Expert Report Regarding the Greenhouse Gas and Climate Implications of the proposed Mt Pleasant Optimisation Project (SSD - 10418)

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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 15 June 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 client, Denman, Aberdeen, Muswellbrook and Scone Healthy Environment Group, in relation to the proposed Mount Pleasant Optimisation Project (SSD-10418) (hereafter, the Project) by MACH Mount Pleasant Operations Pty Ltd (hereafter, the Applicant).

3) My independent expert advice has been sought with regard to the greenhouse gases and climate change impacts associated with the Project, and the causes, trends and impacts of climate change generally, and with respect to New South Wales (hereafter, NSW).

4) The Project is an expansion of the Applicant's existing Mount Pleasant Operations in the in the Upper Hunter Valley of NSW, near Muswellbrook. The Project would extend the life of the coal mine from 2026 until 2048, increase the annual run-of-mine (ROM) coal extraction, construct associated infrastructure, and result in an estimated 406 million tonnes (Mt) of ROM coal extracted.[1]

5) 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.''*

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

[1] MACH (31 March 2022) MACH Response to Greenhouse Gas Queries, Accessed at: https://pp.planningportal.nsw.gov.au/major-projects/projects/mount-pleasant-optimisation-project

7) Culminating years of work, the United Nations' Intergovernmental Panel on Climate Change (IPCC) has recently released three assessment reports in its sixth series, one from each of its Working Groups. As a compendium of recent science, these reports form an important evidentiary base and are referred to often in this Report. They are:

a) Climate Change 2021: The Physical Science Basis (hereafter, AR6 WGI)[2]

b) Climate Change 2022: Impacts, Adaptation and Vulnerability (hereafter, AR6 WGII)[3] and

c) Climate Change 2022: Mitigation of Climate Change (hereafter, AR6, WGIII)[4]

8) A curriculum vitae of my relevant qualifications and experience is attached as Appendix B of this Report.

[2] IPCC (2021) 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/

[3] 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/

[4] IPCC (2022) Climate Change 2022: Mitigation of Climate Change, Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, accessed at: https://www.ipcc.ch/report/ar6/wg3/

Executive Summary

9) 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.

10) Unabated climate change is likely to be greatest overall threat to the environment and people of NSW because it is comprehensively dangerous, global, fundamental, rapid, compounding, self-reinforcing, has delayed effects and, in some cases, including effects currently underway, is irreversible. [Section 2]

11) 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 2 and 5.1]

12) 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 2 and 2.9]

13) 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]

14) 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]

15) All weather effects are affected to some extent by climate change. Scientists are now able to quantity the effect of climate change on many individual events. [Section 3.2]

16) About 90% of the CO_2 emitted by humans each year is from the burning of fossil fuels: coal, gas, and oil. [Section 3.4]

17) The proposed Project would recover approximately 406 million tonnes (Mt) of run-of-mine (ROM) coal through 2048, resulting in totals of `equivalent' (over 100-year time scales) of

13.89 Mt CO_2-e in Scope 1 emissions, 2.17 Mt CO_2-e in Scope 2 emissions, and 860.14 Mt CO_2-e in Scope 3 emissions. [Section 4]

18) Due to likely under-reporting of fugitive emissions from Australian coal mines, extended post-mining fugitive emissions from coal mines, and the considerably lower fugitive emissions factor used for the Project compared to National Greenhouse Accounting factors for NSW open cut mines, it is advised that estimates for fugitive methane emissions from the Project over its projected lifetime may be underestimated by factors of at least two to three. Furthermore, given the large effect of methane as a GHG over 20-year timescales, the effect of Project fugitive emissions on the climate are about three times larger than the traditionally-reported 100-year values of CO_2-e over the lifetime of the Project. [Section 4.3]

19) 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 5.1.1]

   a) Increases in the Earth's energy imbalance, the difference between the amount of solar energy absorbed and the amount of energy radiated into space at a given time, has been 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.

20) 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 2019/20 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 5.1.2]

21) 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 2022 floods have had devastating effects across large portions of the State, some of which are still recovering from Black Summer fires. [Sections 5.1.3]

22) 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 current trend of rising emissions continues, in just 80 years, global warming could be 3°C – 4°C above pre-industrial temperatures. [Section 5.2.1]

23) Climate impacts are hitting harder and sooner than previous scientific assessments have expected. [Section 5.2.2]

24) Future impacts depend on the level of warming that is reached, some of which are detailed in Table 1 below. [Sections 5.2.2, 5.2.3, and 5.2.4]

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 will 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 finfish, 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.

25) 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 inconsistent with global warming of 1.5°C. [Sections 6.1 and 6.1.1]

26) Based on current policies as opposed to Paris Agreement pledges, warming could go as high as 3.6°C. [Section 6.1]

27) 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. [Section 6.2]

28) 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 6.3]

29) The International Energy Agency's (IEA) global energy sector roadmap for net zero emissions by 2050 lists as a major milestone that no new or extended coal mines be approved, beginning in 2021. [Section 6.3]

30) 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 6.3.2]

31) The Project is inconsistent with holding global warming to well below 2°C and directly works against NSW's ability to close its coal GHG `Production Gap.' [Section 7.1]

32) The Mt Pleasant Optimisation Project is significant compared to the annual task of meeting NSW's and Australia's 2030 GHG targets. At a minimum, the Project will make it 2.3% more difficult for Australia to meet its (new) 2030 target, and 6.36% more difficult for NSW to meet its 2030 target. [Section 7.2]

33) 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 environmental and social effects to NSW. Doing so reveals that approving this single Project would erode the world's carbon budget by more than half that consumed by the entire state of NSW from 2023 until it (presumably) reaches net zero in 2050. [Section 7.2]

34) The Project's Social Cost of Carbon are borne by the world's population and thus are true externalities. Scientifically-derived median values for the Social Cost of Carbon attributable to the Project are about 526 Billion AUD, globally, and about 604 Million AUD for NSW. These scientifically-derived estimates are underestimates of the true externality costs, and yet are more than 500 to 1,100 times larger than the Applicant's assessment of GHG externalities arising from the Project. This raises serious doubt that the Project would represent a true net economic benefit to the people of NSW. [Section 7.3]

35) 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 7.4]

36) The climate change externalities of the Project, will be borne disproportionately by younger and future generations, with no clear recourse or path to remediation. Taken together with the evidence supplied by this Report of the enormous risks posed by global warming surpassing 2°C, including irreversible consequences, and the contribution of the Mt Pleasant Optimisation Project in increasing that likelihood, it is my view that any benefits from the Project are far outweighed by costs borne by the majority of NSW inhabitants, particularly its youngest. [Section 7.4]

37) The specific IEA World Energy Outlook 2021 scenarios that the Applicant, through its legal representative Ashurst, relies upon to assess future demand for coal are precisely those that are incompatible to holding warming to 2.0°C, and which the IEA itself says put "the world off track to reach net zero emissions by 2050." [Section 8]

2 Why Climate Change is Different to other Threats

38) **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.

39) 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. 1).[5]

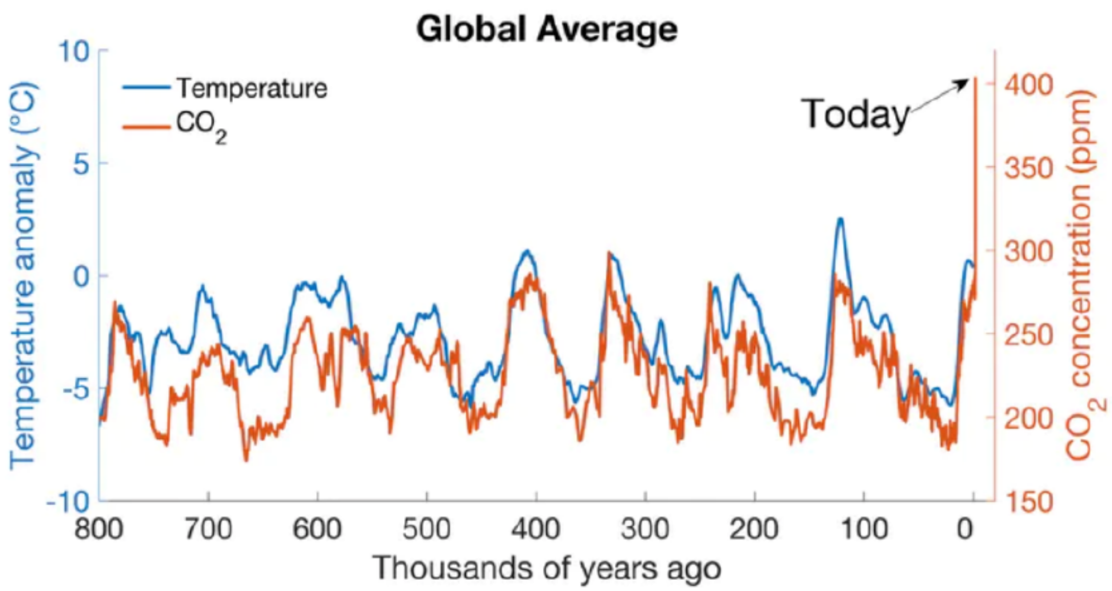

Fig. 1: Global average temperature difference (blue) and atmospheric concentration of CO_2 (orange) over the last 800,000 years. Low periods are ice ages, whilst high periods are interglacials; Only about 5°C separates the two. Plot from Henley and Abram (2017).

[5] 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

40) 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.

2.1 Climate change is fundamental to the environment

41) 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.[6] (See Fig. 2 below.)

[6] 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

42) **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.**

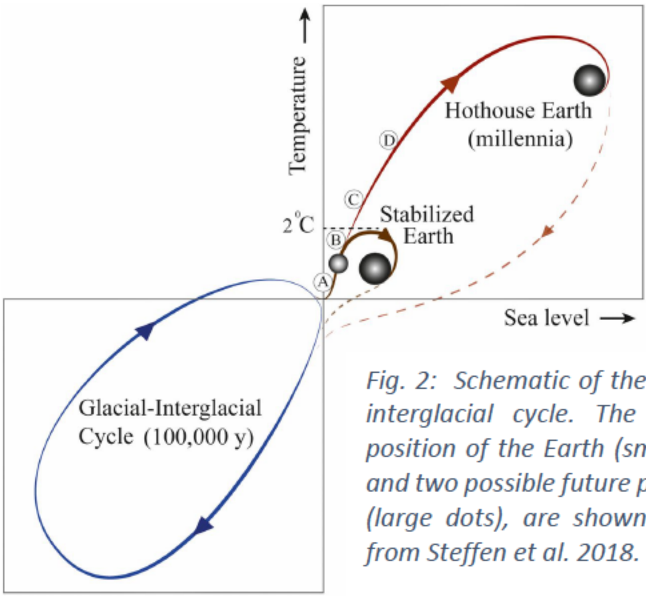

Fig. 2: Schematic of the glacial-interglacial cycle. The current position of the Earth (small dot) and two possible future positions (large dots), are shown. Figure from Steffen et al. 2018.

43) **Anthropogenic GHG emissions are now pushing the Earth System rapidly away from the glacial-interglacial cycle of stability** (see Fig. 2) **toward new, hotter climatic conditions and a profoundly different biosphere.**

2.2 Climate change is global

44) 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.**

45) 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.**

2.3 Anthropogenic change is comprehensively dangerous

46) **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[7,8,9] 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 Section 5.2 of this Report. **Nearly every environmental system on Earth will be affected if global warming increases to 3°C – 4°C**.

2.4 Anthropogenic climate change is rapid

47) 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.[10]

48) 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.[11]

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[7] 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/

[8] 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.

[9] 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/

[10] 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

[11] 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.

2.5 Climate change has delayed effects

49) **The full climatic effects of greenhouse gases (especially CO_2) are not felt until long after the time of emission** (see Section 3.1). 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 been emitted.[12]

50) 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**.[13] This is an example of how global emission decisions made in the period 1990 to 2020 have a delayed effect.

51) 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.[14] **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**.

2.6 Climate change is compounding

52) **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.**[15,16]

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[12] 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/

[13] 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)

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

[15] 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

[16] 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/

53) 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.

54) 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.[17] 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.

2.7 Climate change can be self-reinforcing

55) 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*.

56) ***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**.[18,19]

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[17] 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
[18] Raupach MR, et al. (2014) The declining uptake rate of atmospheric CO2 by land and ocean sinks. Biogeosciences 11:3453–3475.
[19] 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

57) ***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:[20]

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.

58) The combined effect of all climate feedback processes is net positive, that is, acting to amplify the climate response.[21]

2.8 Some climate changes are irreversible

59) 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.**"[22] 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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[20] 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

[21] 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

[22] 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*).

60) AR6 WGII details how **these irreversible effects 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: [23]

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*).

f) Some losses are already irreversible, such as the first species extinctions driven by climate change (*medium confidence*). Other impacts are approaching irreversibility,

[23] 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/

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*).

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

61) 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.[24,25]

62) *Tipping points*[26] 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**.

63) **Recent research indicates that tipping point risks are now much higher than earlier estimates**. Over **half of previously identified**[27] **tipping elements are now 'active,'** that is, they are moving in the direction that could cause irreversible change (see Fig. 3 below).[28]

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[24] 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

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

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

[27] 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

[28] 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

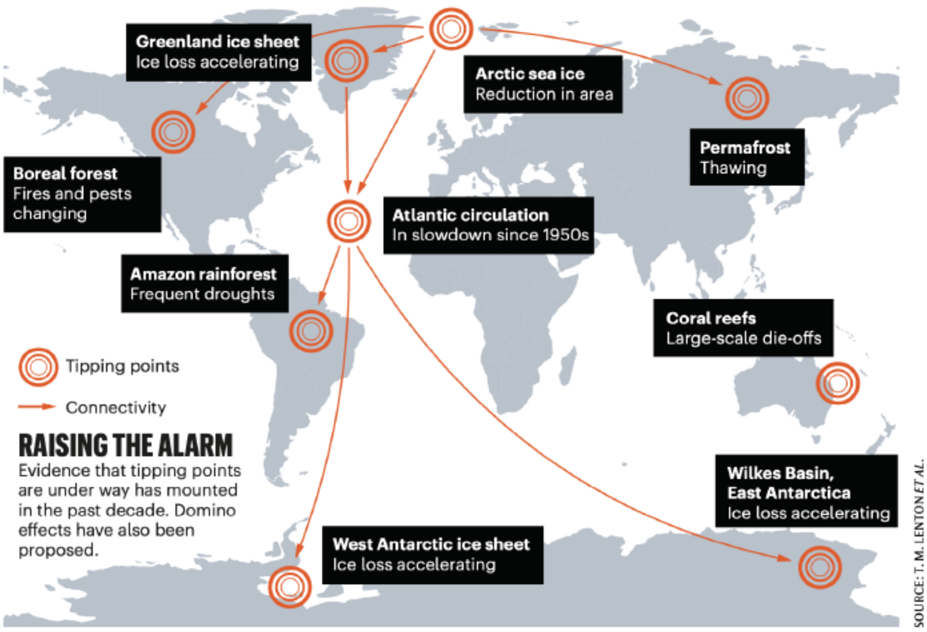

Fig. 3: Tipping elements that are currently changing, and their interactions with one another. (Figure from Lenton et al. 2019).

64) 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*).**"[29]

65) **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.**[30]

66) **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.**[31]

67) **One of the most significant tipping elements is the Atlantic Meridional Overturning Circulation (AMOC),**[32] a complex of deep and surface currents in the Atlantic Ocean that

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[29] 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

[30] 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

[31] 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

[32] 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**.[33]

68) **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.[34]

69) **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'.** [35] 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.

70) 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.**[36]

71) 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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[33] 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

[34] 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

[35] 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

[36] 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

3 Greenhouse Gas Emissions and Climate Change

72) This section is a brief review of greenhouse gases (GHGs) and their role in human-induced climate change.

3.1 Increases in greenhouse gases drive global warming

73) GHGs trap energy that would otherwise escape from the Earth's upper atmosphere; they have kept the Earth's surface at temperatures suitable for modern human civilisation and agriculture for thousands of years.

74) 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.** The additional GHGs caused by human activity create an energy imbalance. **Extra energy is returned to the Earth's surface, causing the global warming that fuels changes in the global climate.**

75) 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**.

76) Excess amounts of CH_4 and N_2O persist in the atmosphere for about 12 and 109 years, respectively.[37] 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.**[38] 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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[37] 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/

[38] 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 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/

77) Due to their different chemical properties and residency times in the atmosphere, GHGs have different global warming potentials (GWPs), that is, per kilogram 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[39] 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.**[40]

78) **In order to describe the warming effect of a given GHG over a particular period of time compared to CO_2, its `carbon dioxide equivalent ($CO_2$-e)' can be calculated using its GWP.** For example, over 100 years, 17 tonnes of fossil $CH_4$ can be accounted as 17 x 29.8 = 506.6 tonnes of $CO_2$-e. This `equivalence' only applies to the time frame of the GWP.

79) 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.

80) **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. 4).[41]

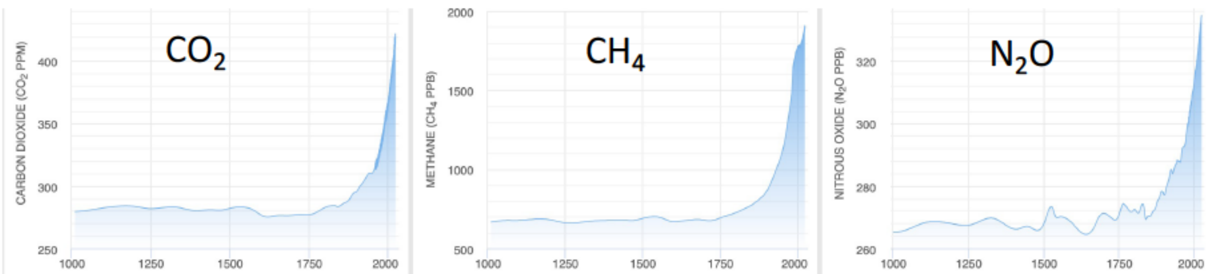

Fig. 4: The rise of GHGs in the atmosphere from 1000AD to present. Graph prepared by the Two Degree Institute, based on ice core records (CSIRO) and in situ measurements (Scripps).

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[39] 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.

[40] 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/

[41] 2 Degrees Institute (2020) Accessed at: https://www.climatelevels.org/

81) 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.[42]

82) **The rate at which atmospheric concentrations of the main GHGs is increasing is *itself* increasing**, as illustrated in Fig. 5 at right.[43]

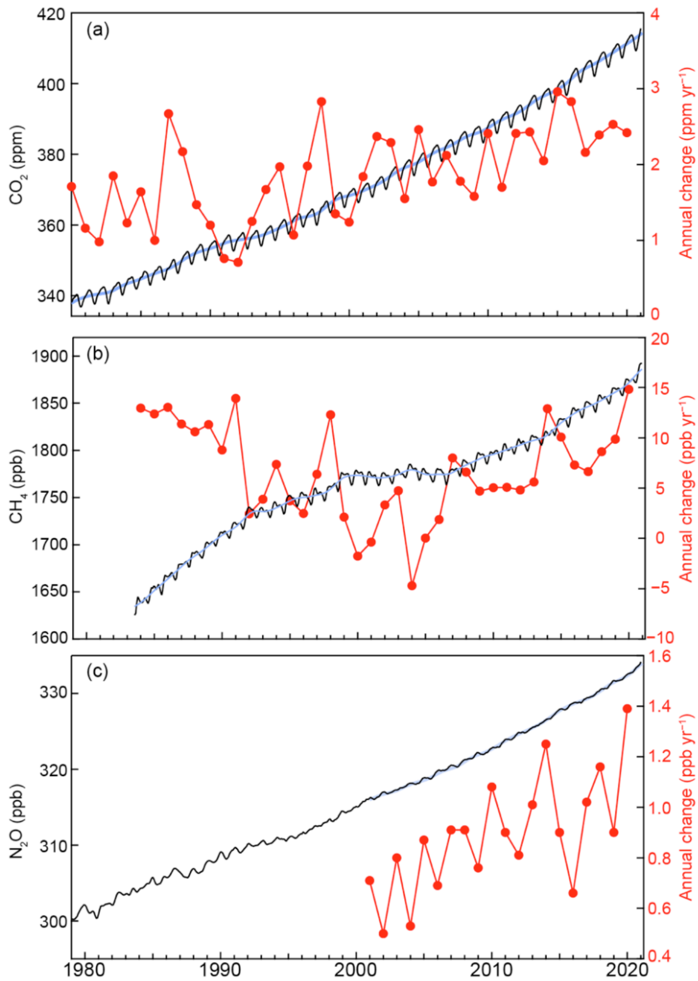

Fig. 5: Dark lines: Increases in the atmospheric concentration of CO_2, CH_4 and N_2O from 1980 to 2020. Note that the vertical scales do not start at zero. Red lines: Increases in each year compared to the previous year. This figure derives from Figure 2.50 of Blunden and Boyer (2020).

83) 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,**[44] and **concentrations of CH_4 and N_2O are higher than at any time in at least 800,000 years**.[45] See Fig. 6 below.

[42] 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
[43] 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
[44] Fedorov, A.V. et al (2013) Patterns and mechanisms of early Pliocene warmth, in Nature, 496, doi:10.1038/nature12003.
[45] 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

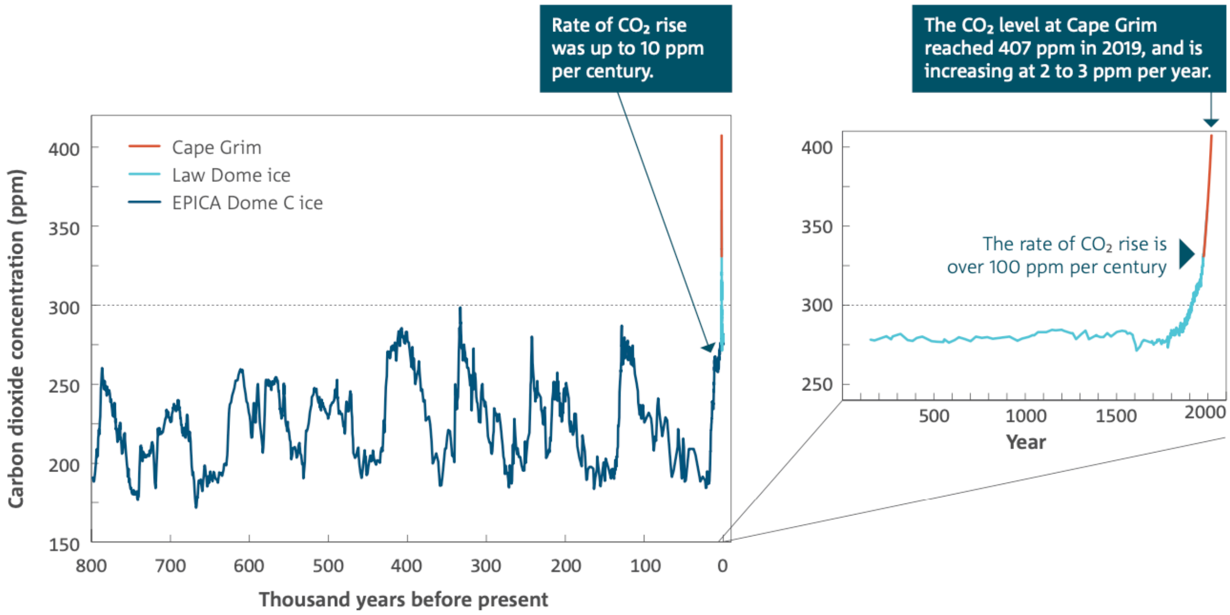

Fig. 6: Current increases in atmospheric CO_2 compared to last 800,000 years. Figure from CSIRO/BOM (2020).

84) 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. 6 above.)[46]

85) **Since 1970, the global average surface temperature has been rising at a rate** of 2.0°C per century,[47,48] **about 200 times faster than the average rate of change** of about 0.01°C per century **for the last 7,000 years**.[49]

3.2 Individual extreme events can be linked directly to global warming

86) 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.[50] The field of **attribution science is now allowing**

[46] CSIRO/BOM (2020), State of the Climate 2020, Commonwealth of Australia. http://www.bom.gov.au/state-of-the-climate
[47] 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
[48] 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/
[49] 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
[50] 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

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.

87) 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**.[51]

88) **The widespread coral bleaching of the Great Barrier Reef during 2016 was made 175 times more likely due to climate change**.[52]

89) **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**.[53]

90) According to the United Kingdom (UK) Met Office,[54] **human-induced climate change has made the 2018 record-breaking UK summer temperatures about 30 times more likely** than they would naturally occur.

91) 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.[55]

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

[52] 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.

[53] 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/

[54] 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

[55] 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

92) **The 2019-2020 Australian bushfires were made 30 – 80% more likely due to anthropogenic climate change**.[56]

93) A recent meta-analysis[57] 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**.

94) **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**.[58]

95) In the period 1991–2018, **37% of warm-season, heat-related human deaths have been attributed to anthropogenic climate change**.[59]

96) 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.[60]

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

97) ***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**.

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[56] 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

[57] 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.

[58] 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/

[59] 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

[60] 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/

98) **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.[61]

99) The AR6 WGI[62] makes clear the direct relationship between humans and the global warming driving climate change (my emphasis):

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."

100) **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**.[63] The more quickly emissions are brought and held to zero, the lower the peak global warming temperature will be.

3.4 Human greenhouse gas emissions come primarily from fossil fuels

101) **At present, about 90% of the additional CO_2 emitted per year is from the burning of coal, gas, and oil**,[64] with most of the remainder due to land use changes (e.g., deforestation which removes a natural sink for CO_2).

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[61] 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
[62] 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
[63] 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
[64] 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/

102) **Human CO_2 emissions from fossil fuel use continue to rise,** although at a smaller rate than in the first decade of this century.[65] (See Fig. 7.)[66]

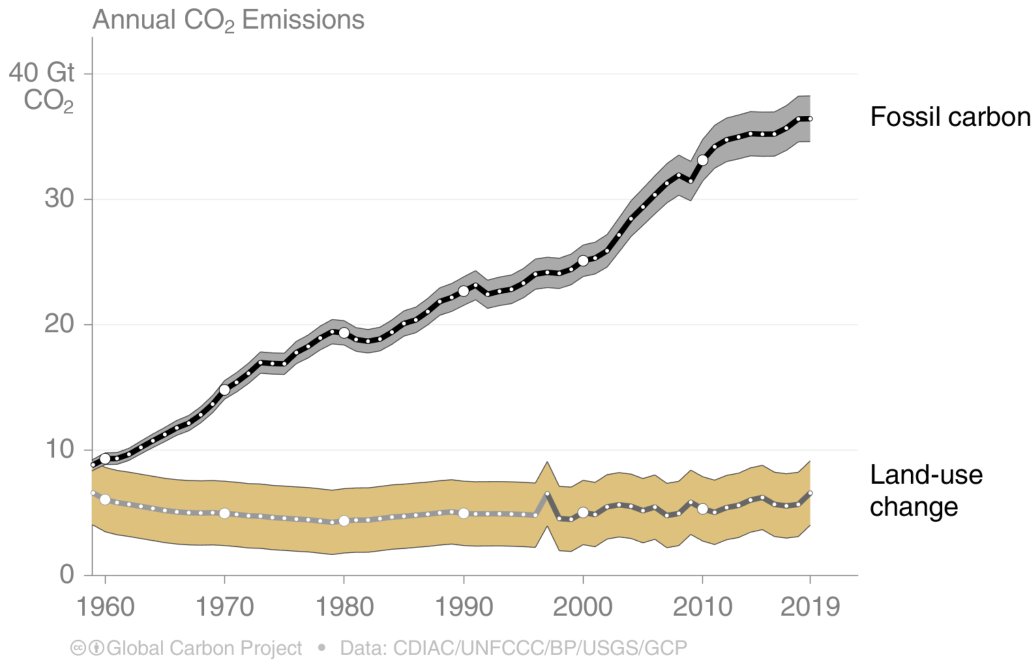

Fig. 7: Global human emissions from fossil sources continue to grow, whilst those from land-use changes (primarily deforestation) have remained relatively constant. Combined, humans emitted about 42 billion tonnes (Gt) of CO_2 into the atmosphere in 2019. Data from Friedlingstein et al (2020).

103) The growing trend in emissions continues: **year-on-year CO_2 emissions from fossil fuels are now more than 300% of 1960s levels.**[67]

104) The production, delivery and combustion of **fossil fuels is also associated with the release of CH_4.**[68] **A recent surge in atmospheric methane over the past decade is attributed in equal parts to agriculture (particularly livestock) and fossil fuels.**[69]

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[65] 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

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

[67] 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

[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] 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

4 Greenhouse Gas Emissions from the Mt Pleasant Optimisation Project

105) In this section, the expected Project GHG emissions are set out as presented in the Project's Environmental Impact Statement[70] (the EIS), and as later modified[71] by Todoroski Air Sciences, at the request of the Applicant.

106) According to the Project's EIS:[72]

a) The Mount Pleasant Operation is an open cut coal mine and associated infrastructure, located approximately 3 kilometres (km) north-west of Muswellbrook in the Upper Hunter Valley of NSW.

b) The **Mount Pleasant Operation currently extracts thermal coal using open cut mining methods** with an **approved operational capacity of up to 10.5 million tonnes per annum (Mtpa) of run-of-mine (ROM) coal until 22 December 2026.**

c) The Project proposed by the Applicant includes the extraction of additional coal, and extension of the life of the Mount Pleasant Operation.

d) Specifically, the **Project would recover approximately 406 million tonnes (Mt) of ROM coal**, yielding a mining total of approximately 444 Mt of ROM coal from Mount Pleasant Operations (from both approved operations and the proposed Project). This ROM coal would be processed to create thermal products to be transported by rail to the Port of Newcastle for export or domestic use.

e) **The Applicant seeks, through the Project, development consent to extend open cut mining operations by 22 years, that is, until 22 December 2048**, and to increase ROM

[70] MACH Energy (22 January 2021) Mount Pleasant Optimisation Project Environmental Impact Statement (EIS). Accessed at: https://pp.planningportal.nsw.gov.au/major-projects/projects/mount-pleasant-optimisation-project

[71] Todoroski Air Sciences (30 March 2022) Mount Pleasant Optimisation Project Greenhouse Gas Assessment – Additional Information, attached to MACH Energy's response to Departmental Queries concerning greenhouse gases. Accessed at: https://pp.planningportal.nsw.gov.au/major-projects/projects/mount-pleasant-optimisation-project

[72] EIS: Section 1, Introduction. Accessed at: https://pp.planningportal.nsw.gov.au/major-projects/projects/mount-pleasant-optimisation-project

coal extraction, handling and processing progressively to 21 Mtpa, double the current limit of 10.5 Mtpa.

