 report states that:

i) **For most of the Australian coast, extreme sea levels that had a probability of occurring *once in a hundred years* are projected to become an *annual event* by the end of this century with lower emissions, and by mid-century for higher emissions**.

j) **The year 2019 was Australia's hottest year on record. That temperature is expected to be an *average* year when global mean warming reaches 1.5 °C above the pre-industrial baseline period of 1850–1900**.

k) **While the current decade is warmer than any other decade over the last century, it is also likely to be the *coolest* decade for the century ahead**.

183) Australian continental temperatures are observed to be about 1.4 times greater than global average temperatures.[189] Thus, global warming between 1.5°C and 2°C above 1850-1900 levels translates into average temperature increases of 2.1°C and 2.8°C for Australia. (See Fig. 19 from the CSIRO below.)[190]

[189] In general, the surface of land masses warm more quickly than the ocean due to differences in reflectivity and heat capacity. The poles or land near the poles warm more quickly due to ice loss which would otherwise have a cooling effect. Other factors are also at play. See: e.g., https://climate.mit.edu/ask-mit/which-parts-planet-are-warming-fastest-and-why

[190] CSIRO/BOM (2020) State of the Climate 2020, Commonwealth of Australia. http://www.bom.gov.au/state-of-the-climate/

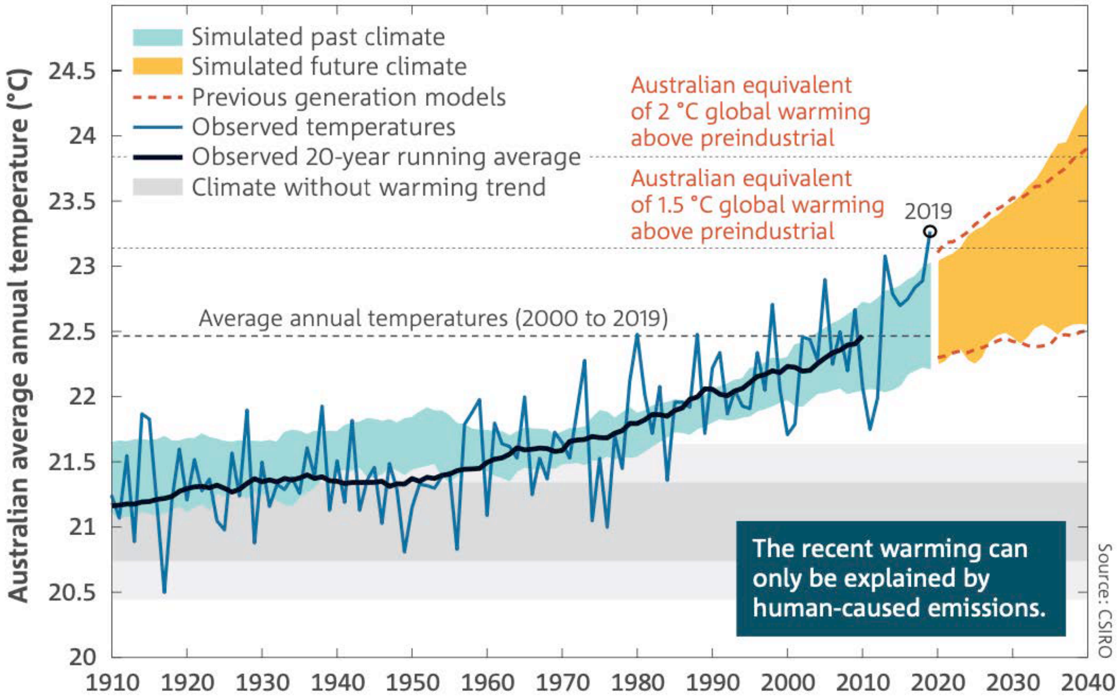

Fig. 19: Average Australian temperatures over time and projected into the future. Natural variation (without climate change) would give temperatures with the grey horizontal bands. Recent warming is due to human GHG emissions. Additional warming will cause greater average temperature changes in Australia than the global average, leaving Australia particularly exposed to more detrimental effects.

184) The **intensity, frequency and duration of heatwave extremes are projected to increase in the future due to climate change.**[191] For example, **for every °C of global temperature rise, Australians will see about 16 more heatwaves days**, with the longest heatwave increasing in length by about 5 days.

185) Already **peak heatwaves that occurred only once per 30 years in pre-industrial (1861-1890) times in Australia**, can now be expected every 5 years. **At a global warming of 1.5°C** (which we are likely to experience by the mid-2030s), **this frequency will nearly double to once every 2.7 years.** In a world **with 3°C of average warming**, Australians will see such peak heatwaves **nearly every year**.[192]

[191] Perkins-Kirkpatrick, S. E. & Gibson, P. B. (2017) Changes in regional heatwave characteristics as a function of increasing global temperature. Sci. Rep. 7, 12256.
[192] Perkins-Kirkpatrick, S.E. and Gibson, P.B. (2017) Changes in regional heatwave characteristics as a function of increasing global temperature. Nature Scientific Reports, 7: *12256.* DOI:10.1038/s41598-017-12520-2

186) **For Australia, warming of 2.0°C would be substantively different to that of 1.5°C** above pre-industrial temperatures. Added to the increased risks faced globally, the IPCC[193] has listed **Australia as a region where the change in risk in moving from 1.5°C of global warming to 2°C is particularly high with regard to**:

a) Water stress and drought,

b) Shifts in biomes in major ecosystems, including rainforests,

c) Changes in ecosystems related to the production of food,

d) Deteriorating air quality,

e) Declines in coastal tourism,

f) Loss of coral reefs, sea grass and mangroves,

g) Disruption of marine food webs, loss of fin fish, ecology of marine species,

h) Heat-related mortality and morbidity, and

i) Ozone-related mortality.

187) **Average global temperatures in the latter half of this century, and the heat waves they induce, depend critically on human actions over the next twenty years**. Because Australia's average warming is about 1.4 times the global mean, **average warming in Australia before the end of this century may reach 2.7°C (even for a rapid action SSP1-RCP2.6 sustainable pathway) to as high as 7°C (for a continued fossil fuel focused SSP5-RCP8.5 pathway)** above pre-industrial levels.[194]

188) Based on the Keetch-Byram Drought Index (KBDI), an indicator of soil-moisture deficit, one study[195] finds that the climate conditions expected late this century (2070 – 2100) may result in high fire potential extending to seven months in Australia (August to February). **Extreme fire danger weather like that during the Black Summer bushfire season is**

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[193] IPCC SR1.5 (2018) Intergovernmental Panel on Climate Change Special Report on Global Warming of 1.5°C. Accessed at: http://ipcc.ch/report/sr15/

[194] Grose, M. R. et al. (2020) Insights from CMIP6 for Australia's Future Climate. Earth's Fut. 8, e2019EF001469.

[195] Liu, Y., J. Stanturf, and S. Goodrick (2010) Trends in global wildfire potential in a changing climate. *For. Ecol. Manage.*, **259**, 685–697, doi:10.1016/j. foreco.2009.09.002

projected to be four times more likely if global warming reaches 2°C, compared to conditions typical in 1900.[196]

189) **Regional temperatures are key to fire development.** This is important because Australian temperatures are higher than global averages. Modelling indicates that *regional* warming of around 4°C or more above pre-industrial is sufficient to allow megafires to occur in southeast Australia irrespective of whether drought occurs simultaneously.[197] In other words, **if GHG emissions are not curbed sharply, Black Summer-like megafires may be a common Australia feature by late century even in years with plentiful rainfall**.

190) Specifically designed to study regions in Australia, the NSW/ACT Regional Climate Modelling (NARCliM)[198] project uses downscaled climate data over 50-km regions over all of Australia to measure climate changes from the 'recent past' (1990–2009), to what might be expected in the `near' (2020–2039) and `far future' (2060–2079).

191) The NARCliM 1.0 future projections **use a high-emissions scenario** (SRES A2).[199] **Current emissions are tracking along this scenario; whether they do in future will depend most critically on the extent to which fossil fuels contribute to the world's future energy mix.** When reading these projections, it is **instructive to note that an Australian born today will spend childhood and teen years in the 'near future', and middle age in the 'far future'**.

192) The NARCLiM 1.0 study[200] found the following results for Australia **under their high-emissions scenario**:

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[196] Oldenborgh, G.J. et al. (2020) Attribution of the Australian bushfire risk to anthropogenic climate change, Natural Hazards and Earth System Sciences Discussions, Accessed at: https://doi.org/10.5194/nhess-2020-69

[197] Sanderson, B. M. & Fisher, R. A. (2020) A fiery wake-up call for climate science. Nat. Clim. Change. 10, 175–177

[198] Herold, N. (2018) Australian climate extremes in the 21st century according to a regional climate model ensemble: Implications for health and agriculture, Weather and Climate Extremes, 20, 54–68, https://doi.org/10.1016/j.wace.2018.01.001

[199] According to NARCLiM, "The projected warming for SRES A2 for the 2090 to 2099 period, relative to 1980 to 1999, is given by IPCC AR4 as 2.0°C to 5.9°C, with a best estimate of 3.4°C."

[200] Herold, N. (2018) Australian climate extremes in the 21st century according to a regional climate model ensemble: Implications for health and agriculture, Weather and Climate Extremes, 20, 54–68, https://doi.org/10.1016/j.wace.2018.01.001

a) **Daytime temperature extremes are projected to increase by up to 3.5°C** in the far future, depending on season and location.

b) Heatwave frequency, number and duration will increase significantly in the near and far future. **All capital cities will experience, at minimum, a tripling of heatwave days each year by the far future compared to the recent past, with the effect more extreme in the north**.

c) **Implications for mortality are severe**, with projected future climates leading to increases in mortality due to high temperatures in all examined capital cities. As an example, **the number of heatwave days in Brisbane would increase from about 10 in the recent past to over 50 in the period centred on 2070, resulting in higher heat-related mortality** in the city.

d) Moderate to severe drought conditions are expected in the far future in the southwest and southeast of Australia during spring.

e) The **number of days at or above 30°C in the major Australian wheat-growing regions will increase substantially**, particularly during spring when wheat is most vulnerable to temperature. Projected decreases in precipitation would **decrease the likelihood of meeting historical production levels.**

193) **Key risks of increased global warming particular to Australia** that have been identified in the AR6 WII include[201]:

a) **Degradation of tropical shallow coral reefs** and associated biodiversity and ecosystem service values,

b) **Loss of human and natural systems in low-lying coastal areas** due to sea-level rise,

c) **Impact on livelihoods and incomes** due to decline in agricultural production,

d) **Increase in heat-related mortality and morbidity for people and wildlife**, and

e) **Loss of alpine biodiversity** due to less snow.

[201] IPCC (2022) Summary for Policy Makers, in Climate Change 2022: Impacts, Adaptation and Vulnerability, Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, accessed at: https://www.ipcc.ch/report/ar6/wg2/

194) **The Australian Academy of Science has released a report[202] describing the risks to Australia should global warming reach 3°C or higher, as it is likely to if humanity continues its current emissions trajectory**. Some of the identified key risks to Australia at 3°C (over and above those at 1.5°C to 2°C) of global warming include:

a) **Extreme events such as heatwaves, severe storms, major floods, bushfires and coastal inundation from sea level rise would be more intense and frequent**.

b) **Many locations in Australia would become uninhabitable** due to projected water shortages.

c) Severe impacts to both flora and fauna would cause **many of Australia's ecological systems** to **become unrecognisable**,

d) Existing tree plantations would change substantially.

e) Fisheries and aquaculture industries would experience declines in profitability, and **many aquaculture fisheries enterprises may cease to exist**.

f) **Many properties and businesses would become uninsurable**.

g) **A decline in profits and business viability would likely lead to increased unemployment and possibly higher suicide rates**.

h) **Health issues related to heat stress and acute and chronic psychological stressors would increase**.

i) **Declining river flows would reduce water availability for irrigated agriculture and increase water prices**.

j) **Crop yields would decline by 5 to 50%, depending on location**.

k) **Sea level rise would transform Australia's coastal regions, with severe impacts on natural ecosystems, urban infrastructure and rural settlements, putting the health and wellbeing of many people at increasingly severe risk.**

[202] Australian Academy of Science (2021). *The risks to Australia of a 3°C warmer world* (and references therein.) Accessed at: https:// www.science.org.au/warmerworld

6.4 Possible NSW Futures

195) **Future climate change will increase many already deleterious impacts for NSW.** The severity will depend on the level of global warming (and thus emission trajectories) before net zero emissions is reached. Some risks are described below.

196) **NSW crosses five subcluster regions** used to project more local future effects of climate change, namely **East Coast** (incl. Sydney), **Central Slopes** (incl. Dubbo and Narrabri), **Rangelands** (incl. Broken Hill), **Murray Basin** (incl. Wagga Wagga), and the **Southern Slopes**, (incl. Batemans Bay).[203] (See Fig. 20 below).[204]

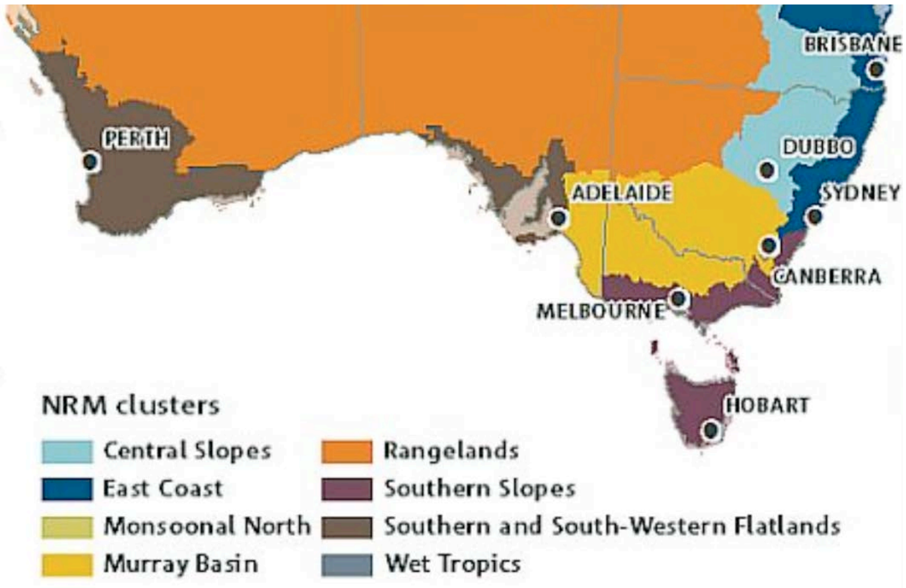

Fig. 20: Colour-coded regional clusters used to project future climate.

197) Joint work[205] by the CSIRO and BoM **projects future climate conditions** by combining several global climate simulations with fine resolution "downscaled" data appropriate to local regions. **All five subclusters of NSW can expect the following in future**:

a) **Temperatures increase in all seasons, with fewer frosts in winter**.

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[203] Climate Change in Australia: NRM Regions. Accessed at: https://www.climatechangeinaustralia.gov.au/en/overview/methodology/nrm-regions/
[204] Climate Change in Australia: Projections for Australia's NRM Regions. NRM Regions. Accessed at: https://www.climatechangeinaustralia.gov.au/en/overview/methodology/nrm-regions/
[205] Climate Change in Australia (2015): Projections for Australia's NRM Regions. Accessed at: https://www.climatechangeinaustralia.gov.au/en/climate-projections/future-climate/regional-climate-change-explorer/sub-clusters/

b) **Substantial increases in the temperature on hot days, the frequency of hot days, and the duration of warm spells.**

c) **Less cool season rainfall and increased intensity of extreme rainfall events**.

198) In addition, the East Coast South subcluster containing the Muswellbrook – Singleton region **in which the proposed Project would be sited, and its intended export port of Newcastle, can expect harsher fire weather and an increasing height of extreme sea-level events.**[206]

199) **For NSW, runoff, that is the water available to feed dams and rivers, will decrease markedly with the multiple effects of climate change**. It is estimated[207] that **for every one degree of global warming, runoff will be reduced by 15%,** which matches what is currently being experienced. With current emissions trends leading to a possible *additional* 2°C to 3°C of temperature increase (for a total increase of 3°C to 4°C), the NSW region could be faced with water reductions of 45 – 60%, compared to mid-last century.[208] This has **profound consequences for water availability for human and environmental use**.

200) The difference in global warming between 1.5°C and 2.0°C greatly increases the frequency of extreme temperatures over many regions. For southern Australia, a median of 4–8 extra heatwave days per year is projected for every additional degree of warming.[209] Consequently, **in a world with 1.5°C of warming, NSW can expect about 2–4 more heatwave days than currently, and 4–8 more with 2°C of global warming.** Should global warming reach **3°C or more**, as indicated by current policy settings in Australia and

[206] Climate Change in Australia: Regional Climate Change Explorer. https://www.climatechangeinaustralia.gov.au/en/projections-tools/regional-climate-change-explorer/sub-clusters/

[207] Reisinger, A., et al. (2014) Australasia. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1371-1438.

[208] ACT Climate Change Council (2020), Learning from Canberra's Climate-Fuelled Summer of Crisis, accessed at: https://www.environment.act.gov.au/__data/assets/pdf_file/0003/1611471/learning-from-canberras-climate-fuelled-summer-of-crisis.pdf

[209] Perkins-Kirkpatrick, S.E. and Gibson, P.B. (2017) Changes in regional heatwave characteristics as a function of increasing global temperature. Nature Scientific Reports, 7: *12256.* DOI:10.1038/s41598-017-12520-2

elsewhere in the world, **NSW will incur one or two more weeks in heatwave every year in addition to what it now endures.**[210]

201) The non-linear complexity of Earth's climate system is such that the most extreme of extreme temperature events do not scale simply with an additional amount of warming. One study from 2017 (before Black Summer) **concluded that major Australian cities, such Sydney or Melbourne, could therefore incur maximum summer temperatures of 50°C under 2°C of global mean warming.**[211]

202) Penrith recorded 48.9°C (whilst many other sites in metropolitan Sydney exceeded 47°C) on 4 January 2020, at a time when global warming was about 1.1°C. This raises the possibility that **current models may be underestimating the extreme heat that NSW will feel at 1.5°C, let alone, at 2°C of global warming.**

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[210] Perkins-Kirkpatrick, S.E. and Gibson, P.B. (2017) Changes in regional heatwave characteristics as a function of increasing global temperature. Nature Scientific Reports, 7: *12256.* DOI:10.1038/s41598-017-12520-2

[211] Lewis, S. C., King, A. D., & Mitchell, D. M. (2017). Australia's unprecedented future temperature extremes under Paris limits to warming. Geophysical Research Letters, 44, 9947–9956. https://doi.org/10.1002/2017GL074612

7 Why We are Tracking Toward more Dangerous Climate Change

203) The world is emitting greenhouse gases on a trend that would lead to substantially more dangerous climate change. Indications that this is the case, and explicit requirements for reversing this trend significantly and quickly enough to minimise the damage are discussed in this section of this Report.

204) Specifically, I outline:

a) how current nationally determined contributions to the Paris Agreement are insufficient to hold warming to levels agreed by Paris Agreement signatories;

b) the shrinking remaining global 'carbon budget' to hold warming to various levels; and

c) the gap between current and planned production of fossil fuels and limiting global warming to 1.5° or even 2°C above pre-industrial temperatures.

7.1 National Contributions to the Paris Agreement

205) **The Paris Agreement**[212] **commits signatories to "holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C."** Signatory nations, such as Australia, have made separate, voluntary, Nationally Determined Contributions (NDCs) as a first step to meet these goals.

206) In late 2019, it was estimated that the 2019 NDCs, if achieved, would result in global warming by 2100 of 2.9°C—3.4°C relative to pre-industrial levels, increasing thereafter.[213]

207) **After many countries updated their NDCs in 2020**, the UNFCCC noted in its early 2021 analysis[214] prior to the UN Conference of the Parties in Glasgow that even after consideration of the 48 new or updated NDCs submitted by 31 December 2020, the total

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[212] UN (2015), Paris Agreement, Accessed from https://unfccc.int/sites/default/files/english_paris_agreement.pdf

[213] WMO 2019, United in Science, Report prepared for the UN Climate Action Summit 2019, https://wedocs.unep.org/bitstream/handle/20.500.11822/30023/climsci.pdf

[214] UNFCCC (2021) Synthesis Report: Nationally determined contributions under the Paris Agreement, Accessed at: https://unfccc.int/process-and-meetings/the-paris-agreement/nationally-determined-contributions-ndcs/nationally-determined-contributions-ndcs/ndc-synthesis-report

GHG emissions of the Parties to the Paris Agreement was expected to be only 2.1% lower in 2030 than in 2017, falling "far short" of pathways consistent with holding global warming to 1.5°C.

208) A recent UN report[215] estimates the current 'emissions gap' between levels of warming relevant to the Paris Agreement and current NDCs. Specifically, this gap for 2030 is the difference between the estimated total global GHG emissions resulting from the full implementation of the NDCs and the total global GHG emissions from least-cost scenarios that keep global warming to 2°C, 1.8°C or 1.5°C with varying levels of likelihood. Compared to previous unconditional NDCs, the **new pledges for 2030 reduce projected 2030 emissions by only 7.5%, whereas a 30% reduction (on 2010 levels) is needed for 2°C and a 55% reduction is needed for 1.5°C**. The stark difference is illustrated in Fig. 21, which visually illustrates the declines that must occur by 2030 to achieve Paris Agreement goals.

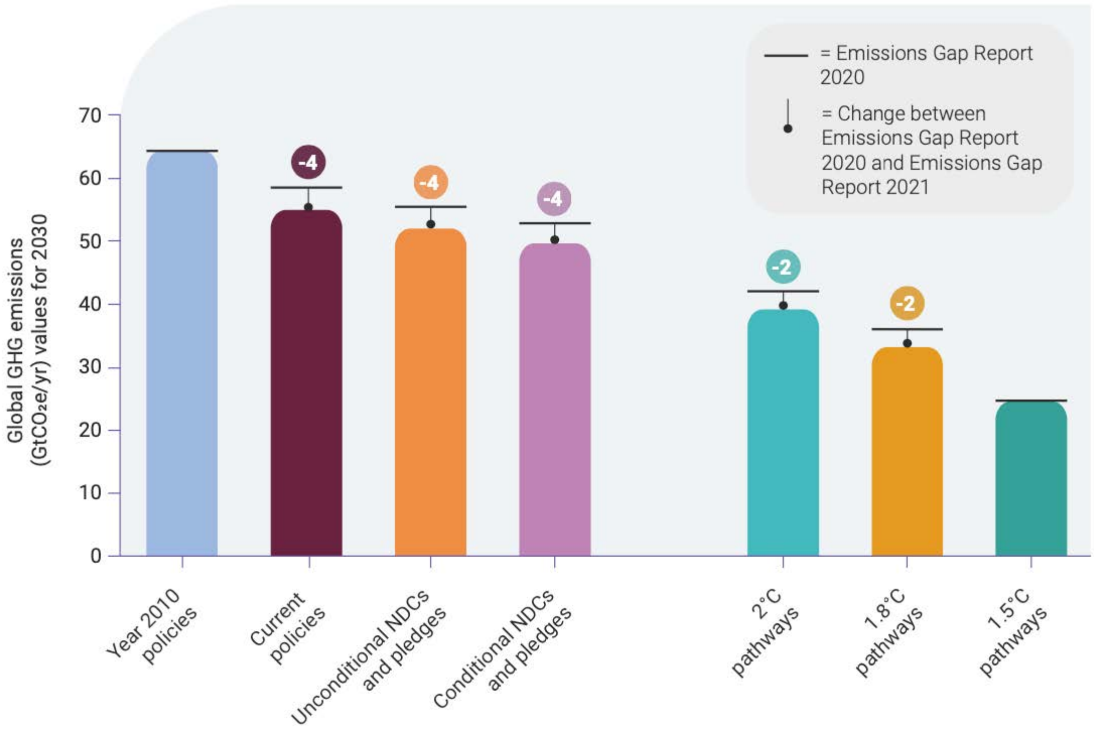

Fig. 21: Overview of changes in GHG emission projects for 2030 for different scenarios compared to global policies in 2010. Figure from the UNEP 2021 Emissions Gap Report.

[215] United Nations Environment Programme (2021) Emissions Gap Report 2021: The Heat is On – A World of Climate Promises Not Yet Delivered. Nairobi. Accessed at: https://www.unep.org/resources/emissions-gap-report-2021

209) In its most recent analysis, Climate Action Tracker[216] estimates that **global warming between 1.9°C and 3.0°C could result from current post-Glasgow commitments — if honoured** — still falling far short of the Paris Agreement targets, but slightly improved from expectations two years ago (see Fig. 22).

210) Aggravating this state of affairs, **most nations are not on track to meet their current commitments,** which if not corrected immediately, would result in even more warming. In fact, **based on current *policies* as opposed to *pledges***, Climate Action Tracker estimates that **warming could go as high as 3.6°C** (see Fig. 22).[217]

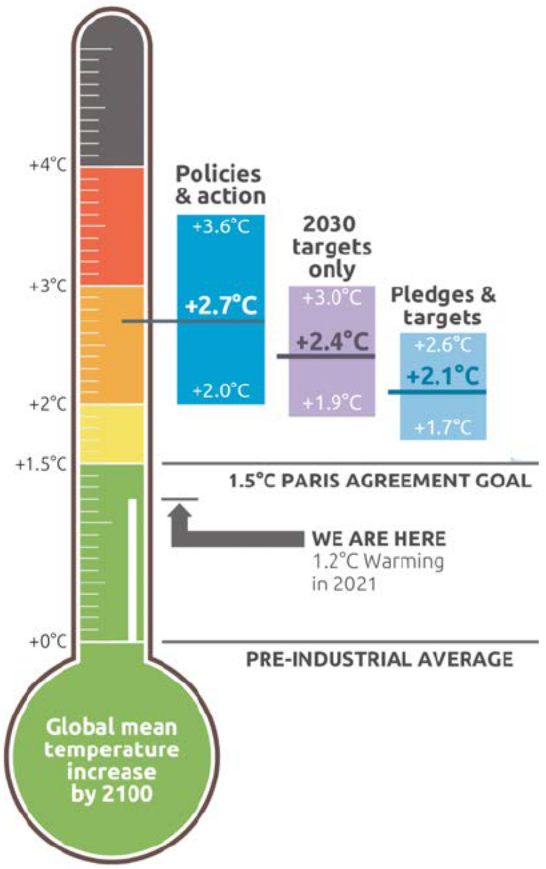

Fig. 22: Global warming projections based on pledges and policies of global nations. (Climate Action Tracker, November 2021 analysis).

211) The devastating consequences of such a world well over 2°C are discussed in Section 6 of this Report.

7.2 The Global 'Carbon Budget'

212) In order **to stabilise the climate at a certain average global temperature, human greenhouse gas emissions must at some point drop to net zero.** The maximum temperature reached is determined by cumulative net global anthropogenic CO_2

[216] Climate Action Tracker (2021), https://climateactiontracker.org/ Accessed 16 March 2022.
[217] Climate Action Tracker (2021), https://climateactiontracker.org/ Accessed 16 March 2022.

emissions up until the time of net-zero CO_2, the level of non-CO_2 radiative forcing[218] in the decades just prior, and the effects of feedbacks in the Earth system (see subsection 4.7).[219]

213) **The 'carbon budget approach' is a conceptually simple and scientifically sound method to estimate the speed and magnitude by which emission reductions must occur in order to meet a desired warming target,**[220] **focussing on CO_2** as the primary greenhouse gas. This approach is used by the IPCC,[221,222] and was adopted by the Australian Climate Change Authority to form its 2014 recommendations[223] for Australia.

214) The manner in which CO_2 moves through the land, ocean and atmosphere is complex, but the full effect of these processes yields an ***approximately* linear relationship** (see Fig. 23)[224] **between**:

a) The **'carbon budget'**: that is, **the cumulative amount of carbon**[225] **emitted as carbon dioxide from human actions since the beginning of industrialisation** (often taken to be about 1870), and

b) The increase in average global surface temperature since that time.

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218 Radiative forcing is the difference between how much energy from the Sun is absorbed by the Earth, and how much energy is radiated back to space. If the net forcing is zero, the Earth will remain at a stable equilibrium temperature. Positive forcing causes the temperature to rise.

219 IPCC SR1.5 (2018) Intergovernmental Panel on Climate Change Special Report on Global Warming of 1.5°C. Accessed at: http://ipcc.ch/report/sr15/

220 Collins, M. et al. (2013) Long-term climate change: Projections, commitments and irreversibility, in Climate Change 2013: The Physical Science Basis, Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, edited by Stocker et al. Cambridge University Press, pp. 1029-1136.

221 IPCC SR1.5 (2018) Intergovernmental Panel on Climate Change Special Report on Global Warming of 1.5°C. Accessed at: http://ipcc.ch/report/sr15/

222 IPCC (2021) Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, accessed at: https://www.ipcc.ch/report/ar6/wg1/#SPM

223 CCA (Climate Change Authority) (2014) Reducing Australia's Greenhouse Gas Emissions: Targets and Progress Review—Final Report, https://www.climatechangeauthority.gov.au/reviews/targets-and-progress-review-3

224 IPCC (2021) Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Fig. SPM.10 accessed at: https://www.ipcc.ch/report/ar6/wg1/#SPM

225 NB: Carbon budget numbers presented here are measured in the weight of carbon emissions, not carbon dioxide. CO_2 weighs more than the carbon it contains. CO_2-e, carbon dioxide equivalent, counts greenhouse gases whose effects have already been tallied in the budget.

215) The **budget is not annual, but cumulative: for all time—past, present and future. Once the carbon budget has been 'spent' (emitted as GHGs), emissions must be held to net zero**[226] from that point onward to avoid exceeding the target temperature. Carbon emissions budgets are generally calculated in either billions of tonnes of carbon (Gt C) or billions of tonnes of CO_2 (Gt CO_2). 1Gt CO_2 contains 0.273 Gt C.

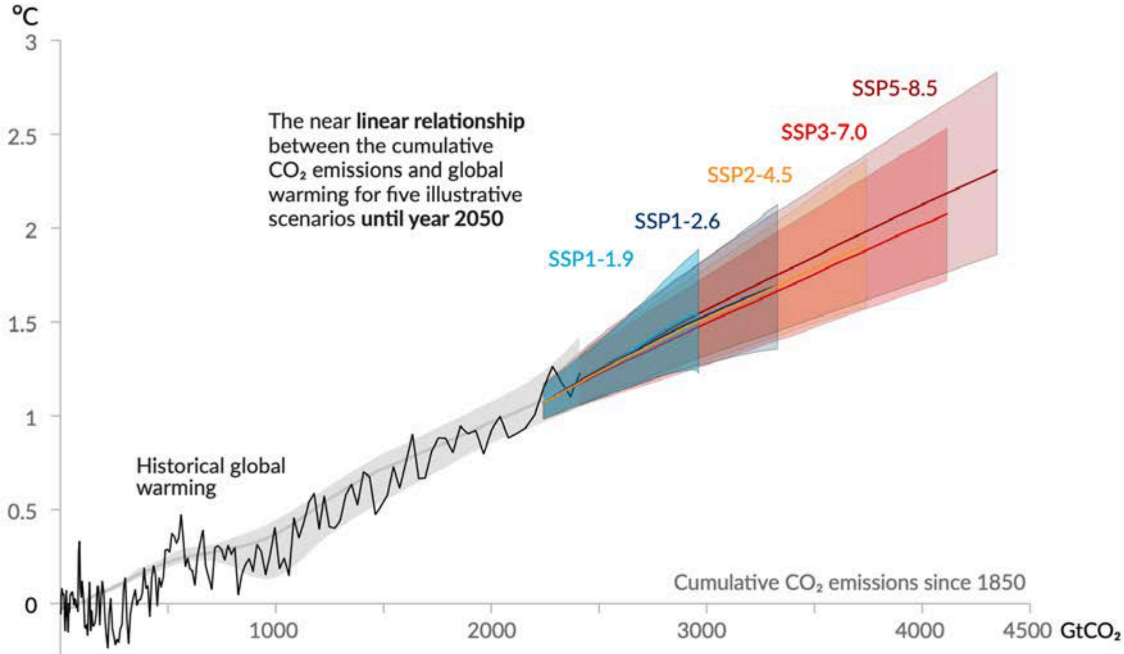

Fig. 23: Global surface temperature increase [on vertical axis in °C since the period 1850-1900] as a function of the cumulative CO_2 emissions [on horizontal axis in $GtCO_2$] projected out until the year 2050. This nearly linear (straight-line) relationship is the basis for computing a `carbon budget' for a particular amount of global warming. Figure is taken from the IPCC AR6 WGI Summary for Policymakers.

216) Several assumptions influence the size of the global carbon budget for a given warming target. Key among them are:

a) What is considered an 'acceptable' probability of meeting the target,

b) The date period used for 'pre-industrial,'

c) The accounting of other greenhouse gases (particularly CH_4 and N_2O),

d) Whether or not 'temporary overshoot' of the desired warming target is allowed, and

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[226] NB: The term 'net zero' used here means that CO_2 emissions *into* the atmosphere are matched in magnitude by CO_2 removal *from* the atmosphere. Carbon capture and storage and many other `Negative Emission Technologies' are not yet viable at scale.

e) If, and how, carbon feedbacks in the climate system are accounted. Carbon feedback occurs when warming causes the Earth to release some of its own sequestered CO_2.

217) The goal is to ascertain the ***remaining*** **amount of carbon** (in the form of CO_2) **that humans can still release** into the atmosphere **without exceeding global warming at a prescribed level,** for example warming of 1.5°C. The *remaining* carbon budget, the amount humans have 'left to spend,' is **different from the total carbon budget, for three primary reasons**.

a) Substantial historical emissions from pre-industrial times through to the present have already been emitted, and must be subtracted from the total budget to arrive at the much smaller amount remaining.

b) Assumptions about the future emissions of *non*-CO_2 GHGs are implicit in carbon budget estimates. Should actual trajectories differ from those assumptions, the remaining carbon budget will change.

c) Some carbon cycle feedbacks, such as the abrupt shift of the Amazon rainforest to a savanna, GHG emissions from permafrost thaw, and the effects of increased wildfire are not accounted for in many Earth System models or in some carbon budget approaches. This could reduce the remaining carbon budget further.[227,228]

218) AR6, WGI [229] gives remaining carbon budgets for selected values of global warming and for selected likelihoods of occurring. These are reproduced in Table 2 below.

219) Large uncertainties could push these remaining carbon budgets higher or lower, though neglected or underestimated positive carbon feedbacks will always work to decrease carbon budgets.

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[227] Ciais P et al. (2013) Carbon and Other Biogeochemical Cycles, in Climate Change 2013: The Physical Science Basis, Fifth Assessment Report of the IPCC, edited by Stocker TF, et al., Cambridge University Press, pp. 465–570, doi:10.1017/CBO9781107415324.015.
[228] Steffen W et al. (2018) Trajectories of the Earth System in the Anthropocene. *Proc. Natl. Acad. Sci. (USA)* doi:10.1073/pnas.1810141115 and associated Appendix https://www.pnas.org/content/pnas/115/33/8252.full.pdf
[229] IPCC (2021) Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Table SPM.2, accessed at: https://www.ipcc.ch/report/ar6/wg1/#SPM

Table 2: Remaining global carbon budgets from 2020 as given by IPCC AR6 for various temperature limits and success likelihoods

Approximate global warming relative to the period 1850-1900 until the temperature limit (°C)	Estimated remaining carbon budgets from the **beginning of 2020** ($Gt\ CO_2$) *Likelihood of limiting global warming to temperature limit*				
Temperature Limit	17%	33%	50%	67%	83%
1.5	900	650	500	400	300
1.7	1450	1050	850	700	550
2.0	2300	1700	1350	1150	900

220) Notably, higher or lower reductions in accompanying non-CO_2 GHG emissions could alter the carbon budgets by 220 Gt CO_2 or more. In this context, however, it is important to note that **AR6 carbon budgets** in Table 2 **assume that non-CO_2 emissions are reduced sharply as well. Specifically, for methane, this implies at least a 30% reduction in 2030 compared with 2010, and a 50% reduction in 2050.**[230]

221) At the moment, **global methane emissions are rising, which means that remaining carbon budgets are shrinking.** In fact, since 2012, CH_4 emissions have been tracking the *warmest* scenarios assessed by the IPCC[231], and atmospheric concentrations have been rising at an increasing rate since about 2006 (refer to Fig. 2).

222) In order to establish the *remaining* carbon budgets from the beginning of 2022, the budget quantities in Table 2 must be reduced by the total CO_2 emissions released in 2020 and 2021, namely by about 80 Gt CO_2 (equivalent to 21.1 Gt C).[232]

223) **In this Report, I focus on carbon budgets that correspond to at least a 67% chance (two-in-three chance) of meeting the indicated temperature target**, noting that a 50% likelihood is equivalent to basing the most critical of environmental outcomes on the flip of a coin. Table 3 thus presents remaining carbon budgets from the beginning of 2022 for at least a 67% likelihood of limiting global warming to 1.5°C, 1.7°C and 2.0°C.

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[230] United Nations Environment Programme (2021). *Emissions Gap Report 2021: The Heat Is On – A World of Climate Promises Not Yet Delivered*. Nairobi. Accessed at: https://www.unep.org/resources/emissions-gap-report-2021
[231] Saunois, M. et al. (2020) The Global Methane Budget 2000 – 2017, Earth System Sci. Data, 12, 1561, https://doi.org/10.5194/essd-12-1561-2020
[232] Friedlingstein, P et al. (2021) Global Carbon Budget 2021, Earth Syst. Sci. Data https://essd.copernicus.org/preprints/essd-2021-386/

Table 3: Remaining global carbon budgets from 2022 for a 67% chance of holding warming to various temperature limits (rounded to the nearest 10 Gt CO_2)

Approximate global warming relative to the period 1850-1900 until the temperature limit	Paris Agreement Significance*	Estimated remaining carbon budget from the **beginning of 2022** ($GtCO_2$)
Temperature Limit		*67% likelihood of limiting global warming to temperature limit*
1.5 °C	Required Level of Effort	320
1.7 °C	Consistent	620
2.0 °C	Not Consistent	1070

224) In order to place these quantities in perspective, note that global annual emissions are now estimated to have rebounded from a small decline caused by COVID-19 restrictions, and now stand at about 40 Gt CO_2 per annum.[233] Thus, **only about 8 years remain at current emission levels before the remaining 1.5°C carbon budget** (from Table 3) **is exhausted**. This is one of many ways to understand why the period until 2030 is so critical.

7.3 The Fossil Fuel Production Gap

225) The primary reason why current global policies place the world on track for about 3°C of warming is that future fossil fuel production is not being curtailed quickly.

226) A 2021 special report by the **International Energy Agency (IEA)[234]** specifically designed for the **global energy sector** as a **roadmap** for achieving a net zero pathway (by 2050) listed (among other measures) **three significant milestones in the report's pathway that illustrate the scope of the changes required**:

a) **Beginning in 2021: No new oil and gas fields approved for development; no new coal mines or mine extensions; no new unabated coal plants approved for development.**

b) **By 2030: Phase-out of unabated coal in advanced economies.**

c) **By 2040: Phase-out of all unabated coal and oil power plants.**

[233] Friedlingstein, P et al. (2021) Global Carbon Budget 2021, Earth Syst. Sci. Data https://essd.copernicus.org/preprints/essd-2021-386/

[234] IEA (2021) Net Zero by 2050: A Roadmap for the Global Energy Sector, accessed at: https://www.iea.org/reports/net-zero-by-2050

227) A 2015 economic analysis **based on only a 50% chance of achieving 2°C** concluded that **a third of oil reserves,**[235] **half of gas reserves, and over 80% of coal reserves** (as defined in 2015) **must remain unused** from in the period from 2010 to 2050 **in order to meet a warming target of 2°C**, above Paris Agreement goals.[236]

228) Updating this work in 2021, a new research paper[237] estimates that in order to have at least a **50% probability** of keeping the global temperature increase to about **1.5°C, 58% of oil, 59% of fossil methane gas, and 89% of coal reserves** (as identified in the 2018 reserve base) **must not be extracted**. This means that very high shares of reserves considered economic today could not be extracted if the world is to meet a global 1.5 °C target.

229) Underscoring this point are recent reports[238,239,240] that analyse the gap between different nations' expectations for the production of fossil fuels and the Paris Agreement warming target that the same nations support. The 2021 analysis shows that **governments are still planning to produce about 45% more fossil fuels by 2030 than would be consistent with a 2°C pathway and more than double than would be consistent with a 1.5°C pathway.**

230) **The disconnect between the intention to produce more fossil fuels and the simultaneous commitment to reduce emissions to meet the Paris Agreement has been called the `Production Gap.'** This Production Gap is illustrated in Fig. 24 below, taken from the latest Stockholm Environment Institute (SEI et al.) report.[241]

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[235] Here, 'reserves' is taken to mean a subset of known resources that are defined to be recoverable under current economic conditions and have a specific probability of being produced.
[236] McGlade C and Ekins P (2015) The geographical distribution of fossil fuels unused when limiting global warming to 2°C. *Nature* 517: 187-190.
[237] Welsby, D, Price, J, Pye, S, and Elkins, P (2021) Unextractable fossil fuels in a 1.5C world, Nature, 597, Accessed at: https://www.nature.com/articles/s41586-021-03821-8
[238] SEI, IISD, ODI, Climate Analytics, CICERO, and UNEP (2019) The Production Gap: The discrepancy between countries' planned fossil fuel production and global production levels consistent with limiting warming to 1.5°C or 2°C. https://productiongap.org/2019report/
[239]SEI, IISD, ODI, E3G, and UNEP (2020) The Production Gap Report: 2020 Special Report. https://productiongap.org/2020report/
[240] SEI, IISD, ODI, E3G, and UNEP (2021) The Production Gap Report: 2021 Report. Governments' planned fossil fuel production remains dangerously out of sync with Paris Agreement limits. https://productiongap.org/2021report/
[241] SEI, IISD, ODI, E3G, and UNEP (2021) The Production Gap Report: 2021 Report. https://productiongap.org/2021report/

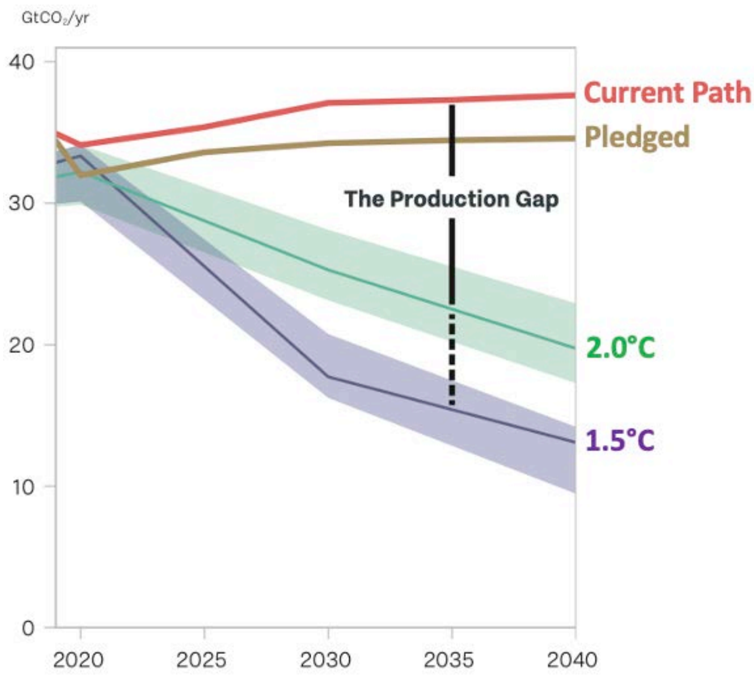

Fig. 24: Possible trajectories of global CO_2 emissions from all fossil fuels from 2019 to 2040 in units of $GtCO_2$ emitted in each year. In red is the current trajectory, whilst the gold line indicates what would be achieved if all Paris Agreement pledges were met. Lavender and turquoise trajectories reflect world fossil fuel production consistent with a 50% chance of holding warming to 1.5°C, or 66% chance of holding warming to 2.0°C, respectively. Shaded regions indicate uncertainty ranges for the 1.5°C and 2.0°C trajectories.