107) In other words, **the Project would increase the total ROM coal extracted from the Mt Pleasant mine by a factor of about 11.7, double the rate that could be extracted in any one year, and extend open cut mining at the site for 22 years until just one year away from the Australian and NSW net zero emissions target date of 2050.**

4.1 Indicative Mining Schedule

108) As most GHG emissions from the project depend strongly on the amount of coal mined and consumed, an important starting point is an indicative mining schedule. This is provided in Table 2-1 of Attachment A of EIS Appendix S,[73] and as Table 1 of Attachment 1 in the March 2022 reassessment by Todoroski Air Services.[74] These indicative mining schedules agree, although the latter also provides estimates for product thermal coal; it is reproduced as Fig. 8 (below) of this Report.

[73] EIS: Appendix S, Greenhouse Gas Assessment. Accessed at: https://pp.planningportal.nsw.gov.au/major-projects/projects/mount-pleasant-optimisation-project

[74] Todoroski Air Sciences (30 March 2022) Mount Pleasant Optimisation Project Greenhouse Gas Assessment – Additional Information, attached to MACH Energy's response to Departmental Queries concerning greenhouse gases. Accessed at: https://pp.planningportal.nsw.gov.au/major-projects/projects/mount-pleasant-optimisation-project

Year	ROM	Bypass	CHPP Feed	Product
2023	10.5	0.4	10.2	7.8
2024	10.5	0.4	10.2	7.6
2025	10.5	0.4	10.2	7.7
2026	10.5	0.4	10.2	7.8
2027	10.5	0.4	10.2	7.9
2028	15.8	3.9	11.8	12.9
2029	15.8	3.9	11.8	12.5
2030	15.8	3.9	11.8	12.5
2031	15.8	3.9	11.8	12.5
2032	15.8	3.9	11.8	12.6
2033	15.8	3.9	11.8	12.6
2034	21.0	5.3	15.8	16.6
2035	21.0	5.3	15.8	16.6
2036	21.0	5.3	15.8	16.9
2037	21.0	5.3	15.8	16.7
2038	20.4	5.1	15.3	16.4
2039	20.6	5.2	15.4	16.6
2040	20.6	5.3	15.3	16.6
2041	21.0	5.3	15.8	16.8
2042	21.0	5.1	15.9	16.8
2043	20.8	5.3	15.5	16.4
2044	18.6	4.7	13.9	14.9
2045	13.8	3.6	10.3	10.9
2046	9.3	2.5	6.7	7.4
2047	8.7	2.1	6.6	7
2048	0.9	0.3	0.9	1

Fig. 8. Indicative mining schedule for the Project as given in Table 1 of Todoroski Air Services (March 2022). All quantities are given in Megatonnes (Mt).

109) **I note that the total ROM coal assigned to the Project, as derived from the indicative mining schedule** in Fig. 8 is 407 Mt, **as is easily verified.** This **matches, within round-off uncertainties, the value of 406 Mt given by the Applicant in 31 March 2022**.[75]

110) **The indicative mining schedule for the Project shown in Fig. 8 will be used in this Report as an underlying assumption in assessing GHG emissions from the Project**.

4.2 Applicant Estimates of Project Greenhouse Gas Emissions

111) For geographical reporting purposes, GHGs are often accounted in one of three `Scopes,'[76] as follows:

[75] MACH (31 March 2022) MACH Response to Greenhouse Gas Queries, Accessed at: https://pp.planningportal.nsw.gov.au/major-projects/projects/mount-pleasant-optimisation-project
[76] E.g., see Australian Clean Energy Regulator (2018) Greenhouse gases and energy, http://www.cleanenergyregulator.gov.au/NGER/About-the-National-Greenhouse-and-Energy-Reporting-scheme/Greenhouse-gases-and-energy

a) **Scope 1**: Emissions released to the atmosphere as a direct result of an activity, or series of activities at a facility level. Sometimes referred to as direct emissions.

b) **Scope 2**: Emissions released to the atmosphere from the indirect consumption of an energy commodity.

c) **Scope 3**: Indirect greenhouse gas emissions other than Scope 2 emissions that are generated in the wider economy as a consequence of the activities of a facility, but from sources not owned or controlled by that facility's business.

112) **GHG estimates for the Project have been prepared by Todoroski Air Sciences, both in the original EIS[77] and in a subsequent report completed in March 2022** (hereafter Todoroski 2022),[78] for each of the three Scopes defined in paragraph 111). These totals, over the life of the proposed Project up to 2048, are reproduced as Table 2 (below) of this Report. Emissions from the decommissioning phase are excluded in Table 2 estimates.

Table 2: Estimated GHG emissions from the Project in Mt CO_2-e over its proposed life to 2048

	Scope 1	Scope 2	Scope 3
Original EIS	12.0	2.17	860
As revised by Applicant March 2022	13.9	2.17	860

113) The two estimates differ only in Scope 1 emissions, and were updated based on revised fugitive emission estimates for the Project using contemporary site-specific measurements.[79] To my knowledge, a tabulated version of these updated fugitive estimates is not publicly available, but Todoroski 2022 includes (as its Fig. 1) a chart of the original and revised fugitive emission profiles, which is reproduced below as Fig. 9 (below) of this Report. **A noticeable increase in fugitive emissions from 2035 onward is indicated in the revised estimate, as well as an indication that fugitive emissions do not drop to zero in the final year of the Project** (2048).

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77 EIS: Appendix S, Greenhouse Gas Assessment. Accessed at: https://pp.planningportal.nsw.gov.au/major-projects/projects/mount-pleasant-optimisation-project

78 Todoroski Air Sciences (30 March 2022) Mount Pleasant Optimisation Project Greenhouse Gas Assessment – Attachment 2 to MACH Energy's response to Departmental Queries concerning greenhouse gases. Accessed at: https://pp.planningportal.nsw.gov.au/major-projects/projects/mount-pleasant-optimisation-project

79 See Todoroski Air Sciences (30 March 2022).

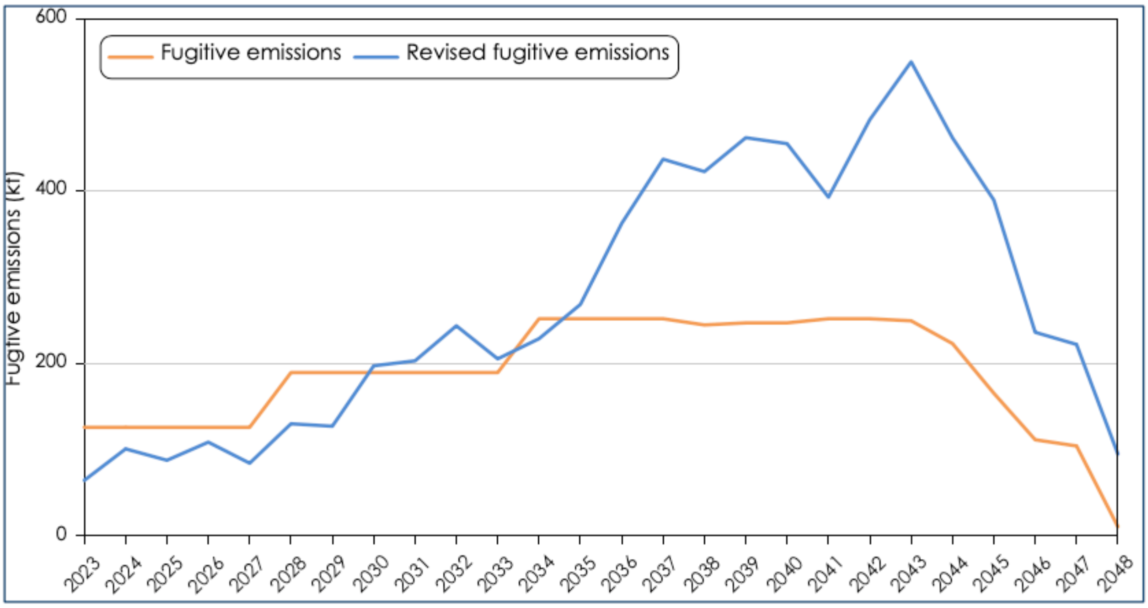

Fig. 9. Original and revised estimates of fugitive emissions for the Project in kilotonnes (Kt) of CO_2-e. Figure taken from Todoroski 2022, and units are Kt of CO_2-e.

114) It is beyond the scope of this Report to review the detailed methodology and individual sources of Project GHG emissions estimated by the Applicant. **I will use the revised GHG estimates prepared by Todoroski Air Sciences** (hereafter, the revised Todoroski GHG Estimates), **together with the indicative mining schedule** in Fig. 8 **and the revised fugitive emissions** estimate shown in Fig.9 **to draw conclusions in the remainder of this Report**.

115) **In Table 3 (below) I summarise the revised[80] Todoroski GHG Estimates for all three Scopes for three different time periods relevant to points discussion in this Report, namely: 2023–2030 inclusive; 2023–2048 inclusive; and 2023–2053, inclusive.** Emissions are given in millions of tonnes (Mt) of CO_2-e to three decimal places for ease of reading.

Table 3: Revised Todoroski GHG Estimates from the Project

Category of Emissions (Mt CO_2-e)	2023 – 2030 inclusive	Requested Period of Mining 2023 – 2048 inclusive	Emissions over Life time including Decommissioning Phase 2023 – 2053 inclusive
Scope 1	2.748	13.89	14.15
Scope 2	0.532	2.17	2.17
Scope 3	204.894	860.14	860.16
All Scopes	**208.174**	**876.20**	**876.47**

Table 3 Notes: Numbers are given to three decimal places (in Mt CO_2-e) and are for periods inclusive of the indicated beginning and ending years.

[80] Neither the EIS or Todoroski 2022 provide a table of the revised fugitive emissions presented in Fig. 9. I have converted the graph in Fig. 9 to tabular numbers using https://apps.automeris.io/wpd/

116) Emissions from the Project decommissioning phase are excluded the summary tables provided in EIS Appendix S and Todoroski 2022, but can be found in Todoroski 2021, which is Attachment A of EIS Appendix S. These have been estimated as 53 Kt CO_2-e Scope 1 emissions and 3 Kt CO_2-e Scope 3 emissions in each year 2049-2053, inclusive, and are included in Table 3 (above). **The Applicant has not provided estimates of post-mining fugitive emissions in publicly available documents.**

4.3 Fugitive Methane Emissions from the Project and Climate Change

117) All coal seams contain some level of gas; these gases escape (become 'fugitive') during both open-cut and underground mining operations. Unless captured or flared, the prominent GHG in fugitives, methane (CH_4), is released into the atmosphere accelerating climate change. Unless captured and reused, fugitive gases yield no economic benefit.

118) In this Section of this Report, I describe why the Applicant's estimates of fugitive emissions from the Project have been underestimated, perhaps by factors of 2 to 3, and why the effect of these emissions is much larger than described over the proposed lifetime of the Project.

119) **Estimates of CH_4 fugitive emissions from the Project depend critically on the assumed emission factor per tonne of ROM coal. The factor used in the original EIS is 0.012 t CO2-e/t ROM coal**, whilst **revised values** (from a 2022 re-assessment by CoalBed) **resulted in a higher average factor of 0.0201 t CO2-e/t ROM coal**.[81] **The revised value is about one-third the National Greenhouse Accounts (NGA)**[82] **default factor** of 0.061 t CO2-e/t ROM coal **for open cut mines in NSW**.

120) Particularly **noteworthy and puzzling is that NSW Department of Planning, Industry and Environment (DPIE)** (now Department of Planning and Environment [DPE]) **noted**[83]

[81] MACH (31 March 2022) MACH Response to Greenhouse Gas Queries, Accessed at: https://pp.planningportal.nsw.gov.au/major-projects/projects/mount-pleasant-optimisation-project
[82] Department of Industry, Science, Energy and Resources (2021) National Greenhouse Accounts Factors August 2021 (NGA Factors). Accessed at: https://www.industry.gov.au/data-and-publications/national-greenhouse-accounts-factors-2021
[83] NSW DPIE (10 December 2021) Advice on GHG Assessment.

that discussions with the Commonwealth Department of Industry, Science, Energy and Resources (DISER) led it to consider a factor of 0.003 t CO2-e/t ROM coal for the Project, despite this not reflecting any value in the NGA. This DPIE suggested value is 4 times lower than that used by the Applicant in its original EIS, nearly 7 times lower than the Applicant's revised factor, and more than 20 times DISER's own NGA factors for open cut mines in NSW.

121) **The revised Todoroski GHG estimates for Project fugitive methane**, as derived from Fig. 9 of this report, **is about 7 Mt CO2-e over the life of the Project**, using a GWP potential of 28, as per current NGER regulations. **On 20-year times scales, however, a GWP of 82.5** (see paragraph 77) is relevant, which yields Project fugitive methane having a 20-year effect on the climate equivalent to **20.6 Mt of CO_2, 50% more than all the Scope 1 emissions quoted for the Project over its lifetime** (see Table 3).

122) This has important consequences for climate change because even if though CH_4 from Project fugitive emissions will leave the atmosphere more quickly than would CO_2, the increased warming it causes in the shorter term could increase feedbacks in the Earth System and speed the onset of irreversible tipping points in the Earth System (see Sections 2.7, 2.8). Indeed, **a recent report**[84] studying methane sinks and sources **concludes that the climate sensitivity to methane is likely four times greater than given in AR6 WGI**, which would make CH_4 a more potent accelerant of global warming than previously thought.

123) An oft overlooked aspect of continued and increased coal mining is the emissions produced *after* the mine is closed or abandoned. Recent work[85] 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**

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[84] Cheng, C-H. et al (2022) Impact of interannual and multidecadal trends on methane-climate feedbacks and sensitivity. Nature Communications, 13: 3592. Accessed at: https://www.nature.com/articles/s41467-022-31345-w

[85] 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

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. These after-mine-closure emissions are not included in the Applicant's estimates of fugitive emissions.**

124) Evidence,[86] including from the International Energy Agency (IEA), indicates that fugitive emissions from Australian coal mining is larger than reported, so that it is possible that fugitive methane emissions from the Project may be considerably higher than shown in Fig. 9. In particular, **the IEA estimates**[87] **that Australian coal mines emitted 1,754 Mt of methane in 2021, over twice as much as the 846 Mt reported in the National Greenhouse Gas Inventory (NGGI) for 2020**.[88]

125) **A recent study**[89] **of Queensland fugitive emissions using two years of satellite measurements has shown that one open-cut mine (Hail Creek) had methane missions 15% higher than the reported emissions from *all* of Queensland's surface mines combined, and 88% of *all* Australian surface mines combined, suggesting a large under-reporting of fugitive emissions in the Australian nation inventory for surface coal mines.**

126) On the basis of the foregoing, I submit that **reasonable estimates for total fugitive methane emissions from the Project over its projected lifetime range are likely to larger than the value reported by the Applicant, by factors of at least two to three. Furthermore, the effect of methane emissions on the climate are about three times larger than that of CO_2 over the lifetime of the Project.**

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[86] Ember (2022) Tackling Australia's Coal Mine Methane Problem, and sources therein, Accessed at: https://ember-climate.org/insights/research/tackling-australias-coal-mine-methane-problem/

[87] https://www.iea.org/articles/methane-tracker-data-explorer#total-comparison-sources

[88] https://ageis.climatechange.gov.au/ Accessed 27 Jun 2022.

[89] Sadavarte, P. et al (2021) Methane Emissions from Superemitting Coal Mines in Australia Quantified Using TROPOMI Satellite Observations, Environ. Sci. Technol. 2021, 55, 16573-16580, Accessed at: https://pubs.acs.org/doi/10.1021/acs.est.1c03976?ref=PDF

5 Current Climate Impacts and Possible Climate Change Futures

127) This section describes some of the current and expected future impacts of climate change for the globe, Australia, and NSW in particular. **Future climate impacts depend most critically on fossil fuel emissions in the two decades over which the Applicant is requesting that the life of the Mt Pleasant mine be extended.**

5.1 Current Impacts

128) Average global warming is currently about 1.1°C – 1.2°C above pre-industrial levels. This Section briefly describes some resulting impacts at this level of warming.

5.1.1 Global

129) Growing GHG concentrations in the atmosphere cause an imbalance between the rate at which energy is absorbed by the Earth and that which is 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**.[90]

130) Most of this additional energy is absorbed by Earth's oceans, especially in the upper 700m but also as deep as 2km. The rise is dramatic since 1990 (See Fig. 10).

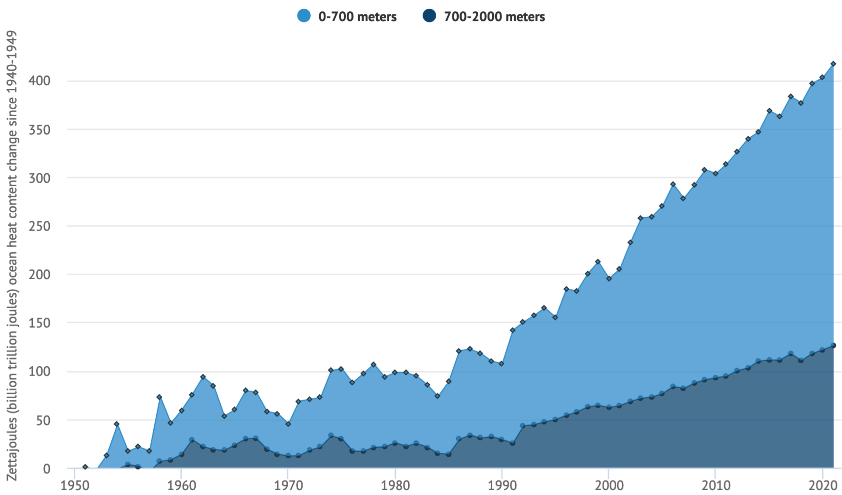

Fig. 10: Annual global ocean heat content (in zettajoules – billion trillion joules, or 10^{21} joules) for layers 0-700 metres (medium blue) and 700-2000 metres (dark blue) beneath the surface. Chart is taken from Carbon Brief (https://www.carbonbrief.org/state-of-the-climate-how-the-world-warmed-in-2021/) based on data from Cheng, et al. 2022, Advanced in Atmospheric Sciences, 39, 373-385.

[90] 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

131) Since the 1980s, each successive decade has been warmer than any preceding decade since 1850.[91] Since 1978, no year has had a global mean temperature below the 1961–1990 average;[92] 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.**

132) At the time of writing, the hottest year on record is 2020, at nearly the same temperature as 2016. Despite 2021 being slightly cooler than previous years due to the cooling effect of La Niña, it is still one of the hottest seven years on record.[93] **In fact, the past seven years have been the hottest seven years on record**.[94]

133) 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 (0.88°C).[95] Given that the rate of global warming averages about 0.2°C per decade,[96] **underlying trends in global warming place the world at about 1.2°C above pre-industrial periods in 2022**, with year-to-year fluctuations.

134) **Current effects of climate change worldwide include**:[97] **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'**

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[91] 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

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

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

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

[95] 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

[96] 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/

[97] 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.

that would accelerate climate change and greatly intensify its impacts,[98] **perhaps irreversibly.**

135) Global effects of climate change are already substantial and costly: [99,100]

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.

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.[101] That first-place record has now been eclipsed by July 2021.[102]

e) **Intensification of the hydrological cycle**: that is, 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.

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

99 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

100 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

101 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

102 NOAA (2021) https://www.noaa.gov/news/its-official-july-2021-was-earths-hottest-month-on-record

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

136) 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,[103] 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."

137) **In 2020 and 2021 alone** the following extraordinary climate events were recorded,[104,105, 106,107] 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.

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[103] 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/

[104] 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

[105] 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

[106] WMO (2021) State of the Global Climate 2020, Accessed at: https://library.wmo.int/index.php?lvl=notice_display&id=21880#.YOwDJOgzbIV

[107] 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

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 homes**. The area burnt in California in 2021 is larger than that burnt in 2020,[108] which itself set records for the state.

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 1,200 years.[109]

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[108] https://www.fire.ca.gov/stats-events/

[109] 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

138) **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**.[110]

5.1.2 Australia

139) 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.[111]

140) Specifically, the Australian Bureau of Meteorology (BOM) and the CSIRO[112,113,114] 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.

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[110] https://www.yahoo.com/news/eastern-antarctica-registers-temperatures-70-173500030.html and sources therein.
[111] 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
[112] BOM (2020), Annual Climate Statement 2020, accessed at: http://www.bom.gov.au/climate/current/annual/aus/
[113] CSIRO/BOM (2020), State of the Climate 2020, Commonwealth of Australia. http://www.bom.gov.au/state-of-the-climate
[114] CSIRO/BOM (2021), State of the Climate 2020, Commonwealth of Australia. http://www.bom.gov.au/state-of-the-climate

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. 11 below.)[115]

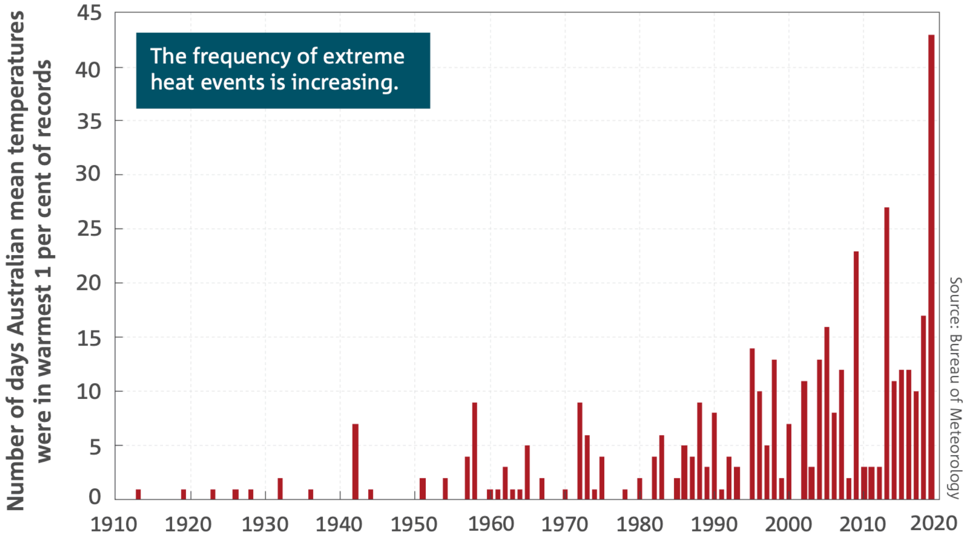

Fig. 11: Number of extreme (top 1%) heat days from 1910 to 2019. Figure from BOM.

e) In December 2019, there were 11 days for which the *national area-averaged* maximum temperature was 40 °C or above[116] (see Fig. 12 below). Only 11 other such days have been recorded since 1910, seven of which occurred in the summer of 2018–19.

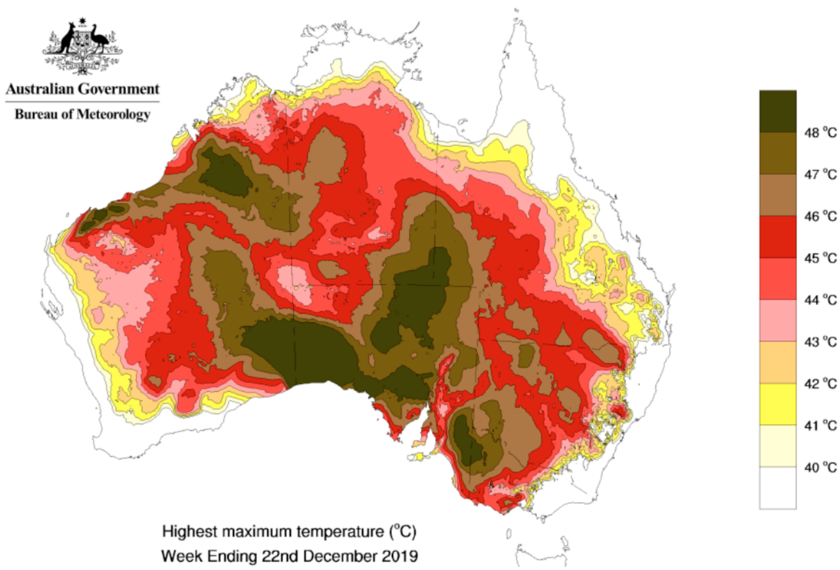

Fig. 12: Highest daily maximum temperature from 16-22 Dec 2019. Figure from BOM.

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

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

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 witnesses up to 25 more days with weather conditions conducive to extreme bushfires compared to 1950-1985.**[117] (See Fig. 13.)

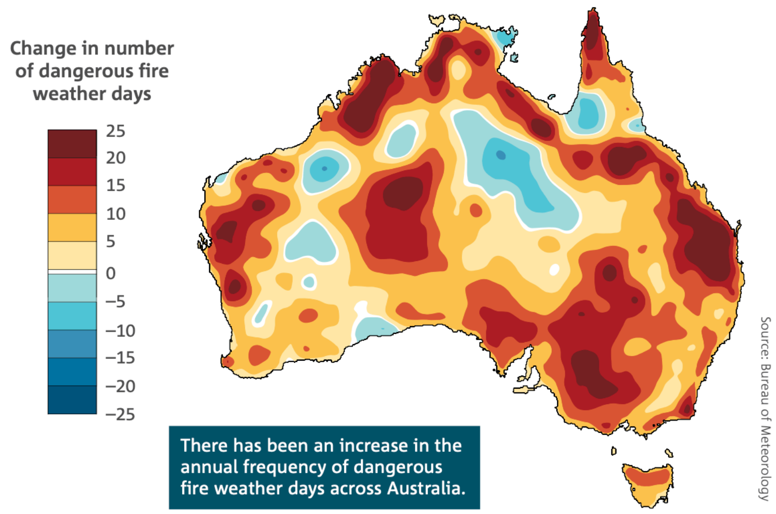

Fig. 13: Change in number of days of dangerous fire weather in 1985-2020 compared to 35 years earlier, 1950-1985.

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. 14 below.)[118]

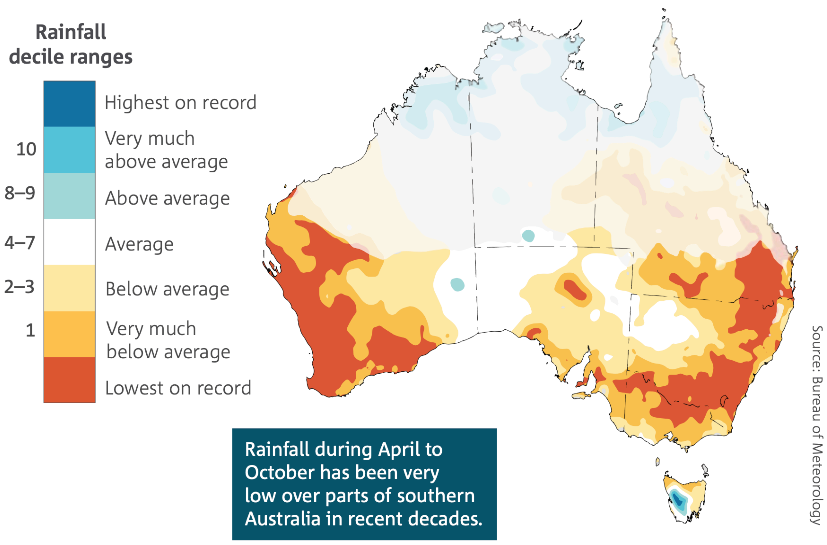

Fig. 14: April to October rainfall deciles for the last 20 years (2000 – 2019) compared to the total entire rainfall record since 1900. Figure from BOM.

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

[118] 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 Sections 5.1.3 and 5.1.4)**.**

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**.[119]

141) 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**.[120]

142) 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**.[121]

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[119] 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.
[120] 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
[121] 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

143) **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).[122]

144) 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."** [123]

145) 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."**

5.1.3 The 2019/2020 Black Summer Fires and the 2022 Floods

146) 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. This has placed enormous strain on communities, the environment, and emergency and medical response. **In some areas, recovery from one catastrophe has hardly begun before another takes place**.

147) **Australia is the most fire-prone continent on Earth**.[124,125] The accumulation of charcoal (fire residue) in Australia is now higher than at any other time in the last 70,000 years.[126]

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

[123] 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/

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

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

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

148) **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.**

149) **In 2019, the national annual accumulated FFDI was its highest since 1950, when national records began.**[127] Accumulated FFDI reached record high values in areas of all States and Territories in Spring 2019,[128] including essentially all of NSW.

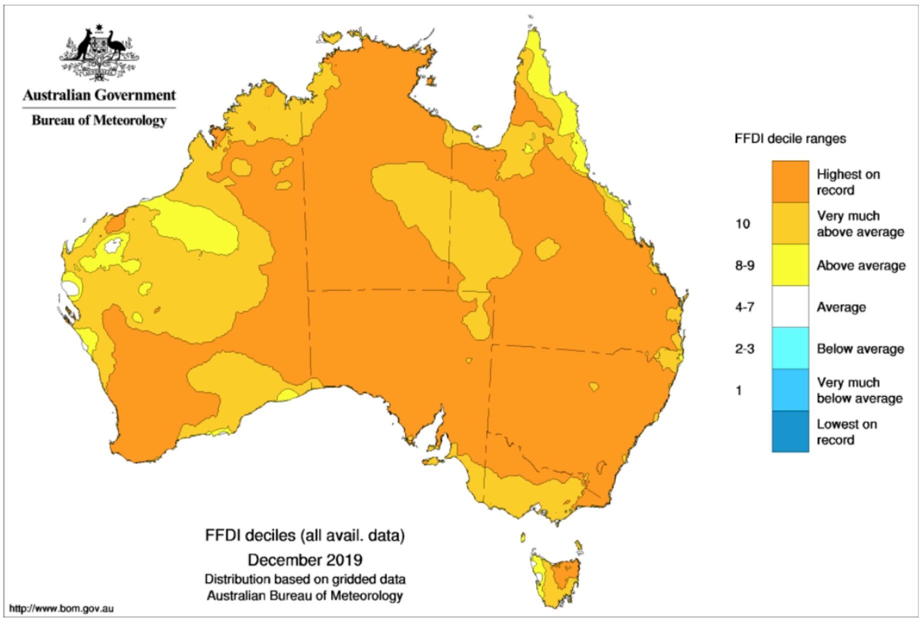

Fig. 15: FFDI deciles for December 2019, showing large areas of Australia had highest values on record for that month (dark orange colour). Figure from BOM Climate Statement 73.

150) 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. 15 above).[129]

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

151) It is not surprising, therefore, that **the Australian 2019/20 bushfires were the worst on record on many measures**.[130,131]

152) **Nearly 80% of all Australians were affected directly or indirectly by the 2019/20 bushfires,**[132] **which have now come to be known as the 'Black Summer' fires.**

153) The Black Summer fires resulted in extensive social, environmental and economic impacts. The direct social impacts included the loss of 33 lives[133] and the destruction of over 3,000 houses.[134]

154) 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,[135] and **was judged to be Australia's costliest natural disaster up to 2020**.[136] It remains to be seen whether those costs will be surpassed by the 2022 floods.

155) The tourism sector alone is likely to have lost at least $4.5 billion due to effects of the fires.[137] 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

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[130] 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.