231) The world is emitting about 36 Gt CO_2 per year from fossil fuels[242] (see Fig. 4). By 2030, this must *drop* to about 18 Gt CO_2 per year or 26 Gt CO_2 per year in order to hold warming to 1.5°C or 2°C, respectively (central estimates). Yet, current global policies associated with fossil fuel production are consistent with *increasing* the fossil CO_2 to at least 2040. In other words**, it is primarily the "overproduction" of fossil fuels that is preventing the world from being on-track to meeting a global warming limit of 1.5° – 2°C**.

232) **Furthermore, the production of *each* of coal, oil, and gas must drop immediately and sharply before 2030 to provide sufficiently significant cuts before 2030 for even a 50% chance of holding global warming to 1.5°C, according to the Production Gap Report. For a 66% chance of holding warming to 2°C, the report concludes that oil and gas production must fall after 2030, and coal production must steadily and quickly decline well before 2030**.[243] (See Fig. 25 below).

[242] Friedlingstein, P et al. (2020) Global Carbon Budget 2020, Earth Syst. Sci. Data, 12, 3269-3340, https://doi.org/10.5194/essd-12-3269-2020 Table 6 on p3292 noting units there are GtC not $GtCO_2$.
[243]SEI, IISD, ODI, E3G, and UNEP (2021) The Production Gap Report: 2021 Report. https://productiongap.org/2021report/

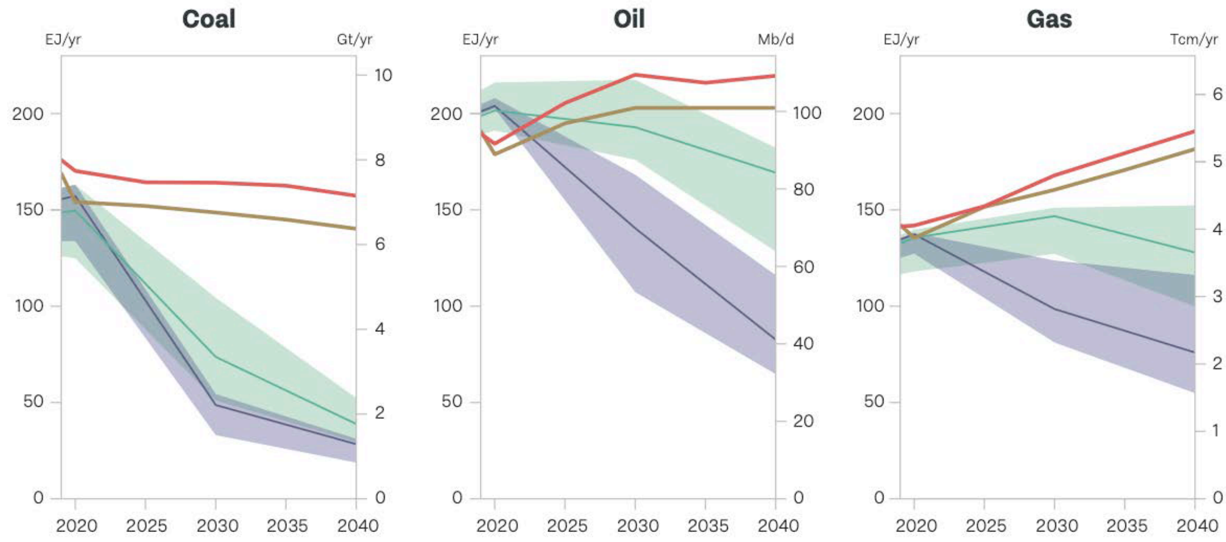

Fig. 25: Global emissions trajectories for coal, oil, and gas production based on current production and projections (red) and as implied by climate pledges (gold). Also shown is a range of trajectories consistent with holding global warming to 2.0°C with a 66% chance (light green), and with holding global warming to 1.5°C with a 50% chance (lavender). From SEI et al. 2021.[244]

233) Redressing this fossil fuel production gap cannot be met by *adding* fossil fuel development, even that which may have already planned. Instead, **new fossil fuel development and expansion must cease, and ageing facilities brought to rapid close if global warming is to be halted at 1.5°C or even 2.0°C above pre-industrial times**. The longer we wait, the more difficult the transition becomes.

7.4 Australia's Contribution

234) In this subsection, I examine **Australia's contribution to global warming from the three perspectives** discussed earlier, namely emission trajectories and NDCs to the Paris Agreement, Australia's share of the global carbon budget, and Australia's contribution to the Production Gap.

7.4.1 Australia's NDC to the Paris Agreement and Current Emissions Trajectory

235) As a nation, **Australia's Paris Agreement NDC is to reduce its emissions by 26%–28% (on 2005 levels) by 2030.**[245] It has also stated an ambition to reach net zero emissions by

[244]SEI, IISD, ODI, E3G, and UNEP (2021) The Production Gap Report: 2021 Report. https://productiongap.org/2021report/

[245] Commonwealth of Australia, Australia's 2030 Emissions Reduction Target Fact Sheet, https://pmc.gov.au/sites/default/files/publications/fact_sheet-aus_2030_climate_change_target.pdf

2050.[246] Australia did not update its NDC targets in 2020, whereas many other nations did so. Since Australia's emissions were 624 millions tonnes (Mt) CO_2-e in 2005,[247] a reduction of (at least) 26% implies emissions in 2030 of no more than 462 Mt CO_2-e.

236) As Fig. 26 below shows, there is no indication that such a decline is occurring based on the last five years of available Paris Agreement reporting data (which extends only to 2019). On current trends, then, **Australia's emission pathway is thus inconsistent with holding warming to 1.5°C**.

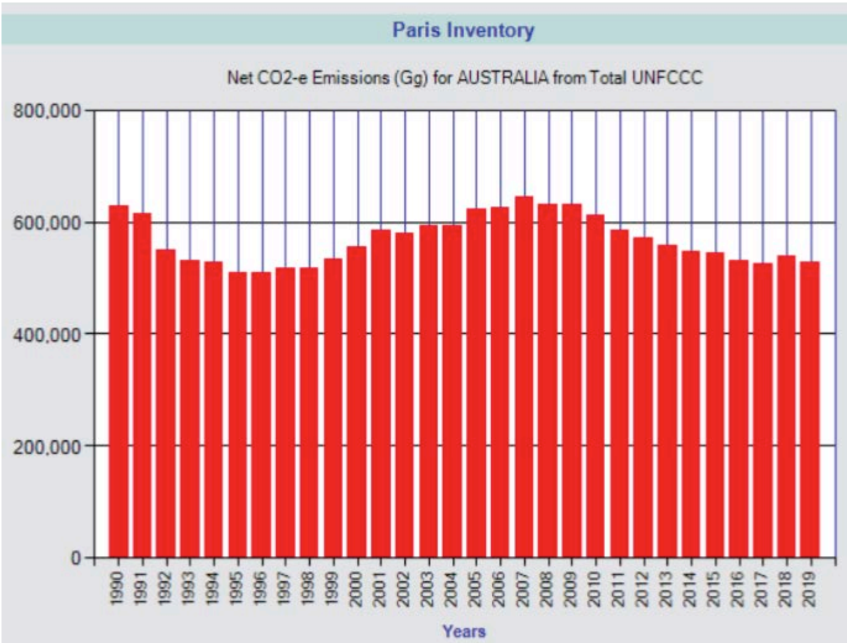

Fig 26: Australia's trend since 1990 in total emissions reported for the Paris Agreement Inventory. The plot is taken from the National Greenhouse Gas Inventory (NGGI) website. Note that the units are Gg (Giga grams) of CO_2-e, which is the same as Kt CO_2-e. (To convert to Mt CO_2-e, numbers on the vertical axis should be divided by 1000.)

237) **Australia's 2030 NDC target has been rated "highly Insufficient"** (by Climate Action Tracker)[248] **to hold global warming to below 2°C, let alone 1.5°C.** The "Highly insufficient" rating indicates that Australia's climate policies and commitments are not Paris Agreement compatible. Their analysis indicates that **Australia's 2030 emissions reduction target is consistent with warming of 4°C if all other countries followed a similar level of ambition.**

238) Another perspective on the NDC target is provided by the Australia-focussed component of a six-part series of reports[249] (CAT Report) examining how countries can scale up climate action in four key sectors: electricity, transport, industry, and buildings.

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[246] See, e.g. https://www.pm.gov.au/media/australias-plan-reach-our-net-zero-target-2050
[247] National Greenhouse Gas Inventory, https://ageis.climatechange.gov.au
[248] Climate Action Tracker (2022), https://climateactiontracker.org/countries/australia/, https://climateactiontracker.org/climate-target-update-tracker/australia/ Accessed on 16 Mar 2022.
[249] Climate Action Tracker (CAT) (2020) Scaling up Climate Action Australia, Accessed at: https://climateactiontracker.org/publications/scalingup/

239) **The CAT Report[250] lists reduction targets for each of these sectors for years 2030, 2040 and 2050 that begin with Australia's current emission profile and reduce it over time in a manner consistent with holding warming to 1.5°C.** The result is shown in Fig. 28 as a combined pathway for Australia's emissions.

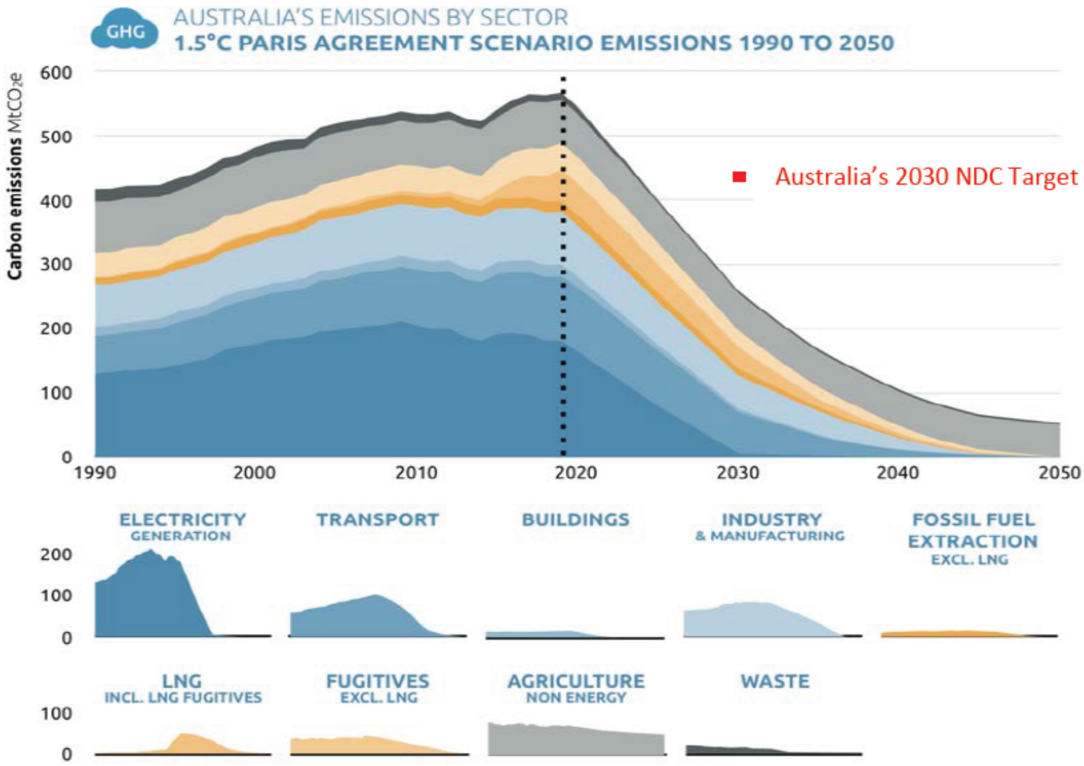

Fig. 27: A combined pathway for Australian sectoral emissions that is consistent with holding global warming to 1.5°C (according to CAT 2020). Negative emissions from land sector sinks are not shown, but could enable net zero in emissions 2050. The red square indicates Australia's 2030 Paris Agreement target over all sectors of the Australian economy. Figure from CAT 2020 report.

240) Australia's stated policy goal[251] to reduce its emissions by 26%–28% (on 2005 levels) by 2030 translates to a 2030 target of 449–462 Mt CO_2-e.[252] Examination of Fig. 27 above shows that **Australia's current 2030 target lies far above the combined sectoral pathway consistent with 1.5°C.**

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[250] Climate Action Tracker (CAT) (2020) Scaling up Climate Action Australia, Accessed at: https://climateactiontracker.org/publications/scalingup/

[251] Commonwealth of Australia, Australia's 2030 Emissions Reduction Target Fact Sheet, https://www.pmc.gov.au/sites/default/files/publications/fact_sheet-aus_2030_climate_change_target.pdf

[252] Note: CO_2-e is a commonly used measure that combines the effects of different greenhouse gases into an "equivalent" amount of CO_2. Unless otherwise stated, it refers to the effects of GHGs over a 100-year time frame after they are emitted.

7.4.2 Australia’s share of the Remaining Global Carbon Budget

241) **The remaining carbon budgets** presented in Table 3 **for the whole globe can be translated into notional remaining carbon budgets for regional areas, such as Australia or NSW** by considering an ‘appropriate’ fractional amount. Arguments can be made as to how much a region can or should be allowed to emit, based on history, industrial base, international trade, population and ethical or normative considerations. Nature is blind to these distinctions.

242) **For this reason, regional carbon budgets can be formulated in any of a number of ways, each with its own set of driving principles**. Examples[253,254,255,256] include:

a) Remaining carbon budgets are divided equally on a per capita basis;

b) Remaining carbon budgets are divided in proportion to current emissions;

c) Responsibility for emissions reductions is based on past emissions;

d) Remaining burden to reduce emissions is based on fraction of world GDP;

e) Per capita emissions are set equal across the globe at some fixed point in future;

f) Some combination of the above.

243) **For this report, the remaining carbon budgets** of Table 3 **are apportioned equally among the world’s population as they are expected to be in 2040** (sometimes referred to as the ‘Equality’ or ‘Contraction and Convergence’ approach)’ to arrive at notional population share values for Australia and NSW. **This approach has been chosen because it is relatively simple to calculate, and because it has been shown to lie in the middle of a spectrum of choices for Australia’s fair share of the global emissions reduction burden.**

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[253] Carbon Brief (2014) How to divide up carbon budgets fairly, Accessed at: https://www.carbonbrief.org/how-to-divide-up-carbon-budgets-fairly

[254] Climate Change Council (2018) What is a Carbon Budget? Accessed at: https://www.environment.act.gov.au/__data/assets/pdf_file/0006/1297707/What-is-a-Carbon-Budget.pdf

[255] Rodriguez-Fernandez, L, et al. (2020) Allocation of Greenhouse Gas Emissions Using the Fairness Principle: A Multi-Country Analysis, and references cited therein. Sustainability, 12, 5839. Accessed at: https://www.mdpi.com/2071-1050/12/14/5839

[256] CCA (Climate Change Authority) (2014) Reducing Australia’s Greenhouse Gas Emissions: Targets and Progress Review—Final Report, https://www.climatechangeauthority.gov.au/reviews/targets-and-progress-review-3

An analysis aimed at developing a GHG budget for Victoria[257] has shown that an 'Equal per capita 2040 convergence' approach produced a value that was the middle of five approaches considered.

244) For this estimate, the relevant projected 2040 populations[258,259,260] are taken to be: 9.20 billion (world), 33.6 million (Australia), and 10.6 million (NSW). Results are given in Table 4 below. Note that the carbon budget numbers for Australia and NSW are in *millions* of tonnes of carbon dioxide (Mt CO_2), not *billions* of tonnes of carbon dioxide (Gt CO_2).

Table 4: Remaining carbon budgets to limit (with a 67% chance) global warming to various levels, apportioned by projected 2040 population, and rounded to the nearest 10 Gt or Mt CO_2

Share based on equal 2040 per capita share (`Equality share')	1.5°C (67% chance)	1.7°C (67% chance)	2.0°C (Not Paris compliant) (67% chance)
World	320 **Gt CO_2**	620 **Gt CO_2**	1070 **Gt CO_2**
Australia	1170 **Mt CO_2**	2260 **Mt CO_2**	3910 **Mt CO_2**
New South Wales	370 **Mt CO_2**	710 **Mt CO_2**	1230 **Mt CO_2**

245) To put these local carbon budgets in perspective using the most recent National Greenhouse Gas Inventory[261] data, note that Australia directly emitted about 374 million tonnes of CO_2 in 2019, while NSW emitted 98 million tonnes of CO_2 in that year. (For the purposes of carbon budget comparisons, only CO_2 emissions are counted, not other GHGs.) **Thus, on current trends, only three years remain of Australia's 'equality' carbon budget for a 67% chance of achieving 1.5°C; about four years remain for NSW's portion.**

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[257] Meinshausen, M., Robiou Du Pont, Y. and Talberg, A. (2018), Greenhouse Gas Emissions Budgets for Victoria, Briefing Paper for the Independent Expert Panel on Interim Targets, May 2018. Accessed at: https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0016/421702/Greenhouse-Gas-Emissions-Budgets-for-Victoria.pdf . See in particular, their Table 3.
[258] United Nations (2019) Population data, Standard Projections. Accessed at: https://population.un.org/wpp/Download/Standard/Population/, using medium fertility variant
[259] Australia Bureau of Statistics (2018) https://www.abs.gov.au/statistics/people/population/population-projections-australia/latest-release#data-download , using their middle series
[260] New South Wales Government (2019) Accessed at: https://www.planning.nsw.gov.au/Research-and-Demography/Population-projections/Projections
[261] National Greenhouse Gas Inventory, maintained by the Australian Government's Department of the Industry, Science, Energy and Resources. Accessed at http://ageis.climatechange.gov.au/

246) If the **Australian Government's current 2030 total GHG target** of 26 – 28% reductions *on 2005 levels*, **were applied to Australia's CO_2 only emissions**, then the 453 Mt CO_2 emitted in 2005 would drop to between 326 and 335 Mt CO_2 in 2030. If the higher ambition of 326 Mt CO_2 were approached with a linear drop from 2019 to 2030, **then by 2030 Australia will have** emitted about 3,850 Mt CO_2 over that period and thus **nearly exhausted its equality share of even the 2.0°C carbon budget** shown in Table 4. This is one way in which to understand that **Australia's 2030 target is incompatible with the Paris Agreement warming target**.[262]

247) The IPCC AR6 WGI carbon budgets used here as a starting point are predicated on the assumption that deep reductions in methane occur concurrently – at least a 30% reduction in 2030 compared with 2010, and a 50% reduction by 2050 (see paragraph 220). In 2010, Australia's methane emissions were 4.86 Mt CH_4. Since then, they have dropped only slightly to 4.48 Mt CH_4 in 2019,[263] a drop of only 7.8% over that period. **If Australia fails to reduce its methane emissions much more quickly, its share of the remaining carbon budget will shrink even faster**.

248) A recent independent report[264] has reassessed Australia's emissions targets, using the carbon budget methodology used by the Government-established Australian Climate Change Authority (CCA) to arrive at its 2014[265] and 2015[266] recommendations for Australian GHG reduction targets, namely, a 40 – 60% reduction on 2000 levels by 2030. **The new report concludes that in order to be consistent with holding warming to 1.5°C with just a 50% chance, Australia's 2030 emissions reduction target must be 74% below**

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[262] I stress that 2.0°C of warming is not compatible with the Paris Agreement, and its climate consequences are severe (as discussed in Section 6.

[263] National Greenhouse Gas Inventory, maintained by the Australian Government's Department of the Industry, Science, Energy and Resources. Accessed at http://ageis.climatechange.gov.au/

[264] Hewson, J., Steffen, W., Hughes, L, and Meinshausen, M. (2021) Australia's Paris Agreement Pathways: Updating the Climate Change Authority's 2014 Emissions Reduction Targets, https://www.climatecollege.unimelb.edu.au/files/site1/docs/%5Bmi7%3Ami7uid%5D/ClimateTargetsPanelReport.pdf

[265] CCA (Climate Change Authority) (2014) Reducing Australia's Greenhouse Gas Emissions: Targets and Progress Review—Final Report, https://www.climatechangeauthority.gov.au/reviews/targets-and-progress-review-3

[266] CCA (Climate Change Authority) (2015) Final Report on Australia's Future Emissions Reduction Targets, https://www.climatechangeauthority.gov.au/sites/default/files/2020-07/Final-report-Australias-future-emissions-reduction-targets.pdf

2005 levels, with net-zero emissions reached by 2035. This level of emissions reduction by 2030 is nearly three times that of Australia's Paris NDC.

7.4.3 Australia and the Production Gap

249) Australia's (and NSW's) effect on global warming and climate change goes far beyond its direct emissions (or Scope 1) of greenhouse gases. **Australia has a large indirect contribution to climate change through the emissions of countries that burn our nation's exported fossil fuels. These are called 'Scope 3' emissions.**

250) Although the *National Greenhouse and Energy Reporting Act 2007* (the NGER Act)[267] does not require reporting of Scope 3 emissions for Australian entities, all emissions arising directly or indirectly from an activity lead to global warming and climate change, regardless of where they are emitted. Thus, **all emissions, including Scope 3 emissions** released when fossil fuels are combusted by any end user, **must be included when considering the effect on the climate of a given activity. To do otherwise is to assume that the fuel is never used for its intended purpose.**

251) **Australia is the world's** second **leading exporter of coal** (by weight)[268] **and the largest exporter of LNG.**[269] Australia's annual production of coal has risen sharply over the past decades, and then dropped slightly as brown coal production has decreased (see Fig. 28). Black coal production has approximately levelled over the past five years.

252) **As the world's fifth largest producer of coal, and world's largest exporter of black coal,**[270] **Australia has an enormous responsibility, and an enormous opportunity, to contribute to closing the Production Gap to a climate stabilised well below 2°C of warming compared to pre-industrial times.**

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[267] Accessed at: https://www.legislation.gov.au/Details/C2019C00044
[268] International Energy Agency (2021) Coal 2021 https://www.iea.org/reports/coal-2021
[269] International Gas Union (IGU 2021), 2021 World LNG Report. https://www.igu.org/resources/world-lng-report-2021/
[270] IEA data for 2019-2020 referenced by Geoscience Australia. Accessed at: https://www.ga.gov.au/digital-publication/aecr2021/coal#data-download-section

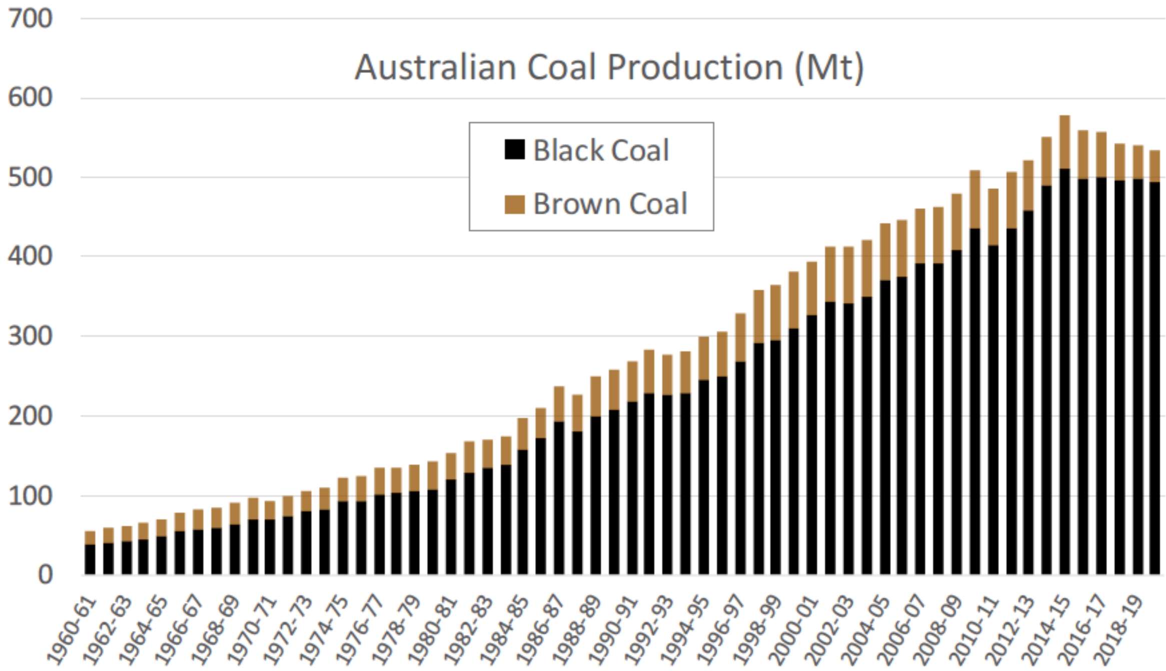

Fig. 28: Australia's production of brown and black coal (in Mt) is shown for every fiscal year from 1960-61 through 2019-20. Data are from Australian Government (2021) Australian Energy Statistics, Table P2, Dept of Industry, Science, Energy and Resources, September 2021. Total coal production is indicated by the total height of the bar in a given year. Data were accessed at: https://www.energy.gov.au/publications/australian-energy-update-2021

253) Despite this, the Commonwealth Government is anticipating steady coal production through 2030.[271] **Australian Government modelling published in 2021 anticipates (Scope 1 and 2) emissions from coal mining to remain constant over the period 2019 to 2030, implying that the total amount of coal extracted annually will stay approximately the same over this period.** Oil and gas extraction emissions, on the other hand, are projected to rise by 7% over the period.[272] **These forecasts are highly inconsistent with trends in coal, gas and oil production required to hold warming to 1.5°C, and for coal, highly inconsistent with even holding warming to 2.0°C** (see Fig. 25).

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[271] Department of Industry, Science, Energy and Resources (2021) Australia's emissions projections 2021. See their Tables 8, 9, 15 and associated text. Accessed at: https://www.industry.gov.au/data-and-publications/australias-emissions-projections-2021
[272] Department of Industry, Science, Energy and Resources (2021) Australia's emissions projections 2021. See their Tables 8, 9, 15 and associated text. Accessed at: https://www.industry.gov.au/data-and-publications/australias-emissions-projections-2021

254) Recent international reports have analysed Australia's projections,[273,274] **concluding that Australia's extraction-based** (also called production-based) **emissions**[275] **from fossil fuel (coal and gas) production are expected to nearly double by 2030 compared to 2005 levels**, indicating that **Australia is a major contributor to the Production Gap**[276] **between global intended fossil fuel production and the Paris Agreement target for global warming**. In this sense, **Australia is indirectly working against global warming being held to 1.5°C (and even to 2.0°C), through the large Scope 3 emissions associated with its fossil fuel production, which is primarily for export**.

255) Comparison of the historical plot of coal production (Fig. 28) with the future trend in coal production required in order to hold global warming to between 1.5°C to 2.0°C (Fig. 25, left panel) reveals the **huge magnitude of reduction required if Australia is to align its coal production with Paris Agreement targets**.

256) **Recent analysis indicates that 95% of Australia's coal reserves**[277] **– and globally 89% of all coal reserves – must stay in the ground in order for the world to have a 50% chance of holding warming to 1.5°C** (global carbon budget of 580 Gt CO2).[278]

257) Yet, Australia has more capacity in export-oriented coal projects in the pipeline than any other country by far, as illustrated in Fig. 29 below, taken from a 2021 report of the IEA.[279] Australia also leads in the capacity of mine re-openings per country. [280] **Without**

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[273] SEI, IISD, ODI, Climate Analytics, CICERO, and UNEP. (2019). The Production Gap: The discrepancy between countries' planned fossil fuel production and global production levels consistent with limiting warming to 1.5°C or 2°C. http://productiongap.org/

[274]SEI, IISD, ODI, E3G, and UNEP. (2020). The Production Gap Report: 2020 Special Report. https://productiongap.org/2020report/

[275] `Extraction-based' emissions are part of a system of accounting that attributes greenhouse gas emissions from the burning of fossil fuels to the location of fuel extraction. It is an alternate, scientifically valid way to account for emissions.

[276] SEI, IISD, ODI, Climate Analytics, CICERO, and UNEP. (2019). The Production Gap: The discrepancy between countries' planned fossil fuel production and global production levels consistent with limiting warming to 1.5°C or 2°C. http://productiongap.org/

[277] Here, reserves is taken to mean coal that is technically and economically proven given market conditions at the time of study, which is 2018.

[278] Welsby, D, Price, J, Pye, S, and Elkins, P (2021) Unextractable fossil fuels in a 1.5C world, Nature, 597, Accessed at: https://www.nature.com/articles/s41586-021-03821-8

[279] International Energy Agency (2021) Coal 2021 https://www.iea.org/reports/coal-2021

[280] International Energy Agency (2021) Coal 2021 https://www.iea.org/reports/coal-2021

changes to current plans, Australian coal exports will contribute to the global warming Production Gap, disproportionately so, for decades to come.

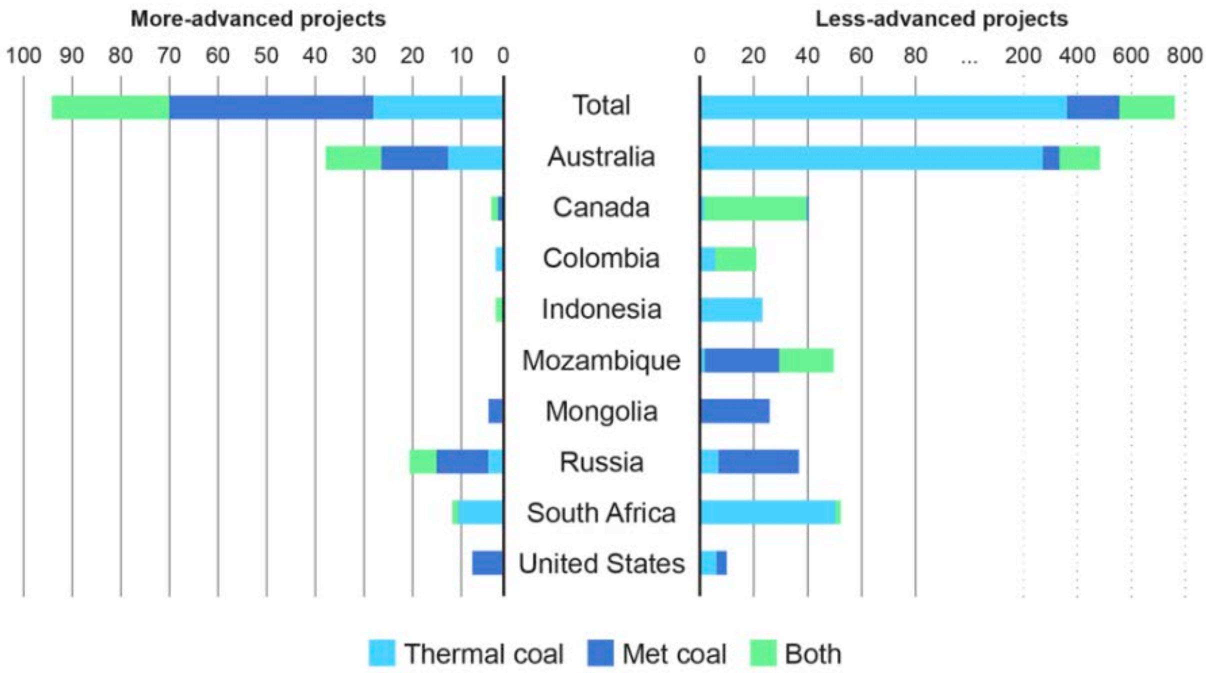

Fig. 29: Top countries by the capacity (measured in Mt of coal per annum) of new export projects for coal, as assessed by the IEA in 2021. `More-advanced' projects are those that have been approved and obtained a final investment decision or are under construction, while `less-advanced' projects are at the feasibility or environmental assessment stage, or they are awaiting approval. `Met' coal is metallurgical (or coking) coal.

258) GHG emissions arising from the burning of Australia's coal by end users (wherever that combustion may occur) are just as harmful to Australia's environment – on a tonne per tonne basis – than Scope 1 emissions arising within Australian borders.

259) In order to estimate the magnitude of the total effect, I have used the data displayed in Fig. 28 for coal production and the emission factors for different types of coal given in the National Greenhouse Accounts Factors.[281] As there are different grades of black coal, I have used sub-bituminous coal to give a lower estimate (1.895 tCO_2-e/t coal) and coking coal to give an upper estimate (2.761 tCO_2-e/t coal) for Australia's black coal production. Brown coal is assumed to have an emission factor of 0.957 tCO_2-e/t coal. The results are shown in Fig. 30 below.

[281] Australian Government (2021) National Greenhouse Accounts Factors. See their Table 1.

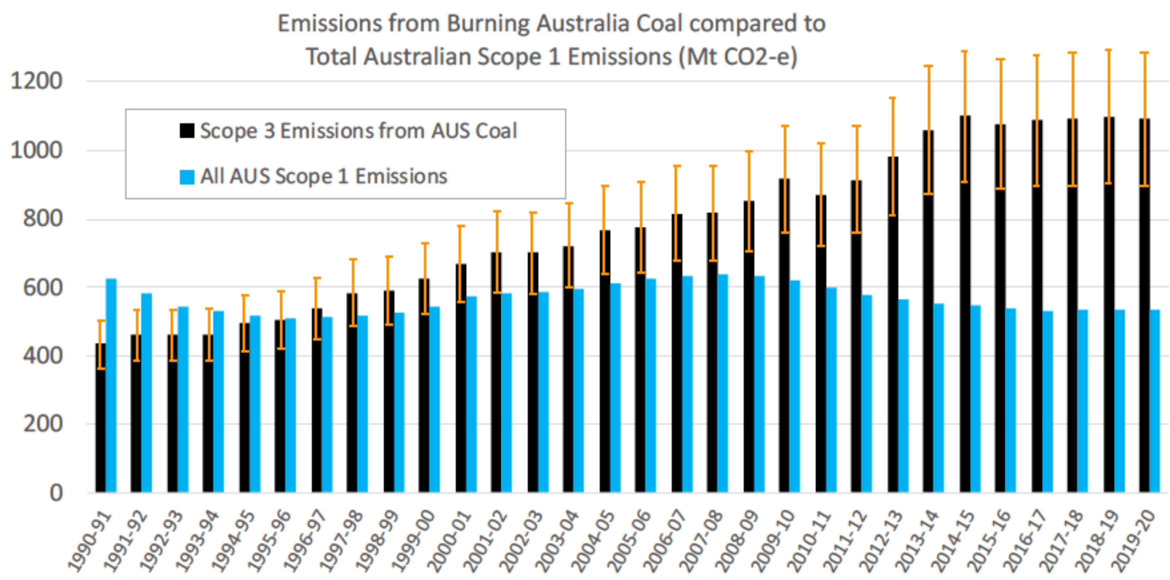

Fig. 30: Estimated emissions from the burning of Australian coal by the end user (black) compared to the total of all Australia's territorial (Scope 1) emissions (blue) over the period 1990 to 2019. The orange bars indicate the wide range of assumptions about the emissions intensity of Australia black coal (see text).

260) As Fig. 30 shows, **over the past five years, GHG emissions from the burning of Australia coal have** been twice that of all GHG emissions directly emitted by Australians in those years, having therefore, **twice the detrimental effect on the Australian environment as do all the emissions emitted directly by Australians within the national borders.**

7.5 NSW's Contributions

261) In this subsection, I examine NSW's contribution to global warming from the perspectives of emission trajectories, share of the global carbon budget, and contribution to the Production Gap.

7.5.1 NSW's Current Emissions Trajectory

262) **NSW has committed to achieving zero net emissions by 2050, with an interim target to reduce emissions by 50% below 2005 levels by 2030,** representing a considerable increase in ambition from its previous 2030 target of 35% reduction.[282]

[282] NSW Government (2021) Net Zero Plan Stage 1: 2020-30 Implementation Update. Accessed at: https://www.environment.nsw.gov.au/research-and-publications/publications-search/net-zero-plan-stage-1-2020-30-implementation-update

263) Whereas NSW's total Scope 1 emissions did drop between 2007 and 2015, the trend has been rather flat since then, as illustrated in Fig. 31, which is taken from the national GHG Inventory.[283]

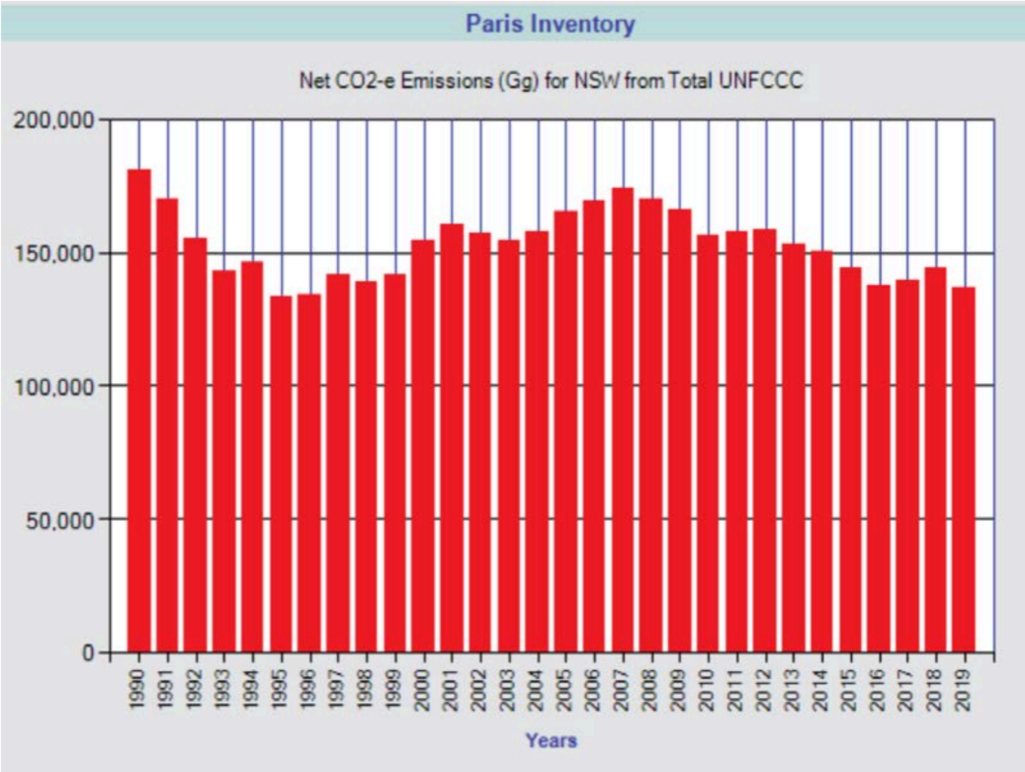

Fig. 31: New South Wales' trend since 1990 in total Scope 1 GHG emissions. The plot is taken from the National Greenhouse Gas Inventory website. Note that the units are Gg (Giga grams) of CO_2-e, which is the same as Kt CO_2-e. (To convert to Mt CO_2-e, numbers on the vertical axis should be divided by 1000.)

264) **In order to achieve a 50% reduction on total 2005 GHG emissions**, which were 165 Mt CO_2-e, **NSW's emissions in 2030** must be no more than 83 Mt CO_2-e, **requiring a considerable drop from its current emissions**, at annual rate of about 3.75% from now until 2030.

265) As I show in subsection 8.2, **the approximately 2.264 Mt CO_2-e** (Scope 1) **expected to be emitted by the Project up to 2030 will make meeting NSW's emissions target appreciably more difficult to achieve.**

[283] National Greenhouse Gas Inventory. Accessed at http://ageis.climatechange.gov.au/

7.5.2 NSW's Share of the Remaining Global Carbon Budget

266) Table 4 gives NSW's `equality' share of the world's remaining carbon budgets for holding global warming to each of 1.5°C, 1.7°C and 2.0°C, with at least a 67% chance, as 370 Mt CO_2, 710 Mt CO_2, and 1,230 Mt CO_2, respectively. The most recent National Greenhouse Gas Inventory[284] data show that NSW emitted 98 million tonnes of CO_2 in 2019. (For the purposes of carbon budget comparisons, only CO_2 emissions are counted, not other GHGs.) **Consequently, NSWs 'equality' carbon budget for a 67% chance of achieving 1.5°C will be exhausted by 2026 on current emission rates.**

267) If **NSW's 2030 total GHG target** of 50% reductions *on 2005 levels* **were applied to its CO_2 only emissions**, then the 112 Mt CO_2 emitted in 2005 would drop to 56 Mt CO_2 by 2030. Approaching that result linearly between 2019 to 2030, **NSW will have** emitted 848 Mt CO_2 over that period, and thus, **'overspent' twice over its share of the remaining 1.5°C carbon budget, overshot even its 1.7°C remaining carbon budget, and emitted two-thirds of its share of a 2.0°C budget.** I again stress that 2.0°C of warming is not compatible with the Paris Agreement.

268) On the other hand, up until this point, NSW has been on a trend of declining methane emissions, as can be seen in Fig. 32. In 2010, NSW's methane emissions were 1.45 Mt CH_4. Since then, they have dropped to 1.12 Mt CH_4 in 2019.[285] To achieve a 30% reduction in methane on 2010 levels by 2030, as is assumed in the carbon budget assumptions used by the AR6 WGI (see paragraph 220), NSW CH_4 emissions will need to drop to 1.02 Mt CH_4 by 2030. **NSW is on its way to achieving this specific 2030 goal for methane, but approving further coal projects, whose primary Scope 1 emissions are from fugitive methane, has the potential to derail the effort.**

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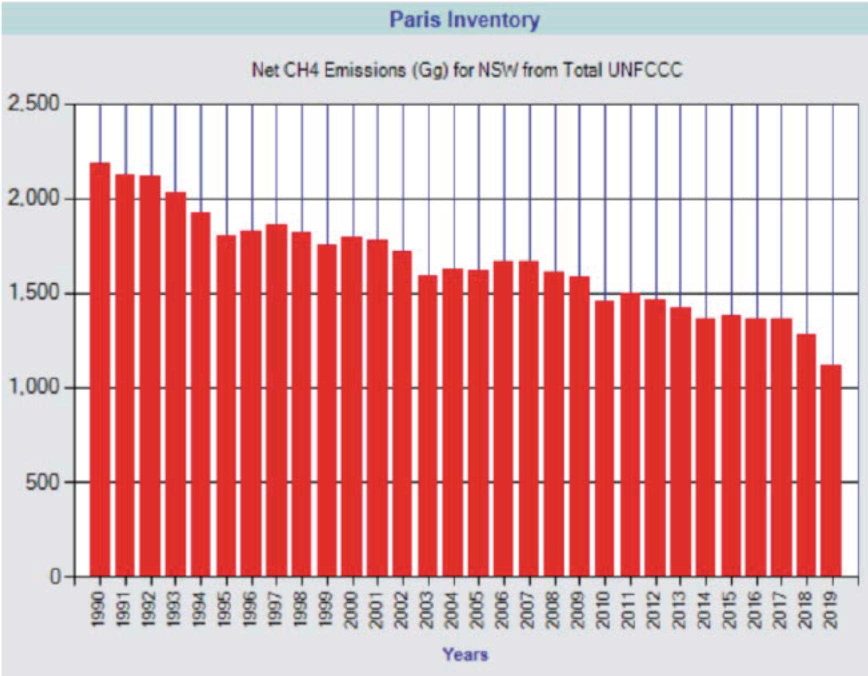
[284] National Greenhouse Gas Inventory, maintained by the Australian Government's Department of the Industry, Science, Energy and Resources. Accessed at http://ageis.climatechange.gov.au/

[285] National Greenhouse Gas Inventory, maintained by the Australian Government's Department of the Industry, Science, Energy and Resources. Accessed at http://ageis.climatechange.gov.au/

Fig. 32: The trend in New South Wales' methane emissions since 1990 are shown. The plot is taken from the NGGI website. Note that the units are Gg (Giga grams) of CH_4, which is the same as Kt CH_4. (To convert to Mt CH_4, numbers on the vertical axis should be divided by 1000.)