[131] 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

[132] 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

[133] 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.

[134] 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

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

[136] 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

[137] 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/

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.**[138]

156) Indirect health impacts attributed to smoke exposure include an estimated 417 lives lost and 3,151 hospitalisations.[139] 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.**[140] 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.[141]

157) 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.[142] 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.[143]

158) 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.[144]

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[138] 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

[139] 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.

[140] 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

[141] 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

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

[143] 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

[144] 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

159) **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.**[145] **These ecosystems are not considered to be resilient to fire**.[146,147] 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.[148] Recurrent fire damage in some areas may impair the ability of ecosystems to recover.[149]

160) **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.[150]

161) 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**.[151]

162) 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**,[152,153] which is **longer than the time left to reach net zero emissions,**

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[145] 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).
[146] Bowman, D. M. J. S. (2000) Australian Rainforests: Islands of Green in a Land of Fire. (Cambridge University Press, 2000).
[147] 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/
[148] 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.
[149] 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.
[150] Boer MM, Resco de Dios V, & Bradstock RA (2020) Unprecedented burn area of Australian mega forest fires, Nature Climate Change.
[151] 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
[152] 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.
[153] Land for Wildlife. How to Age Trees. Accessed at: https://www.lfwseq.org.au/how-to-age-trees/

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.[154]

163) Consequently, **local tipping points in some Australian forests may have already been crossed.**[155] 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**.

164) Australia's Black Summer is consistent with previous scientific assessments dating back at least 30 years that human-caused climate warming will increase the duration, frequency and intensity of forest fires in southeast Australia.[156,157,158]

165) **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.**[159,160,161]

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[154] 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
[155] 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
[156] Beer, T., Gill, A. M. & Moore, P. H. R. (1988) in Greenhouse: Planning for Climatic Change (ed. Pearman, G. I.) 421–427 (CSIRO Publishing)
[157] 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).
[158] 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).
[159] Harris, S. & Lucas, C. (2019) Understanding the variability of Australian fire weather between 1973 and 2017. PLoS ONE 14, e0222328.
[160] Dowdy, A. J. (2018) Climatological variability of fire weather in Australia. J. Appl. Meteorol. Climatol. 57, 221–234.
[161] 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

These trends are strengthening. **Key climate change drivers of fire risk,** particularly in southeast Australia, **are becoming stronger**.[162,163]

166) **The 2022 Australian Floods placed an additional burden, particularly in NSW and Queensland, on communities and environments not yet fully recovered from climate extremes experienced just two to three years ago**.

167) Climate change is associated with extremes in the hydrological cycle. 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.[164] Increasingly extreme rainfall events and flooding due to global warming have been predicted for Australia and NSW, in particular. (see e.g., paragraphs 140), 210) and 223)).

168) 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:[165]

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.

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[162] 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

[163] 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

[164] 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/

[165] 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/

b) The Wilsons River in the Northern Rivers district of NSW, 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.

169) **As of 9 March 2022, at least 22 people have been reported to have died from the 2022 Australian Floods,**[166] **but the number of people affected are in the tens of thousands**. According to the Climate Council:[167]

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 NSW SES flood rescues – over 932.

170) It is reported[168] that **damages claimed from the February 2022 floods in Queensland and NSW has reached $4.8 billion** from around 225,000 insurance claims, making the event **the third costliest natural disaster for insured losses in Australian history**.

171) Without adaptation, **projected increases in direct flood damage are 1.4 – 2 times higher at 2°C, and 2.5 – 3.9 times at 3°C of warming, compared to 1.5°C.** [169] **This is another example of the large negative consequences of allowing global warming to rise beyond 2°C.**

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[166] 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

[167] 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/

[168] ABC News (28 June 2022) Insurance bill for February floods reaches $4.8b, victims could wait years for repairs, Accessed at: https://www.abc.net.au/news/2022-06-28/qld-brisbane-flood-insurance-claims-figures-supply-shortages/101186734

[169] 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/

5.1.4 New South Wales and the Upper Hunter Valley

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

173) Most of the **climate change impacts experienced by Australia are being felt in NSW**.[170,171,172,173] 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 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. 16 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 Section 5.1.3).

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[170] BOM (2019), Annual Climate Statement 2019, NSW, accessed at: http://www.bom.gov.au/climate/current/annual/nsw/archive/2019.summary.shtml
[171] BOM (2020), Annual Climate Statement 2020, NSW, accessed at: http://www.bom.gov.au/climate/current/annual/nsw/archive/2020.summary.shtml
[172] BOM (2020) Special Climate Statement 73 update, Accessed at: http://www.bom.gov.au/climate/current/statements/
[173] BOM (2021) Annual Climate Statement 2021, NSW, accessed at: http://www.bom.gov.au/climate/current/annual/nsw/archive/2021.summary.shtml

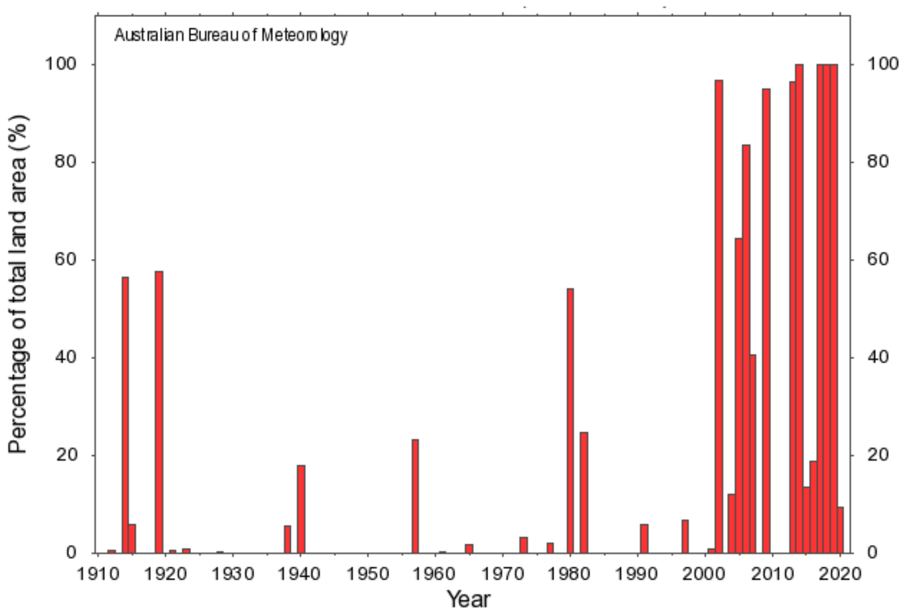

Fig. 16: The percentage of NSW area (from 0 to 100%) that experienced a maximum annual temperature in the top 10% of all records. These data from BOM cover years 1910 through 2021.

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.[174]

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**.[175]

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[174] 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

[175] BOM (2021) Special Climate Statement 74, Accessed at: http://www.bom.gov.au/climate/current/statements/

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.[176] **Muswellbrook, just 3 km to the northwest of the proposed Project, broke its annual rainfall record,** previously set in 1988.[177]

174) **The first half of 2022 brought even more dramatic and dangerous flooding to NS**W, which was particularly bad along the coast. **Persistent intense rainfall in Sydney and along the central NSW coast caused widespread flash flooding and major riverine flooding, particularly in the Hawkesbury-Nepean Valley.** The widespread intense rainfall quickly overwhelmed local stormwater and drainage systems, resulting in significant flash flooding across regional and metropolitan Sydney as well as along the NSW coast. Severe weather and major flood warnings were issued, and thousands of people were evacuated from the affected areas.[178]

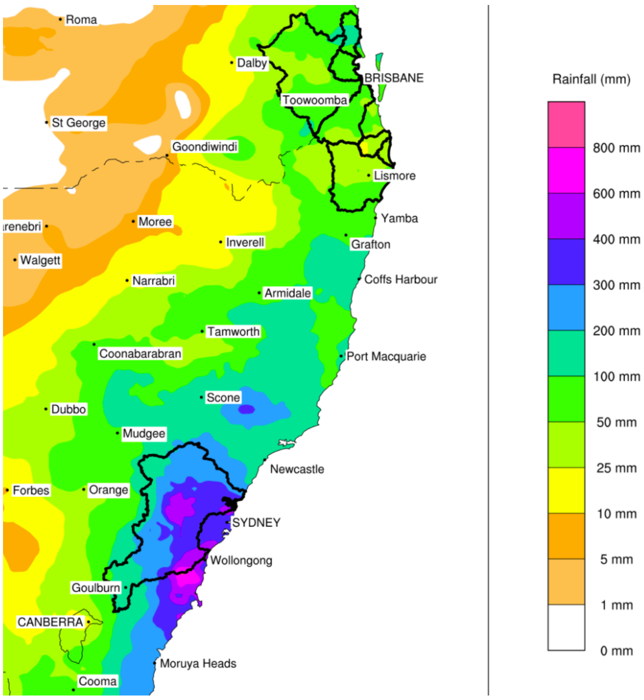

Fig. 17: Map of 7-day rainfall totals for south-eastern Queensland and eastern NSW for the week ending 9 March 2022.

Source: BOM (2022) Special Climate Statement 76.

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[176] BOM (2021) Special Climate Statement 75, Accessed at: http://www.bom.gov.au/climate/current/statements/

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

[178] BOM (2022) Special Climate Statement 76, Accessed at: http://www.bom.gov.au/climate/current/statements/

175) Whilst **the Lismore area felt the most devastating effects overall, the Hawkesbury-Nepean catchment recorded its wettest 9- and 14-day periods on record (since 1900) to 9 March 2022**, with major flooding recorded at locations along the Nepean and Hawkesbury Rivers. Major flooding was also recorded in the NSW Hunter Valley (see Fig. 17 above).

176) According to BOM,[179] the 7-day period from 2–8 March, was comparable to the wettest 7-day period on record (since 1900) for the Hawkesbury-Nepean catchment average rainfall, which was set just two years earlier in February 2020. Fourteen-day totals were even more significant, with the **Hawkesbury-Nepean, Upper Nepean, Georges-Sydney Coast and Wollongong Coast catchments all setting records (since 1900) by substantial margins**.

177) There has been an increase in the intensity of heavy rainfall events in Australia. The intensity of short-duration (hourly) extreme rainfall events has increased by around 10% or more in some regions in recent decades, with larger increases typically observed in the north of the country.

178) A warmer atmosphere can hold more water vapour than a cooler atmosphere; this relationship alone can **increase moisture in the atmosphere by 7% for every degree Celsius of global warming, causing likelihood of heavy rainfall events**. Increased atmospheric moisture can also provide more energy for some processes that generate extreme rainfall events, which further increases the likelihood of heavy rainfall.[180] In future, **NSW can expect more frequent extreme precipitation events like those of February and March 2022.**

179) Despite the increase in discrete heavy rainfall events, 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.[181] In Fig. 18, I have graphed the number of days

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[179] BOM (2022) Special Climate Statement 76, Accessed at: http://www.bom.gov.au/climate/current/statements/
[180] CSIRO/BOM (2020) State of the Climate 2020, Commonwealth of Australia. http://www.bom.gov.au/state-of-the-climate/
[181] BOM and CSIRO (2019) Hunter NSW Weather and Climate Guide, accessed at: http://www.bom.gov.au/climate/climate-guides/

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

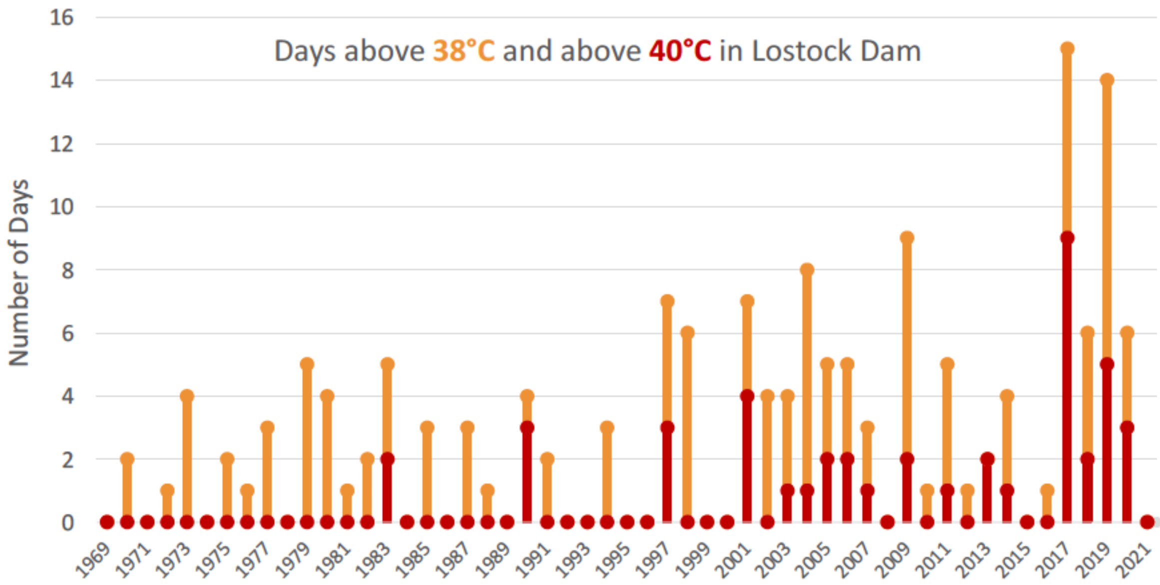

Fig. 18: The number of days each year above 38°C (orange) and 40°C (red) registered at the Lostock Dam weather station from 1969 to 2021. The trend of increasing extreme heat days due to climate change is evident. Data are from BoM.

180) **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. 19 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.[182]

[182]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. 19: 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.

181) NSW Health Department information on heat-related illnesses,[183] 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.**

182) **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.**[184]

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

[184] 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

5.2 Future Impacts of Climate Change

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

184) 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 Sections 2.7, 2.8 and 2.9 of this Report.)

185) A brief overview of possible emission trajectories and their consequences for global warming levels is presented in Section 5.2.1, making comparisons with the warming target of the UNFCCC **Paris Agreement,**[185] 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.

186) Possible climate futures for the world, Australia and NSW are sketched below in Sections 5.2.2 , 5.2.3, and 5.2.4, respectively. Which of these futures is realised depends on the trajectory of human GHG emissions.

5.2.1 Why emissions trajectories matter

187) 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[186] labelled RCP6.0 and RCP8.5 by the fifth Assessment Report (AR5) of the IPCC,[187] based on extrapolation of observed

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

[186] 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.

[187] 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,[188] and consistent with recent analyses.[189] In this case, **global warming could be 3—4°C above pre-industrial times in just 80 years.**

188) AR6 WGI,[190] 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.[191] They are similar, 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. 20 below.

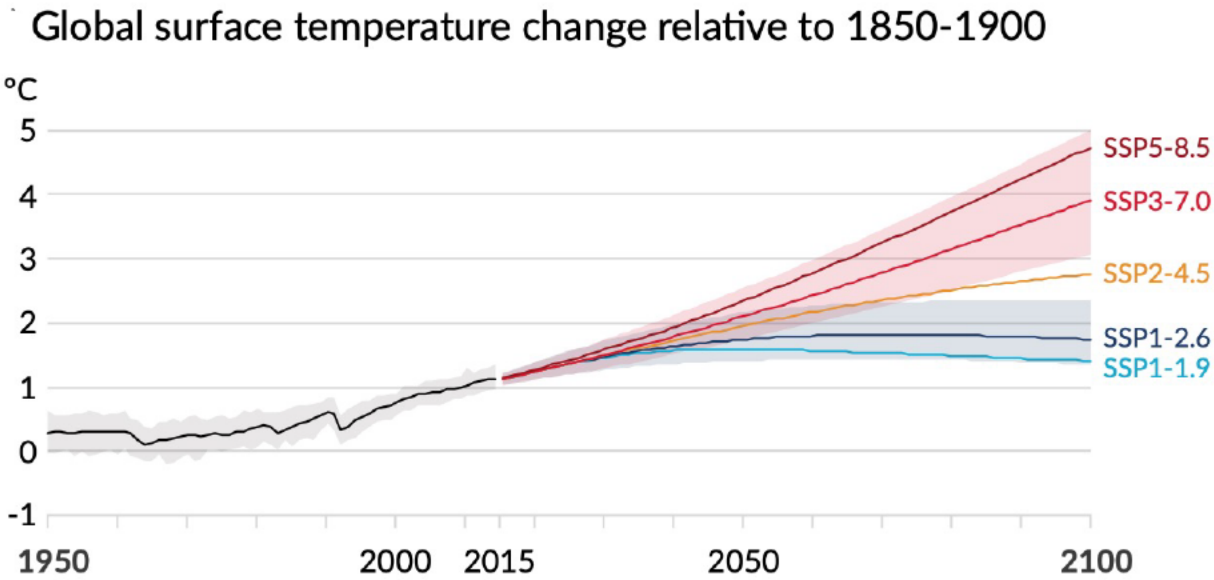

Fig 20: Projections for each of the five AR6 emission scenarios are shown in colour. The black curve indicates past warming. Shaded regions show the 'very likely' ranges for the SSP1-2.6 and the SSP3-7.0 scenarios. Figure reproduced from the IPCC ARC WGI Summary for Policymakers, Fig. SPM.8.

189) ***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

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[188] 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

[189] Climate Action Tracker (2020) https://climateactiontracker.org/global/cat-thermometer/

[190] https://www.ipcc.ch/report/ar6/wg1/#FullReport

[191] 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.[192] **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.**

190) 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.**[193]

191) **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**,"[194] according to the AR6 WGI report.

192) 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**.

193) 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**.

5.2.2 Possible Global Futures

194) **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

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[192] 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
[193] 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.
[194] 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

assessments for people, ec systems and economies worldwide **A comparison of these "Reasons for Concern"** (see Fig. 21 below based on the WMO 2019 report and AR6 WII)[195] **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.

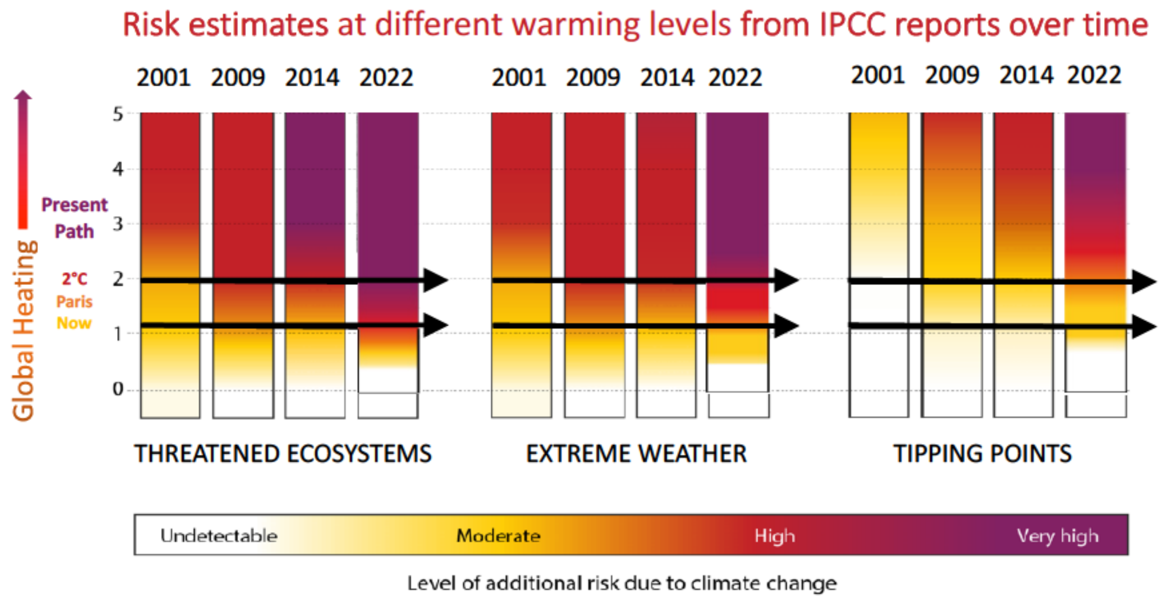

Fig. 21: As temperature (above pre-industrial time) climbs upward, climate risks increase (shown by deeper, dark colours). Indicated are the present (marked as "now"), the Paris Agreement Range, a 2°C scenario, and the present path trajectory leading to 3°C to 4°C of global heating. Results from more recent IPCC reports (arrows moving left to right) indicate higher risks than did earlier reports at the same temperature.

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

196) We now know that the Earth will experience 1.5°C of warming (see paragraph 189), and so it is clear that the world faces still greater risks from climate change.

197) **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. 21 shows.

[195] 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

198) 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*)."[196]

199) 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**.[197]

200) **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**.[198]

201) **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.**[199]

202) 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 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.**[200]

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[196] 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

[197] 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

[198] 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/

[199] 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/

[200] 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

203) 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**.[201]

204) 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.**[202]

205) **At 2°C of warming, which current policies and actions would ensure** (see Section 6.1), **13% of the Earth's surface will undergo complete ecosystem transformations.**[203]

206) **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:[204]

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

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.[205]

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[201] 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

[202] 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/

[203] 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/

[204] 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.

[205] 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

207) **Over the next 2,000 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*).[206]

208) **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. 18), **it has been estimated[207] 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.**

5.2.3 Possible Australian Futures

209) **Key risks of increased global warming particular to Australia** that have been identified in the AR6 WII include[208]:

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.

210) **Regardless of emission scenarios**, the CSIRO and BOM[209] report that **Australia will certainly experience more extreme climate effects**, including:

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

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[206] 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

[207] 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

[208] 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/

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

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.

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.

l) Australian continental temperatures are observed to be about 1.4 times greater than global average temperatures.[210] 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.

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[210] 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

211) The **intensity, frequency and duration of heatwave extremes are projected to increase in the future due to climate change.**[211] For example, **for every degree °C of global temperature rise, Australians will see about 16 more heatwaves days**, with the longest heatwave increasing in length by about 5 days.

212) 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**.[212]

213) **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[213] 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 finfish, ecology of marine species,

h) Heat-related mortality and morbidity, and

i) Ozone-related mortality.

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[211] Perkins-Kirkpatrick, S. E. & Gibson, P. B. (2017) Changes in regional heatwave characteristics as a function of increasing global temperature. Sci. Rep. 7, 12256.

[212] 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

[213] 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/

214) **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 (see footnote 210), **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.[214]

215) Based on the Keetch-Byram Drought Index (KBDI), an indicator of soil-moisture deficit, one study[215] 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 projected to be four times more likely if global warming reaches 2°C, compared to conditions typical in 1900.**[216]

216) **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.[217] 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**.

217) Specifically designed to study regions in Australia, the NSW/ACT Regional Climate Modelling (NARCliM)[218] project uses downscaled climate data over 50-km regions over all

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[214] Grose, M. R. et al. (2020) Insights from CMIP6 for Australia's Future Climate. Earth's Fut. 8, e2019EF001469.
[215] 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
[216] 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
[217] Sanderson, B. M. & Fisher, R. A. (2020) A fiery wake-up call for climate science. Nat. Clim. Change. 10, 175–177
[218] 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

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).

218) The NARCliM 1.0 future projections **use a high-emissions scenario** (SRES A2).[219] **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'**.

219) The NARCLiM 1.0 study[220] found the following results for Australia **under their high-emissions scenario**:

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

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[219] 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."

[220] 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

to temperature. Projected decreases in precipitation would **decrease the likelihood of meeting historical production levels.**

220) **The Australian Academy of Science has released a report**[221] **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.**

[221] 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

5.2.4 Possible NSW Futures

221) **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.

222) **NSW crosses five subcluster regions** used to project more local future effects of climate change, namely **East Coast South** (incl. Wollongong), **Central Slopes** (incl. Dubbo and Narrabri), **Rangelands** (incl. Broken Hill), **Murray Basin** (incl. Wagga Wagga), and the **Southern Slopes**, (incl. Batemans Bay).[222] (See Fig. 22 below).[223]

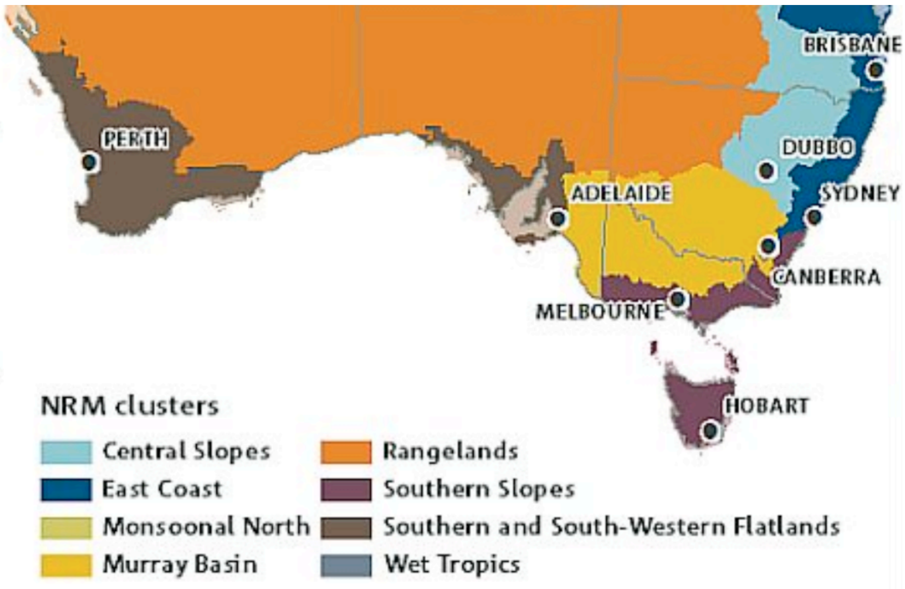

Fig. 22: Colour-coded regional clusters used to project future climate for Australia in the BOM and CSIRO `Climate Change in Australia' project.

223) Joint work[224] 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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[222] Climate Change in Australia: NRM Regions. Accessed at: https://www.climatechangeinaustralia.gov.au/en/overview/methodology/nrm-regions/
[223] Climate Change in Australia: Projections for Australia's NRM Regions. NRM Regions. Accessed at: https://www.climatechangeinaustralia.gov.au/en/overview/methodology/nrm-regions/
[224] 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**.

224) 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.**[225]

225) **For many areas of NSW, runoff, that is the water available to feed dams and rivers, will decrease markedly with the multiple effects of climate change**. This is because runoff depends not only on precipitation, but also soil moisture content and soil permeability, and vegetation cover, all of which can be affected by increased surface temperature.

226) It is estimated[226] that **for every one degree of global warming, runoff will be reduced by 15%,** which matches current experience. With current global policies (see Section 6.1) 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 runoff reductions of 45 – 60%, compared to mid-last century.[227] This has **profound consequences for water availability for human and environmental use**.

227) Figure 23 shows the changes in runoff in 2085 projected to affect the region surrounding the proposed Project, **if global emissions follow a trajectory similar to RCP 4.5** (see Section 5.2.1), which would place global warming around 2.5 or more by 2100. All of the region **is expected to experience runoff reductions, with most areas experiencing at least a reduction of 25% per year** compared to the 30-year period 1976-

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

[226] 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.

[227] 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

2005, and over half of the area experiencing up to 50% reductions compared to the recent past.[228]

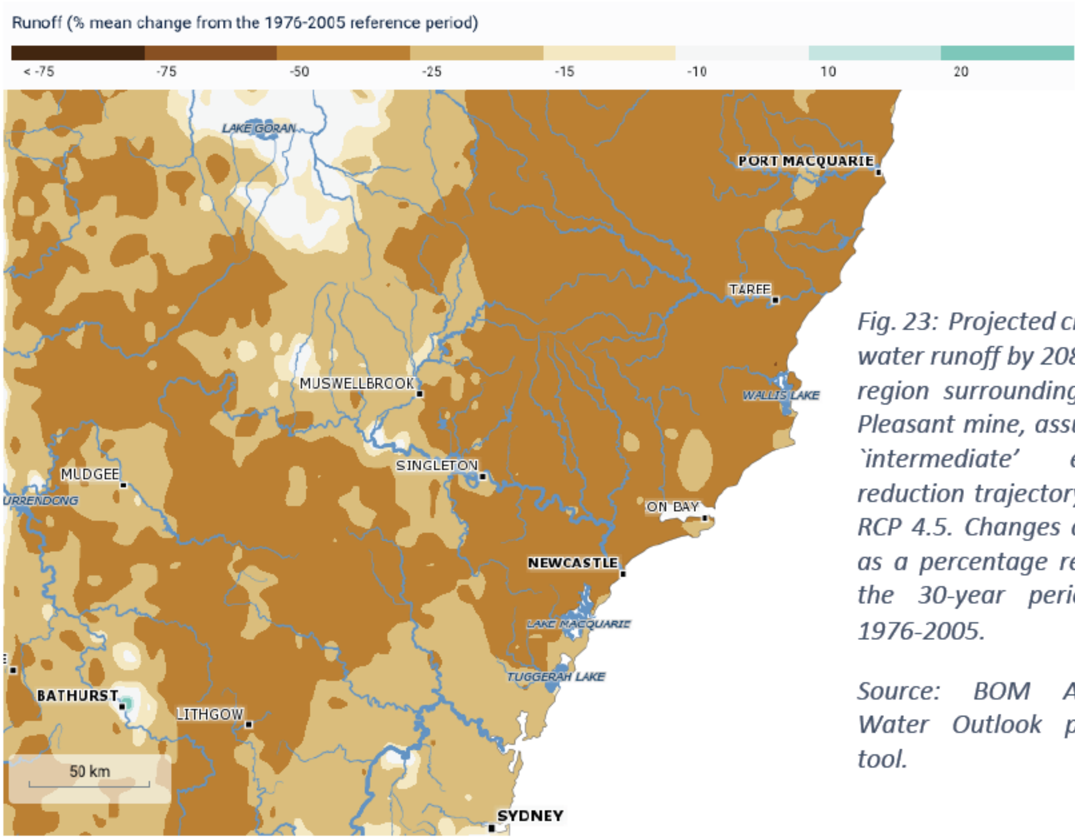

Fig. 23: Projected changes in water runoff by 2085 for the region surrounding the Mt Pleasant mine, assuming an `intermediate' emissions reduction trajectory such as RCP 4.5. Changes are given as a percentage relative to the 30-year period from 1976-2005.

Source: BOM Australian Water Outlook projection tool.

228) 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.[229] 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

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[228] Data and figure from BOM's Australian Water Outlook projection tool, accessed at: https://awo.bom.gov.au/products/projection/runoff/9,-34.230,150.777/nrm,-34.835,149.003/a/y/rcp45/2085

[229] 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.**[230]

229) 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.**[231]

230) It is important to note that **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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[230] 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

[231] 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

6 Why We are Tracking Toward more Dangerous Climate Change

231) 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.

232) Specifically, I outline:

a) how current Nationally Determined Contributions (NDCs) 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.

6.1 National Contributions to the Paris Agreement

233) **The Paris Agreement**[232] **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, NDCs as a first step to meet these goals.

234) 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.[233]

235) A recent UN report[234] 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

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

[233] 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

[234] 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

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. 24, which visually illustrates the declines that must occur by 2030 to achieve Paris Agreement goals.

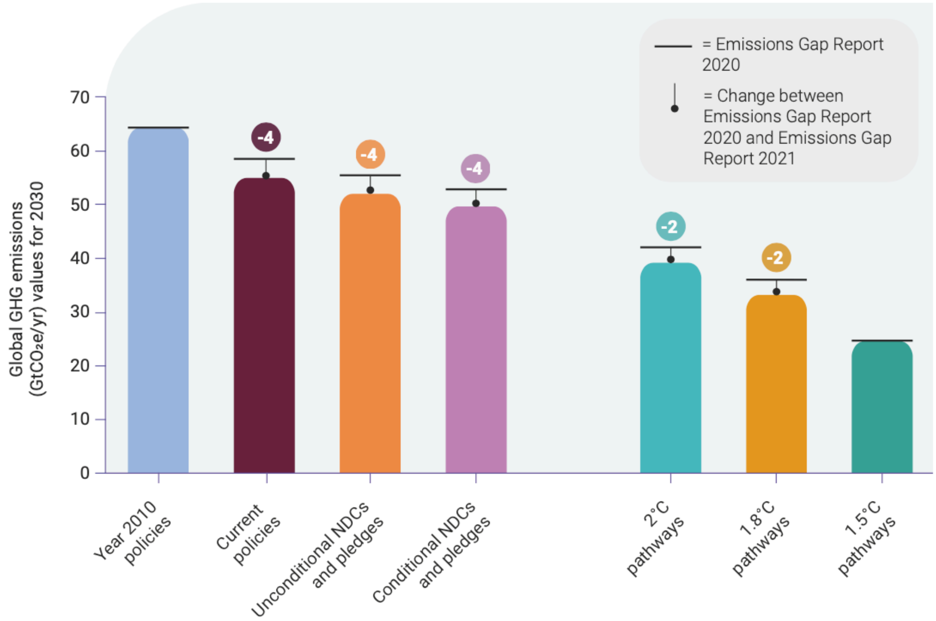

Fig. 24 (above): Overview of changes in GHG emission projects for 2030 for different scenarios compared to global policies in 2010. Figure from the UNEP 2021 Emissions Gap Report.

236) In its most recent analysis, Climate Action Tracker[235] estimates that **global warming between 1.7°C and 2.6°C could result from current post-Glasgow pledges and targets — if honoured —** still falling far short of the Paris Agreement targets, but improved from expectations two years ago (see Fig. 25).

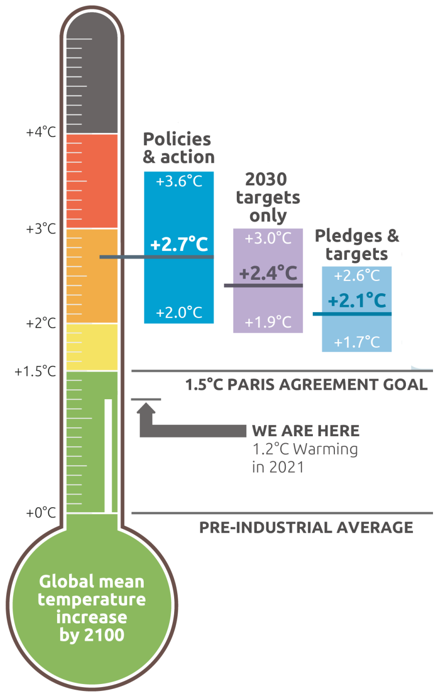

Fig. 25(at right): Global warming projections based on pledges and policies of global nations. (Climate Action Tracker, November 2021 analysis).

237) 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**

[235] Climate Action Tracker (2022), https://climateactiontracker.org/ Accessed 7 June 2022.

on current *policies* as opposed to *pledges*, Climate Action Tracker estimates that **warming could go as high as 3.6°C** (see Fig. 25)**.**[236]

238) A separate analysis indicates that **global warming might be held to `just' below 2°C if all conditional and non-conditional pledges to the Paris Agreement are implemented in full, on time, and extend indefinitely beyond the time frames for which they were promised**.[237] The analysis showed that **to improve upon this situation, 2030 targets must be strengthened, rather than 2050 targets.**

239) A very recent review[238] of the scientific literature concludes "**analyses of the alignment of current national targets with global temperature goals have unanimously concluded that targets are not yet sufficient to maintain temperatures within the 1.5°C to well below 2°C goal of the Paris Agreement.**"

240) The devastating consequences of a world 2°C and higher are discussed in Section 5.2 of this Report.

6.1.1 Australia's Nationally Determined Contribution

241) Australia did not update its NDC targets in 2020, whereas many other nations did so. However, on 16 June 2022, the newly-elected **Australian Government formally submitted a new Paris Agreement NDC**,[239] **committing to reduce Australia's emissions by 43% (on 2005 levels) by 2030,** recommitting to net zero emissions by 2050. Since Australia's emissions were 621.1 million tonnes (Mt) CO_2-e in 2005,[240] a reduction of 43% implies emissions in 2030 of no more than 354 Mt CO_2-e.

242) As Fig. 26 below shows, achieving such a 2030 would require Australia to follow the declining trend established in the period from around 2005 to 2015, but exceeded in subsequent years.

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[236] Climate Action Tracker (2022), https://climateactiontracker.org/ Accessed 7 June 2022.
[237] Meinshausen, M. et al. (2022) Realization of Paris Agreement pledges may limit warming just below 2°C, Nature, 604, 304.
[238] Matthew, H.D. and Wynes, S. (2022) Current global efforts are insufficient to limit warming to 1.5°C, in Science, 376, 1404-1409, 24 June 2022.
[239] Commonwealth of Australia (2022): https://www.pm.gov.au/media/stronger-action-climate-change
[240] National Greenhouse Gas Inventory, Accessed 26 June 2022 at https://ageis.climatechange.gov.au

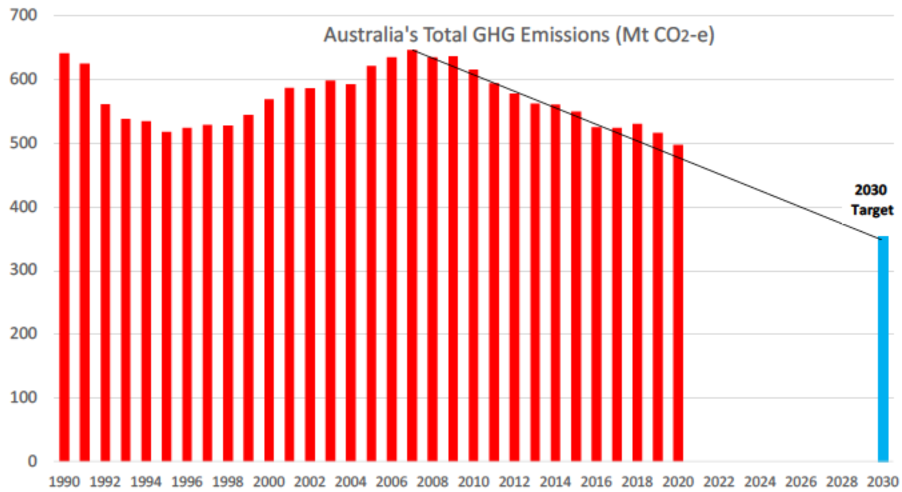

Fig 26: Australia's trend since 1990 in total `net' emissions reported for the Paris Agreement Inventory. The new 2030 NDC is shown in blue.

Data are from the National Greenhouse Gas Inventory (NGGI) website.

243) In analysis completed before the change of Government in May 2022, Australia's climate targets, policies and climate finance were rated `Highly insufficient' (by Climate Action Tracker; hereafter, CAT).[241] The `Highly insufficient' rating indicates that climate policies and commitments are not Paris Agreement compatible. Specifically, according to CAT, Australia's previous 2030 domestic emissions reduction target was consistent with warming of 4°C if all other countries followed a similar level of ambition.

244) CAT notes that **the new Labor Government in Australia has committed to strengthening the country's NDC target to a 43% reduction in GHG emissions below 2005 levels by 2030** (including Land Use, Land Use Change and Forestry; hereafter LULUCF). However, they conclude that **this is still far short of a reduction compatible with holding warming to 1.5°C, which would require at least a reduction of 57% in Australian domestic GHG reductions by 2030.**[242]

245) A recent independent report[243] has reassessed Australia's emissions targets, using the carbon budget methodology used by the Government-established Australian Climate

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[241] Climate Action Tracker (2022), https://climateactiontracker.org/countries/australia/, https://climateactiontracker.org/climate-target-update-tracker/australia/ Accessed on 29 June 2022.
[242] Climate Action Tracker (2022), https://climateactiontracker.org/countries/australia/, https://climateactiontracker.org/climate-target-update-tracker/australia/ Accessed on 29 June 2022.
[243] 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

Change Authority (CCA) to arrive at its 2014[244] and 2015[245] 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 2005 levels, with net-zero emissions reached by 2035. This level of emissions reduction by 2030 is nearly twice that of Australia's current Paris NDC.**

246) It is instructive to deconstruct Australia's emissions trends into the five main categories under which they are reported under the Paris Agreement: Energy, Industrial Processes, Agriculture, LULUCF and Waste. Fig 27. (below) shows this deconstruction.

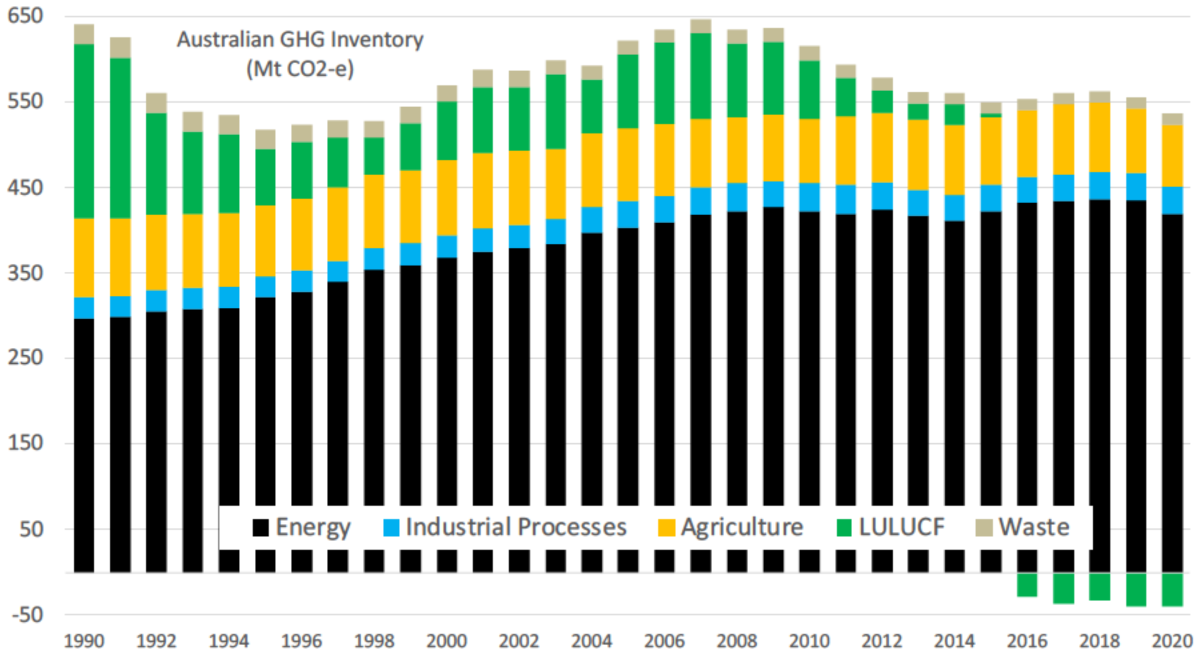

Fig 27: Australia's trend since 1990 in emissions (in Mt CO_2-e) over five main categories reported for the Paris Agreement Inventory. From bottom to top: black=energy; blue=industrial processes; gold=agriculture; green=LULUCF; and tan= waste. Data are from NGGI as of 29 June 2022.

247) Australian emissions from energy, which are overwhelming dominated by fossil fuels used in stationary energy and transport, have grown over time, with a slight dip in 2020

[244] 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

[245] 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

due primarily to COVID-19 restrictions. Emissions from industrial processes have also grown with time, whilst those from agriculture and waste have declined to 79% and 55% of their 1990 levels, respectively.

248) However, a key component in the general downward trend of reported Australian emissions is the LULUCF sector. **According to the latest Government reporting, LULUCF has gone from a net source of emissions, to a sink, masking the rise in emissions from the energy sector which in 2020 stood at 141% of its 1990 level**.

249) According to a 2021 report from the World Wildlife Fund,[246] Australia is the only developed nation[247] to have significant deforestation fronts where large areas of remaining forest are under direct threat and over which deforestation increased significantly in the period 2004 to 2017.

250) The Australian Government has regularly recalculated LULUCF for historical and projected emissions. The recalculations highlight the uncertainty of this sector: data changes have significant repercussions on Australia's progress in meeting emissions targets. **Effective climate policy, particularly in the emissions-intensive energy and industry sectors, would reduce the need to rely on uncertain LULUCF carbon sinks**.

6.2 The Global `Carbon Budget'

251) 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

[246] World Wildlife Fund International (2021) Deforestation Fronts: Drivers and Responses in a Changing World. Accessed at: https://wwf.panda.org/discover/our_focus/forests_practice/deforestation_fronts_/

[247] Also see: The Guardian (13 Jan 2021) Australia the only developed nation on world list of deforestation hotspots. Accessed at: https://www.theguardian.com/environment/2021/jan/13/australia-the-only-developed-nation-on-world-list-of-deforestation-hotspots

emissions up until the time of net-zero CO_2, the level of non-CO_2 radiative forcing[248] in the decades just prior, and the effects of feedbacks in the Earth system (see Section 2.7).[249]

252) **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,**[250] **focussing on CO_2** as the primary greenhouse gas. This approach is used by the IPCC,[251,252] and was adopted by the Australian Climate Change Authority to form its 2014 recommendations[253] for Australia.

253) 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. 28)[254] **between**:

a) The **'carbon budget'**: that is, **the cumulative amount of carbon**[255] **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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248 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.

249 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/

250 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.

251 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/

252 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

253 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

254 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

255 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.

254) 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**[256] 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.

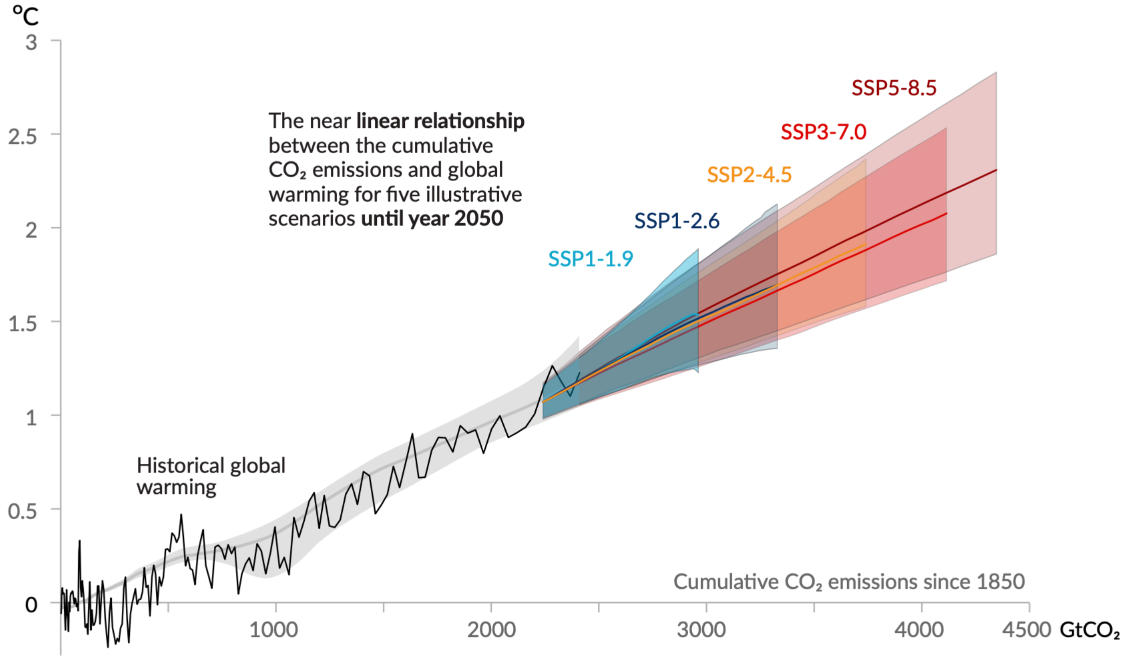

Fig. 28: Global surface temperature increase [on vertical axis in °C since the period 1850-1900] as a function of the cumulative CO_2 emissions [on horizontal axis in GtCO_2] projected out until the year 2050. This nearly linear (straight-line) relationship is the basis for computing a `carbon budget' for a particular amount of global warming. Figure is taken from the IPCC AR6 WGI Summary for Policymakers.

255) 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

[256] 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.

256) 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.[257,258]

257) AR6 WGI [259] gives remaining carbon budgets for selected values of global warming and for selected likelihoods of holding warming to these values. These budgets are reproduced in Table 4 below.

258) 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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[257] 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.
[258] 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
[259] 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 4: 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

259) 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 4 **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.**[260]

260) 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[261], and atmospheric concentrations have been rising at an increasing rate since about 2006 (refer to Fig. 5).

261) 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).[262]

262) **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 5 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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[260] 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

[261] 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

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

Table 5: 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

263) 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.[263] Thus, **only about 8 years remain at current emission levels before the remaining 1.5°C carbon budget** (from Table 5) **is exhausted. This is one of many ways to understand why the period until 2030 is so critical.**

264) **Thus, approving this Project is tantamount to considering the Project as one of only 650 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 1.5°C carbon budget.** If humanity's 1.5°C carbon budget were to be distributed according to population, Australia would be allotted two 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.

6.3 The Fossil Fuel Production Gap

265) 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.

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

266) A 2021 special report by the **IEA**[264] 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.**

267) A 2015 economic analysis **based on only a 50% chance of achieving 2°C** concluded that **a third of oil reserves,**[265] **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.[266]

268) Updating this work in 2021, a **new research** paper[267] 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 cannot be extracted if the world is to meet a global warming target of 1.5 °C above pre-industrial temperatures.

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

[265] 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.

[266] McGlade C and Ekins P (2015) The geographical distribution of fossil fuels unused when limiting global warming to 2°C. *Nature* 517: 187-190.

[267] 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

269) Underscoring this point are recent reports[268,269,270] 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.**

270) **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. 29 below, taken from the latest Stockholm Environment Institute (SEI et al.) report.[271]

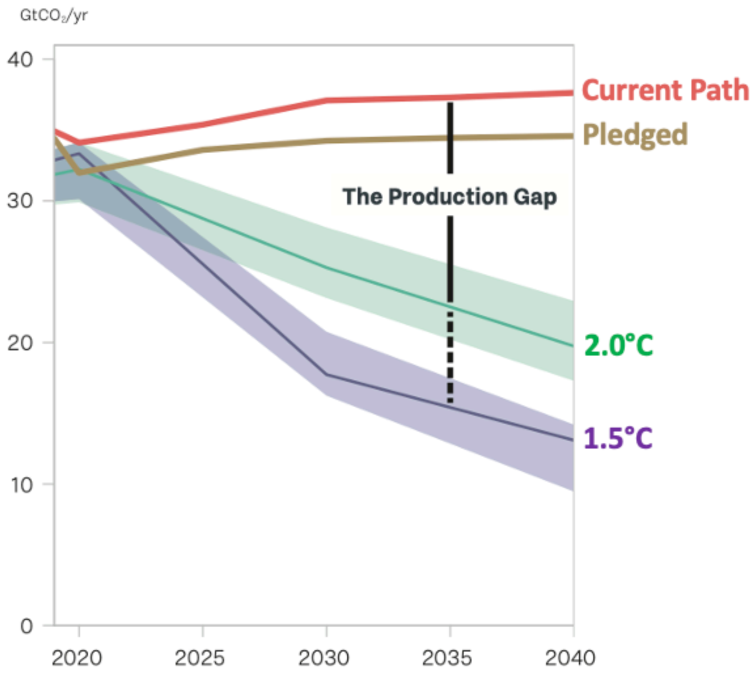

Fig. 29: Possible trajectories of global CO_2 emissions from all fossil fuels from 2019 to 2040 in units of $GtCO_2$ emitted in each year. In red is the current trajectory, whilst the gold line indicates what would be achieved if all Paris Agreement pledges were met. Lavender and turquoise trajectories 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.

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[268] 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/

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

[270] 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/

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

271) The world is emitting about 36 Gt CO_2 per year from fossil fuels[272] (see Fig. 7). 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**.

272) **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.**[273] (See Fig. 30 below).

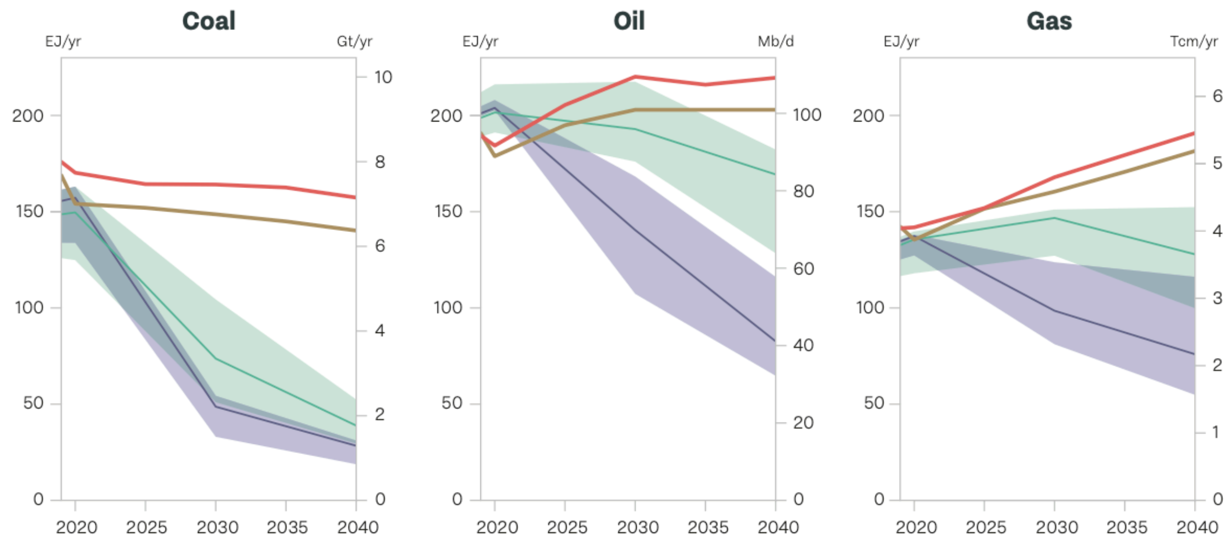

Fig. 30: Global emissions trajectories for coal, oil, and gas production based on current production and projections (red) and as implied by climate pledges (gold). Also shown is a range of trajectories consistent with holding global warming to 2.0°C with a 66% chance (light green), and with holding global warming to 1.5°C with 50% chance (lavender). From SEI et al. 2021.[274]

273) 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**

[272] 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 $GtCO_2$.
[273]SEI, IISD, ODI, E3G, and UNEP (2021) The Production Gap Report: 2021 Report. https://productiongap.org/2021report/
[274]SEI, IISD, ODI, E3G, and UNEP (2021) The Production Gap Report: 2021 Report. https://productiongap.org/2021report/

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.

6.3.1 Australia and the Production Gap

274) 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 part of Australia's 'Scope 3' emissions.**

275) Although the *National Greenhouse and Energy Reporting Act 2007* (the NGER Act)[275] 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.**

276) **Australia is the world's second leading exporter of coal** (by weight)[276] **and the largest exporter of LNG.**[277] 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. 31). Black coal production has approximately levelled over the past five years.

277) **As the world's fifth largest producer of coal, and world's largest exporter of black coal,**[278] **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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[275] Accessed at: https://www.legislation.gov.au/Details/C2019C00044
[276] International Energy Agency (2021) Coal 2021 https://www.iea.org/reports/coal-2021
[277] International Gas Union (IGU 2021), 2021 World LNG Report. https://www.igu.org/resources/world-lng-report-2021/
[278] IEA data for 2019-2020 referenced by Geoscience Australia. Accessed at: https://www.ga.gov.au/digital-publication/aecr2021/coal#data-download-section

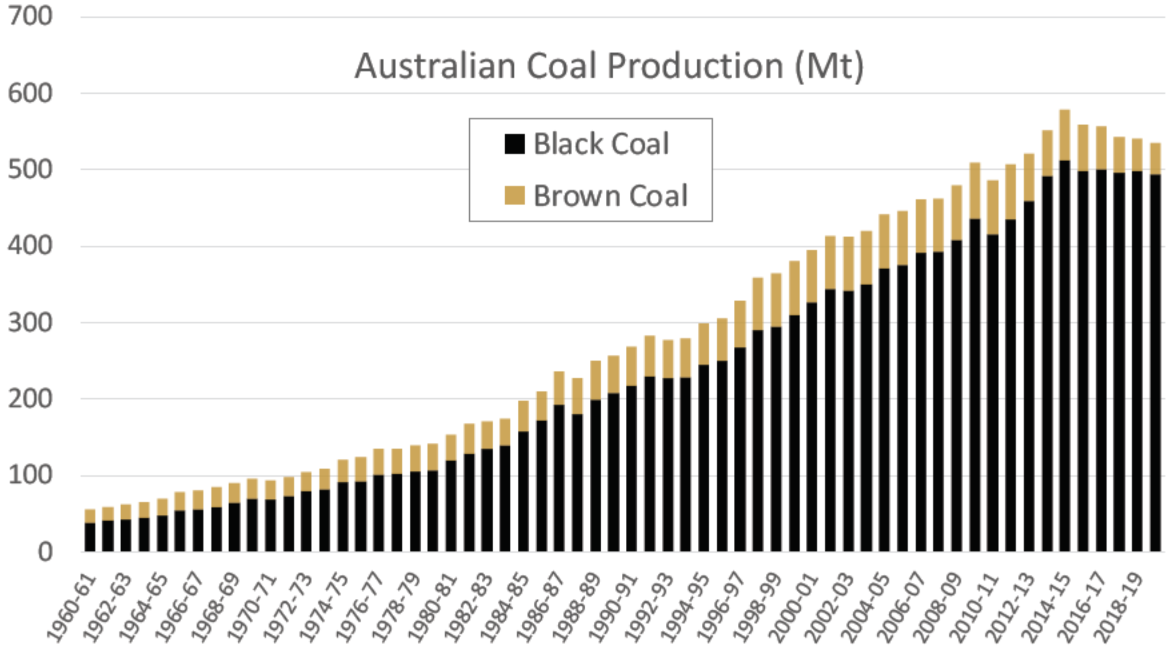

Fig. 31: Australia's production of brown and black coal (in Mt) is shown for every fiscal year from 1960-61 through 2019-20. Data are from Australian Government (2021) Australian Energy Statistics, Table P2, Dept of Industry, Science, Energy and Resources, September 2021. Total coal production is indicated 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

278) Despite this, the Commonwealth Government is anticipating steady coal production through 2030.[279] **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.[280] **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. 30).

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[279] 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

[280] 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

279) Recent international reports have analysed Australia's projections,[281,282] **concluding that Australia's extraction-based** (also called production-based) **emissions**[283] **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**[284] **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**.

280) Comparison of the historical plot of coal production (Fig. 31) with the future trend in coal production required in order to hold global warming to between 1.5°C to 2.0°C (Fig. 30, left panel) reveals the **huge magnitude of reduction required if Australia is to align its coal production with Paris Agreement targets**.

281) **Recent analysis indicates that 95% of Australia's coal reserves**[285] **– 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**.[286]

282) So-called `committed emissions' from proposed or existing fossil fuel infrastructure is incompatible with holding warming to 1.5°C,[287] implying that **staying below 1.5°C may require governments and companies not only to cease licensing and development of**

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[281] 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/

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

[283] `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.

[284] 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/

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

[286] 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

[287] Tong, D. et al. (2019), Committed emissions from existing energy infrastructure jeopardize 1.5 °C climate target, in Nature, 572, 373-7.

new fields and mines, but also to prematurely decommission a significant portion of those already developed.[288]

283) Yet, Australia has more capacity in export-oriented coal projects in the pipeline than any other country by far, as illustrated in Fig. 32 below, taken from a 2021 report of the IEA.[289] Australia also leads in the capacity of mine re-openings per country. [290] **Without changes to current plans, Australian coal exports will contribute to the global warming Production Gap, disproportionately so, for decades to come.**

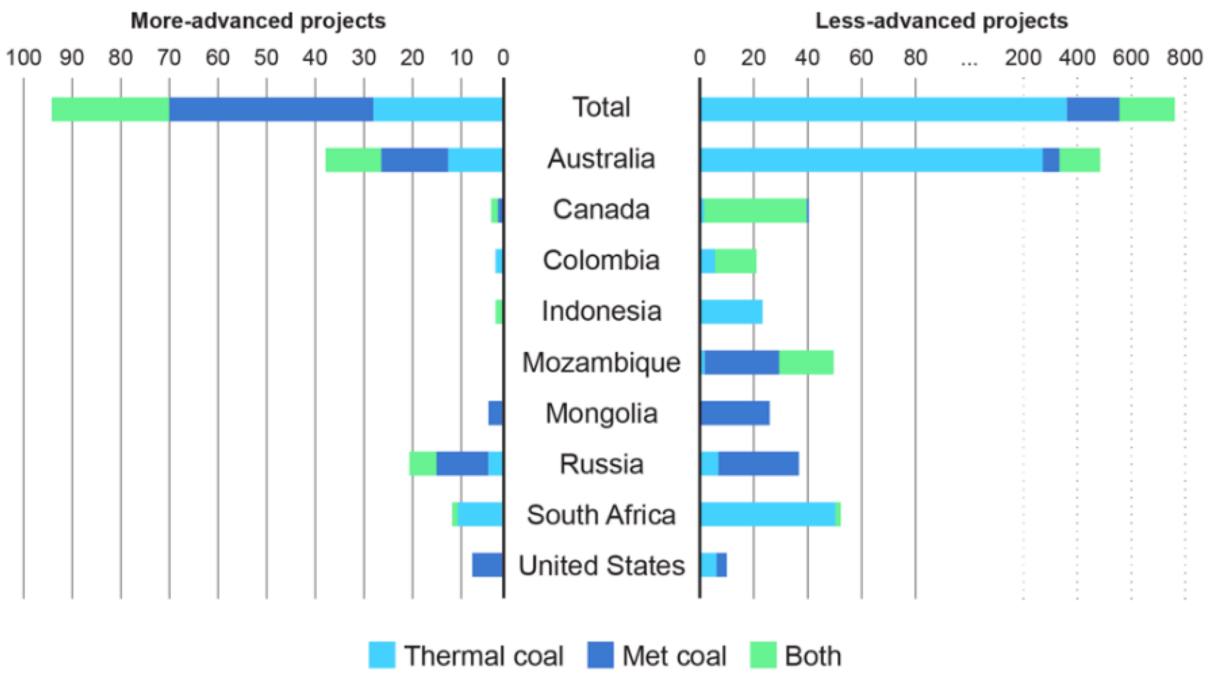

Fig. 32: Top countries by the capacity (measured in Mt of coal per annum) of new export projects for coal, as assessed by the IEA in 2021. `More-advanced' projects are those that have been approved and obtained a final investment decision or are under construction, while `less-advanced' projects are at the feasibility or environmental assessment stage, or they are awaiting approval. `Met' coal is metallurgical (or coking) coal.