269) All coal seams contain some level of gas; these gases escape (become 'fugitive') during both open-cut and underground mining operations. **In 2019, fugitive methane emissions from coal mining in NSW were nearly 80% of all methane emissions from agriculture in the state**, as illustrated in Fig. 33, in which agricultural CH_4 emissions are shown in green and fugitive coal mining CH_4 emissions in black.

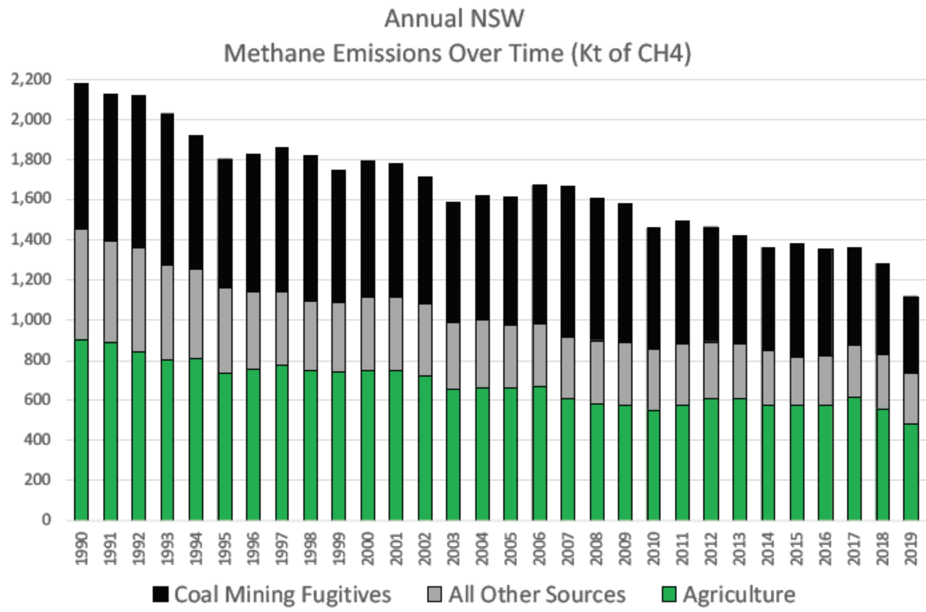


Fig. 33: Trend in annual New South Wales methane (CH_4) emissions from agriculture (green), fugitive emissions from coal mining (black), and all other sources (grey). Data are taken from the National Greenhouse Gas Inventory; units are kilotonnes of methane (Kt CH_4).

7.5.3 NSW and the Production Gap

270) **NSW is central to closing Australia's Production Gap in order to meet the Paris Agreement warming target and avoid the devastating climate impacts at 2°C of warming or more. Despite this, coal production in NSW, one of Australia's two largest black coal-producing States, shows no sign yet of declining.**

271) In 2019-20, production of black coal in Australia fell slightly from its all-time peak the year before, but the production in NSW continued to grow.[286] The trend in annual production of black coal NSW is shown in Fig. 34. Comparison of this historical plot with the future trend in coal production required in order to hold global warming to between 1.5°C to 2.0°C (see Fig. 25, left panel) shows the **huge magnitude of reduction required if NSW is to align its production with Paris Agreement targets.**

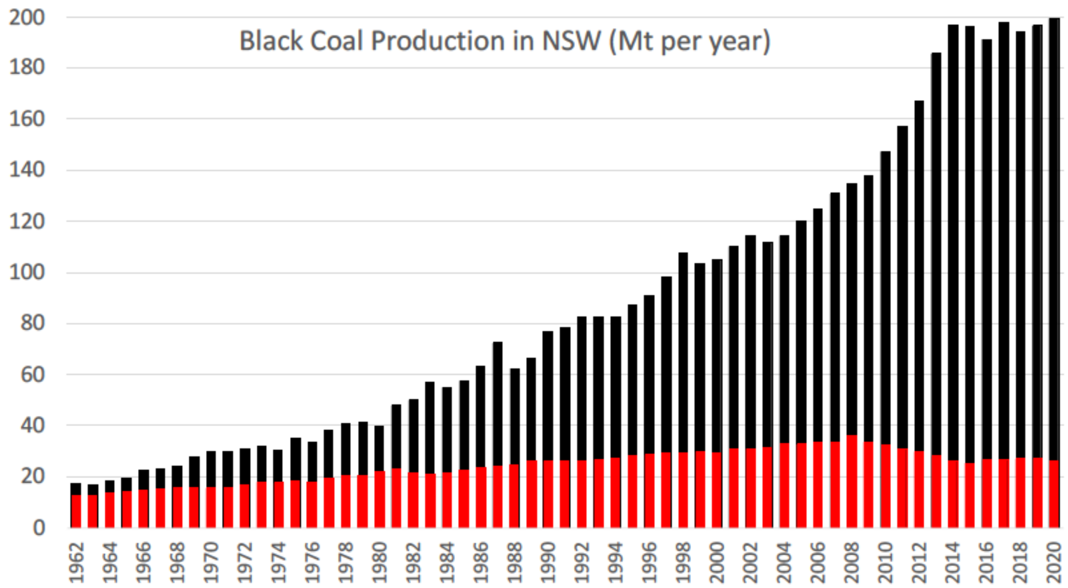


Fig. 34: NSW black coal production in thousands of tonnes (Kt) from 1960-61 to 2018-19. In red is the part of this black coal that is consumed in New South Wales in each year. Data are from Table I4 of Australian Energy Statistics 2021.

[286] Australian Government (2021) Australian Energy Statistics, including Table I4, Dept of Industry, Science, Energy and Resources, September 2021. Accessed at: https://www.energy.gov.au/publications/australian-energy-update-2021

272) Cumulatively, over the past six decades, NSW has produced 5.0 billion tonnes (Gt) of black coal.[287] Using a carbon content of typical bituminous coal,[288] this is equivalent to about 12.2 Gt CO_2 due to combustion at its final destination, or about 0.88% of the world's total CO_2 emissions from fossil fuels and cement production over this time,[289] despite NSW accounting for only about 0.10% of the world's population.

273) **In the ten years 2011 to 2020, the average *annual* production of NSW black coal has been responsible, when combusted, for about 459 Mt CO_2-e released into the atmosphere every year. These Scope 3 emissions from black coal combustion are over three times the State's entire average Scope 1 annual CO_2-e emissions over the same period**. On a per tonne basis, these Scope 3 emissions have an identical effect on NSW's future climate as do the Scope 1 emissions, yet the total amount is three times larger.

274) **As a result, NSW is a major contributor to the Production Gap**[290] between global intended fossil fuel production and the Paris Agreement agreed warming target range. In this sense, **NSW is indirectly working against global warming being held to 1.5°C (and even to 2.0°C), through the large Scope 3 emissions associated with its black coal production, primarily for export**. **Any new or expanded fossil fuel development in the State will aggravate this situation.**

275) The size of this effect compared to NSW's own domestic Scope 1 emissions indicates that **the State could have a major role in limiting climate change by quickly reducing its production of fossil fuels, particularly those which are exported**.

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[287] Australian Government (2021) Australian Energy Statistics, including Table I4, Dept of Industry, Science, Energy and Resources, September 2021. Accessed at: https://www.energy.gov.au/publications/australian-energy-update-2021https://www.energy.gov.au/publications/australian-energy-update-2021

[288] Australian Government (2021) National Greenhouse Accounts Factors. See their Table 1.

[289] Using data downloaded from https://ourworldindata.org/co2-emissions

[290] SEI, IISD, ODI, Climate Analytics, CICERO, and UNEP. (2019). The Production Gap: The discrepancy between countries' planned fossil fuel production and global production levels consistent with limiting warming to 1.5°C or 2°C. http://productiongap.org/

8 Glendell Mine Extension and Climate Change

276) Glendell Mine forms part of the Mount Owen Complex located within the Upper Hunter Valley of New South Wales (NSW), approximately 20 km northwest of Singleton and 24 km southeast of Muswellbrook. The Mount Owen Complex is owned by subsidiaries of Glencore. According to the Executive Summary and Introduction of the Project's Environmental Impact Statement (the Project EIS), prepared by Umwelt (Australia) Pty Limited on behalf of Glencore: [291]

a) Mining activities commenced at the Glendell Mine in 2008, with the **current development consent allowing for mining up to 4.5 million tonnes per annum (Mtpa) of coal through to June 2024.**

b) Glendell is one of three operating pits at the Mount Owen Complex, which also includes the Mount Owen (North Pit) and Ravensworth East (Bayswater North Pit) operations. Coal from all three operations is either transported to the Port of Newcastle for export or railed to domestic customers. The Project intends to export all of its product coal.

c) **The Project requests approval** to continue open cut mining to the north of the existing Glendell Mine **into a new mining area, providing access to approximately 135 Mt of additional coal reserves, and extending the life of mining operations at Glendell to approximately 2044.**

d) **The Project also requests an increase to the existing approved maximum rate of mining from 4.5 Mtpa up to approximately 10 Mtpa of coal**, stating that this increase would coincide with a decrease in production rates at the other Mount Owen Complex pits to maintain the currently approved throughput at the Mount Owen Coal Handling Preparation Plant (CHPP), which is 17 Mtpa of run-of-mine (ROM) coal.

[291] Glencore (2019) Glendell Continued Operations Project Environmental Impact Statement. Main Text. Accessed at: https://www.planningportal.nsw.gov.au/major-projects/projects/glendell-continued-operations-project-2

277) The original GHG assessment for the Project was submitted with the Project EIS as Appendix 28.[292] In a Response to Submissions, Part A (hereafter, the Glencore Response)[293] that contains comments regarding climate change and GHGs in its Section 5.1.3, the Project's original GHG assessment is revised and attached as Appendix 2 of the Glencore Response. Both assessments were prepared by Umwelt (Australia) Pty Ltd.

278) The revised GHG assessment by Umwelt (hereafter, Project GHG Assessment) describes its scope as:

a) "estimating direct and indirect (Scopes 1, 2 and 3) greenhouse gas emissions associated with the Project"

b) "estimating energy use directly associated with the Project"

c) "qualitatively assessing how the Project's greenhouse gas emissions may impact the environment"

d) "estimating the impact of the Project's emissions on State, national and international greenhouse gas emission targets/policies"

e) "assessing reasonable and feasible measures to minimise the greenhouse gas emissions and ensure energy use efficiency."

279) In this section of the Report, **I aim to provide a deeper analysis** on several of the areas described in paragraph 278), **as they relate to how the Project's GHG emissions impact on state and national trajectories and targets, and the magnitude of those emissions compared to cuts in coal production consistent with holding global warming well below 2°C.** Finally, I comment on the **appropriateness and necessity to consider the cumulative effects of GHGs, rather than**, as the Proponent suggests, **to consider the Project `in isolation' with regard to its impact on climate change.**

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[292] Glencore (2019) Glendell Continued Operations Project Environmental Impact Statement. Appendix. Accessed at: https://www.planningportal.nsw.gov.au/major-projects/projects/glendell-continued-operations-project-2

[293] Glencore (May 2020) Glendell Continued Operations Project, Response to Submissions, Part A. Accessed at: https://www.planningportal.nsw.gov.au/major-projects/projects/glendell-continued-operations-project-2

8.1 Greenhouse Gas Emissions from the Project

280) In order for different GHGs to be expressed in a common unit (namely, `carbon dioxide equivalent', or CO_2-e), the Global Warming Potential (GWP) approach (see paragraph 45), is generally used. **The Project GHG Assessment** indicates that it **uses** emission factors and methodology from *National Greenhouse Accounts (NGA) Factors* 2018,[294] which recommends **GWP values of 1, 25 and 298 for CO_2, CH_4, and N_2O, respectively, that are now out of date.** This point is also made in an internal NSW Planning, Industry and Environment (hereafter, the Department) letter of advice.[295]

281) Current NGER regulations,[296] require GWP values of: 1, 28 and 265 for CO_2, CH_4, and N_2O, respectively, coinciding with the most recent publication *National Greenhouse Accounts (NGA) Factors* 2018.[297] **The most recent scientifically derived values from the AR6 WGI** are: 1, 29.8, 273 for GWP over a 100-year timescale or 1, 82.5, 273 over a 20-year timescale, for **CO_2, CH_4, and N_2O, respectively** .[298]

282) As most of the Project's Scope 1 emissions are from methane (CH_4), **the most important consequence of the Project's outdated choice for GWP values is an underestimation of Project Scope 1 emissions as measured in Mt CO_2-e.**

283) Consequently, **throughout this Report** and in the figures and tables that follow, **the emission estimates given in the Project GHG Assessment are used, with the exception that I use NGER GWPs in order to bring the Scope 1 estimates in agreement with the currently legislated value for the GWP of CH_4 and N_2O.**

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[294] Department of Energy and Environment (July 2018) National Greenhouse Account Factors. Accessed at: https://www.industry.gov.au/data-and-publications/national-greenhouse-accounts-factors-2018
[295] NSW DPIE (10 December 2021) Letter of Advice from Director CAS to Director Resource Assessments
[296] See Division 2, Section 7 of https://www.legislation.gov.au/Details/F2020C00673
[297] Department of Industry, Science, Energy and Resources (August 2021) National Greenhouse Account Factors. Accessed at: https://www.industry.gov.au/data-and-publications/national-greenhouse-accounts-factors-2021
[298] Forster P., T. et al. (2021) The Earth's energy budget, climate feedbacks, and climate sensitivity, Chapter & of Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Table 7.15, accessed at: https://www.ipcc.ch/report/sixth-assessment-report-working-group-i/

284) As no detailed timeline for Project coal production or GHG emissions was provided in the Project GHG Assessment, **I have assumed that: the Project is notionally approved in 2022; its construction period lasts two years; the final year, 2044, is devoted to decommissioning with minimal GHG emissions; and that coal production and GHG emissions are spread evenly over a 20-year operational period from 2024-2043, inclusive.** I note that **the Project GHG Assessment excluded some sources of GHG emissions**, in cases where data were not available or thought by the authors to be immaterial (see their Table 2.3); **in that sense the estimates may be underestimates**.

285) Noting the points in 284), and recalling that I am using the NGER values for the GWP of CO_2, CH_4, and N_2O, my summary of the Project's GHG emissions, for Scopes 1, 2 and 3, are provided in Table 5 below, over three different time periods.

Table 5: Estimated emissions from the Glendell Extension Project

Category of Emissions ($Mt\ CO_2$-e)	**Construction 2022-2023**	**Total in period 2024 – 2030 inclusive**	**Lifetime 2022 – 2044 inclusive**
Scope 1	0	2.264	6.457
Scope 2	0	0.1783	0.5094
Scope 3	0.1370	77.13	220.3
All Scopes	**0.1370**	**79.57**	**227.3**

Table 5 Notes: Numbers are given to four significant figures (in Mt CO2-e) and are for periods inclusive of the indicated beginning and ending years. See text for assumptions.

286) Scope 1 emissions will all be emitted in NSW; Scopes 1 and 2 will be emitted in Australia, and most of Scope 3 will be emitted by the end user of the coal products. **All three emission scopes have an equal effect on the climate of NSW on a per tonne basis, but due to the magnitude of Scope 3 emissions, Scope 3 dominates in its effect on the NSW environment.**

287) The **average annual Scope 1 GHG emissions from the Project over its coal production lifetime would be 0.3234 Mt CO_2-e**. This **corresponds to about 0.24% of NSW's total emissions in 2019**. However, as NSW (presumably) meets its 2030 emissions target and begins to approach net zero by 2050, the Project will form a higher percentage of the State's annual emissions.

288) Figure 35 compares the notional emissions trajectory of the Project with a trajectory for NSW that meets the State's 2030 and 2050 emission targets, in a simple linear manner. **Despite the apparently small contribution of the Project compared to the emissions**

trajectory of NSW, I will show in the next section **the exceedingly negative effects the emissions of the Project would have on the ability of the country and the State to meet 2030 emissions targets.**

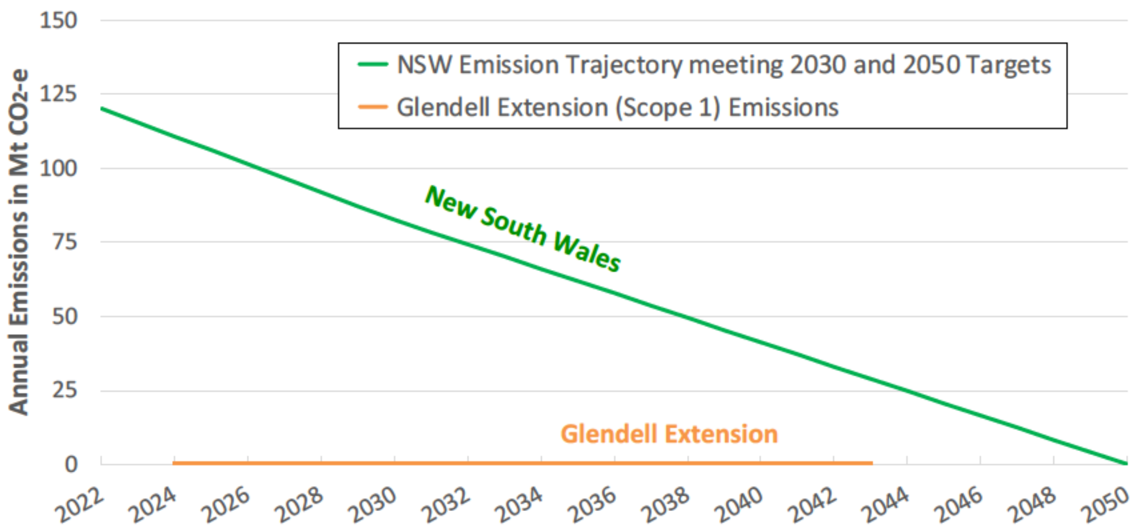

Fig. 35: Comparison of a simple (linearly-falling) Scope 1 emissions trajectory for New South Wales that meets its 2030 and 2050 targets (green) and the assumed Scope 1 emissions trajectory of the Glendell Extension Project (orange). As Section 8.2 will demonstrate, the effect of the Project is larger than a cursory examination of these two trajectories might seem to imply.

8.2 Implications of the Project for National and State Emissions Targets

289) **Comparisons to current emissions or to emissions targets set by governments in a given year are often used as a proxy for assessing climate change impact.** Such comparisons are an **imperfect and often misleading measure for climate impact assessments** because:

a) Current levels of emissions are already causing dangerous levels of climate change,

b) Emission targets may not reflect the actual speed, magnitude or risk of climate change,

c) Regional targets that count only regional (Scope 1) emissions, ignore the real consequences of any Scope 3 emissions from local activities on local climate, and

d) A similar argument could be made for any number of projects, whose cumulative effect would then exceed the intent of setting the target in the first place.

290) In Table 6 below, **annual Project GHG emissions are compared not only to the current levels of annual GHG emissions for Australia and for NSW, but also to the size of annual emissions *reduction* that will be required annually from 2022 in order for the country**

and the State to achieve their respective 2030 GHG emission targets. Values are expressed both in Mt CO_2-e, and as a percentage.

291) The most recent values Australian and NSW emissions are taken from the National Greenhouse Gas Inventory[299] at the time of writing of this Report, namely for the year 2019. In calculating the annual reductions required from 2022 to meet 2030 emission targets, it has been assumed that 2020 CO_2-e emissions will be 88.9% of those from 2019 due to COVID restrictions, and that 2021 CO_2-e emissions be 91.5% of those in 2019. These assumptions are based on global changes in CO_2 (only) emissions in 2020 and 2021 compared to 2019 levels.[300, 301]

Table 6: Average effect of Project on meeting 2030 emission reduction targets

	Annual Quantity	**Glendell Extension Mod 4 Average Annual Contribution**
Australia's projected 2021 direct emissions (Scope 1)*	484.06 Mt CO_2-e	0.349 Mt CO_2-e or 0.07% (Scopes 1 & 2)
AUS 2030 Target Annual *change* from 2022 required to meet 26% reduction on 2005 levels (624.2 MtCO_2-e) by 2030	– 2.46 Mt CO_2-e	0.271 CO_2-e or +11.0% in the wrong direction
New South Wales projected 2021 direct emissions (Scope 1)*	124.91 Mt CO_2-e	0.323 Mt CO_2-e or 0.26% (Scope 1 only)
NSW 2030 Target Annual *change* from 2022 required to meet 50% reduction on 2005 levels (165.0 MtCO_2-e) by 2030	– 4.71 Mt CO_2-e	0.252 Mt CO_2-e or + 5.3% in the wrong direction

**Table 6 Note: Paragraph 291) explains how emissions were projected forward to 2021.*

292) The results of the analysis displayed in Table 6 above show that the **average annual** (Scope 1 + Scope 2) **emissions** from the **Project** over its operational lifetime are 0.349 Mt CO_2-e, approximately 0.33% of Australia's current annual emissions. The Project, through annual Scope 1 emissions directly attributable to NSW under the NGER

[299] https://ageis.climatechange.gov.au/
[300] Friedlingstein, P. et al. (2020) Global Carbon Budget 2020, Earth Syst. Sci. Data, 12, 3269-3340, https://doi.org/10.5194/essd-12-3269-2020
[301] Friedlingstein, P. et al. (2021) Global Carbon Budget 2021, submitted to Earth Syst. Sci. Data, https://doi.org/10.5194/essd-2021-386

scheme, **would add approximately 0.26% to NSW's current annual emissions, a sum equivalent to the total current emissions of over 20,000 individual NSW residents**, when considering the State's emissions on a per capita basis.

293) **A more relevant, measure, however, is to compare the annual emissions from the Project to the annual emissions *reduction* required in order for Australia and NSW to meet their 2030 targets.** The Australian 2030 target, if approached linearly, requires an average *new reduction* of 2.46 $MtCO_2$-e per year, year on year, from 2022 up to and including 2030. In other words, to meet its stated 2030 Paris NDC, Australia will need to not only maintain its reduction from the previous years, but find another *further reduction* of 2.46 $MtCO_2$-e each year through 2030.

294) In comparison, the Project would *add* an average of 0.271 MtCO2-e in every one of those years. **Thus, despite being operational for only a portion of this decade, the Project alone would make Australia's 2030 target 11% more difficult to meet**, since with it, Australia would need to find 2.73 $MtCO_2$-e (instead of 2.46 $MtCO_2$-e) of new emission reductions each year through 2030.

295) **The sizeable effect that Scope 1 and Scope 2 emissions from the Project would have on Australia's 2030 GHG target – despite being a small fraction of current Australian emissions – is shown in Fig. 36**. For this figure, which is aimed at illustrating the approximate effect of the Project on stated Australian policy goals, it is assumed that Australia meets its 2030 emission reduction target on a linear path beginning in 2022.

296) Meeting the NSW's 2030 target will require an annual new *reduction* of about 4.71 $MtCO_2$-e per year, year on year, whereas the Project would *add* 0.252 Mt CO_2-e in Scope 1 emissions every year to 2030 on average**. Thus, if the Project were to proceed,** NSW would need to find a total of 4.96 Mt CO_2-e (rather than 4.71 $MtCO_2$-e) new emission reductions each year through 2030, and **the difficulty of meeting the State's 2030 target would be increased by more than 5%.**

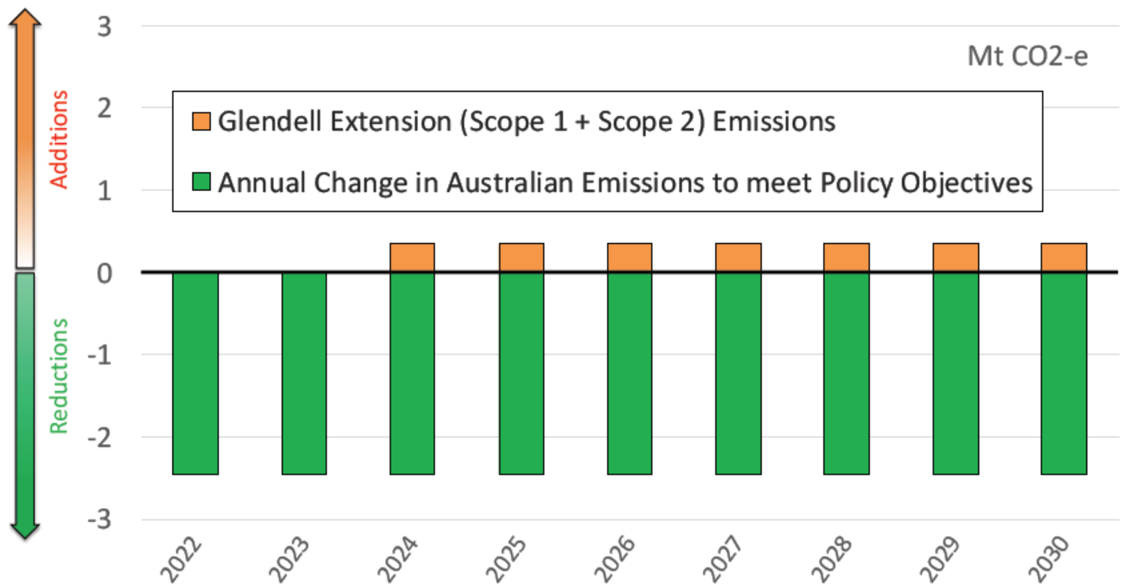

Fig. 36: Annual Scopes 1+2 emissions from the Project (orange) compared to the annual reductions necessary in a simple linear model in order for Australia to meet its stated 2030 GHG reduction target (green). Despite being a small percentage of current Australian emissions, Project emissions are sizeable compared to the emissions reduction task required by national policy.

297) Figure 37 below illustrates the magnitude of the Project emissions compared to reductions required to meet NSW's 2030 and 2050 targets. Comparison of Figs. 35 and 37 graphically illustrates why **it is misleading to consider only the fraction of a Project's emissions to current State emissions, rather than to the climate emissions policy of the State, particularly one with relatively ambitious targets.**

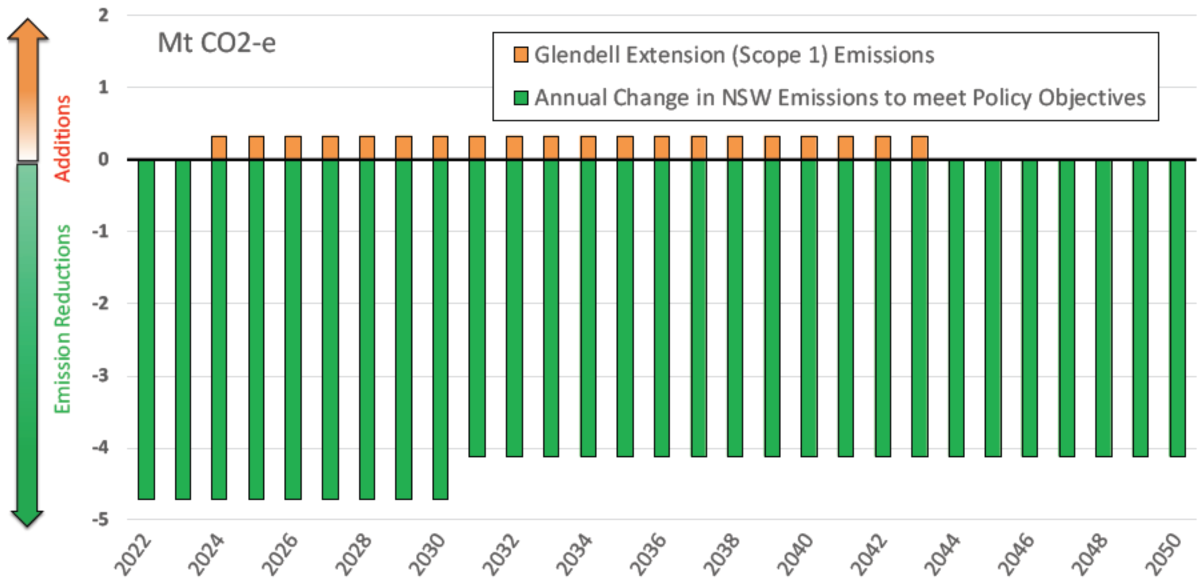

Fig. 37: Size of annual NSW Scope 1 emissions from the Project (orange) compared to the annual reductions necessary in a simple model in order for New South Wales to meet both its stated 2030 and 2050 targets in the linear fashion (green).

298) The analysis I have provided can be compared to the proponent's statements in the Project EIS and in pubic correspondence to the Department regarding the Project's effects on Australian and NSW GHG policy and targets. In the Project GHG Assessment, the following conclusions are drawn by the proponent [*emphasis* is mine]:

a) "Glencore has reviewed the Project's forecasts greenhouse gas emissions inventory, and *believes* the Project is unlikely to materially increase the national effort required to reach Australia's 2030 greenhouse gas mitigation target. Further, the Project *in isolation* is unlikely to limit Australia achieving its national mitigation targets."

b) "The Project is *unlikely* to affect the objectives of the NSW Climate Change Policy Framework in a *material* way."

299) **The Project GHG Assessment provides no quantitative analysis to justify the statements in paragraph 298), and does not even mention NSW's 2030 emissions target** (either its older target of 35% on 2005 levels, or its current target of 50% on 2005 levels). **I submit that increasing the difficulty of NSW's stated emissions goal for 2030 by more than 5% is not only material effect, but a significant one, for a single extension project in a single industry in NSW to make.** Furthermore, the **Project should not be considered 'in isolation,' given that other new activities approved by the Independent Planning Commission (IPC) are already adding emissions that will make meeting the 2030 target more challenging** (see paragraphs 307) and 308).

300) After prompting by the Department to "*Please provide further consideration of the Project's greenhouse gas emissions against the latest NetZero Plan Stage 1 2030, which includes a revised target of 50% emissions reduction by 2030 compared to 2005 levels,"* the proponent discusses intentions it has with regard to its global business practices, which appear to be irrelevant to the question posed. The proponent response[302] continues, however:

a) "Glencore has reviewed the Project's forecast greenhouse gas emissions inventory, and believes the Project is unlikely to materially increase the State or national effort

[302] Glencore (11 November 2021) Letter of Response to Team Leader of Resource Assessment, DPIE dated 20 October 2021, from Coal Assets Australia, Glencore

required to reach the NSW Government's revised NetZero Plan Stage 1: 2020-2030 emission reduction target or Australia's 2030 greenhouse gas mitigation target (as previously discussed in the project's RTS Part A). The Project is forecast to produce on average 253,000 t CO2-e per annum of scope 1 emissions, which equates to around 0.3% of the NSW Governments 2030 emissions target of 78,900,000-87,600,000 t CO2-e (47-52% below 2005 levels) as outlined in the current publicly available NetZero Plan Stage 1: 2020-2030 Implementation Update (September 2021). In comparison, the existing Glendell open cut reported 158,721 t CO2-e of scope 1 emissions in 2019/20. Overall, the Project will result in a net increase in scope 1 emissions of around 100,000 t CO2-e per annum or approximately 0.1% of the NSW Governments 2030 emissions target."

301) **Two key points must be made about Glencore's quantitative statements** in its response in paragraph 300)a) to the **Project's effect on NSW's 2030 emissions target**:

a) **First, it compares apples and oranges, or one might say, apples and oysters. An estimate of *annual* Scope 1 emissions from the Project is compared to NSW target emissions level in 2030, not the size of the emissions *reduction* required to meet that target, let alone the *annual* emissions reduction required by the target.** The effect of this comparison is to make Project emissions seem small.

b) **Second, this misdirection is further compounded by using not the full amount of the Project's annual emissions, but only the amount expected to exceed current Glendell output. However, at the time the NSW 2030 target was established, the current Glendell consent was in place, and set to expire in 2024**, and its emissions with it.

302) **The effect of the Project on NSW's 2030 emissions target** can be seen visually in Fig. 37 and numerically in Table 6 of this Report, and **is up to 50 times larger (5.3% vs 0.1%) that implied by the proponent's statements on the matter**. In view of this, it is puzzling that the Department has reiterated Glencore's misdirecting statement in paragraph 300)a) on the Project's effect on NSW meeting its 2030 target in its *support* for the Project's approval (See Section 9.4).

303) Finally, I note that an oft overlooked aspect of continued and increased coal mining is the emissions produced *after* the mine is closed or abandoned. Recent work[303] shows that methane emissions from the growing population of abandoned mines will increase faster than those from active ones. By considering the number, size and depth of coal mines, the type of coal, the rate of abandonment, and end-stage measures (such as whether mine is flooded), it has been estimated **that abandoned mine methane accounted for 17% of total global coal mining emissions in 2010**. These emissions will grow in time, and will do so faster if coal mining development increases rather than declines. **If the Project is approved, it will continue to emit additional methane long after the mine is closed.**

8.3 Why Approving the Project is Inconsistent with Warming well below 2°C

304) The phrase 'well below 2°C' is widely known to be associated with the UNFCCC Paris Agreement[304] commits signatories to "**keeping a global temperature rise this century well below 2°C above pre-industrial levels** and to pursue efforts to limit the temperature increase even further to 1.5°C." But this would be **the scientifically advisable goal whether the Paris Agreement existed or not, because (a) it is still achievable from a carbon budget point of view** (see Section 7.2) **and (b) temperatures of 2.0°C and above are associated with grave consequences and compounding risks to ecosystems and humans** (see Sections 4 and 6).

305) **The most important step to achieving this goal is to dramatically reduce the production of fossils fuels – the overwhelming cause of anthropogenic climate change** (see Section 26). **The deepest and swiftest reduction must occur in coal production** (see Fig. 25, left panel), which must drop worldwide by a minimum 67% between 2020 and 2030 for a flip-of-coin chance (50%) of holding warming to 1.5°C.[305] Coal production must drop by a minimum of 36% in this period to hold warming to 2°C (with a 67% chance).

[303] Kholod, N. et al. (2020) Global methane emissions from coal mining to continue growing even with declining coal production. Journal of Cleaner Production, 256, 120489. Accessed at: https://www.sciencedirect.com/science/article/pii/S0959652620305369?via%3Dihub

[304] UN (2015), Paris Agreement, Accessed from https://unfccc.int/sites/default/files/english_paris_agreement.pdf

[305] SEI, IISD, ODI, E3G, and UNEP (2021) The Production Gap Report: 2021 Report, using data provided in Supplementary Information. https://productiongap.org/2021report/

Consequently, **to hold warming to well below 2°C, coal production must drop by *considerably more* than 36% on 2020 levels by 2030, which is less than 8 years away.** Simply put, approving new coal mines or extensions to new ones is not consistent with holding warming to 2°C, let alone warming *well below* 2°C.

306) In 2020, NSW mined 200 Mt of black coal.[306] **In order to align its production with the requirements for a trajectory consistent with holding warming well below 2°C, NSW must cut production by** about 50% (chosen to be intermediate between the minimum amounts for 1.5°C and 2.0°C quoted in paragraph 305) on 2020 levels by 2030, requiring a reduction of **about 10 Mt coal per annum through 2030. Over this period, the Project, if approved, would be *adding* about 3.8 Mt product coal (**5.9 Mt ROM coal) per annum on average[307] **to NSW's Production Gap.** This size of this effect is illustrated in Fig. 38, showing that Project would be producing coal at about third the rate required for NSW to reduce its coal output and close the Production Gap in line with the Paris Agreement global warming target of well-below 2.0°C

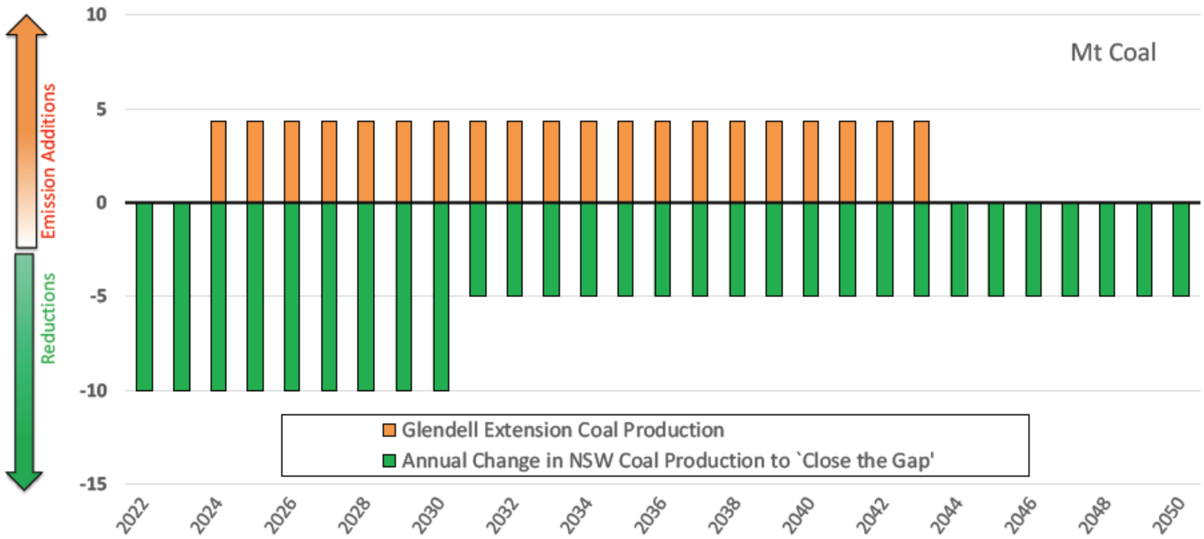

Fig. 38: Annual coal production from Glendell Extension Project (orange) compared to the annual reductions necessary in a simple linear model in order for NSW to close its coal Production Gap in a manner consistent with the Paris Agreement warming goals, namely well-below 2°C (green). See paragraph 306) for details.

[306] Australian Government (2021) Australian Energy Statistics, including Table I4, Dept of Industry, Science, Energy and Resources, September 2021. Accessed at: https://www.energy.gov.au/publications/australian-energy-update-2021
[307] Using the assumptions listed in paragraph 284), and the assumed 86.14 Mt coal product given in Appendix B of the Project GHG Assessment.

307) Furthermore, closing NSW's coal production gap will take place against background of other recently approved coal development projects in NSW that themselves are adding to the future coal production trajectory of the State. Some of these projects[308] are listed in Table 7 below.

Table 7: Recently approved coal development projects in NSW.

Approved Project	Proponent	Consent Until	Maximum ROM Coal per annum (Mt)
Mangoola Continued Operations	Mangoola Coal Operations Pty Ltd	31 Dec 2030	13.5
Maxwell Underground	Maxwell Ventures (Management) Pty Ltd	30 Jun 2047	8.0
Rix's Creek South	Bloomfield Collieries Pty Ltd	12 Oct 2040	3.6
Russell Vale Underground Expansion	Wollongong Coal Ltd	5 years from commencement	1.2
Tahmoor South	Tahmoor Coal Pty Ltd	31 Dec 2033	4.0
United Wambo	United Collieries Pty Limited	21 Aug 2042	10.0
Vickery Extension Project	Vickery Coal Pty Ltd	12 Aug 2045	10.0
TOTAL			**50.3**

308) Although the numbers in the rightmost column of Table 7 are for maximum allowed run-of-the-mine (ROM) takes, these data make clear that **recently approved coal mine operations in NSW could be adding 35 Mt product coal annually to the State's production over a period in which a *reduction* of 10 Mt per year is needed to be consistent with warming well below 2°C**. **Approving the Project would increase this possible addition to about 40 Mt coal per annum from now to 2030.** Furthermore, the Project, like most of those in Table 7, will run far beyond 2030, confounding later efforts to reduce coal production in line with warming well below 2°C.

309) It is worth noting here that **the Glencore Response implicitly agrees with the conclusion that the Project is not consistent with holding global warming well below 2°C**. On page 120 of the Glencore Response, it is acknowledged that:

[308] All data from NSW IPC website at: https://www.ipcn.nsw.gov.au/projects

a) " . . . **the Project is consistent with the A2 SRES emissions scenario**, that is, the Project aligns better with the A2 SRES emissions scenario than other alternative SRES scenarios."

b) "The A2 SRES emissions scenario generates an emission trajectory approximately midway between RCP6 and RCP8.5, however, the **A2 SRES scenario is likely to generate radiative forcing outcomes closer to RCP8.5 (worst case emission scenario)**."

310) The A2 SRES is one of a set of four emission scenario families introduced by the IPCC over twenty years ago in 2000.[309] Scenarios used by the IPCC have evolved over the time since, with the fifth assessment report (AR5) using the RCP scenarios mentioned in paragraph 309)b) above (and in paragraph 160) in Section 6.1 of this Report). These were subsequently superseded by the SSP set of pathways used in the AR6 (see paragraph 161) and Fig. 17). In the Glencore Response, the A2 SRES scenario is mentioned in connection with its use in the first version of NARCliM to describe possible climate futures in a high emissions scenario.

311) The point I wish to make here is that, from a climate and global warming point of view, **the A2 SRES scenario is** similar to RCP 8.5 and SSP5-8.5, and thus **consistent with 3 – 4°C of warming by 2100, or more, with temperatures rising even more thereafter** (see, e.g., Fig. 17). A summary of what the **devastating consequences of such a possible future** has been presented in Table 1 and Section 6 of this Report. **This is the world most consistent with the Project, according to the Glencore Response.**

312) In conclusion, as mentioned previously (see paragraph 226), the IEA's global energy roadmap[310] for achieving a net zero pathway by 2050 includes as a headline determination: **No new oil and gas fields approved for development; no new coal mines or mine extensions; no new unabated coal plants approved for development, beginning in 2021. It is 2022, and the Project is an application for a coal mine extension in NSW.**

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[309] IPCC (2000) Emission Scenarios. Accessed at: https://www.ipcc.ch/report/emissions-scenarios/
[310] IEA (2021) Net Zero by 2050: A Roadmap for the Global Energy Sector, accessed at: https://www.iea.org/reports/net-zero-by-2050

8.4 Cumulative Effects and the Project

313) The Project EIS and the Glencore Response make frequent reference to cumulative effects on water and some aspects of air pollution in the Hunter Valley Region caused by the Project and other activities.