284) 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.

285) In order to estimate the magnitude of the total effect, I have used the data displayed in Fig. 31 for coal production and the emission factors for different types of coal given in

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[288] Trout, K. et al. (2022) Existing fossil fuel extraction would warm the world beyond 1.5°C, in Environ. Res. Letters, 17, 064010.
[289] International Energy Agency (2021) Coal 2021 https://www.iea.org/reports/coal-2021
[290] International Energy Agency (2021) Coal 2021 https://www.iea.org/reports/coal-2021

the National Greenhouse Accounts Factors.[291] 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. 33 below.

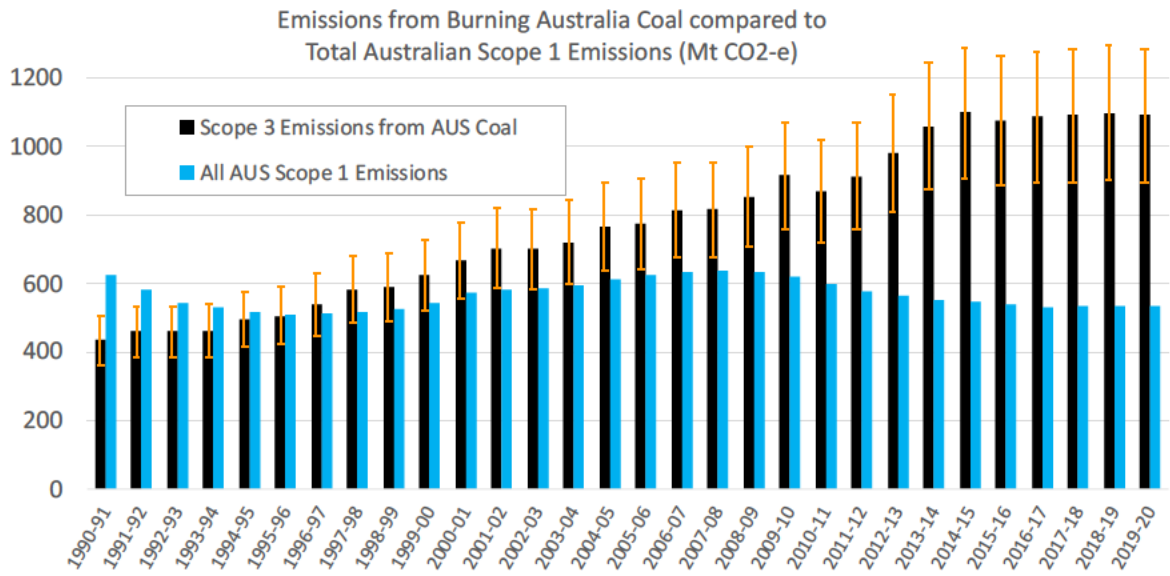

Fig. 33: Estimated emissions from the burning of Australian coal by the end user (black) compared to the total of all Australia's territorial (Scope 1) emissions (blue) over the period 1990 to 2019. The orange bars indicate the wide range of assumptions about the emissions intensity of Australia black coal (see text).

286) As Fig. 33 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 from all other activities within the national borders.**

6.3.2 New South Wales and the Production Gap

287) NSW is central to closing Australia's Production Gap (see Section 6.3.1) 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.

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

288) 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.[292] 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. 30, left panel) shows the **huge magnitude of reduction required if NSW is to align its production with Paris Agreement targets.**

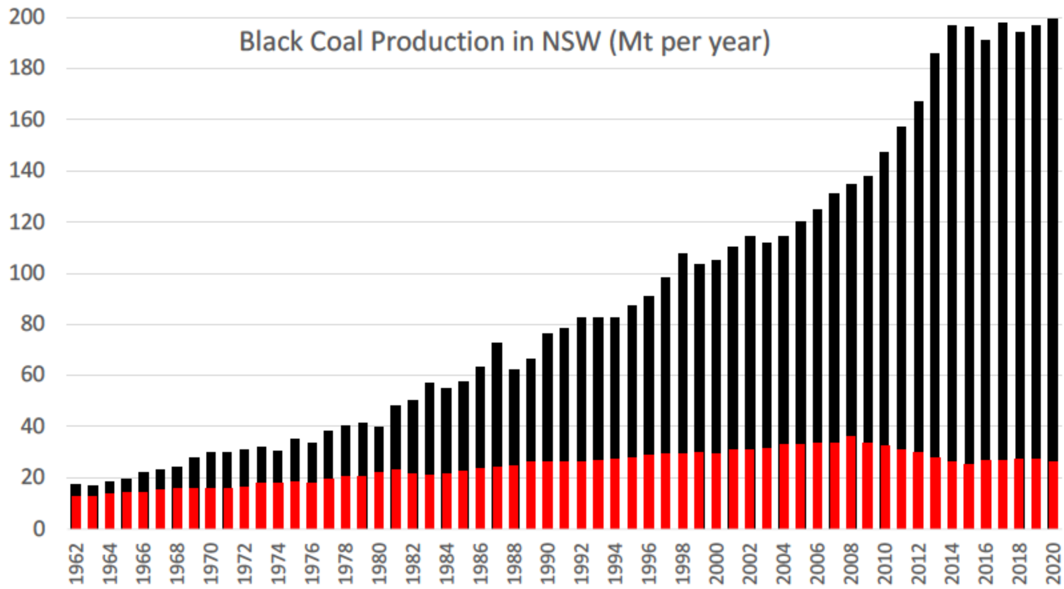

Fig. 34: NSW black coal production in thousands of tonnes (Kt) from 1960-61 to 2018-19. In red is the part of this black coal that is consumed in New South Wales in each year. Data are from Table I4 of Australian Energy Statistics 2021.

289) Cumulatively, over the past six decades, NSW has produced 5.0 billion tonnes (Gt) of black coal.[293] Using a carbon content of typical bituminous coal,[294] 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,[295] despite NSW accounting for only about 0.10% of the world's population.

[292] 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

[293] 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

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

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

290) **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.

291) **As a result, NSW is a major contributor to the Production Gap**[296] 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, including the Mt Pleasant Extension, will aggravate this situation.**

[296] 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/

7 The Mt Pleasant Coal Mine Expansion Project and Climate Change

292) 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.**

293) In this section of the Report, I place the GHG emissions from the Project into a larger context that recognises their cumulative effect on climate change, by providing an analysis that considers:

a) why the Project is inconsistent with holding global warming well below 2°C,

b) implications of GHG emissions from the Project on the ability of the nation and NSW to meet their respective GHG targets,

c) the Social Cost of Carbon of all GHG emissions derived directly, or indirectly, from the Project (i.e., Scopes 1, 2 and 3), given that on a tonne-per-tonne basis they affect the climate of NSW equally, and

d) how the climate consequences of the Project are related to the Precautionary Principle and Intergenerational Equity.

7.1 Approving the Project is Inconsistent with Warming of 1.5°C or well below 2°C

294) The phrase 'well below 2°C' is widely known to be associated with the UNFCCC Paris Agreement[297] 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 6.2) **and (b) temperatures of 2.0°C and above are associated with grave consequences and compounding risks to ecosystems and humans** (see Section 5.2).

295) **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 Sections 33). **The deepest and swiftest reduction must occur in coal production** (see Fig. 30, 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.[298] Coal production must drop by a minimum of 36% in this period to hold warming to 2°C (with a 67% chance). 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**.

296) **Simply put, approving new coal mines or extensions to existing ones, such as the Mt Pleasant Optimisation Project, is not consistent with holding warming to 2°C, let alone warming *well below* 2°C.**

297) In 2020, NSW mined 200 Mt of black coal.[299] **In order to align its production with a trajectory consistent to holding warming to 1.5°C**, **NSW coal production must follow a trajectory similar to the lavender trajectory shown in Fig. 30**. **In order to align its production with the requirements for a trajectory consistent with holding warming well**

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

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

[299] 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

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 295) on 2020 levels by 2030, requiring a new reduction of **about 11.1 Mt coal per annum from 2022 through 2030** (assuming 2021 levels were similar to those in 2020). This would result in the turquoise `well-below 2°C' profile shown in Fig. 35 below.

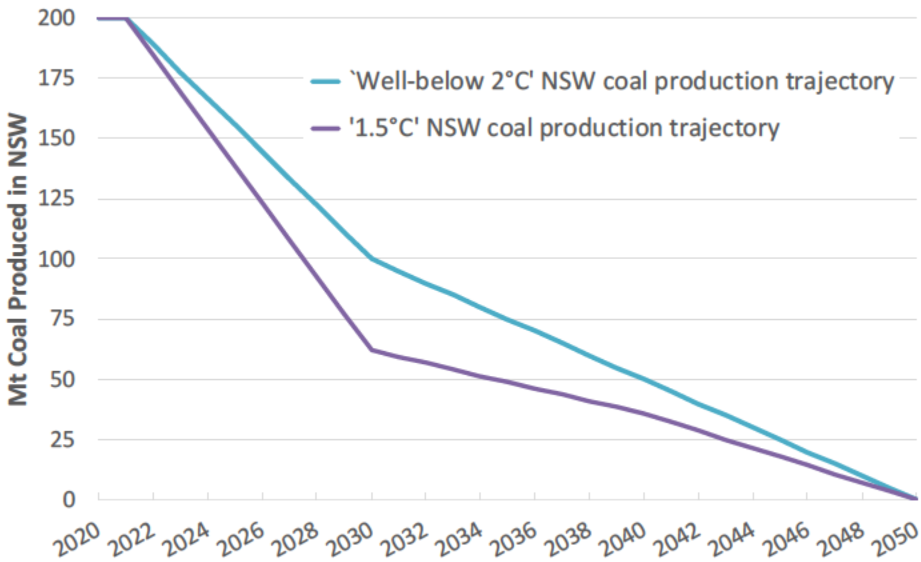

Fig. 35: Two simple linear model in order for NSW to close its coal Production Gap in a manner consistent with the Paris Agreement warming goals, namely well-below 2°C (turquoise), and pursuing efforts to hold warming to no more than 1.5°C (lavender).

298) **If approved, the Project, on the other hand, would be *adding* product coal, frustrating attempts to close NSW's `Production Gap.'** This size of this effect is illustrated in Fig. 36, showing that over all primary years of production the Project would *produce* coal rates at least 50% of those required for NSW to *reduce* its coal output consistent with the Paris Agreement warming targets. **After 2030, this Project alone would produce coal at 2 to 6 times the rate of annual reduction required for NSW to close its coal `Production Gap.'** The temporal profile of the Project's coal production (as well as ROM extraction) is given in Table 1 of Todoroski 2022,[300] and is used, together with the profiles of Fig. 35, to create Fig. 36 below.

[300] Todoroski Air Sciences (30 March 2022) Mount Pleasant Optimisation Project Greenhouse Gas Assessment – Attachment 2 to MACH Energy's response to Departmental Queries concerning greenhouse gases. Accessed at: https://pp.planningportal.nsw.gov.au/major-projects/projects/mount-pleasant-optimisation-project

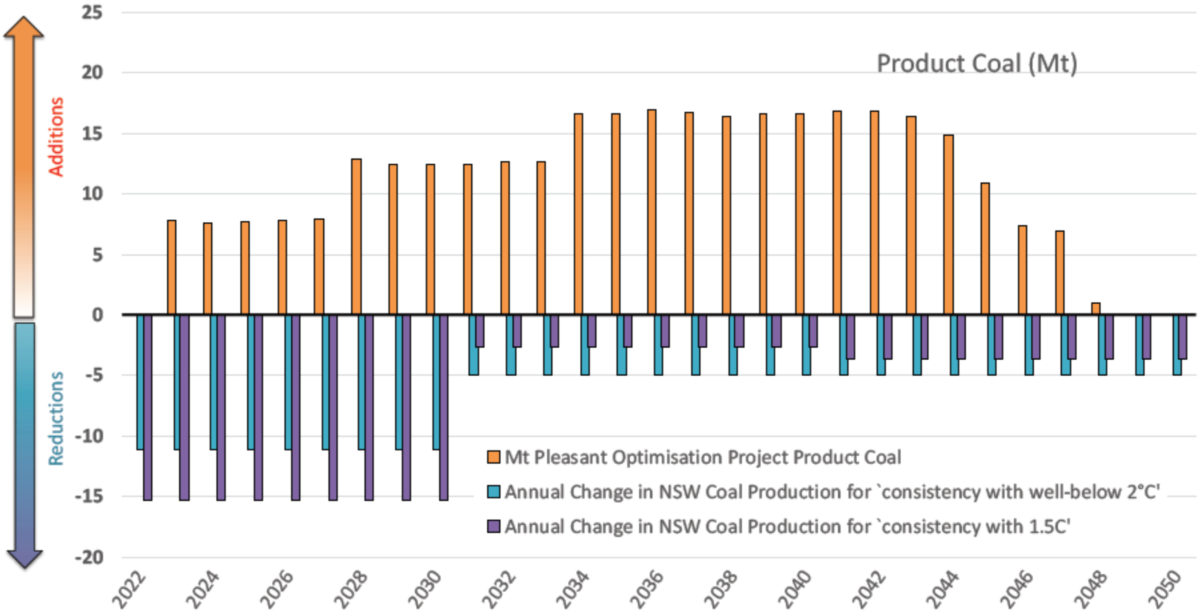

Fig. 36: Annual coal production from the proposed Project (orange) compared to the annual reductions necessary in simple linear models (see Fig. 35) allowing NSW to close its coal Production Gap in a manner consistent with holding warming to well-below 2°C (turquoise) or 1.5°C (lavender).

299) Furthermore, closing NSW's coal production gap will need to take place against the background of other recently approved coal development projects in NSW (see Table 6)[301] that themselves are adding to the future coal production trajectory of the State.

Table 6: 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
Narrabri	Narrabri Coal Operations Pty Ltd	31 December 2044	11.0
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			61.3

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

300) Although the numbers in the rightmost column of Table 6 are for maximum allowed run-of-the-mine (ROM) takes, these data make clear that **recently approved coal mine operations alone could be *adding* on the order of 30 – 50 Mt product coal annually to the State's production. Yet in the period from 2022 to 2030, new annual *reductions* of about 15 Mt are needed to be consistent with holding warming to 1.5°C, or 11 Mt of new reductions per year for consistency well below 2°C**. **Approving the Project would increase NSW production over this period still further.** Furthermore, the Project, like most of those in Table 6, will run beyond 2030, confounding later efforts to reduce coal production in line with warming on the safer side of 2°C.

301) The Applicant has submitted a plot[302] that indicates the extraordinary continued coal production (on-going or proposed) in the Hunter Valley alone; that plot is reproduced below as Fig. 37 (below) of this Report.

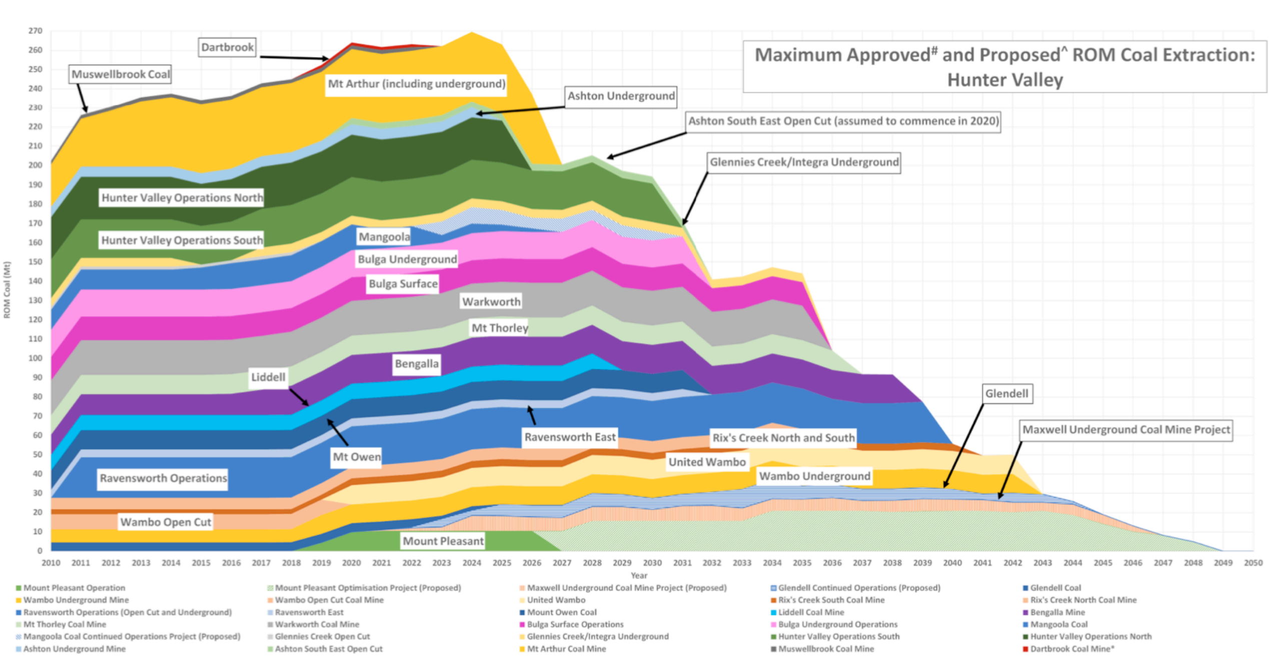

Fig. 37: Maximum approved and proposed ROM coal extraction in the Hunter Valley from 2010 to 2050. The vertical scale measures ROM coal in Mt, with the upper label at 270 Mt. Individual colours correspond to ROM extraction profiles for individual mines or proposed projects. For greater detail, see Appendix S of the EIS, from which this plot was taken.

302) The Applicant uses Fig. 37 to argue that "*the coal produced by the Project would not necessarily result in, or coincide with, a net* ***increase*** *in coal production globally, or in the Hunter Valley, compared to current levels of production*." [**emphasis** mine]. However, in

[302] EIS Appendix S, Graph 1.

order to have a reasonable chance of a world in which global warming is held 1.5°C, or even 2°C, it is insufficient to ensure that coal production does not increase. Rather, as indicated in Fig. 30, coal production must drop dramatically.

303) My analysis of Fig. 37 (taken at face value) is that current mines and proposed mines (if approved), put Hunter Valley's coal production on a rising trend to 2025. **Further, if all Hunter Valley mines operate through their planned lifetimes, and all currently planned mines in the Hunter Valley** (but no others) **are approved, about 3,000 Mt**[303] **(or 3.0 Gt) of ROM coal will have been extracted in this region of NSW alone from 2022 to 2050**. Using a product-to-ROM coal ratio of 0.8, and an emission factor of 2.617 appropriate to anthracite,[304] **this Hunter Valley coal would produce well over 6 Gt of CO_2-e when combusted, or about 2% of the entire globe's remaining carbon budget for holding warming to 1.5°C** (refer to Table 5)**.**

304) Based on this evidence, in my opinion, **the recent approval of new or extended coal production in NSW has been inconsistent to holding warming to well-below 2°C, let alone 1.5°C, and continuing this trend with the approval of the Project exacerbates this situation.** Further, **it would be difficult to reconcile with the spirit of NSW's stated intent to reach net zero by 2050,**[305] **given the advice of the IEA** (see paragraph 266) **that beginning in 2021, no new oil and gas fields should be approved for development, nor new coal mines or mine extensions** for consistency with its Net Zero by 2050 plan for the global energy sector.

7.2 Implications of the Project for National and State Emissions Targets

305) **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:

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[303] Based on the area under the curve defined by total ROM coal production between 2020 and 2050.
[304] See: https://www.industry.gov.au/data-and-publications/national-greenhouse-accounts-factors-2021
[305] 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

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, or Scope 1 + Scope 2) 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**.

306) Nevertheless, comparing Project emissions to NSW and national GHG targets is an important step in guiding action to meet those targets.

307) **NSW has committed to achieving zero net emissions by 2050, with an interim target to reduce emissions by 50% below 2005 levels by 2030,** an increase in ambition from its previous 2030 target of 35% reduction.[306] **In order to achieve a 50% reduction on state 2005 GHG emissions**, which were 161.6 Mt CO_2-e, **NSW's emissions in 2030** must be no more than 81 Mt CO_2-e, **requiring a considerable drop from its current emissions**.

308) **Australia has committed to achieving zero net emissions by 2050, and formally (through the Paris Agreement) to reduce its emissions by 43% by 2030** on 2005 levels.[307] **In order to achieve a 43% reduction on national 2005 GHG emissions**, which were 621.1 Mt CO_2-e, **Australia's emissions in 2030** must be no more than 354 Mt CO_2-e, **also requiring a significant drop from current emissions.**

309) Figure 38 compares the notional (Scope 1 + Scope 2) emissions trajectory of the Project with simple linear trajectories for NSW and Australia that meet their current respective Government's GHG reduction targets for 2030 (50% for NSW and 43% for the Commonwealth on 2005 levels) as well as net zero by 2050. The starting point for the

[306] 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

[307] Commonwealth of Australia (2022): https://www.pm.gov.au/media/stronger-action-climate-change

national and NSW trajectories is based on the most recent values (2020) values from the NGGI[308] at the time of writing of this Report.

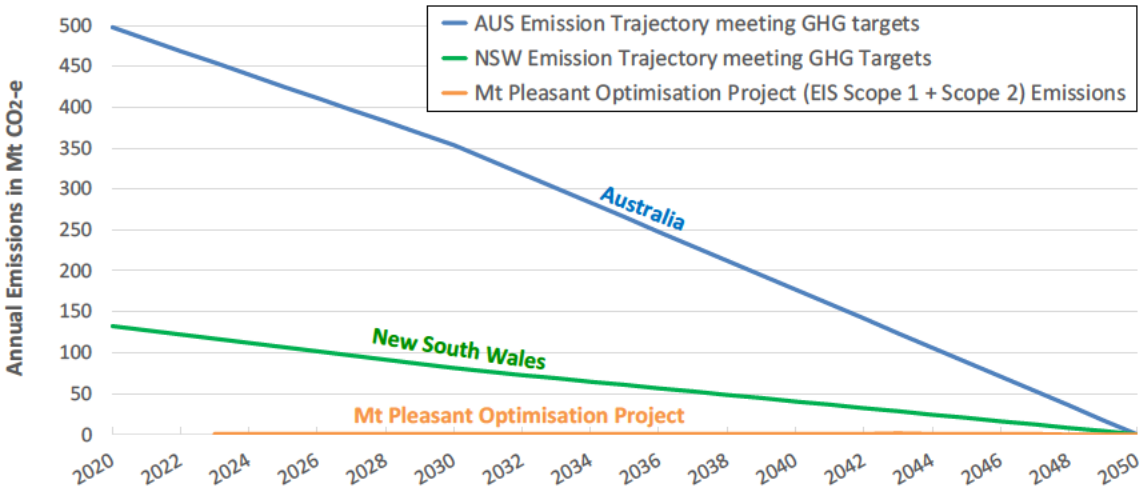

Fig. 38: Comparison of a simple (linearly-falling) emissions trajectories for Australia (blue) and NSW (green) that meet their respective GHG targets and the assumed Scope 1 + Scope 2 emissions trajectory of the Mt Pleasant Optimisation Project (orange). The effect of the Project is larger than a cursory examination of these trajectories might seem to imply, as shown in Fig. 39.

310) Despite the apparently small contribution of the Project compared to the emissions trajectory of NSW, **the Project would have noticeable negative effects on the ability of the country and the State to meet 2030 emissions targets.** A more relevant measure than comparing GHG emissions to state and national totals is to **compare the annual Scope 1 + Scope 2 emissions from the Project to the annual emissions *reduction* required in order for Australia and NSW to meet their 2030 targets.**

311) The Australian 2030 target, if approached linearly, requires an average *new reduction* of 14.37 Mt CO_2-e per year, year on year, from 2020 up to and including 2030. In other words, to meet its 2030 Paris Agreement NDC, Australia will need to not only maintain its reduction from the previous years, but find another *further reduction* of 14.37 Mt CO2-e each year through 2030. NSW will have to find an average *new reduction* of 5.16 MtCO_2-e per year, year on year, from 2020 up to and including 2030. Fig. 39 illustrates the size of these NSW reductions compared to Scope 1 and Scope 2 emissions from the Project.

[308] https://ageis.climatechange.gov.au/

Fig. 39: Size of annual Scope 1 + Scope 2 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).

312) As Fig. 39 illustrates, **the Project is quite significant compared to the annual task in meeting NSW's GHG targets, both before and after 2030. Over most of its proposed lifetime, this single Project would be *adding* emissions at 5% – 25% of the rate that NSW was attempting to *reduce* them.** Comparison of Figs. 38 and 39 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.**

313) In Table 7 (below), average annual Project GHG emissions (Scopes 1 and 2) in the years 2020 to 2030 are compared to the size of annual emissions *reduction* that will be required annually from 2020 in order for the country and the State to achieve their respective 2030 GHG emission targets.

Table 7: Average effect of the Project on meeting 2030 emission reduction targets

	Annual Quantity	**Mt Pleasant Extension Average Annual Contribution over this period**
AUS 2030 Target Annual *change* from 2020 required to meet 43% reduction on 2005 levels (621.1 Mt CO_2-e) by 2030	– 14.37 Mt CO_2-e	0.328 CO_2-e or + 2.3% in the wrong direction
NSW 2030 Target Annual *change* from 2020 required to meet 50% reduction on 2005 levels (161.6 Mt CO_2-e) by 2030	– 5.16 Mt CO_2-e	0.328 Mt CO_2-e or + 6.36% in the wrong direction

314) The results displayed in Table 7 (above) show that the **average annual** (Scope 1 + Scope 2) **emissions** from the **Project** through 2030 is 0.328 Mt CO2-e, which is 0.25% of NSW 2020 total emissions, and **equivalent to the total current emissions of over 20,000 individual NSW residents**, when considering the State's emissions on a per capita basis.

315) **Despite being operational for only a portion of this decade, the Project alone would make Australia's 2030 target 2.3% more difficult to meet**, since with it, Australia would need to find 14.698 Mt CO_2-e (instead of 14.37 MtCO_2-e) of new emission reductions each year through 2030.

316) NSW's 2030 target requires an annual new *reduction* of about 5.16 MtCO_2-e per year, year on year, whereas the Project would *add* 0.328 Mt CO_2-e every year through 2030 on average. **Thus, if the Project were to proceed,** NSW would need to find a total of 5.488 Mt CO_2-e (rather than 5.16 Mt CO_2-e) in new emission reductions each year 2020 to 2030, and **the difficulty of meeting the State's 2030 target would be increased by over 6%.**

317) Finally, **when considering the effect of the Project on climate change, one must consider all its emissions, both direct and indirect, which contribute to climate change and the environment of NSW equally on a tonne-per-tonne basis.** In order to visualise this effect, compared to the GHG reductions that NSW will be undertaking to meet its climate goals, I plot in Figure 40 the total of all Scopes (1, 2 and 3) from the Project over its lifetime, as given in the revised Todoroski GHG Estimates.

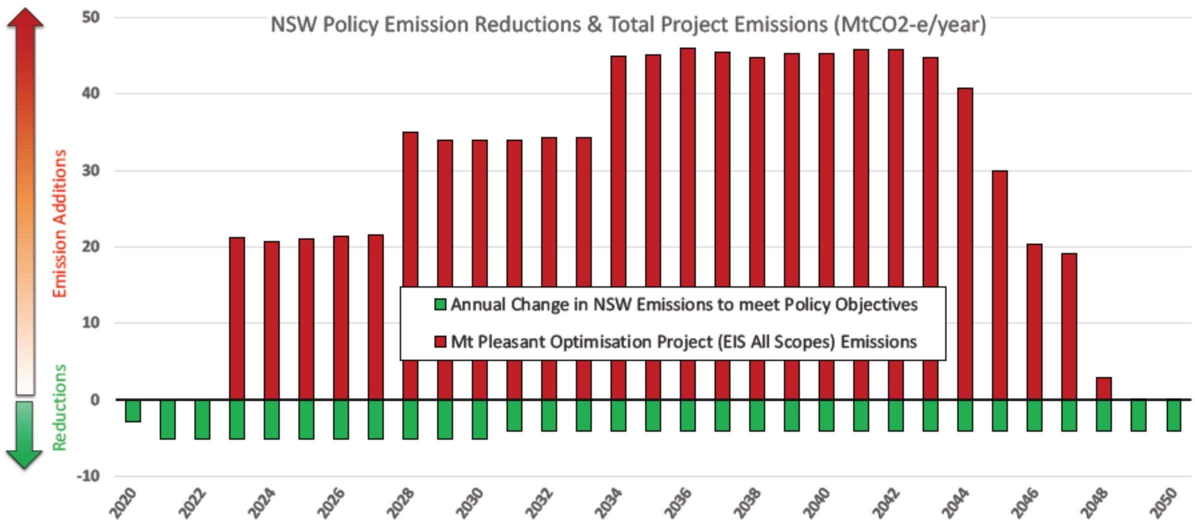

Fig. 40: Size of annual total emissions (Scopes 1, 2 and 3) from the Project (red) compared to the annual reductions necessary in a simple model in order for NSW to meet both its stated 2030 and 2050 targets in the linear fashion (green).

318) Figure 40 makes clear that **in each of the years 2023 through 2047** all emissions associated with **Mt Pleasant Optimisation Project negate several times over the annual GHG reductions efforts expected to be taken by the State.**

319) Over its proposed lifetime from 2023 to 2048, the Project would consume, via its direct and indirect emissions, 860 Mt CO_2-e of the global carbon budget. If NSW is to meet its 2030 and 2050 targets on an approximately linear trajectory (e.g., that shown in Fig. 38), the State will consume about 1550 Mt CO_2-e. **In other words, approving this single Project will erode the world's carbon budget by more than half that consumed by the entire state of NSW from 2023 until it (presumably) reaches net zero in 2050**.

7.3 The Social Cost of Carbon Arising from the Project

320) 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. 41 below) and specifically that:[309,310]

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**.

[309] 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

[310] NOAA (2022) https://www.climate.gov/news-features/blogs/beyond-data/2021-us-billion-dollar-weather-and-climate-disasters-historical

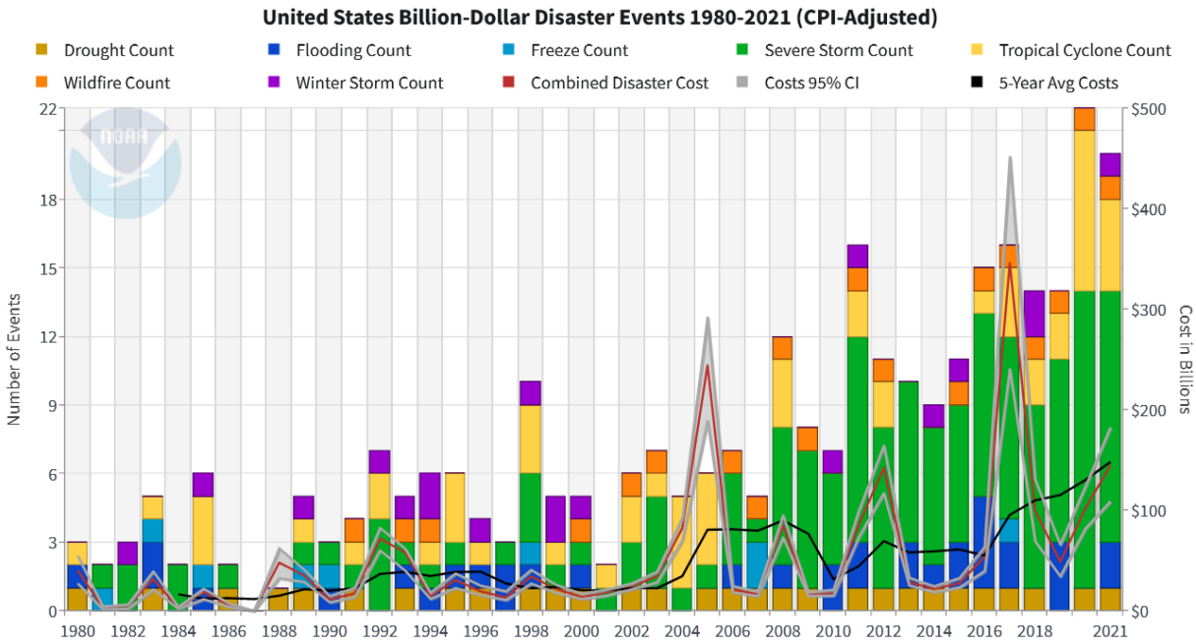

Fig. 41: Over the past 40 years, billion-dollar disasters in the USA have increased sharply in frequency (coloured vertical bars) and total annual costs (lines, with costs given on right-hand vertical axis). Costs have been adjusted for inflation. Figure is from the NOAA.

321) 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 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.**[311]

322) In Australia, the economic cost of climate change to Australia is estimated to have doubled since the 1970s,[312] 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.**[313]

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[311] Climate Central (6 October 2021) Disaster Fatigue, accessed at: https://medialibrary.climatecentral.org/resources/disaster-fatigue

[312] 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

[313] Kompas, T. cited in Silvester B. (2020) Trillions up in smoke: The staggering economic cost of climate change inaction. New Daily, 10 September 2020.

323) Another recent report[314] 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.**

324) Any justifiable estimate of the **cost to NSW resulting from climate change is likely to be an underestimate** because:

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 Section 2.8 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 194) and Fig. 21).

325) 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.**

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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

[314] 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

326) A large amount of research on increasing climate change costs is yet to be factored into current scientific estimates of the Social Cost of Carbon, and results from individual studies can vary considerably. However, a useful 2018 survey of the scientific literature at that time yielded a **median global Social Cost of Carbon of 417 USD per tCO_2, with a 'reasonable' (66% confidence) range of 177–805 USD.**[315]

327) **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[316] 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**.

328) With this background, **I calculate estimates for the Social Cost of Carbon arising from the Project and compare these to the estimates of `externality costs' of GHG associated with the Project as submitted by the Applicant.** My estimates are summarised in Table 8 (below) in millions of 2022 AUD (MAUD).

329) NSW values are derived from global values by assigning the Social Cost of Carbon equally across expected population in 2040. 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. An analysis aimed at developing a GHG budget for Victoria[317] has shown that an `Equal per capita 2040 convergence' approach produced a value that was the middle of five approaches considered. Since NSW enjoys a larger fraction of global GDP than global

[315] 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

[316] 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

[317] 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.

population, estimates for NSW would be even larger if GDP were used to apportion the global Social Cost of Carbon.

330) Emission quantities are taken from Table 3 of this Report, using tonnes of CO_2-e as a proxy for tonnes of CO_2.

Table 8: Estimates of Social Cost of Carbon associated with the Project over its proposed Lifetime

All values in 2022 MAUD	Scopes 1 + 2	Scope 3	All Scopes
Global Median	9,630	516,000	**526,000**
Global Range	4,100 – 18,600	219,000 – 996,000	223,000 – 1,010,000
NSW Median	11.1	593	**604**
NSW Range	4.71 – 21.4	252 – 1,140	257 – 1,170

Table 8 Notes: Costs are calculated following values given in paragraphs 326) and 327). Values are given to three significant figures in millions of AUD (MAUD).

331) Although Table 8 lists values for Scopes 1+2 and Scope 3 separately, from a Social Cost of Carbon perspective, this is non-sensical since all Scopes (on a tonne per tonne basis) effect the global climate and NSW's climate equally. For that reason, on this analysis **the Social Cost of Carbon attributable to the Project** are best represented in Table 8 **by the median values of 526 Billion AUD for the globe, and 604 Million AUD for NSW. The range of these values is about 223 Billion AUD to just 1.01 Trillion AUD for the globe, and 257 Million AUD to about nearly 1.17 Billion AUD for NSW. I again stress that these are underestimates of the true cost of externalities associated with GHG arising from the Project** for the reasons described in paragraphs 324) and 327).

332) **The Project's Social Cost of Carbon are borne by the world's population (rather than the Project's emitters at extraction or combustion), and thus are true externalities.** The Corporate Finance Institute[318] defines externalities as follows. *"An externality is a cost or benefit of an economic activity by an unrelated third party. The external cost or benefit is not reflected in the final cost or benefit of a good or service. Therefore, economists generally view externalities as a serious problem that makes markets inefficient, leading to market failures. The externalities are the main catalysts that lead to the tragedy of the commons."*

[318] See: https://corporatefinanceinstitute.com/resources/knowledge/economics/externality/

333) This brings me to the *global* `externality cost' of Project GHG emissions prepared by AnalytEcon and submitted by the Applicant.[319] These values range from 431 Million AUD to 857 Million AUD (in 2020 dollars), compared to the range of global Social Cost of Carbon estimates for the Project from this Report of 223 Billion AUD to 1.01 Trillion AUD. In other words, the **estimates given in this report for the global GHG externalities arising from the Project are more than 500** (low range) **to more than 1100** (high range) **times larger than the estimates suggested by the Applicant.**

334) The AnalytEcon assessment states that it "*was prepared in accordance with the NSW Government's 'Guidelines for the economic assessment of mining and coal seam gas proposals' (NSW Government, 2015a; 'the EA Guidelines'), and the 'Technical Notes supporting the Guidelines for the Economic Assessment of Mining and Coal Seam Gas Proposals' (NSW Government, 2018; 'the EA Technical Notes').* On that basis, AnalytEcon has made the choice to:

a) exclude Scope 3 GHG emissions arising from the Project,

b) use carbon `prices' that are based in policy or carbon trading (rather than carbon damages, the true externality borne by the population).

335) Furthermore, only the fraction of the Scope 1 and Scope 2 emissions that reflects NSW's fraction of global population or NSW's fraction of global GDP, are eventually assigned to NSW and enter into the AnalytEcon's cost-benefit analysis of the Project.

336) In response, I 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

[319] AnalytEcon (2022) Mount Pleasant Optimisation Economic Assessment: (revised)Cost Benefit Analysis -Greenhouse Gas Emissions Update, Table 3-1.

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.**

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%,**[320] **considerably less than the 3% used by AnalytEcon when considering the interim policy `Social Cost of Carbon' estimates used by the US Government.**

337) In summary, **the true GHG externalities likely to be borne by the world (and as an extension, by NSW) as a result of proposed project far exceed those submitted by the Applicant, by factors of more than 500 to 1100. As a consequence, I conclude that the Project would not result in a true net economic benefit to the people of NSW**.

7.4 Precautionary Principle and Intergenerational Equity

338) As this Report has set out, **the effects of climate change – which are caused by anthropogenic GHG emissions – are already serious; more than that, they are in fact dangerous. Furthermore, some of these effects are already irreversible and more will become so with even relatively small amounts of additional warming beyond that of 1.5°C, which is already locked in**.

339) 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.

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[320] 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

340) Unabated climate change is likely to be greatest overall threat to the environment and people of NSW because it is comprehensively dangerous, global, fundamental, rapid, compounding, self-reinforcing, has delayed effects and, in some cases, is irreversible.

341) 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.**

342) **The argument** put by the Applicant **that Project emissions represent a very small fraction of NSW, 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.**

343) **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. Currently, **the `polluter pays' principle is certainly not being applied to the damages associated with GHG emissions**.

344) In conclusion**, based on the evidence presented in this Report of the enormous risks posed by global warming surpassing 2°C, including irreversible consequences, and the contribution of the Mt Pleasant Extension in increasing that likelihood, it is my view that any benefits of the Project are far outweighed by costs borne by the majority of NSW inhabitants, particularly the youngest.**

8 Comments on the Ashurst Written Submission to the IPC

345) The legal firm Ashurst Australia (hereafter Ashurst) has submitted two documents to the IPC on behalf of their client, the Applicant. The first submission (hereafter, the Ashurst Submission),[321] dated 4 July 2022, relates to GHG emissions and climate change. The second submission (hereafter, the Further Ashurst Submission, relates to future coal markets and is based on a report by CRU Consulting, which is attached as an appendix to the Further Ashurst Submission.[322]

346) The Ashurst Submission contains three parts:

a) In Part A, opinions are offered on the law regarding the consideration of GHG emissions and climate change in determining development applications under the EP&A Act;

b) In Part B, opinions are offered on international, national and NSW climate change law and policy; and

c) In Part C, opinions are offered on the future demand for coal and the quality of the Project's product coal.

347) **As my personal expertise is not law, I will not comment on Part A of the Ashurst Submission, with one exception where Ashurst makes a remarkable, unsubstantiated claim that relates to impacts of GHGs and climate change. My expertise does allow me to address Part C, and due to incorrect conflating of matters of law and matters of science in Part B that could be seriously misleading in the current context, I will make comments with respect to Part B as well.** In this Report, I do not address the Further Ashurst Submission of 5 July 2022.

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[321] Ashurst Australia (4 July 2022, the Ashurst Submission), available at: https://www.ipcn.nsw.gov.au/projects/2022/05/mt-pleasant-optimisation-project-ssd-10418#

[322] Ashurst Australia (5 July 2022, the Further Ashurst Submission, available at: https://www.ipcn.nsw.gov.au/projects/2022/05/mt-pleasant-optimisation-project-ssd-10418#

8.1 Part A of the Ashurst Submission: GHG and Climate Impacts related to the Project

348) With respect to Part A of the Ashurst Submission, I wish to refer only to Paragraph 31, which states: "*The Applicant submits that the IPC can be satisfied that the climate change impacts and GHG emissions generated by the Project or the combustion of the Project's coal by other developments do not outweigh the significant social and economic benefits that the Project will deliver at a local, regional and State level (which are addressed in other documents already before the IPC).*"

349) **This remarkable statement** (in paragraph 348) **on behalf of the Applicant that the "IPC can be satisfied" that Project benefits exceed the climate change impacts caused by the Project's emissions is made without any reference to the magnitude of the Project's GHG emissions, including those associated with the combustion of the Project's coal, or reference to the current and future impacts of climate change**.

350) As I have shown in Section 7.3, **the Applicant's assessment of global GHG externalities arising from the Project are more than 500 to 1100 times smaller than the estimates given in this Report, which are based on the scientific literature. The Applicant's submission on this point is simply not credible and has no basis in science.**

8.2 Part B of Ashurst Submission: Relevance of Paris Accounting to the Environment

351) Rather than address every paragraph of Part B, I refer to paragraphs 13 and 14 of the Executive Summary of the Ashurst Submission, which state, in turn:

*a) "Almost all of the Project's Scope 3 emissions will be counted under the Paris Agreement as the Scope 1 GHG emissions of the Expected Export Countries in which the coal is used. Any mitigation in relation to the use of coal in electricity generation in those countries will count towards their Nationally Determined Contributions (**NDCs**) under the Paris Agreement".*

*b) "The Expected Export Countries are parties to the Paris Agreement (save for Taiwan) and have announced or adopted domestic laws and policies to achieve their GHG emissions targets as set out in their NDCs (or Intended Nationally Determined Contribution (**INDC**) in the case of Taiwan)."*

352) I do not disagree with these **statements made by Ashurst**, but regard them as **entirely irrelevant in assessing the environmental and societal impacts of the Project**.

353) First, **how signatories to the Paris Agreement have decided to `account for,' or in other words, `add up,' global GHG emissions is of no consequence to the amount of damage caused by GHG emissions resulting from any project or activity, which is a matter of science.**

354) **Second**, from a scientific standpoint, whether or not the Expected Export Countries for the Project's coal are parties to the Paris Agreement and have submitted Nationally Determined Contributions (NDCs) reflecting their stated voluntary intentions is also irrelevant, particularly in light of the fact that the **current NDCs fall far short of meeting the primary goal of the Paris Agreement**, which is **"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."**[323] As noted at paragraph 235) of this Report, the UN has assessed that "**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**."

355) Under current Paris Agreement accounting, it is appropriate for the Project's Scope 3 emissions to be accounted for and reported by the respective Expected Export Countries as Scope 1 emissions generated in those countries. **However, I am not aware of any suggestion in the Paris Agreement that countries should *not* also attempt to reduce their Scope 3 emissions, by regulation or any other means. In fact, such a suggestion would seem contrary to the very spirit and purpose of the Paris Agreement.**

356) **Certainly, ignoring the effects of Project Scope 3 GHG emissions would be deleterious to the environment of NSW, as every tonne of Scope 3 emissions from this Project has the same effect on the environment of NSW as any tonne of Project Scope 1 or 2 emissions.**

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

8.3 *Part C of Ashurst Submission: WEO 2021 Scenarios*

357) Part C of the Ashurst Submission makes reference to four scenarios in IEA's World Energy Outlook 2021 (hereafter, WEO 2021).[324] These are the Stated Policies Scenario (STEPS), the Announced Pledges Scenario (APS), the Sustainable Development Scenario (SDS), and the Net Zero Emissions by 2050 Scenario (NZE). The NZE is intended to be consistent with limiting the global temperature rise to 1.5°C. The others are not, which is clearly illustrated in a plot from the WEO 2021,[325] as Fig. 42 below.

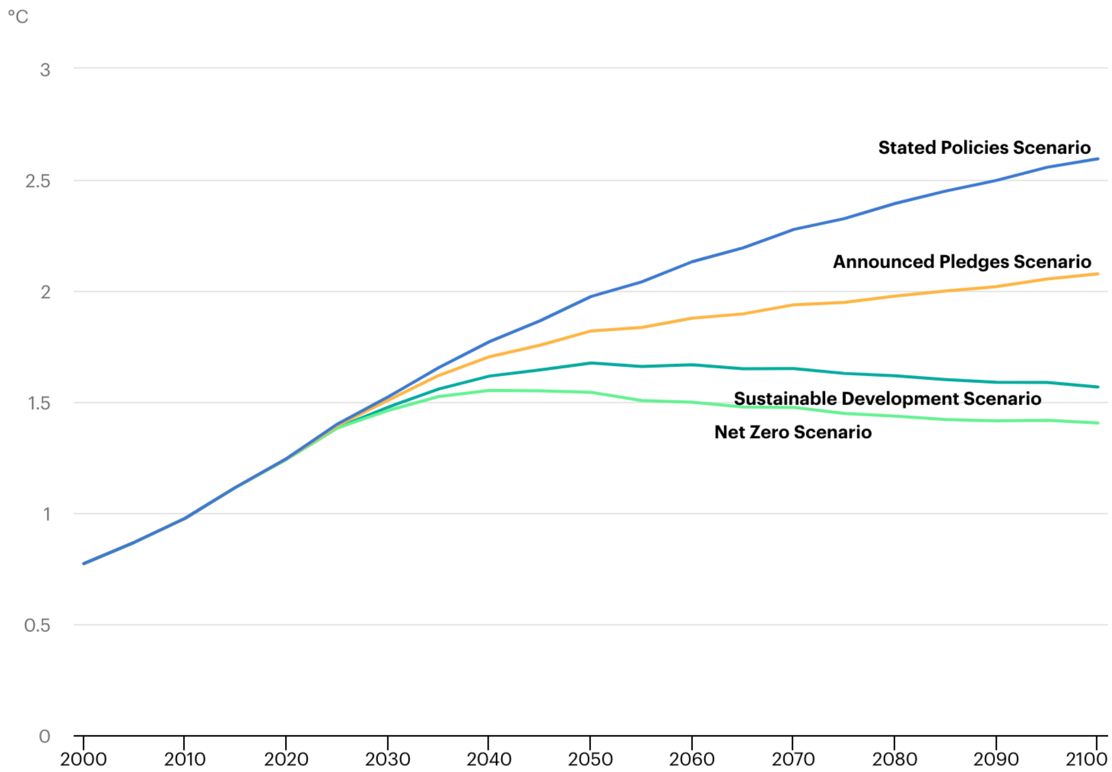

Fig. 42: Global median surface temperature rise in the WEO-2021 scenarios, as displayed on the IEA website for the WEO 2021 Report and included as its figure 1.5 in WEO 2021. Note that only the Sustainable Development Scenario and the Net Zero Scenario are compatible with the Paris Agreement goal, and only the Net Zero Scenario holds warming to 1.5°C by 2100.

358) As noted in paragraph 55 of the Ashurst Submission: "*In the WEO 2021, the global demand for thermal coal declines under all scenarios. Global unabated coal use in the energy system falls by around 5% to* ***2030*** [**emphasis** mine] *in the STEPS, by 10% in the APS, and by 55% in the NZE*." A figure showing this expected decline in the WEO 2021 (as its

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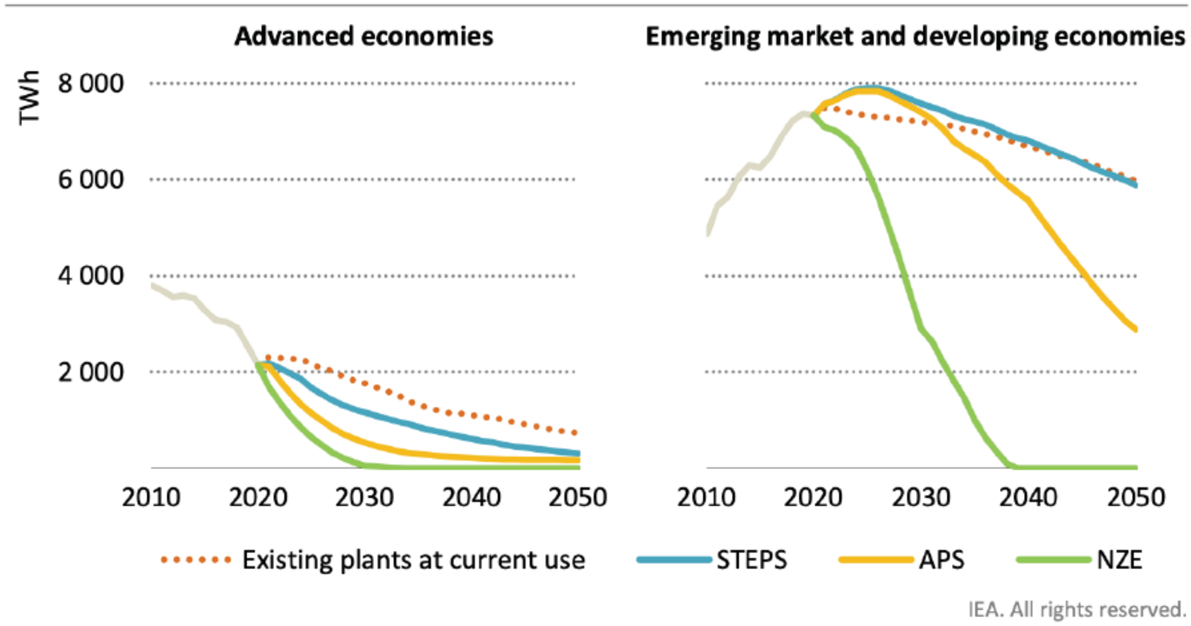
[324] IEA (2021) World Energy Outlook 2021. Accessed at: https://www.iea.org/reports/world-energy-outlook-2021

[325] See: https://www.iea.org/data-and-statistics/charts/global-median-surface-temperature-rise-in-the-weo-2021-scenarios-2000-2010

Figure 4.25) reproduced below as Fig. 43. The only scenario compatible with holding global warming to 1.5°C by 2100, NZE, shows a sharp to nearly zero coal-fired electricity in `advanced' economies by 2030 and a very sharp drop of over 50% for all other economies by that date.

Unabated coal-fired electricity generation by scenario, 2010-2050



Unabated coal is set to decline, but even in the APS it continues to be used widely: this puts the world off track to reach net zero emissions by 2050

Fig. 43: Electricity generation supplied by coal in each of the three main world energy scenarios of WEO 2021 and included as its figure 4.25. Note that only scenario compatible with holding global warming to 1.5°C by 2100, NZE, shows a sharp to near zero of coal-fired electricity in `advanced' economies around 2030 and a very sharp drop of over 50% for all other economies.

359) As **the IEA itself notes** in its figure caption (shown in the turquoise colour in Fig. 43 of this Report), "**. . .** ***the APS scenario*** **[reflecting current Paris NDCs] . . .** ***puts the world off track to reach net zero emissions by 2050***." Net zero by 2050 is a stated policy goal of NSW and Australia.

360) If the Applicant is basing its business plan (and the future of the Project jobs for NSW workers) on the STEPS or APS scenario, then it is predicated on global warming exceeding 2°C above pre-industrial times. I have detailed some of the climate consequences of such a world in Table 1 and Section 5.2 of this Report. **I cannot conceive how any positive benefits from the Project could possibly outweigh the grave consequences for NSW in such a world.**

361) In summary, **the WEO 2021 scenarios on which the Applicant, through its legal representative Ashurst, relies to assess future demand for coal are precisely those which are incompatible to holding warming to 2.0°C, and which the IEA itself says put `the world off track to reach net zero emissions by 2050.**

362) Finally, I reiterate that the 2021 special report by the **IEA**[326] 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.

363) It is now 2022, with eight years remaining to 2030. For this reason, and all the others contained in this Report, **it is my view that the Project should not be approved on greenhouse gas and climate change grounds.**

Respectfully submitted on 14 July 2022,

[redacted]

Professor Penny D Sackett

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

Appendix A: Brief Provided to Author by the EDO

See attached pages.

Environmental Defenders Office

15 June 2022

Distinguished Professor Penny d Sackett
Strategic Advisory Services

By email: [redacted]

CONFIDENTIAL AND PRIVILEGED

Dear Professor Sackett

Brief to Expert – Mount Pleasant Optimisation Project (SSD-10418) – NSW Independent Planning Commission Public Hearing

1. We act for Denman, Aberdeen, Muswellbrook and Scone Healthy Environment Group (**DAMSHEG**)) in relation to the proposed Mount Pleasant Optimisation Project (SSD-10418) (**Project**) by MACH Mount Pleasant Operations Pty Ltd (**Applicant**), a joint venture between MACH Energy Australia Pty Ltd and Japan Coal Development Australia Pty Ltd.

2. The Project is an expansion to the existing Mount Pleasant Operations in the in the Upper Hunter Valley of New South Wales (**NSW**), near Musswellbrook. The Proponent proposes to extend the life of the mine from 2026 until 2048, increase the run-of-mine coal (**ROM**) extraction from 10.5 million tonnes per annum (**mtpa**) up to 21 mtpa and construct associated infrastructure. Over the life of the mine, an additional 247 million tons of ROM coal is proposed to be extracted.

3. Our client is a grassroots organisation whose mission is protect Australia's natural, cultural and agricultural resources from inappropriate mining. The major concerns of our client are the impact of the Project on visual amenity, greenhouse gas emissions, air quality, water resources, rehabilitation and the socio-economic impact on Muswellbrook including signals tower interference (Rossgole television and radio tower).

4. The Department of Planning and the Environment (**Department**), formerly the Department of Planning, Industry and Environment has released its Assessment Report of the Project and has referred the matter to the Independent Planning Commission (the Commission) for public hearing and determination.

5. The public hearing will be held on **7 and 8 July 2022**, with **11 July 2022** also set aside if necessary. Our client wishes to ensure the Commission receives independent expert advice on the Project. Accordingly, our client wishes to retain your services to act as an expert to provide an expert report for submission to the Commission and to present your expert views to the Commission at the public hearing.

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E brisbane@edo.org.au **W** edo.org.au
3/28 Donkin St, West End Qld 4101
ABN: 72002 880 864

Purpose of your expert report

6. We note as a preliminary matter that our primary purpose in briefing you to prepare your report is to assist the decision maker for the Project. We do not ask you to be an advocate for our client. You are requested to prepare an independent report that is clear and well-written.

7. In this respect, we draw your attention to Division 2 of Part 31 of the *Uniform Civil Procedure Rules 2005* (**UCPR**), and the Expert Witness Code of Conduct (**Code of Conduct**) contained in Schedule 7 of the UCPR, both of which govern the use of expert evidence in NSW Courts (**attached**). We understand that the public hearing is not a Court proceeding, however, we are of the view that the same Code of Conduct should be adhered to in this instance.

8. In particular, clause 2 of the Code of Conduct states 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."*

9. Your expert report must contain an acknowledgment that you have read the Expert Witness Code of Conduct and that you agree to be bound by it.

10. Your expert report will be used as evidence in chief of your professional opinion. Information of which you believe the decision maker should be aware must be contained in your expert report.

11. In providing your opinion to the decision maker you must set out all the assumptions upon which the opinion is based. This may include, for example, facts observed as a result of fieldwork or 'assumed' facts based on a body of scientific opinion. If the latter, you should provide references which demonstrate the existence of that body of opinion.

12. Your expert report must also set out the process of reasoning which you have undertaken in order to arrive at your conclusions. It is insufficient for an expert report to simply state your opinion or conclusion reached without an explanation as to how this was arrived at. The purpose of providing such assumptions and reasoning is to enable the decision maker and experts engaged by other parties to make an assessment as to the soundness of your opinion.

Overview of work requested

13. We request that you undertake the following work:

    a. review the documents listed below;
    b. prepare a written expert report that addresses the issues identified below ('Issues to address in your expert report'), and ensure that the work is prepared in accordance with Part 31, Division 2 of the UCPR; and

c. appear as an expert witness at the IPC public hearing for the purpose of giving oral evidence.

Documents

14. We enclose the Code of Conduct and Part 31 Division 2 of the UCPR.

15. Full Project documentation is available at the following websites:
    a. NSW Government Planning Portal: https://pp.planningportal.nsw.gov.au/major-projects/projects/mount-pleasant-optimisation-project
    b. Independent Planning Commission website:https://www.ipcn.nsw.gov.au/projects/2022/05/mt-pleasant-optimisation-project-ssd-10418.

16. The following documents relating to the Project are provided for your particular consideration:

Environmental Impact Statement

a. Executive Summary
b. Section 3 - Project Description
c. Section 7 – Environmental Assessment
d. Section 8 – Evaluation and Conclusion
e. Appendix S – Greenhouse Gas Assessment

Response to Submissions

a. Submissions Reports: Request RTS (19 Mar 2021)
b. Submissions Report: Att G & H
c. Submissions Report - Main Text and Att A to F

Additional Information

a. EES Advice on GHG Assessment
b. MACH Response to GHG Queries (31 Mar 2022)
c. Revised CBA with Updated GHG Emissions

Department's Assessment Report

a. Department's Assessment Report
b. Recommended Conditions

Other Documents

a. Net Zero Plan Stage 1: 2020-2030: https://www.environment.nsw.gov.au/topics/climate-change/net-zero-plan .
b. Australia's Long-Term Emissions Reduction Plan https://www.industry.gov.au/data-and-publications/australias-long-term-emissions-reduction-plan
c. Strategic Statement on Coal Exploration and Mining in NSW https://www.regional.nsw.gov.au/meg/nsw-resources/coal

17. Please let us know as soon as possible if you require further information for the purpose of giving your expert opinion.

Issues to address in your expert report

18. We ask that your report address the following issues:
    a. Please summarise any greenhouse gas emissions predicted to arise as a consequence of the Project.
    b. Provide a brief description of the causes and effects of anthropogenic climate change.
    c. Provide a brief description of any anthropogenic climate change already being experienced, including within the state of NSW.
    d. Provide a brief description of anthropogenic climate change projections and impacts on current emissions trends.
    e. Provide an estimate of any social cost of carbon, applied to any greenhouse gas emissions predicted to arise as a consequence of the Project, to the extent it is within your area of expertise.
    f. In your opinion, is approval of the Project consistent with a goal of limiting anthropogenic climate change to 1.5 or well below 2 degrees Celsius above pre-industrial levels. Please provide reasoning for your response.
    g. Provide any further observations or opinions which you consider to be relevant.

19. We request that you provide us with a draft of your report for review before finalising it. We emphasise that the purpose of this is not to influence the conclusions or recommendations you make but to ensure that the language and expression of the report is clear and complies with the formal legal requirements of an expert report.

Key dates

20. The public hearing will be held on **Thursday 7 and Friday 8 July 2022**, with **Monday 11 July 2022** also set aside should a third day be necessary. The public hearing will be conducted remotely, with registered speakers participating via tele- and/or videoconference.

21. To speak at the electronic public hearing, you must complete the registration form on the IPC website by no later than **12pm AEDT on Monday 27 June 2022**. Registration can be completed here.

22. The IPC will accept written comments on the Project until **5pm AEDT on Friday 15th July 2022**.

23. We kindly request that you please provide your draft expert advice by no later than by **Wednesday 29 June 2022**.

Duty of confidentiality

24. Please treat your work as strictly confidential until your expert report is provided to the IPC, unless authorised by us.

Fees and Terms

25. Thank you for agreeing to provide your advice in this matter on a pro bono (volunteer) basis. EDO relies on experts such as you to assist our clients accessing justice in matters with very little financial compensation.

26. Please note the following terms:

    a. your work will only be used by EDO to relation to this matter;
    b. our client may choose to make your expert advice publicly available. Any public release of your report, whether by our client or by way of publication on the Commission's website, may result in disclosure of any works in your report over which you may claim copyright;
    c. EDO will take all reasonable steps to prevent your work being used for purposes other than that mentioned above, but we accept no responsibility for the actions of third parties;
    d. regardless of the above points, EDO may choose not to use your work; and
    e. you will not be covered by the EDO's insurance while undertaking the above tasks.