314) Yet throughout the **documents submitted by the Proponent**, the reader is encouraged to **consider the Project `in isolation' when considering its GHG emissions**. A set of examples follows:

a) "*The Project, in isolation, is unlikely to materially influence global emission trajectories*." [Glencore Response 5.1.3.4, 5.1.3.5, and 5.1.8.1; Project GHG Assessment 4.2, 4.3.1; Project EIS Main Text, 7.13.3.6, 8.3.2]

b) "*The Project in isolation is unlikely to limit Australia achieving its national mitigation targets*." [Project GHG Assessment Executive Summary, 4.3.1]

315) Greenhouse gases are a pollutant released into the atmosphere, most of which are well-mixed on relatively short time scales with global GHGs released from other human activities. The **cumulative effect of these GHGs causes climate change, and climate damages and risks to the people and environment of NSW.** Furthermore**, the cumulative effects are maintained for decades, centuries and millennia.** It is therefore **appropriate and in fact necessary,** in my view, **to consider the cumulative effect of GHGs when assessing the impact of the Project.**

9 Other Important Considerations

9.1 Future Climate Impacts on the Project, its Employees, and the Community

317) Not only will the Project affect the climate, and through it the rest of the environment, but the changing climate is likely to affect the Project. The Project proponent is requesting approval to mine through 2044. In the more than intervening 20 years, global warming will increase, and climate extremes and impacts will become more severe. **Depending on the path that world emissions take, including those directly or indirectly caused by the Project, global warming will likely be 1.5°C to 2.0°C by the last years the Project's proposed lifetime** (refer to Fig. 17)**.**

318) **It is not clear from the submissions made by the proponent that the effects of future climate on the Project itself and its workers, and subsequent consequences for the wider community have been adequately investigated or addressed.** Section 4.2.4 of the Project EIS titled `Climate' is a brief summary of past mean (average) climate statistics, with no discussion of extremes or future climate. Section 7.13 of the Project EIS, devoted to GHGs, does not discuss effects of climate on the Project. Table 7.63 in the section of the Project EIS titled 'Public Health and Safety,' which identifies a number or risks to public safety, does not include risks related to increased climate change. Although bushfire is mentioned, the increasing risk of increasingly powerful firestorms is not discussed.

319) It is beyond the scope of this Report to consider in detail the effects of climate change on Project operations and its workforce. Nevertheless, the following **potential risks associated with the *future* climate in which the Project would be operating have been identified**:

a) Section 7.9.4 of the Project EIS states "Based on the history of mining operations at Mount Owen Complex, it is considered that there is a low propensity for spontaneous combustion to occur within coal reject and overburden emplacement areas on site." **How might this propensity to spontaneous combustion change in the 2030s and 2040s, when NSW heatwaves will be longer, the extraordinarily hot summer of 2019 would then be an `average' summer, and the fire weather that produced Black Summer is up to four times more common?** (See Table 1 of this Report.)

b) Table 2.1 of the Project EIS indicates that the Project is intended to operate 24 hours a day, 7 days a week. **What does such a work schedule imply for Project worker health and safety in the 2030s and 2040s, when NSW heatwaves will be longer and the extraordinarily hot summer of 2019 is now an 'average' summer, particularly noting the extreme dangers to human health posed by temperatures above 35°C?** (Refer to Table 1 and to Figs. 15 and 16 of this Report.)

c) **Given that the Project will affect both ground and surface water** (Section 7.5 of the Project EIS, **how might the Project's assessment change with respect to water in a world of 1.5°C to 2.0°C of warming? As NSW agriculture would then be experiencing up to a 30% reduction in runoff water** (see Table 1), **how would this affect the Project's water takes and their impact on local agriculture? Given that more extreme events are expected in the future climate, and that a previously assessed 'once-in-1000-year' flood was experienced by NSW in 2022** (see subsection 5.2.2), **are risks associated with spills or contaminated runoff from the Project appropriately assessed in the Project EIS?**

d) Section 7.5.1 of Project EIS states that the surface water assessment considers as its most extreme flood event one with 0.2% (1:500 year) annual exceedance probability, and a 'Probable Maximum Flood,' based on historical data. **Should the annual exceedance probabilities be re-evaluated based on the future climate in which the Project will operate? Has the probability of more extreme floods in a future climate of 1.5°C to 2°C degree of warming been considered on Project infrastructure, coal processing, and coal transport?**

e) A 2018 HSBC-commissioned report[311] studying ports in the Asia Pacific noted identifies the Port of Newcastle as one vulnerable to the accelerating sea-level rise and increasing storm intensity caused by the climate change. **As extreme sea level events will be more frequent and extreme in a climate of 1.5°C to 2°C degree of warming** (see subsection 5.1); **how will this affect the Port of Newcastle on which the Project depends?**

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[311] Asia Research and Engagement (2018) Climate Costs for Asia Pacific Ports. Accessed at: https://www.sustainablefinance.hsbc.com/carbon-transition/climate-costs-for-asia-pacific-ports

f) Whilst discussing air quality and, in particular, air quality exceedances in 2018 and 2019, the Glendell Reponse states: "The use of years with elevated air quality levels, largely driven by extraordinary events or extreme climatic conditions (or both) are avoided in modelling primarily because they do not address the definition of representative.'' Yet **what we would identify in the past as 'extraordinary and extreme climatic conditions'** (drought, extreme heat, bushfire activity etc) **will become more commonplace over the lifetime of the proposed Project. Furthermore, these conditions are associated with the worst outcomes.** In light of this, **would it not be appropriate to consider future cumulative effects on air quality in the Upper Hunter by including data from 2018, 2019, and the years subsequent?** The question is not whether coal mining alone causes these exceedances, but rather how coal mining would *exacerbate* such events, which may be more frequent in future climate.

320) In summary, I conclude that **many aspects of the Project EIS and the Glendell Response do not adequately consider the climate in which the proposed Project will operate, either by largely ignoring some climate risks altogether, or relying historical data that are not representative of the increasingly extreme and dangerous future climate**. The IPC may wish to request further investigations into this overlooked area.

9.2 Project's Climate Costs to State and Globe much Higher than Suggested in EIS

321) An economic analysis of the Project prepared by EY (hereafter, the EY Analysis) is provided in the Project EIS, as Appendix 30. In addition, at the request of the Department an independent report was provided by the Centre for International Economics (hereafter, the CIE Report).[312]

322) As I am not an economist, I will only comment on these two analyses to the extent that they address matters of the climate, climate damages, or the Social Cost of Carbon, which lie within my expertise.

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[312] Centre for International Economics (30 November 2021) Reviewew of economic impact assessment supporting the Glendell Continued Operations Project. Accessed at: https://www.planningportal.nsw.gov.au/major-projects/projects/glendell-continued-operations-project-2

323) It is clear that economic damages due to climate change are large and increasing rapidly. The National Oceanic and Atmospheric Administration (NOAA) of the **US** tallies weather and climate-related disasters and their associated costs in the US. Their most recent work indicates that the numbers and costs of these disasters is rising sharply over time (see Fig. 39 below) and specifically that:[313,314]

a) In 2021, there were **20** separate **billion-dollar weather and climate disaster events** across the United States, associated with costs of 145 billion USD. The **average annual cost** of such disasters **over the last five years** (2017-2021) **is 148.4 billion USD**.

b) Adding the 2021 events to the record that began in 1980, the US has sustained **310 weather and climate disasters** where the overall damage costs reached or exceeded $1 billion. The cumulative cost for these 310 events exceeds **2.15 trillion USD**.

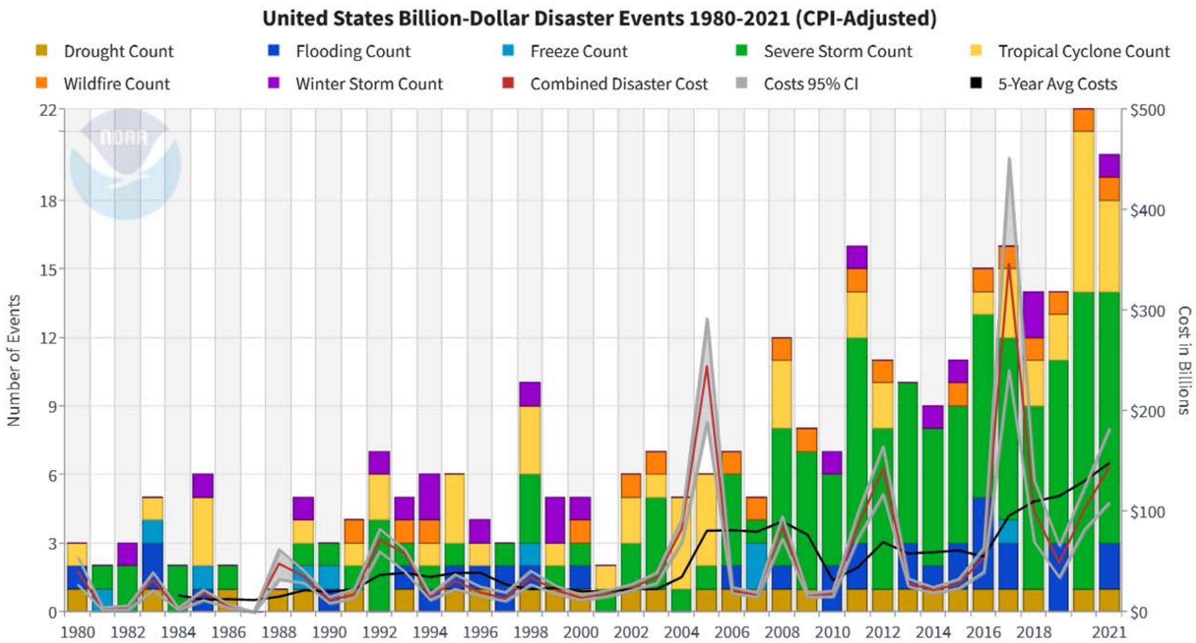

Fig. 39: Over the past 40 years, billion-dollar disasters in the USA have increased sharply in frequency (coloured vertical bars) and total annual costs (lines, with costs given on right-hand vertical axis). Costs have been adjusted for inflation. Figure is from the NOAA.

324) Consequences of more frequent, more costly, and more deadly weather and climate-related disasters include less time to prepare and recover, resources stretched across more than one calamity, and disaster fatigue, especially for first responders. Analysis of

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313 NOAA National Centers for Environmental Information (NCEI) U.S. Billion-Dollar Weather and Climate Disasters (2022). https://www.ncdc.noaa.gov/billions/, DOI: 10.25921/stkw-7w73

314 NOAA (2022) https://www.climate.gov/news-features/blogs/beyond-data/2021-us-billion-dollar-weather-and-climate-disasters-historical

data from the NOAA indicates that the time between billion-dollar disasters has steadily dropped in the US. The average time between such disasters dropped from 82 days in the 1980s to 26 days in the 2010s. **In the five years 2016 – 2020, only 18 days separated billion-dollar disasters in the US, on average**.[315]

325) In Australia, the economic cost of climate change to Australia is estimated to have doubled since the 1970s,[316] with about $35 billion in losses reported in the 2010s. This is expected to rise **if emissions are not curbed sharply. Annual damages from** extreme weather, along with sea-level rise and other impacts of **climate change upon Australia, could exceed $100 billion by 2038, and exceed $1.89 trillion by 2050**.[317]

326) Another recent report[318] suggests that **even under a low emissions scenario the cost of natural disasters in Australia will increase from $38 billion annually now to at least $73 billion annually by 2060**. Given that this estimate is about double that made by the same group four years earlier, **it is reasonable to expect that these estimates will only grow with time**. Importantly, the report found that the **area stretching from South East Queensland to North East NSW is expected to face the greatest increase in costs from natural disasters as the frequency and severity of some natural disaster events increases.**

327) Any justifiable estimate of the **cost to New South Wales resulting from climate change is likely to be an underestimate** because:

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[315] Climate Central (6 October 2021) Disaster Fatigue, accessed at: https://medialibrary.climatecentral.org/resources/disaster-fatigue

[316] Steffen, W. and Bradshaw, S. (2021) Hitting Home: The Compounding Costs of Climate Inaction, and references cited therein. Climate Council of Australia Ltd. Accessed at: https://www.climatecouncil.org.au/resources/hitting-home-compounding-costs-climate-inaction

[317] Kompas, T. cited in Silvester B. (2020) Trillions up in smoke: The staggering economic cost of climate change inaction. New Daily, 10 September 2020. https://thenewdaily.com.au/news/national/2020/09/10/economic-cost-climate-change based on the modelling framework set out in Kompas, T., Pham, V., Che, T. (2018) The effects of climate change on GDP by country and the global economic gains from complying with the Paris Climate Accord. Earth's Future 6 https://doi.org/10.1029/2018EF000922

[318] Australian Business Roundtable for Disaster Resilience and Safer Communities (2021) Special report: Update to the economic costs of natural disasters in Australia. Accessed at: http://australianbusinessroundtable.com.au/our-research

a) **Not all damages due to climate change can be quantified** (including those due to crossing irreversible thresholds in the Earth System as described in subsection 4.8 of this Report).

b) **Not all quantifiable damages can be fully described by an `economic cost'** (e.g., deaths or mental suffering caused by climate change).

c) As our understanding of the impacts of climate change continues to evolve, we realise that **high impacts are occurring at lower global warming values than previously thought** (see paragraph 167) and Fig. 18).

328) Nevertheless, attempts have been made to estimate **the 'Social Cost of Carbon'**, that is, **the value of the net damage caused to society by adding a tonne of carbon dioxide (CO_2) into the atmosphere**. **The Social Cost of Carbon is not the same as a 'price on carbon' that may be introduced by government policies or prices related to emissions trading schemes or carbon `offsets.' These are policy instruments, not assessments of climate damage.**

329) A 2018 survey of the scientific literature yielded a **median global Social Cost of Carbon of 417 USD per tCO_2, with a 'reasonable' (66% confidence) range of 177–805 USD.**[319] **It is important to note that a large amount of research on increasing climate change costs is yet to be factored into these studies.**

330) **Converting the median value of 417 USD per tCO_2 in 2018 to Australian dollars in 2022 (adjusting for inflation) yields 600 AUD per tCO_2 for the Social Cost of Carbon**. This value is actually a substantial underestimate since the research cited[320] does not take into account costs associated with adaptation and mitigation to climate change, biodiversity loss, cultural loss, climate effects with very long-term consequences (sea level rise and ocean acidification) and long-term restructuring of the economy. **Most importantly, such estimates ignore the possibility of crossing tipping points in the climate system, in which case the social costs would be unthinkable and incalculable**.

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[319] Ricke, K., Drouet, L., Caldeira, K. and Tavoni, M. (2018) Nature Climate Change, 8, 895-900. Accessed at: https://www.nature.com/articles/s41558-018-0282-y

[320] Ricke, K., Drouet, L., Caldeira, K. and Tavoni, M. (2018) Nature Climate Change, 8, 895-900. Accessed at: https://www.nature.com/articles/s41558-018-0282-y

331) With this background, I now comment on the two economic assessments for the Project as they relate to climate and climate damages.

332) **The EY Assessment**, which forms part of the Project EIS, includes a section on economic costs associated with GHGs from the Project, which is contained in its Appendix A. It **concludes**: "On a global basis, the total estimated GHG cost is $62.3 million in NPV terms. Attributing the GHG costs based on the NSW population, consistent with the Guidelines, results in **an attributed GHG cost of $0.07 million to NSW in NPV terms.**" **This EY Assessment conclusion is a gross underestimate of the true costs that will be borne by NSW as a result of GHGs attributable to the Project, for the reasons I outline below.**

333) The EY Assessment states that it "*follows the economic assessment framework set out in the Guidelines for the economic assessment of mining and coal seam gas proposals (the Guidelines) released by the NSW Government in December 2015*" and that "*To estimate the environmental, social and transport-related costs, the [assessment] uses the methods outlined in the Technical Notes supporting the guidelines for the Economic Assessment of Mining Coal Seam Gas Proposals.*" On the basis of these Guidelines and Technical notes, the EY Assessment has made the choice to:

a) exclude Scope 3 GHG emissions arising from the Project,

b) only 'price' the fraction of the Scope 1 and Scope 2 emissions that reflects NSW's fraction of global population, and

c) use a carbon price (based on Australia's Emissions Reduction Fund Auctions) of $14.17 (in 2019 AUD) per tonne of CO_2-e.

d) use a 7% discount rate.

334) I have experience in examining matters related to the Social Cost of Carbon as it relates to climate damages, and on that basis make the following observations:

a) **From a scientific perspective, climate damages from a Project should include all its GHG emissions (Scopes 1, 2 and 3).** Nature makes no distinction. **One tonne of \`Scope 3 $CO_2$-e' does precisely the same amount of damage to the NSW environment as one tonne of \`Scope 1 CO_2-e' or one tonne of \`Scope 2 CO_2-e.'**

b) **To exclude Scope 3 Project emissions, and** then **– in addition – diminish the Scope 1 and 2 totals by the fraction of global population** is to double discount a region as one part of the global whole. **This double discount is contrary to any scientific approach to place a cost on regional climate damages related to the Project.**

c) **Carbon auction, trading, or other market 'prices' do not reflect climate damages. Carbon credits or offsets will not protect NSW, nor its people and environment, from the actual costs associated with climate damages. Nevertheless, I note that the value used in the EY Assessment is well-below most other market indicators.** For example, on 18 March 2022, the EUA Futures Price[321] based on the EU Emissions Trading System (ETS), stood at 78.89 Euros per tCO_2-e, or 117.93 AUD per tCO_2-e (**more than 8 times the EY Assessment value)**, whilst the UK ETS Futures Price stood at 80.91 GBP, or 144.02 AUD on the same date, (**more than 10 times the EY Assessment value**). A 2021 report by the ACT Climate Change Council [322] lists several other market- or policy-based carbon prices, all of which exceed the EY Assessment value by factors of 2 to 14.

d) Due to the **long-term (and in some cases irreversible) and thus intergenerational nature of the climate damages,** a large survey of **economists specialising in this area** has recommended **social discount rates about 2%,**[323] **much smaller than the 7% used by the EY Assessment.**

335) **The CIE Report considers that the full cost of Scope 1 and Scope 2 GHG emissions from the Project should be 'attributed' to NSW when computing the economic costs of the Project.** This is one approach to addressing the double discounting of the EY Assessment that I have noted in paragraph 334)b).

336) The CIE Report notes the extraordinarily low estimate of the EY Assessment for the GHG emissions `cost' to NSW**. In its analysis, the CIE Report concludes that a cost of GHG emissions of $64.8m** would be appropriate "based on the EU carbon price, as reflected in

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[321] As given by https://ember-climate.org/data/carbon-price-viewer/

[322] ACT Climate Change Council (2021) The Social Cost of Carbon and Implications for the ACT. Accessed at: https://www.environment.act.gov.au/__data/assets/pdf_file/0004/1864894/the-social-cost-of-carbon-and-implications-for-the-act.pdf

[323] Drupp, M. A., Freeman, M. C., Groom, B. and Nesje, F. (2018) "Discounting Disentangled." American Economic Journal: Economic Policy, 10 (4): 109-34. DOI: 10.1257/pol.20160240

the Guidelines" **and** that a GHG emissions cost of **around $294m** would be appropriate "based on Australian Treasury Clean Energy Future Policy Scenario." This range is **900 to more than 4,000 times larger than the value used in the EY Assessment for the climate costs of the Project to NSW.**

337) Applying a **recent** median ***scientific*** **value for the Social Cost of Carbon**[324] (see paragraph 330) of 600 AUD per tCO_2-e to the full (Scopes 1, 2 and 3) lifetime emissions of the Project (227.3 Mt CO_2-e) yields at least 136 billion AUD of global damages. If this were to be apportioned to NSW on the basis of fraction of world population, **the cost to NSW of the GHGs resulting from approval of the Project** would be in excess of 144 million AUD, with a 66% probability **range of 61 to 277 million AUD, remarkably similar to the values from the CIE Report, though obtained through a different approach**. However, I must stress that **these estimates are almost a considerable underestimate of the true social cost of GHG emissions** from the Project for the reasons outlined in paragraph 327), and should, therefore, be considered a lower bound of these costs to NSW.

9.3 Glencore Observations on recent Climate Change and GHG emissions Litigation

338) As part of the Project EIS, Glencore submitted a set of `observations'[325] (hereafter, the Glencore Observations) related to recent climate change and GHG emissions litigation. As my personal expertise is not law, I will only comment on this document where matters of law and matters of science have been conflated.

9.3.1 Scope 3 Emissions and `Double Counting'

339) The Glencore Observations devote several paragraphs (1.39 through 1.51 inclusive) to the distinction between Scope 1, Scope 2 and Scope 3 emissions, and how they are accounted (added up) in the Paris Agreement, noting that 'double counting' is to be avoided.

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[324] Ricke, K., Drouet, L., Caldeira, K. and Tavoni, M. (2018) Nature Climate Change, 8, 895-900. Accessed at: https://www.nature.com/articles/s41558-018-0282-y

[325] Glencore (2019) Glendell Continued Operations Project Environmental Impact Statement. Appendix 29. Accessed at: https://www.planningportal.nsw.gov.au/major-projects/projects/glendell-continued-operations-project-2

340) I have no particular issue with the statements of fact made, but want to make clear that **those statements in the Glencore Observations are irrelevant when considering the effect of the Project's GHG emissions on the environment and people of NSW.** This is evident in paragraph 1.42 of the Glencore Observations, which states: "*For present purposes, double counting of GHG emissions can generally be described as occurring where the Scope 3 emissions generated by the burning of a mine's coal by other developments are counted twice in the context of calculating a country's GHG emissions for the purpose of tracking progress towards achievement of its NDC*."

341) IPC is not tasked with accounting GHG emissions for the purpose of tracking progress towards the achievement of any country's NDC. It *is* tasked with considering the impact of the Project (including GHG impacts) on the environment and people of NSW. All GHG emissions (labelled Scopes 1, 2 and 3 in some accounting schemes) **that arise from the Project's approval would influence the environment and people of NSW in precisely the same way, on a tonne per tonne basis.** The manner in which signatories of the Paris Agreement report GHG emissions is irrelevant in this context.

342) Naturally, a concern in any accounting method is to avoid `double counting' by considering the same item under two or more different categories which are separately summed. **This Report has been careful to not double count within the two main GHG accounting methods used, geographic and production-based,** as described below.