27. If you would like to discuss this brief further, please contact Jayme Cooper, solicitor [redacted] or Sean Ryan, Managing Lawyer [redacted]) (cc [redacted] and [redacted]

We are grateful for your assistance in this matter.

Yours sincerely,
Environmental Defenders Office

[redacted]

Sean Ryan
Managing Lawyer – Safe Climate

Reference number: S3089

AppendixB: Curriculum Vitae of Author

See attached pages.

Curriculum Vitae
PENNY D. SACKETT

Academic Address:
ANU Institute for Climate, Energy and Disaster Solutions
Australian National University
H.C Coombs Building, 9 Fellows Road, Acton ACT 2601

Penny.Sackett@anu.edu.au

Private Business Address:
Dr Penny D Sackett
Strategic Advisory Services

www.pennysackett.com

Born: 28 February 1956, Lincoln, Nebraska USA
Citizenship: U.S. and Australian
Permanent Residence: Australia
Languages: English: Mother Tongue; Dutch: Good knowledge; Spanish: Beginner's knowledge

Education:

1984	Ph.D. in Physics, University of Pittsburgh, PA, USA Thesis Title: *Scale Parameters for Finite Temperature Actions of Lattice Gauge Theories Coupled to Fermions*
1980	M.S. in Physics, University of Pittsburgh, PA, USA
1978	B.S. in Physics, University of Nebraska-Omaha (UNO), NE, USA
1978	Teaching certification (K-12), Physics and Mathematics, UNO, USA

Distinctions and Honours:

2019	Distinguished Alumni Award, University of Pittsburgh, USA
2016	Omaha (USA) North High Magnet School "Viking of Distinction" Award
2014	UNO College of Arts and Sciences Outstanding Alumni Award
2014	Citation for Alumni Achievement: Univeristy of Nebraska-Omaha (UNO)
2011	Opening Keynote Speaker: 2011 Adelaide Festival of Ideas, SA, Australia
2005	Univ of Canberra-Australian National Univ International Women's Day Lecturer
2004	Finalist, Telstra ACT Business Women of the Year, ACT, Australia
2003	Fellow of the UK Royal Astronomical Society *Election to the Society to honour a person eminent in the field of astronomy and not normally resident in the UK for leadership, enabling activities, etc*
2002	Harley Wood Lecturer, Astronomical Society of Australia
2000	Athena Lecturer, St. Andrews University, Scotland
1998	University of Groningen Teaching Award (Onderwijsprijs), The Netherlands
1992-1994	J. Seward Johnson Fellow, Institute of Advanced Study, Princeton, NJ, USA
1981-1982	O.H. Blackwood Award for Excellence in Teaching, University of Pittsburgh, PA, USA
1979-1981	Andrew Mellon Fellowship, University of Pittsburgh, PA, USA
1978	Summa Cum Laude, University of Nebraska-Omaha, NE, USA
1978	Most Outstanding Physics Student, University of Nebraska-Omaha, NE, USA
1978	Most Outstanding Mathematics Student, University of Nebraska-Omaha, NE
1974-1978	Dean's List, University of Nebraska-Omaha, NE, USA
1974-1978	Nebraska Regent's Scholarship, University of Nebraska-Omaha, NE, USA
1974-1978	National Merit Scholarship, University of Nebraska-Omaha, NE, USA

Professional Society Membership

Astronomical Society of Australia
International Astronomical Union
Royal Astronomical Society

Professional Activity and Appointments

2020-current	Distinguished Honorary Professor (E3), Climate Change Institute, Australian National University, Canberra, Australia *Climate change synthesis and analysis, community engagement*
2011-current	Strategic Scientific Advisor and Principal Penny D Sackett Strategic Advisory Services *Sole trader assisting governments, communities, courts and business with matters of science, climate change and sustainability*
2014-2019	Honorary Professor, Climate Change Institute, Australian National University, Canberra, Australia *Community engagement, science for policy, subnational climate change action*
2008-2014	Academic Adjunct Professor, Research School of Astronomy and Astrophysics, Australian National University, Canberra, Australia *Mentoring early career researchers*
2008-2011	Chief Scientist for Australia, DIISR, Australian Commonwealth Government, Canberra, Australia *Provision of independent, whole-of-government scientific advice, science advocacy, liaison with community, bureaucracy and state governments*
2007-2008	Professor (Level E2), Research School of Astronomy and Astrophysics, Australian National University (ANU), Canberra, Australia *Research, research training, and international research co-ordination*
2002-2007	Director, Research School of Astronomy and Astrophysics, and the Mt. Stromlo and Siding Springs Observatories, ANU, Canberra, Australia *Strategic leadership, budget, human & facility management, liaison, advocacy*
2001-2002	Chaired Professor of (Extra)Galactic Optical/Infrared Astronomy, Kapteyn Astronomical Institute, University of Groningen, The Netherlands *Research, research training, teaching, international program building*
1998-2000	Associate Professor with tenure (Universiteits Hoofd Docent), Kapteyn Astronomical Institute, University of Groningen, The Netherlands *Research, research training, teaching, international program building*
2000	Visiting Member, Institute for Advanced Study, Princeton, NJ, USA (on leave from Kapteyn Institute 1999-2000 academic year) *Research of international standing*
1999	Visiting Scientist, Anglo-Australian Observatory, Epping, Australia (on leave from Kapteyn Institute 1999-2000 academic year) *Research of international standing and international co-ordination*
1995-1997	Assistant Professor with tenure (Universiteits Docent), 75% full time Kapteyn Astronomical Institute, University of Groningen, The Netherlands *Research, research training, teaching, research program building*
1995-1997	Visiting Research Member, School of Natural of Sciences, 25% full time Institute of Advanced Study, Princeton, NJ, USA *Research of international standing*
1992-1994	Research Member & J. Seward Johnson Fellow, School of Natural of Sciences, Institute of Advanced Study, Princeton, NJ, USA *Self-directed research of international standing*

1991-1992	Program Director, Education, Human Resources and Special Programs, Div of Astronomical Sciences, National Science Foundation, Washington, DC, USA *Program management, cross-division initiatives, external liaison*
1990-1992	Research Assistant Professor, Physics and Astronomy Department, University of Pittsburgh, PA, USA *Self-directed research*
1987-1990	Adjunct Assistant Professor, Physics and Astronomy Department, University of Pittsburgh, PA, USA *Self-supported research post*
1988-1989	Visiting Scientist, Kapteyn Astronomical Institute, University of Groningen, The Netherlands *Self-directed independent research*
1987	Scientific Writing Consultant, Pittsburgh Supercomputing Center (PSC), Pittsburgh, PA, USA *Technical writing and editing*
1986-1987	Research Associate, Biological Sciences Department, University of Pittsburgh, PA, USA *Algorithm development and application to cellular activity*
1985-1986	Visiting Assistant Professor, Physics and Astronomy Department, University of Pittsburgh, PA, USA *University physics teaching*
1983-1985	Visiting Assistant Professor, Physics Department, Amherst College, MA, USA *University teaching in liberal arts setting*
Summer 1983	Science Writer Intern, *Science News* Magazine, Washington, DC, USA *Developing and writing science news stories*

Supervision of Junior Researchers

Researcher name	**Sackett Supervisory Capacity**	**Subsequent posting**
Paul Vreeswijk	1997 Honours Thesis Supervisor	Fellow, Weizmann Inst of Science, IL
Jean Philippe Beaulieu	1996-98 Postdoctoral Supervisor	Director of Research, IAP, Paris, FR
Martin Dominik	1997-99 Postdoctoral Supervisor	Reader, Univ of St Andrews, UK
Richard Naber	PhD Thesis (Co-supervisor)	Left field before completion
Scott Gaudi	2001 PhD Thesis (Co-supervisor)	Professor, Ohio State University, USA
Eduard Westra	2003 Honours Thesis Supervisor	Industrial Data Analyist, NL
Ulyana Dyudina	2004 Postdoctoral Supervisor	Assoc Scientist, Space Science Inst, USA
Jelte de Jong	2005 PhD Thesis (Co-supervisor)	Researcher, University of Groningen, NL
David Weldrake	2005 PhD Thesis Supervisor	Asst Director, M-D Basin Authority, AU
Brandon Tingley	2006 PhD Thesis Supervisor	PostDoc, Aarhus University, DK
Christine Thurl	2007 PhD Thesis Supervisor	Industrial Physicist, DE
Thomas Evans	2008 Honours Supervisor	Research Fellow, Univ of Exeter, UK
Daniel Bayliss	2009 PhD Thesis Supervisor	Asst Professor, Univ of Warwick, UK
Karen Lewis	2011 PhD Thesis (Co-supervisor)	Postdoc, Earth Life Science Inst, JP

Selected Major Experiences and Accomplishments

2011-present *As Private Strategic Scientific Advisor:*

– Sole Expert Witness in BSCA vs EPA case in NSW Land and Environment Court
– Foresight analyst for 2025 Strategic Plan of BASF, world's largest chemical producer
– Scientific Assessor for Queensland $20m Smart Futures Fund
– Analyst and advisor to Australian multi-state Climate Action Roundtable

2015-2021 *As Councillor and Chair of ACT Climate Change Council:*

– Spearheaded recommendation for interim GHG emissions targets in the ACT
– With Prof. Will Steffen, introduced carbon budget approach into ACT policy-making
– Led *Canberra's Climate-Fuelled Summer of Crisis* Report

2008-2011 *As Chief Scientist for Australia:*

– Commissioned four cross-disciplinary reports for Prime Minister's Council (PMSEIC):
Challenges at energy-water-carbon intersections
Australia and food security in a changing world
Transforming learning and the transmission of knowledge
Epidemics in a changing world
– Founded Forum of Australian Chief Scientists
– Established two-way communication tools with Australian community

2002-2007 *As Director, Research School of Astronomy and Astrophysics (RSAA)*

– Managed University department and observatory staff of 100
– Responsible for annual budget of 6M AUD plus 4M AUD in 2nd & 3rd steam funds
– Oversaw rebuild of main campus of School after devastating 2003 bush fires
– Led national effort to establish next generation telescope access for Australia
– Established ANU Planetary Science Institute, joint venture with ANU Earth Sciences
– Initiated and carried out large change process at RSAA, managing
mandated 29% increase in salary costs & 20% reduction in recurrent budget
– Spearheaded entry into two major international partnerships:
Giant Magellan Telescope (GMT) and Murchison Wide Field Array (MWA)
– Negotiated awards of two major instrument contracts: Gemini NIFS (II) and GSAOI
– Oversaw 80% increase in research publication rate, 50% growth in PhD student body,
and increase in student completion rate while decrease in time to submission

1989-2010 *As Scientific Researcher and Team Leader in USA, NL and Australia:*

– Streamlined massive searches for transiting planets in the Milky Way
– Founded and Principal Investigator of the international PLANET Collaboration,
managing collaboration of 20 scientists in 7 countries using 5 telescopes to
set first limits for Jupiter-like planets around common dwarf stars,
determine limb-darkening of distant stars for the very first time, and
detect first terrestrial-mass (5-Earth mass) exoplanet around a normal star
– Determined 3-D distribution of dark matter around some galaxies
– Quantified relationship between structure and dark matter in Milky Way
– Determined deep cloud structure in atmosphere of Saturn

1991-1992 *As Program Director at U.S. National Science Foundation (NSF), USA*

– Managed program of small grants to fund high-risk science
– Initiated first newsletter from NSF Astronomy division (AST) to national community
– Managed all cross-division (AST + another NSF division) awards
– Responsible for all AST projects related to education and diversity
– Initiated study into factors correlated to proposal success and failure

Local, National & International Service

2015-2021	Councillor and Chair, Australian Capital Territory (ACT) Climate Change Council
2017-2020	Member, Business Advisory Board, ACT Renewable Energy Innovation Fund
2017-2019	Member, Scientific Advisory Board, Potsdam Institute for Climate Impact Research
2015	Chair, Memorandum Team, Nobel Laureate Symposium: *Climate Change, Changing Cities*
2013	Invited Speaker, 2013 Geological Society of America, Denver, CO, USA Contribution: *Elemental Cycles in the Anthropocene*
2011	Drafting Team, Nobel Laureate Stockholm Memorandum on Global Sustainability
2008-2011	As Chief Scientist for Australia, Member of: Prime Minister's Science, Engineering & Innovation Council, Executive Officer Prime Minister's Science Prize Selection Committee Educational Investment Fund Board Defence Science & Technology Organisation Advisory Board Rural Research & Development Council Higher Education Endowment Fund Assessment Panel Cooperative Research Centres Assessment Panel Climate Change Science Framework Implementation Group, Chair National Youth Science Forum, President Forum of Australian Chief Scientists, Founder and Chair
2005-2010	Board of Directors, Association of Universities for Research in Astronomy (AURA)
2006-2008	Board of Directors, Giant Magellan Telescope (GMT) Organisation
2002-2008	ANU Member Representative to AURA
2008	Australian GMT Advisory Committee to Australia Astronomy, Ltd
2003-2007	NCA Task Force on Extremely Large Telescopes (ELT)
2002-2007	National Committee for Astronomy (NCA), Australian Academy of Science
2002-2007	Australian Gemini Telescope Steering Committee
2002-2007	Board of Management for the Australian Astronomy MNRF Award
2004-2007	Chancellor's Award Committee, Australian National University (ANU)
2004-2006	Canberra Partnership Board, ACT, AU
2003-2005	University Science, Health & Engineering Research Committee, ANU
2000-2005	European OPTICON Extremely Large Telescope (ELT) Science Working Group
2004	International review team of the South African Astro-Geoscience Facilities for the NRF
2002-2003	Academic Board, Australian National University, Canberra, AU
1995-2002	Principal Investigator, International PLANET Collaboration
2001-2002	Science Advisory Committee for the Square Kilometer Array
2001-2002	Curriculum Advisory Committee for Astronomy, Kapteyn Astronomical Institute
2000-2002	European Southern Observatory (ESO) Programmes Committee, Member-at-Large
2000-2001	Chair, Stars and Planets Panel for OPTICON ELT Working Group
1996-1998	ESO Working Group on Exo-Solar Planets
1996-1998	Facilities Program Committee, Netherlands Organisation for Scientific Research

Scientific Organising and Steering Committees:

2013-2015	*Changing Climate, Changing Cities* Nobel Laureates Symposium on Global Sustainability, Hong Kong 2015 also Chair, Symposium Memorandum Drafting Team
2008	*2008 Meeting of the Astronomical Society of Australia* Perth, Australia
2006-2007	*IAU Symposium on Exoplanets: Physics, Dynamics and Evolution* Suzhou, China
2006	*Transiting Extrasolar Planets* 25-28 September 2006, MPIA, Heidelberg, Germany
2003-2004	*Planetary Timescales: Stardust to Continents* 2003 White Conference, National Academy of Sciences, Canberra, AU
2002-2003	*Extrasolar Planets: Today and Tomorrow* 30 June - 4 July 2003, IAP, Paris, France
2001-2002	*Scientific Frontiers in Research on Extrasolar Planets* 11-14 June 2002, Washington, DC, USA
2001	*The SKA: Defining the Future* 9-12 July 2001, Berkeley, CA, USA
2000-2001	*Yale Cosmology Workshop: Shapes of Galaxies and Their Halos* 28-30 May 2001, New Haven, USA
1999-2000	*Planetary Systems in the Universe: Observation, Formation and Evolution* 7-11 August 2000, Manchester, England
1998-2000	*Microlensing 2000: A New Era for Microlensing Astrophysics* 21-25 February 2000, Capetown, South Africa Chair, Scientific Organising Committee
1997-1999	*Impact of Large-Scale Photometry on the Research of Pulsating Stars* IAU Conference, 9-13 August 1999, Budapest, Hungary
1997-1999	*VLT Opening Symposium: From Extrasolar Planets to Brown Dwarfs* 1-4 March 1999, Antofagasta, Chile
1997-1998	*4^{th} International Workshop on Microlensing Surveys* 15-17 January 1998, Paris, France
1990	*Warped Disks and Inclined Rings around Galaxies* Workshop 30 May - 1 June 1990, Pittsburgh PA Scientific and Local Organising Committee

PUBLICATIONS

Over 140 publications, 65 in refereed journals, together garnering
more than 4400 scientific citations and 1000 normalised citations
(Sackett served as PhD or postdoctoral supervisor for authors in italics)

Technical Reports and Communications: Climate Change

Expert Report: On the Environmental Impact Statement of the Winchester South Project as it relates to Climate Change
Penny D Sackett
2021, Part of a submission to the Queensland Coordinator-General

Expert Report: Matter of Bushfire Survivors for Climate Action Inc v Environment Protection Authority
Affirmed as Affidavit D on 10 August 2021
Penny D Sackett
2021, Submission to the NSW Land and Environment Court, Case No. 20/106678

Expert Report: Matter of Bushfire Survivors for Climate Action Inc v Environment Protection Authority
Affirmed as Affidavit C on 5 August 2021
Penny D Sackett
2021, Submission to the NSW Land and Environment Court, Case No. 20/106678

Expert Report: Matter of Bushfire Survivors for Climate Action Inc v Environment Protection Authority
Affirmed as Affidavit B on 4 June 2021
Penny D Sackett
2021, Submission to the NSW Land and Environment Court, Case No. 20/106678

Expert Report: Matter of Bushfire Survivors for Climate Action Inc v Environment Protection Authority
Affirmed as Affidavit A on 5 March 2021
Penny D Sackett
2021, Submission to the NSW Land and Environment Court, Case No. 20/106678

The Social Cost of Carbon and Implications for the ACT
Paul Bannister, Cristopher Brack, Mark Howden, Karen Jesson, Ben Ponton, Penny D Sackett (Chair), Sophia Hamblin Wang
2021, ACT Climate Change Council, Canberra

Expert Submission: Tahmoor South Coal Extension Project (SSD 17-8845)
Objecting: On the basis of greenhouse gas implications
Addendum: Addendum in Response to Additional Material
Penny D Sackett
2020, Submission to the NSW Independent Planning Commission

Expert Report: Matter of Mullaley Gas & Pipeline Accord Inc v Santos NSW Pty Ltd; Independent Planning Commission of NSW
Affirmed as Affidavit C on 5 August 2021
Penny D Sackett
2021, Submission to the NSW Land and Environment Court, Case No. 20/363113

Expert Report: Greenhouse Gas and Climate Implications of the Narrabri Gas Project (SSD 6456)
Response to Additional Material
Penny D Sackett
2020, Submission to the NSW Independent Planning Commission

Expert Report: Greenhouse Gas and Climate Implications of the Narrabri Gas Project (SSD 6456)
Penny D Sackett
2020, Submission to the NSW Independent Planning Commission

Learning from Canberra's Climate-Fuelled Summer of Crisis
Paul Bannister, Cristopher Brack, Mark Howden, Karen Jesson, Ben Ponton, Penny D Sackett (Chair), Sophia Hamblin Wang
2020, ACT Climate Change Council, Canberra

Community Listening Report on Adaptation to Climate Crises: The Extreme Summer of 2019/20
Penny Sackett, Will Steffen and Karen Jessen
2020, ACT Climate Change Council, Canberra

Expert Submission: Tahmoor South Coal Extension Project (SSD 17-8845)
Objecting: On the basis of greenhouse gas implications
Addendum: In Response to the Greenhouse Gas Assessment of the Amended Project
Penny D Sackett
2020, Submission to the NSW Independent Planning Commission

Climate of fear: summit aims to create action consensus
S. Robson and P. Sackett
2020, in "Insight" of the Medical Journal of Australia, 2 March 2020

Expert Submission: Tahmoor South Coal Extension Project (SSD 17-8845)
Objecting: On the basis of greenhouse gas implications
Penny D Sackett
2019, Submission to the NSW Independent Planning Commission

Independent Assessment: Rix's Creek South Continuation of Mining Project (SSD 6300)
Objecting: On the basis of greenhouse gas implications
Penny D Sackett
2019, Submission to the NSW Independent Planning Commission

Who is Counting our Carbon Budget?
P.D. Sackett and W. Steffen
2019, in "Policy Forum" of the Asia and The Pacific Policy Society, 7 May 2019

What is a Carbon Budget?
Penny Sackett, Will Steffen and Karen Jessen
2018, ACT Climate Change Council, Canberra

Sub-National Climate Policies: How does the ACT compare? Part I: Report
Luke Kemp, Penny Sackett, and Frank Jotzo
2015, ACT Climate Change Council, Canberra

Sub-National Climate Policies: How does the ACT compare? Part II: Data Tables
Luke Kemp, Penny Sackett, and Frank Jotzo
2015, ACT Climate Change Council, Canberra

Refereed Scientific Publications

Elemental cycles in the Anthropocene: mining aboveground
Penny D. Sackett
2016, in Geoscience for the Public Good and Global Development: Toward a Sustainable Future, eds. G.R. Wessel and J.K. Greenberg, J.K., Geological Society of America Special Papers 520, p. SPE520-11, doi:10.1130/2016.2520(11)

HATS-3b: An Inflated Hot Jupiter Transiting an F-type Star
Daniel D. R. Bayliss et al (29 authors, including Penny D Sackett)
2013, AJ, 146, 113, arXiv:1306.0624

Endangered Elements: Conserving the Building Blocks of Life
(Invited Review) Penny Sackett
2012, Solutions, Volume 3, Issue 3

HATSouth: a global network of fully automated identical wide-field telescopes
G. Á. Bakos et al (24 authors, including *Daniel D. R. Bayliss* and Penny D. Sackett
2013, PASP, 125, 154, arXiv:1206.1391

The Frequency of Hot Jupiters in the Galaxy: Results from the SuperLupus Survey
Daniel D. R. Bayliss and Penny D. Sackett
2011, ApJ, 743, 103, arXiv:1112.0359

Confirmation of a Retrograde Orbit for Exoplanet WASP-17b
Daniel D. R. Bayliss, Joshua N. Winn, Rosemary A. Mardling & Penny D. Sackett
2010, ApJ Letters, 722, L224-L227, arXiv:1009.5061

An *a priori* Investigation of Astrophysical False Positives in Ground-Based Transiting Planet Surveys
Tom M. Evans & Penny D Sackett
2010, ApJ, 712, 38, arXiv:1002.0886

Microlensing exoplanets
Penny D Sackett
2010, Scholarpedia, 5(1):3991

The Lupus Transit Survey for Hot Jupiters: Results and Lessons
Daniel D. R. Bayliss, *David T. F. Weldrake*, Penny D. Sackett, *Brandon W. Tingley* & *Karen M. Lewis*
2009, AJ, 137, 4368, astro-ph/0903.5121

Possibility of Detecting Pulsar Moons through Time-of-Arrival Analysis
Karen M. Lewis, Penny D. Sackett & Rosemary A. Mardling
2008, ApJL, 685, L153, astro-ph/0805.4263

Lupus-TR-3b: A Low-Mass Transiting Hot Jupiter in the Galactic Plane?
David T. F. Weldrake, *Daniel D. R. Bayliss*, Penny D. Sackett, *Brandon W. Tingley*, Michaël Gillon & Johny Setiawan
2008, ApJL, 675, L37, astro-ph/0711.1746

The Frequency of Large Radius Hot and Very Hot Jupiters in ω Centauri
David T. F. Weldrake, Penny D. Sackett & Terry J. Bridges
2008, ApJ, 674, 1117, astro-ph/0710.3461

A Deep Wide-Field Variable Star Catalog of ω Centauri
David T. F. Weldrake, Penny D. Sackett & Terry J. Bridges
2007, AJ, 133, 1447, astro-ph/0610704

Resolving Stellar Atmospheres I: The Hα line and comparisons to microlensing observations
Christine Thurl, Penny D. Sackett & Peter H. Hauschildt
2006, A & A, 455, 315, astro-ph/0604088

MACHOs in M31? Absence of evidence but not evidence of absence
Jelte T.A. de Jong, Lawrence M. Widrow, Patrick Cseresnjes, Konrad Kuijken, Arlin P.S. Crotts, Alexander Bergier, Edward A. Baltz, Geza Gyuk, Penny D. Sackett, Robert R. Uglesich & Will J. Sutherland
2006, A & A, 446, 855, astro-ph/0507286

Discovery of a cool planet of 5.5 Earth masses through gravitational microlensing
J.-P. Beaulieu, et al (PLANET, OGLE and MOA, 73 authors, includ. Penny D. Sackett)
2006, Nature, 439, 437, astro-ph/0601563

The color signature of the transit of HD 209458 and discrepancies between stellar atmospheric models and observations
B. Tingley, *C. Thurl* & P. Sackett
2006, A & A, 445, L27, astro-ph/0510633

A Photometric Diagnostic to Aid in the Identification of Transiting Extra-solar Planets
Brandon Tingley & Penny D. Sackett
2005, ApJ, 627, 1011, astro-ph/0503575

An Absence of Hot Jupiter Planets in 47 Tucanae: Results of a Wide-Field Transit Search
David T.F. Weldrake, Penny D. Sackett, Terry J. Bridges, & Kenneth C. Freeman
2005, ApJ, 620, 1043, astro-ph/0411233

A Method for the Detection of Planetary Transits in Large Time-Series Datasets
David T.F. Weldrake & Penny D. Sackett
2005, ApJ, 620, 1033, astro-ph/0411234

Phase light curves for extrasolar Jupiters and Saturns
Ulyana A. Dyudina, Penny D. Sackett, *Daniel D.R. Bayliss*, Sara Seager, Carolyn C. Porco, Henry B. Throop & Luke Dones
2005, ApJ, 618, 973-986, astro-ph/0406390

A Comprehensive Catalogue of Variable Stars in the field of 47 Tucanae
David T.F. Weldrake, Penny D. Sackett, Terry J. Bridges, & Kenneth C. Freeman
2004, AJ, 128, 736, astro-ph/0405133

First Microlensing Results for the MEGA Survey of M31
Jelte T.A. de Jong, Konrad H. Kuijken, Arlin P.S. Crotts, Penny D. Sackett, Will J. Sutherland, Robert R. Uglesich, Edward A. Baltz, Patrick Cseresnjes, Geza Guyk, Lawrence M. Widrow (MEGA Collaboration)
2004, A & A, 417, 461-477, astro-ph/0307072

PLANET II: A Microlensing and Transit Search for Extrasolar Planets
Penny D. Sackett, M.D. Albrow, *J.-P. Beaulieu*, J.A.R. Caldwell, C. Coutures, *M. Dominik*, J. Greenhill, K. Hill, K. Horne, U.-G. Jorgensen, S. Kane, D. Kubas, R. Martin, J. Menzies, K.R. Pollard, K.C. Sahu, J. Wambsganss, R. Watson, A. Williams (PLANET),
in Bioastronomy 2002: Life Among the Stars, eds. R. Norris, C. Oliver & F. Stootman
2004, IAU Symposium 213 (San Francisco: ASP), 35, astro-ph/0211098

High-Precision Limb-Darkening Measurement of a K3 Giant Using Microlensing
D.L. Fields, M.D. Albrow, J.H. An, *J.-P. Beaulieu*, J.A.R. Caldwell, D.L. DePoy, *M. Dominik*, *B.S. Gaudi*, A. Gould, J. Greenhill, K. Hill, S. Kane, R. Martin, J. Menzies, R.W. Pogge, K.R. Pollard, P.D. Sackett, K.C. Sahu, P. Vermaak, R. Watson & A. Williams (PLANET), and J.-F. Glicenstein & P.H. Hauschildt
2003, ApJ, 596, 1305, astro-ph/0303638

A Short, Non-Planetary Microlensing Anomaly: Observations and Lightcurve Analysis of MACHO 99-BLG-47
M.D. Albrow, J. An, *J.-P. Beaulieu*, J.A.R. Caldwell, D.L. DePoy, *M. Dominik*, *B.S. Gaudi*, A. Gould, J. Greenhill, K. Hill, S. Kane, R. Martin, J. Menzies, R.W. Pogge, K.R. Pollard, P.D. Sackett, K.C. Sahu, P. Vermaak, R. Watson, A. Williams (PLANET)
2002, ApJ, 572, 1031, astro-ph/0201256

First microlens mass measurement: PLANET photometry of EROS BLG-2000-5
J. An, M.D. Albrow, *J.-P. Beaulieu*, J.A.R. Caldwell, D.L. DePoy, *M. Dominik*, *B.S. Gaudi*, A. Gould, J. Greenhill, K. Hill, S. Kane, R. Martin, J. Menzies, R.W. Pogge, K.R. Pollard, P.D. Sackett, K.C. Sahu, P. Vermaak, R. Watson, A. Williams (PLANET)
2002, ApJ, 572, 521, astro-ph/0110095

Detection of a Thick Disk in the Edge-on Low Surface Brightness Galaxy ESO 342-G017
Mark J. Neeser, Penny D. Sackett, Guido De Marchi, & Francesco Paresce
2002, A&A, 383, 472, astro-ph/0201141

Microlensing Constraints on the Frequency of Jupiter-Mass Companions: Analysis of Five Years of PLANET Photometry
B.S. Gaudi, M.D. Albrow, J. An, *J.-P. Beaulieu*, J.A.R. Caldwell, D.L. DePoy, *M. Dominik*, A. Gould, J. Greenhill, K. Hill, S. Kane, R. Martin, J. Menzies, *R.M. Naber*, J.-W. Pel, R.W. Pogge, K.R. Pollard, P.D. Sackett, K.C. Sahu, P. Vermaak, *P.M. Vreeswijk*, R. Watson, A. Williams (PLANET)
2002, ApJ, 566, 463, astro-ph/0104100

The PLANET microlensing follow-up network: Results and prospects for the detection of extra-solar planets
M. Dominik, M. D. Albrow, *J.-P. Beaulieu*, J. A. R. Caldwell, D. L. DePoy, *B. S. Gaudi*, A. Gould, J. Greenhill, K. Hill, S. Kane, R. Martin, J. Menzies, *R. M. Naber*, J.-W. Pel, R. W. Pogge, K. R. Pollard, P.D. Sackett, K. C. Sahu, P. Vermaak, R. Watson, A. Williams (PLANET collaboration)
2002, Planetary and Space Science, 50, 299-307, astro-ph/9910465

Interpreting Debris from Satellite Disruption in External Galaxies
Kathryn V. Johnston, Penny D. Sackett and James S. Bullock
2001, ApJ, 557, 137, astro-ph/0101543

Hα Equivalent Width Variations across the Face of Microlensed K Giant in the Galactic Bulge
M.D. Albrow, J. An, *J.-P. Beaulieu*, J.A.R. Caldwell, *M. Dominik*, J. Greenhill, K. Hill, S. Kane, R. Martin, J. Menzies, K.R. Pollard, P.D. Sackett, K.C. Sahu, P. Vermaak, R. Watson, A. Williams (PLANET), and P. Hauschildt
2001, ApJL, 550, L173, astro-ph/0011380