343) **Placing the GHG emissions from an activity into a social or environmental context can be done in different ways**, depending on the consideration of the overall goal. **A key component of the consideration is whether or not the emissions are seen as a local output**, divorced from other global social and environmental issues, or whether they are seen **in an inextricably connected global context that, in turn, affects local climate impacts**.

344) Three commonly used approaches to human GHG emissions accounting in the scientific literature[326,327] include:

a) **Territorial, or geographic, accounting**, which focuses on *where* the GHG emissions are actually emitted,

b) **Consumption-based accounting** (sometimes called carbon footprint accounting), which focusses on the *end consumers* of these commodities and services, and

c) **Production-based accounting**, which focuses on the *entities, developments or actions* that *produce* the commodities and services that generate the GHG emissions.

345) In principle, the total GHG emissions for the world could be calculated by any of these methods, and if done carefully and completely, each calculation would result in the same global number. Total global human GHG emissions over time are what determines global warming and anthropogenic climate change. **From a scientific perspective, it is immaterial where the emissions occur, which entities produce the emitting 'economic goods', or who consumes them.**

346) **In large part due to the activities of the United Nations Framework Convention on Climate Change (UNFCCC), which has promoted global cooperation to reduce GHG emissions, including the UN Paris Agreement,[328] regional accounting has become particularly well known.** As nations constitute the UN and are signatories to the Paris Agreement, it is natural the purpose of the Agreement that national (geographical) entities account for the GHGs emitted within their own borders, and substantial tools have been developed to do so. Emissions outside of national borders, for example those involved in international travel and freight are, however, more difficult to account in this method.

347) Due to the global nature of the world's economy in goods and services, both consumption-based and production-based accounting must consider international trade.

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[326] Chen, Z-M. et al. (2018) Nature Communications, 9, 3581, and references therein. Accessed at: https://www.nature.com/articles/s41467-018-05905-y
[327] Davis, S. J., Peters, G. P. and Caldeira, K. (2011). The supply chain of CO2 emissions. In the Proceedings of the National Academy of Sciences, 108(45) 18554. DOI: 10.1073/pnas.1107409108
[328] UN (2015), Paris Agreement, accessed at: https://unfccc.int/sites/default/files/english_paris_agreement.pdf

348) Consumption-based accounting can be useful in allowing consumers (individuals, corporations and governments) to assess how their own choices through the procurement of goods and services can reduce GHG emissions leading to climate change.

349) Production-based accounting traces the GHG emissions back to their source in the production of goods and services, which is particularly instructive in identifying which goods and services are currently contributing to the bulk of global GHG emissions.

350) Throughout this Report, I refer to either geographical accounting (e.g., in Sections 7.1 and 8.2 when referring to policy targets) or production-based accounting (e.g., in Sections 7.3, 7.4.3, 7.5.3, and 8.3 when referring to the Production Gap and the positive climate impact NSW can have in reducing its fossil fuel production.)

351) When considering policy in this Report, Scope 3 emissions are not added to Scope 1 emissions in the geographical accounting method. Nor are emissions from burning Australian coal exported to India (for example) counted both in Australia and in India, where this Report uses production-based accounting.

352) Finally, I wish to point out an apparent **misunderstanding of the nature of GHGs demonstrated** in paragraph 1.98)a and 1.98)b on the **Glencore Observations**, which read: "*However, the following things should be noted about s4.15 of the EP&A Act:*

> *(a) the consent authority is required to consider the likely social, economic and environmental impacts of the Project (both positive and negative), "in the locality";*
>
> *(b) this means that Scope 3 emissions and their impacts cannot and should not feature heavily in the consent authority's consideration and determination of the development application for the Project"*

353) **Regardless of wherever they are initially emitted on Earth, the primary GHGs of CO_2, CH_4, and N_2O quickly spread throughout the atmosphere globally, on timescales that are much shorter than their impact on the climate.** Indeed, this is why they are referred to as 'well-mixed GHGs,' because their atmospheric lifetimes are long enough to be homogeneously mixed in the troposphere (see, e.g., AR6 WGI). **The Project's Scope 3 GHG emissions will not stay `in the locality' in which they are emitted, nor will the detrimental impacts they induce.**

9.3.2 The Carbon Budget Approach

354) The Glencore Observations addresses (in paragraphs 1.52 through 1.54 inclusive) the carbon budget approach (see Subsection 7.2 on this Report), noting that: *"Whilst the "carbon budget" approach is sometimes used by scientists, it is not an approach that is required to be followed under the Paris Agreement, or Australian domestic laws (i.e. federal and NSW legislation) in the context of implementing, or measuring progress towards, achievement of Australia's NDC."*

355) Again, I have no particular issue with this statement of fact reproduced in paragraph 354) above, but want to make clear that this **statement in the Glencore Observations is irrelevant since the IPC is not tasked with implementing, or measuring progress towards, achievement of Australia's NDC.**

356) However, **at paragraph 1.54 of the Glencore Observations there are several statements with which I do disagree strongly**. That paragraph is reproduced in full below as paragraph 357) of this Report.

357) Glencore writes: "*In the absence of a requirement in these laws to apply the "carbon budget" approach, the Proponent would submit that it would be inappropriate for the consent authority to either have regard to or apply the "carbon budget" approach in determining the development application for the Project. The Proponent makes this submission for the following reasons:*

(a) *the "carbon budget" approach does not provide the consent authority with any practical assistance in discharging the function it has been asked to perform (i.e., to determine the development application for the Project), and is a matter that is best left to higher policy circles and the international community;*

(b) *the approach is inconsistent with the approach that has been adopted by the Paris Agreement for achieving the goal set under that agreement, in that:*

(i*) each country has made a commitment (in the form of a NDC) as to how it will contribute to achieving the goal set by the Paris Agreement;*

(ii) the Paris Agreement does not prescribe the measures or mechanisms by which a particular country is to implement actions to facilitate the achievement of its NDC; and

(iii) the application of the carbon budget approach results in double counting of GHG emissions, which is an outcome that the Paris Agreement seeks to avoid.

(c) the approach suffers from numerous deficiencies, including:

(i) Uncertainty: the approach suffers from uncertainties, such as the desired probability of meeting the goal of the Paris Agreement (i.e. the higher one sets the probability for achieving the goal, the more stringent the budget needs to be), accounting for non-CO2 gases (i.e. if non-CO2 gases are not reduced or reduced more slowly than CO2, the budget is reduced accordingly), and the failure to account for carbon cycle feedback (i.e. including estimates of these would reduce the carbon budget further).

(ii) Technology: the approach can be susceptible to ignoring the role that technological advancements can play in reducing CO2 levels globally (e.g. low emission coal technologies including carbon capture and storage, and HELE projects). Any failure of the carbon budget approach to account for such technological advancements would result in the CO2 levels being recorded at levels higher than what they actually are.

(iii) Allocation: the approach has not been accepted by the international community as a means of sharing global mitigation efforts amongst countries. Rather, as explained above, the approach to allocation adopted under the Paris Agreement has been for each country to adopt a NDC and determine, for itself, the measures or mechanisms that will be implemented to achieve that NDC.

358) With regard to paragraph 357)a: **The carbon budget approach does not seek to provide the consent authority with a prescription for making its decisions**. It is **scientifically sound method to estimate the speed and magnitude by which emission reductions must occur in order to meet a desired warming target,**[329] **focussing on CO_2** as the primary greenhouse gas (see paragraph 213). It is used in this Report to place the emissions associated with Project in the context of *remaining* carbon budgets required to hold global warming to 1.5°C or 2.0°C above temperatures in the pre-industrial era, and to assist the consent authority in judging the impact of the Project on a notional regional 'share' of those budgets.

359) With further regard to paragraph 357)a, I submit that **the phrase *"it is a matter that is best left to higher policy circles and the international community"* is at best an opinion. At worst, it diminishes the importance and the authority of the IPC**. As a matter of fact, I note that higher policy circles in Australia, and the international community taken as a

[329] Collins, M. et al. (2013) Long-term climate change: Projections, commitments and irreversibility, in Climate Change 2013: The Physical Science Basis, Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, edited by Stocker et al. Cambridge University Press, pp. 1029-1136.

whole, have to date not produced policies consistent with holding warming to even 2.0°C. If all countries were to follow Australia's lead, the world would be on track to 4.0°C of warming (see Sections 7.1 and 7.4.1 of this Report). **Given** this, and **the catastrophic consequences of these levels of warming, I submit that no person or entity should '*leave the matter*' to higher circles, but rather work at all levels, including at local levels where decisions about thousands of individual sources of GHGs are made.**

360) With regard to paragraph 357)b: Using **the carbon budget** to assess the consequences of future activities that will contribute to climate change through GHG emissions, **is not inconsistent with the Paris Agreement, but indeed complementary, and has been used by the UN itself to do so at a global level, as evidenced by its IPCC reports** (see, e.g. Table 3 in this Report, with numbers taken directly from the AR6 WGI.)

361) With further regard to **paragraph 357)b:** I agree with subpoints (i) and (ii), but **subpoint (iii) is patently false**. The carbon budget approach in no way `double counts' GHG emissions. Indeed, it does not count emissions by Scope 1, 2 or 3 at all, but considers GHG emissions by the natural and anthropogenic sources and sinks in the Earth System.[330] **The suggestion** at paragraph 357)b)iii **that a carbon budget analysis is associated with double-counting represents a serious misconception of this scientific concept.**

362) With regard to paragraph 357)c and 356c)i: **The admission of uncertainties and their dependence on assumptions is not considered a 'deficiency' in science. Rather, it is considered a necessary component of transparency.** For this reason, this Report has noted the general dependence of a carbon budget analysis on assumptions, and specific assumptions used in my analysis (see Section 7.2), as well as providing values for alternate choices.

363) With regard to paragraph 357)c)ii: The **statement made here in the Glencore Observations is nonsensical from a scientific point of view. The calculation of a carbon budget does not depend on 'technology' at all; it is a pure scientific relationship.** How the *remaining* carbon budget is 'spent' (GHGs emitted) into the future *may* depend on

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[330] See, e.g., Friedlingstein, P et al. (2020) Global Carbon Budget 2021, Earth Syst. Sci. Data. https://essd.copernicus.org/articles/12/3269/2020/

technology, if that technology is viable at scale at a time well before the carbon budget is consumed (for a particular desired temperature and probability of obtaining it).

364) With further regard to paragraph 357)c)ii: The statement that "*Any failure of the carbon budget approach to account for such technological advancements would result in the CO2 levels being recorded at levels higher than what they actually are"* is not only false, but truly baffling. Not only because as noted in paragraph 363) a carbon budget has nothing at all to do with technology, but because **atmospheric CO_2 levels are recorded by scientific instruments that have been in existence for 60 years or more, not through any appeal to carbon budget methodology.**

365) With regard to paragraph 357)c)iii: I agree with **statement**, but note that it **is irrelevant with respect to the consent authority's assessment of the damage that would be done to the people and environment of NSW from emissions associated with the Project.**

9.4 The Departmental Assessment and Recommended Conditions of Approval

366) The Department has submitted a Project assessment (hereafter, Departmental Assessment),[331] which recommends approval of the Project with conditions (hereafter, Recommended Conditions). Section 6.5 of the Departmental Assessment contains the Department's view with respect to the GHGs arising from the Project. I wish to make the following remarks on the Department's Assessment with regard to Project GHG emissions.

367) Paragraph 330) of the Departmental Assessment, reads "*The Project is forecast to produce on average 253,000 t CO2-e per annum of Scope 1 emissions, which equates to around 0.3% of the NSW Governments 2030 emissions target as outlined in the NSW Government's Net Zero Plan*."

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[331] NSW DPIE (February 2022) Glencore Continued Operations Project, State Significant Development Assessment (SSD 9349) and Conditions of Approval, Accessed at: https://www.ipcn.nsw.gov.au/resources/pac/media/files/pac/projects/2022/02/glendell-continued-operations-project-ssd-9349/referral-from-the-department-of-planning-and-environment/glendell-cop--assessment-report-recommendation.pdf and https://www.ipcn.nsw.gov.au/resources/pac/media/files/pac/projects/2022/02/glendell-continued-operations-project-ssd-9349/referral-from-the-department-of-planning-and-environment/glendell-cop--recommended-conditions.pdf

368) The Departmental statement in paragraph 367) above, appears to have been drawn from the Glencore Letter of November 2021 to DPIE (see paragraph 300) of this Report). As I have detailed in subsection 8.2, such a comparison is like one of apples to oysters, in that it compares two quite different quantities. The actual **effect of Project's Scope 1 emissions on the ability of NSW to meet its 2030 emissions target is** 5.3% every year through 2030, **more than 17 times the measure used in the Departmental Assessment.**

369) Paragraph 331) of the Departmental Assessment, reads "*The GHGEA predicts that the Project would generate approximately 10 Mt CO_2-e of Scope 3 emissions each year. Compared with 2019 global greenhouse emissions (approximately 33,000 Mt), the Scope 3 emissions from the Project represent a very small proportion of global emissions levels (approximately 0.03%).*" **Unsurprisingly, the Project represents a small proportion of current global emissions; most incrementally defined activities that contribute to climate change impacts could claim the same.** For perspective, I offer this comparison of the Project GHGs emissions. The *remaining* global carbon budget to hold warming to about 1.5°C with a 67% chance is 320 Gt CO_2 (see Table 4). The Project will be associated with about 0.277 Gt CO2-e of GHG emissions over its lifetime (all Scopes, see Table 5), most of it in the form of CO_2, or about 0.087% of this *global* budget.

370) **Thus, approving this Project is tantamount to considering the Project as one of only 1150 global similarly sized (in a GHG sense) projects or collective human activities across energy, transport, agriculture, urban development, industry and so forth that will 'spend' humanity's remaining 1.5°C carbon budget. If this remaining global 1.5°C carbon budget were to be distributed according to population, Australia would be allotted four such Projects in total until net-zero emissions were reached.** I make this comparison not to suggest that the remaining global carbon budget will or should be allocated in this way, but to provide a sense of scale to the GHG emissions of the Project.

371) At paragraph 336) of the Departmental Assessment it is noted that: *"The majority of key consumer countries identified by Glencore are signatories to the Paris Agreement."* Irrespective of whether the countries to which the Project may sell its product coal is relevant to the IPC's decision on this matter, I note that a recent UN report has concluded that "**new [NDC] pledges for 2030 reduce projected 2030 emissions by only 7.5%, whereas a 30% reduction (on 2010 levels) is needed for 2°C and a 55% reduction is**

needed for 1.5°C" (see paragraph 208). Consequently, **signatories to the Paris Agreement have not made pledges, let alone policies, that are sufficient to hold warming even to 2°C, which is above the agreement's stated warming goal; that they may purchase the Project's coal in no way provides a measure of mitigation protection for the people and environment of NSW.**

372) Finally, I note that in its Executive Summary, the Departmental Assessments states [***emphasis*** mine]: *"[Glencore's]* ***cost-benefit analysis, which included consideration of all environmental externalities****, calculates that the Project would have a net benefit of $1.1 billion to the NSW economy in net present value (NPV) terms*."

373) I submit that neither Glencore's **cost-benefit analysis**, as included as Appendix 30 (the EY Assessment) of its EIS, nor the review of that cost-benefit analysis contained in the CIE Report included consideration of all environmental externalities, **neglecting, for example, to include these externalities related to GHG emissions:**[332]

a) Damages associated with irreversible changes in the natural environment (e.g., species extinction) due climate change;

b) Damages associated with irreversible changes in Earth's physical systems (e.g. sea level rise) due to climate change;

c) Economic costs associated with mitigation and adapting to climate change;

d) The full cost of human mortality, morbidity, and loss of mental health due to climate change; and

e) The possibility of incalculable loss associated with crossing tipping points in Earth's climate system.

374) The externalities described in paragraph 373) may never be able to captured appropriately in an economic cost-benefit analysis. In this circumstance, I submit that the IPC must use its own judgement to decide whether the Project's benefits outweigh its costs. The Department contends they do; my judgement, informed by my expertise in climate science and considering the matters set out in this Report, is that they do not.

[332] For clarity, estimates related to the Social Cost of Carbon presented in this Report do not include the cost of these externalities either.

9.4.1 Recommended Conditions

375) With regard to the Recommended Conditions for the Project prepared by the Department, I wish to make point points.

376) First, **the Conditions of Approval do not address the most important component of the Project's emissions that affect the environment of NSW: Scope 3 emissions.**

377) Second, **reliance on offsets** in the event that the Project Applicant exceeds the Scope 1 and Scope 2 CO_2-e performance measures set by the Department (see paragraphs B34 and B35 of the Recommended Conditions) **is unlikely to significant lower the GHGs associated with climate change**, for the following reasons.

a) **Offsets do not reduce global GHG emissions. At best, they negate emissions that have already been released. In order to do so, they must remove the same *amount*, and the same *type* of GHG at the same *time* as the original emissions occur, and they must come from an activity that would not have occurred without the offset.** These conditions are required for a true offset because different GHGs have different GWPs and because the original emission will cause some warming in the time that elapses between the emission and a later offset.

b) **GHGs from fossil fuels cannot be 'offset' – in a climate sense – with biological GHG sinks**.[333] This is because the GHG emissions from fossil fuels add GHGs back into the atmosphere that have not been there for millions of years. Offsets that use biological systems (such as trees, for example) to draw down GHGs (particularly carbon dioxide) will return most of those gases to the atmosphere when they die and decompose in natural cycles of years to centuries. In addition to being temporary, biological offsets can take time to take effect and may be subject to later destruction through changed land practices or, for example, fires exacerbated by climate change itself.

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[333] Watts, K. (2015) Fossil and biological carbon: a tonne is not a tonne, Carbon Market Watch. Accessed at: https://carbonmarketwatch.org/publications/policy-brief-fossil-and-biological-carbon-a-tonne-is-not-a-tonne/

c) **It is becoming increasingly well-recognised that many offset programs are ineffective in producing real reductions in GHGs**. A 2022 research study[334] concluded that "California's forest offsets program creates incentives to generate offset credits that do not reflect real climate benefits" and that nearly a third of the credits offered no real climate benefits. Using satellite data, it has been claimed that Indonesian credits were sold for amounts that exceeded the possible carbon sink.[335] The ineffectiveness of biological credits has been called out by insiders and previous proponents with considerable experience in such programs, both in Canada[336] and in Australia,[337,338] where **up to 80% of the carbon credits issued by Australia's Clean Energy Regulator have been claimed to be flawed in producing their intended purpose**.

378) The conclusion is that **the primary way to reduce GHG emissions is to prevent them from entering the atmosphere in the first place, not by relying on so-called `offsets.'**

9.5 Precautionary Principle and Intergenerational Equity

379) As this Report has set out in Sections 5 and 6, **the effects of climate change – which is caused by anthropogenic GHG emissions – are already serious; they are in fact dangerous. Furthermore, some of these effects are already irreversible** (see e.g., Sections 4.8 and 4.9) **and more will become so with even relatively small amounts of additional warming beyond that of 1.5°C which is already locked in** (see e.g., Section 6.2).

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[334] Badgley, G. et al. (2022) Systematic over-crediting in California's forest carbon offsets program, in Global Change Biology, 28: 1433-1445. Accessed at:

[335] Nikkei (2021) Indonesian carbon credit project appears to betray its purpose. Accessed at: https://asia.nikkei.com/Spotlight/Environment/Climate-Change/Indonesian-carbon-credit-project-appears-to-betray-its-purpose

[336] Bloomberg (17 March 2022) This Timber Company Sold Millions of Dollars of Useless Carbon Offsets, Accessed at: https://www.bloomberg.com/news/articles/2022-03-17/timber-ceo-wants-to-reform-flawed-carbon-offset-market

[337] Australian Financial Review (23 March 2022) Former watchdog goes public with carbon credit `fraud' claims. Accessed at: https://www.afr.com/policy/energy-and-climate/former-watchdog-goes-public-with-carbon-credit-fraud-claims-20220323-p5a77o

[338] The Guardian (23 March 2022) Australia's carbon credit scheme `largely a sham', says whistleblower who tried to rein it in. Accessed at: https://www.theguardian.com/environment/2022/mar/23/australias-carbon-credit-scheme-largely-a-sham-says-whistleblower-who-tried-to-rein-it-in

380) Every tonne of GHG emission leads to (more) dangerous warming. It is not possible to know which amount, from which source, will precipitate environmental subsystems, including those in NSW, to tip irreversibly. In this context, the Precautionary Principle certainly applies.

381) Unabated climate change is likely to be greatest overall threat to the environment and people of New South Wales (NSW) because it is comprehensively dangerous, global, fundamental, rapid, compounding, self-reinforcing, has delayed effects and, in some cases, is irreversible (see Section 4). In my opinion, **environmentally sustainable development is development that avoids the catastrophic risks that climate change poses, noting the special nature of climate change as a risk not only to the natural environment, but also human health, well-being and livelihoods.**

382) **The argument** put by the Project proponent (and Department) **that Project emissions represent a very small fraction of national or global emissions is irrelevant and misleading. If individual consent authorities around the world were to accept this argument and act upon it to approve fossil fuel expansion projects, the climate change predicament would, *per force*, continue to worsen.**

383) **The climate change externalities of the Project will be borne disproportionately by younger and future generations, with no clear recourse or path to remediation.** Given that any future emissions 'lock in' extra warming, there is no possibility for true `remediation' of the climate damages caused by emissions from the Project. These damages include deterioration in the health, diversity and productivity of the environment, and have direct consequences for human health and livelihood.

384) This Report has sought to detail some of the reasons why the health, diversity and productivity of the NSW environment will not be maintained or enhanced by the Project, but will, in fact, be damaged by its approval, including in ways that are irreversible.

Respectfully submitted on 28 March 2022,

[redacted]

Professor Penny D Sackett

Appendix A: Brief Provided to Author by the EDO

See attached pages.

Appendix B: Curriculum Vitae of Author

See attached pages.