Limits on the Abundance of Galactic Planets from Five Years of PLANET Observations
M.D. Albrow, J. An, *J.-P. Beaulieu*, J.A.R. Caldwell, D.L. DePoy, M. Dominik, *B.S. Gaudi*, A. Gould, J. Greenhill, K. Hill, S. Kane, R. Martin, J. Menzies, *R.M. Naber*, J.-W. Pel, R.W. Pogge, K.R. Pollard, P.D. Sackett, K.C. Sahu, P. Vermaak, *P.M. Vreeswijk*, R. Watson, A. Williams (PLANET)
2001, ApJL, 556, L113, astro-ph/0008078

PLANET observations of microlensing event OGLE-1999-BUL-23: Limb-darkening measurement of the source star
M.D. Albrow, J. An, *J.-P. Beaulieu*, J.A.R. Caldwell, D.L. DePoy, M. Dominik, *B.S. Gaudi*, A. Gould, J. Greenhill, K. Hill, S. Kane, R. Martin, J. Menzies, R.W. Pogge, K.R. Pollard, P.D. Sackett, K.C. Sahu, P. Vermaak, R. Watson, A. Williams (PLANET Collaboration)
2001, ApJ, 549, 759, astro-ph/0004243

Discovery of the optical counterpart and early optical observations of GRB990712
K.C. Sahu et al. (49 authors, including P. D. Sackett and the PLANET collaboration
2000, ApJ, 540, 74, astro-ph/0003378

Limits on Stellar and Planetary Companions in Microlensing Event OGLE-1998-BUL-14
M.D. Albrow, *J.-P. Beaulieu*, J.A.R. Caldwell, D.L. DePoy, *M. Dominik*, *B.S. Gaudi*, A. Gould, J. Greenhill, K. Hill, S. Kane, R. Martin, J. Menzies, *R.M. Naber*, R.W. Pogge, K.R. Pollard, P.D. Sackett, K.C. Sahu, P. Vermaak, R. Watson, A. Williams (PLANET)
2000, ApJ, 535, 176, astro-ph/9909325

Detection of Rotation in a Binary Microlens: PLANET Photometry of MACHO 97-BLG-41
M.D. Albrow, *J.-P. Beaulieu*, J.A.R. Caldwell, *M. Dominik*, *B.S. Gaudi*, A. Gould, J. Greenhill, K. Hill, S. Kane, R. Martin, J. Menzies, *R.M. Naber*, K.R. Pollard, P.D. Sackett, K.C. Sahu, P. Vermaak, R. Watson, A. Williams (PLANET), H.E. Bond, I.M. van Bemmel
2000, ApJ, 534, 894, astro-ph/9910307

The Stellar Content of the Halo of NGC 5907 from Deep HST NICMOS Imaging
S.E. Zepf, M.C. Liu, F.R. Marleau, P.D. Sackett, & J.R. Graham
2000, AJ, 119, 1701, astro-ph/0001154

Combined Analysis of the Binary-Lens Caustic-Crossing Event MACHO 98-SMC-1
C. Afonso et. al., C. Alcock et al., S.H. Rhie et al., A. Udalski et al., M.D. Albrow et al. (94 authors in total, including P.D. Sackett: EROS, MACHO/GMAN, MPS, OGLE and PLANET Collaborations)
2000, ApJ, 532, 340, astro-ph/9907247

Detection Efficiencies of Microlensing Datasets to Stellar and Planetary Companions
B.S. Gaudi and P.D. Sackett
2000, ApJ, 528, 56, astro-ph/9904339

A Complete Set of Solutions For Caustic-Crossing Binary Microlensing Events
M.D. Albrow, *J.-P. Beaulieu*, J.A.R. Caldwell, D.L. DePoy, *M. Dominik*, *B.S. Gaudi*, A. Gould, J. Greenhill, K. Hill, S. Kane, R. Martin, J. Menzies, *R.M. Naber*, R.W. Pogge, K.R. Pollard, P.D. Sackett, K.C. Sahu, P. Vermaak, R. Watson, A. Williams (PLANET Collaboration)
1999, ApJ, 522, 1022, astro-ph/9903008

Limb-Darkening of a K Giant in the Galactic Bulge: PLANET Photometry of MACHO 97-BLG-28
M.D. Albrow, *J.-P. Beaulieu*, J.A.R. Caldwell, *M. Dominik*, J. Greenhill, K. Hill, S. Kane, R. Martin, J. Menzies, *R.M. Naber*, J.-W. Pel, K.R. Pollard, P.D. Sackett, K.C. Sahu, P. Vermaak, R. Watson, A. Williams (PLANET Collaboration) and M.S. Sahu
1999, ApJ, 522, 1011, astro-ph/9811479

The Relative Lens-Source Proper Motion in MACHO 98-SMC-1
M.D. Albrow, *J.-P. Beaulieu*, J.A.R. Caldwell, D.L. DePoy, *M. Dominik*, *B.S. Gaudi*, A. Gould, J. Greenhill, K. Hill, S. Kane, R. Martin, J. Menzies, *R.M. Naber*, J.-W. Pel, K.R. Pollard, P.D. Sackett, K.C. Sahu, P. Vermaak, R. Watson, A. Williams (PLANET Collaboration), and R. W. Pogge
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B. Scott Gaudi, *R.M. Naber* & P.D. Sackett
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The 1995 Pilot Microlensing Campaign of PLANET: Searching for Anomalies through Precise, Rapid Round-the-Clock Monitoring
M. Albrow, *J.-P. Beaulieu*, P. Birch, J.A.R. Caldwell, S. Kane, R. Martin, J. Menzies, *R.M. Naber*, J.-W. Pel, K. Pollard, P.D. Sackett, K.C. Sahu, *P. Vreeswijk*, A. Williams & M. Zwaan (PLANET Collaboration)
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J.P. Beaulieu and Penny D. Sackett
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Does the Milky Way have a Maximal Disk?
Penny D. Sackett
1997, ApJ, 483, 103, astro-ph/9608164

The Structure of Dark Halos: Model-Independent Information from HI Rotation Curves
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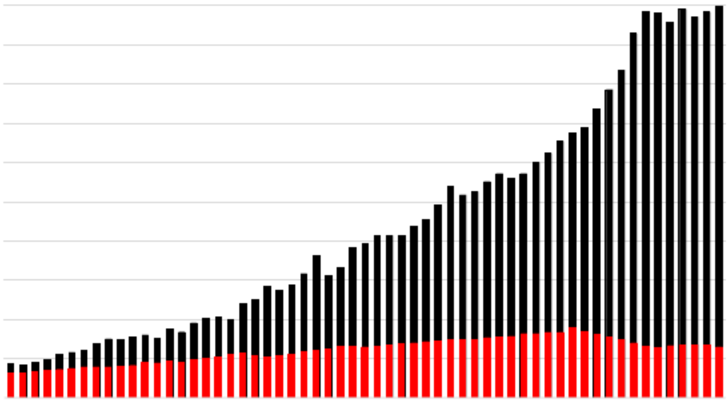
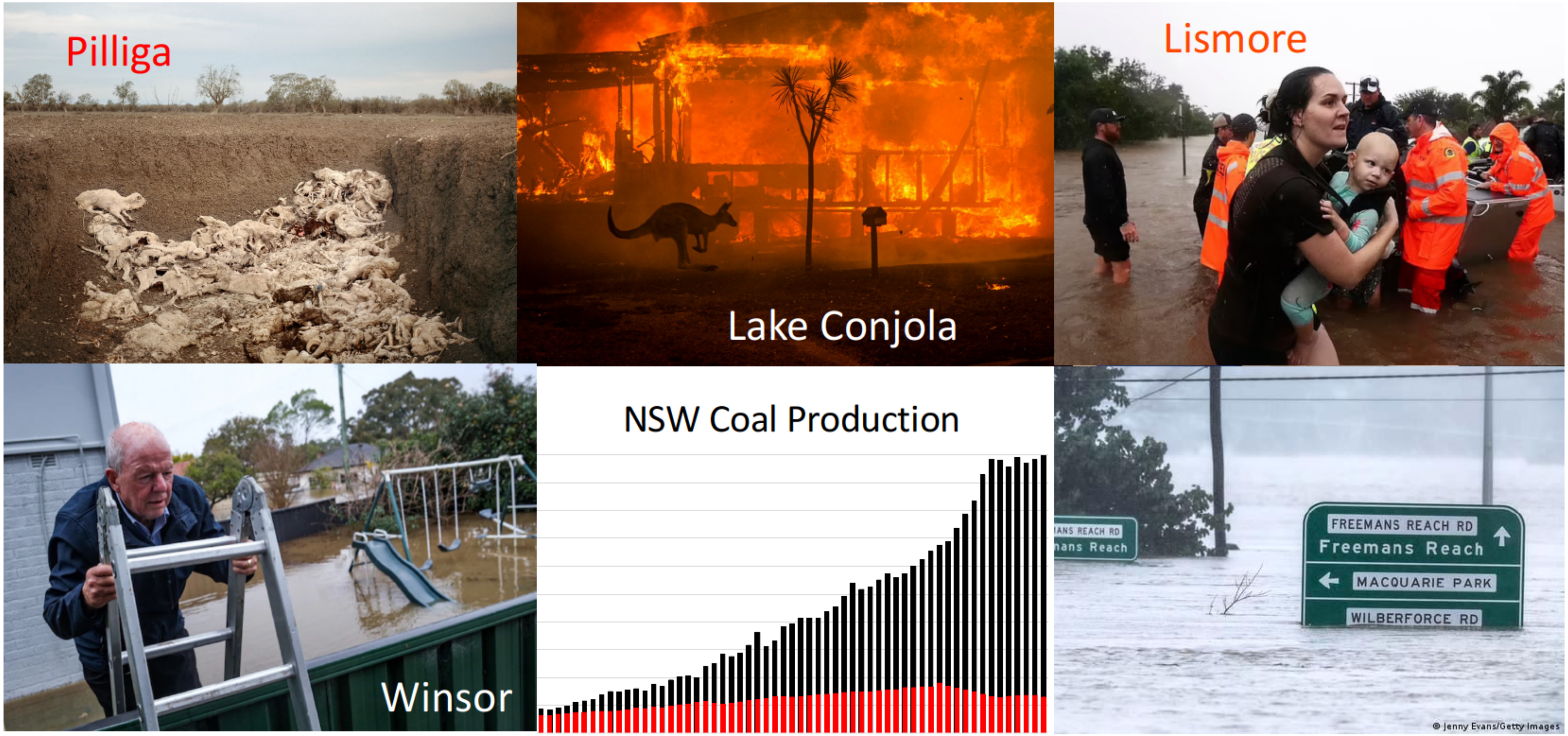
Mt Pleasant Optimisation Project:

Greenhouse Gas and Climate Implications



Professor Penny D Sackett
ANU Institute for Climate, Energy and Disaster Solutions
Presented to NSW Independent Planning Commission
8 July 2022

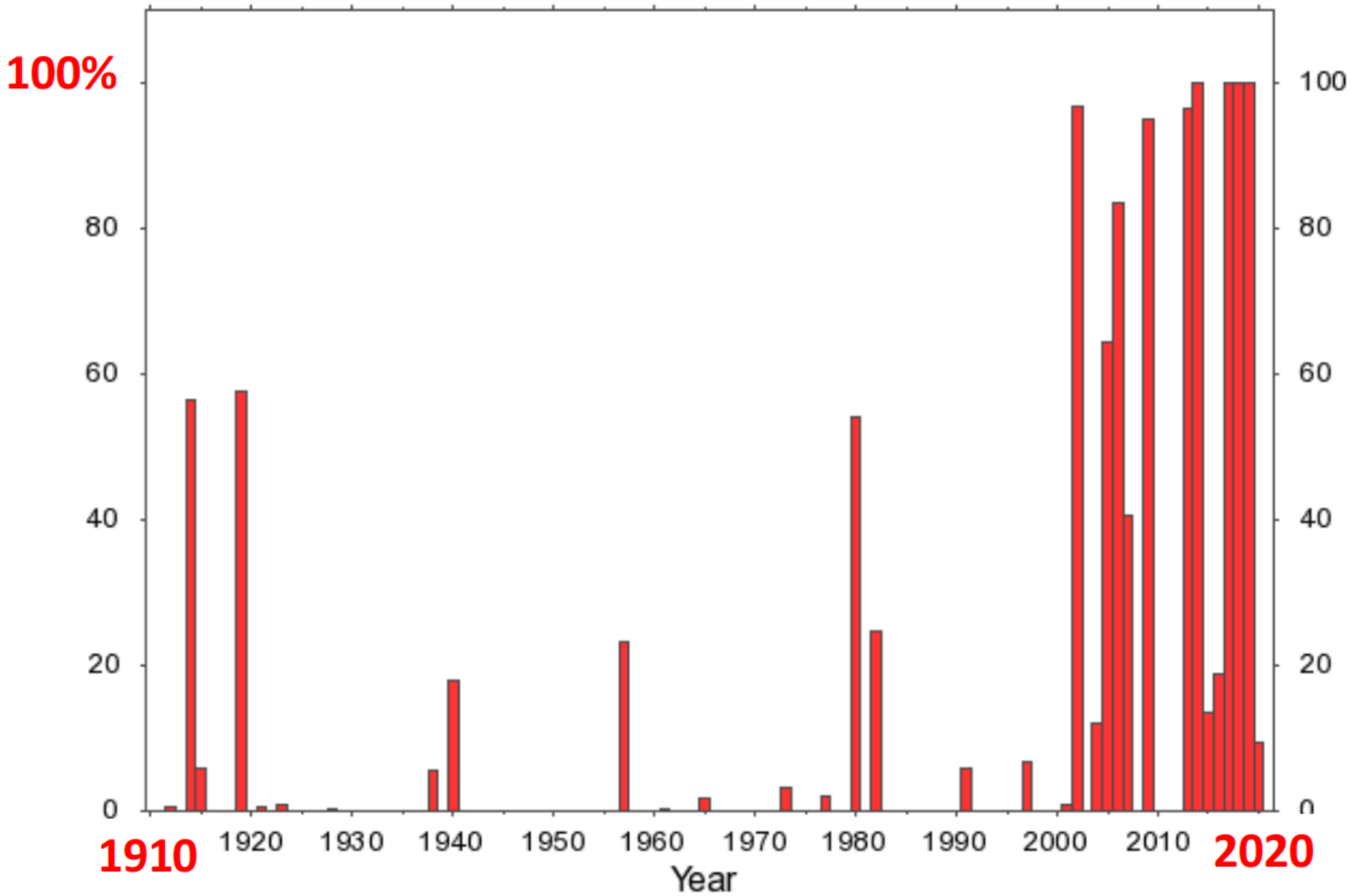


Professor Penny D Sackett
ANU Institute for Climate, Energy and Disaster Solutions
Presented to NSW Independent Planning Commission
8 July 2022

My written report will contain details about

- Points covered in this presentation, and
- Why the effects of methane emissions from this Project are underestimated
- Why the Project will make Australia’s and NSW’s emissions targets more difficult to meet
- Why the social cost of Project greenhouse gas emissions have been drastically underestimated by factors 500 to 1150, compared to the scientific literature.

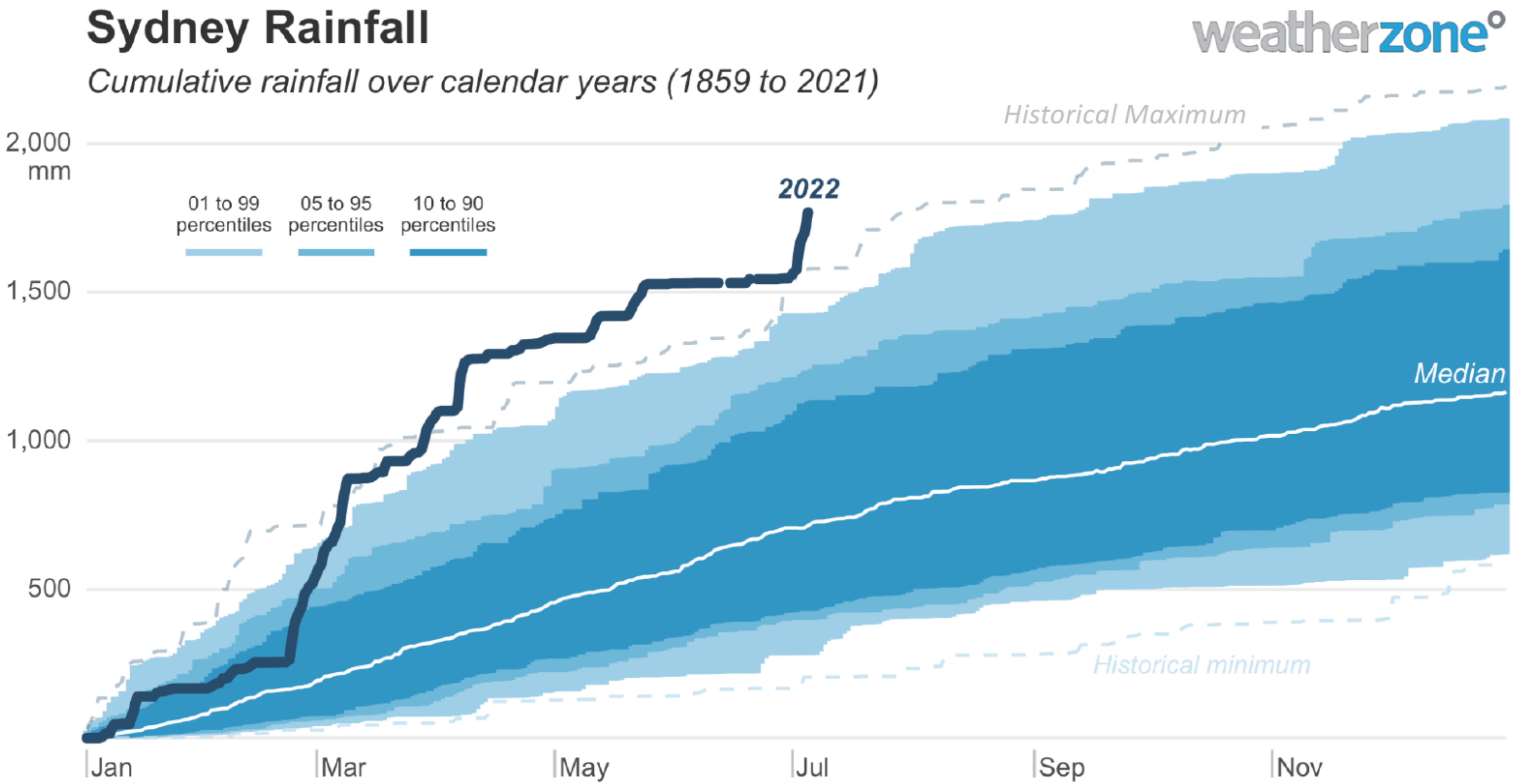
Fraction of NSW area that experienced maximum annual temperature in top 10% of all records since 1910



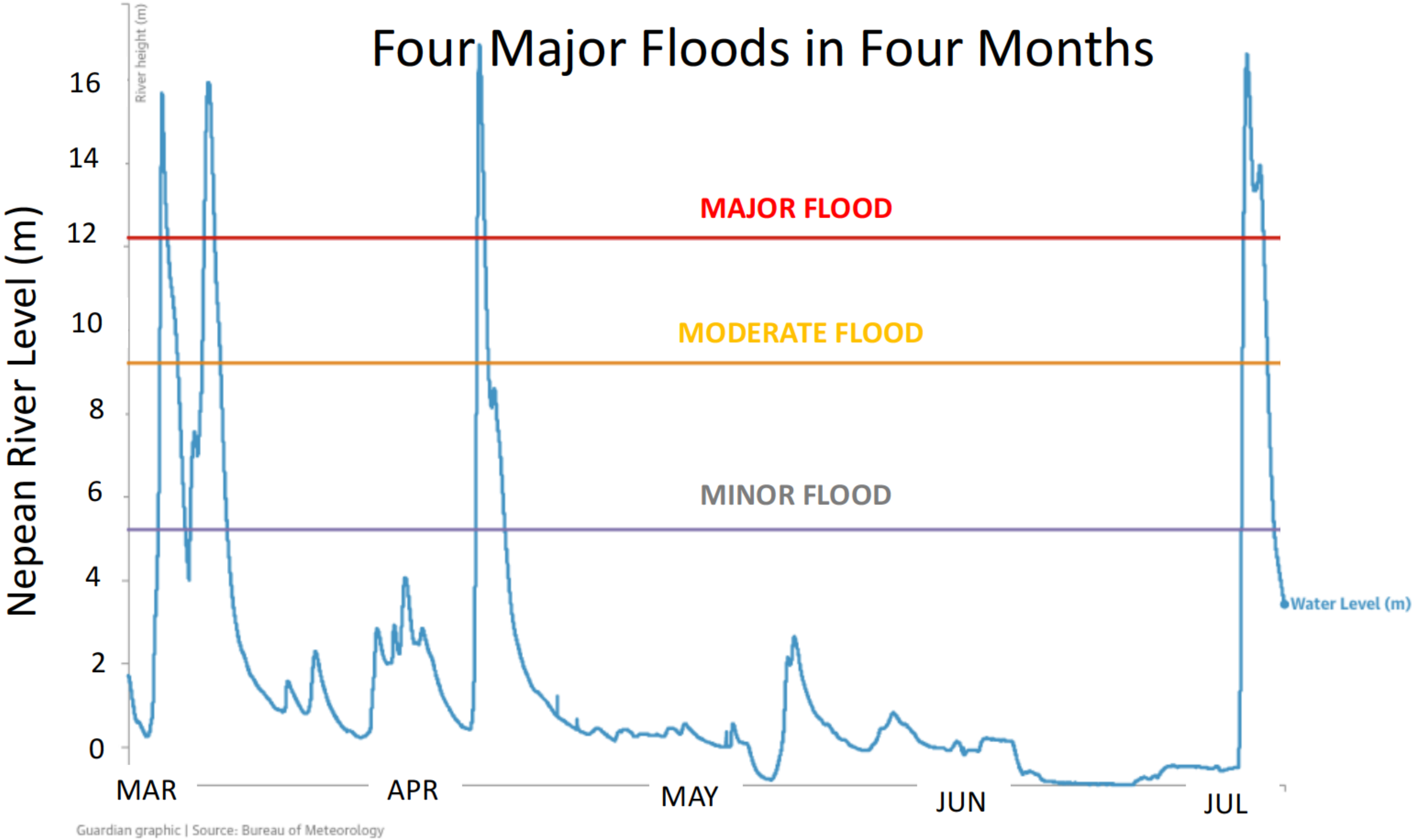
Climate Change has arrived.

It will get worse.

How much worse depends on decisions we make this decade, this year, today.



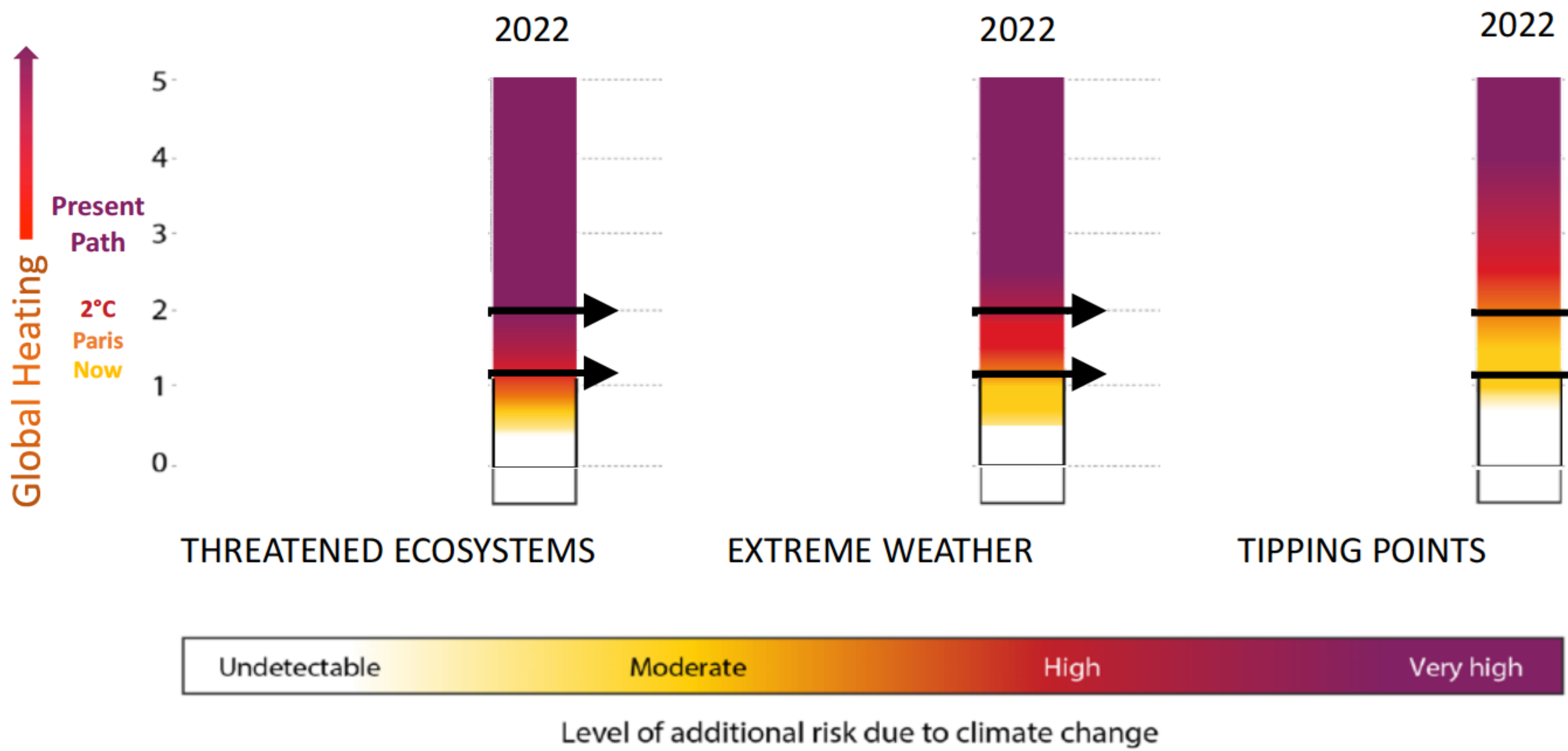
As of 5 July 2022



Four Major Floods in Four Months
Nepean River Level (m)
River height (m)
16
14
12
10
8
6
4
2
0
MAJOR FLOOD
MODERATE FLOOD
MINOR FLOOD
Water Level (m)
MAR
APR
MAY
JUN
JUL
Guardian graphic | Source: Bureau of Meteorology

The more we know, the more we realise . . .

how dangerous even a small amount of warming can be.



The more we know, the more we realise . . .

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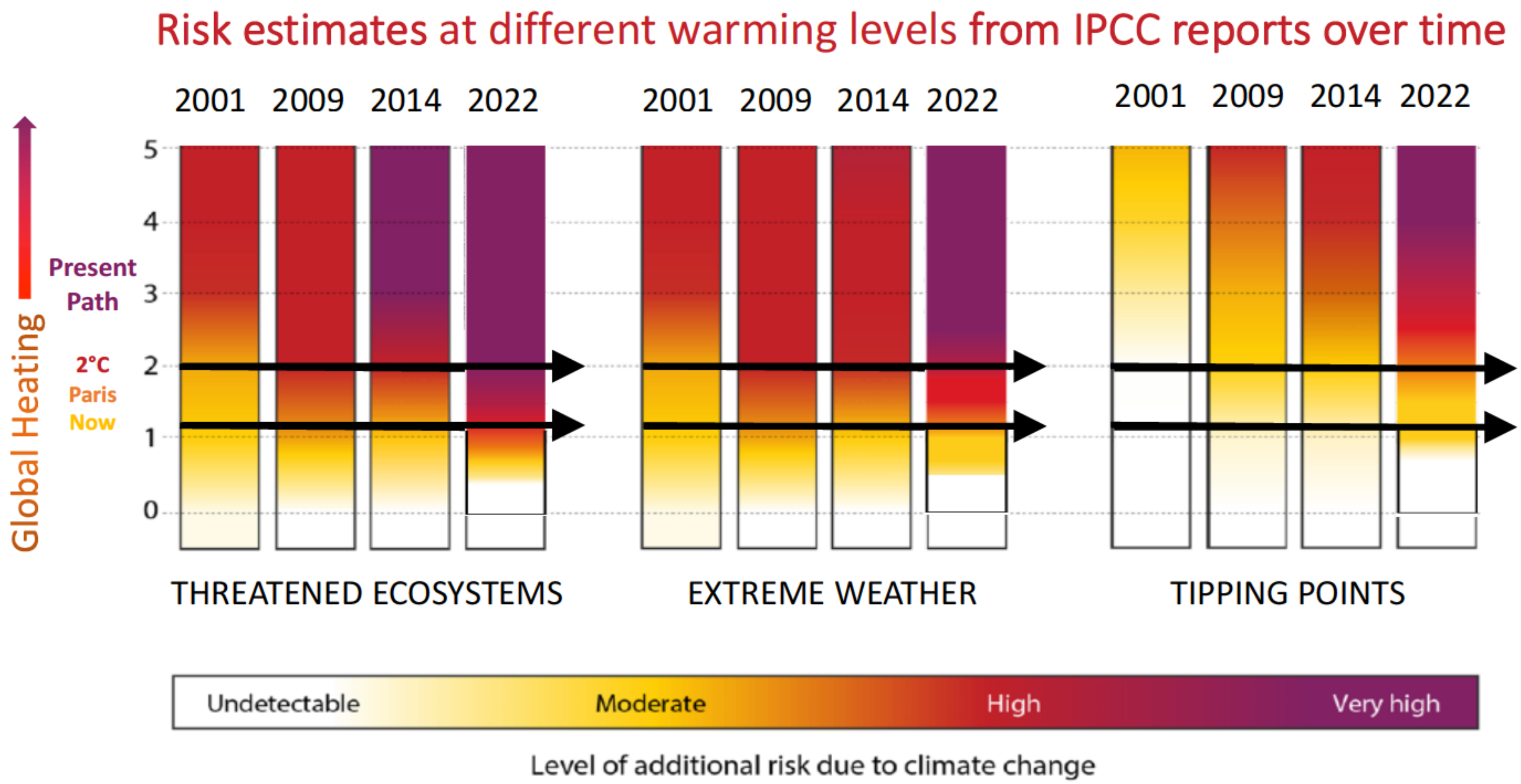


https://www.ipcc.ch/report/ar6/wg1/#SPM

IPCC AR6 WG1

Irreversible Changes are Happening Now

In many cases, even with possible future direct carbon capture from the atmosphere

- **Ocean** temperature, acidification and deoxygenation: irreversible for **100s to 1000s years**.
- Mountain and polar **glaciers** melt: irreversible for **10s to 100s years**.
- Release of **permafrost carbon:** irreversible for **100s of years**.
- **Continued sea-level rise**: irreversible for **100s to 1000s of years**.

Small rise in global temperature: Huge consequences

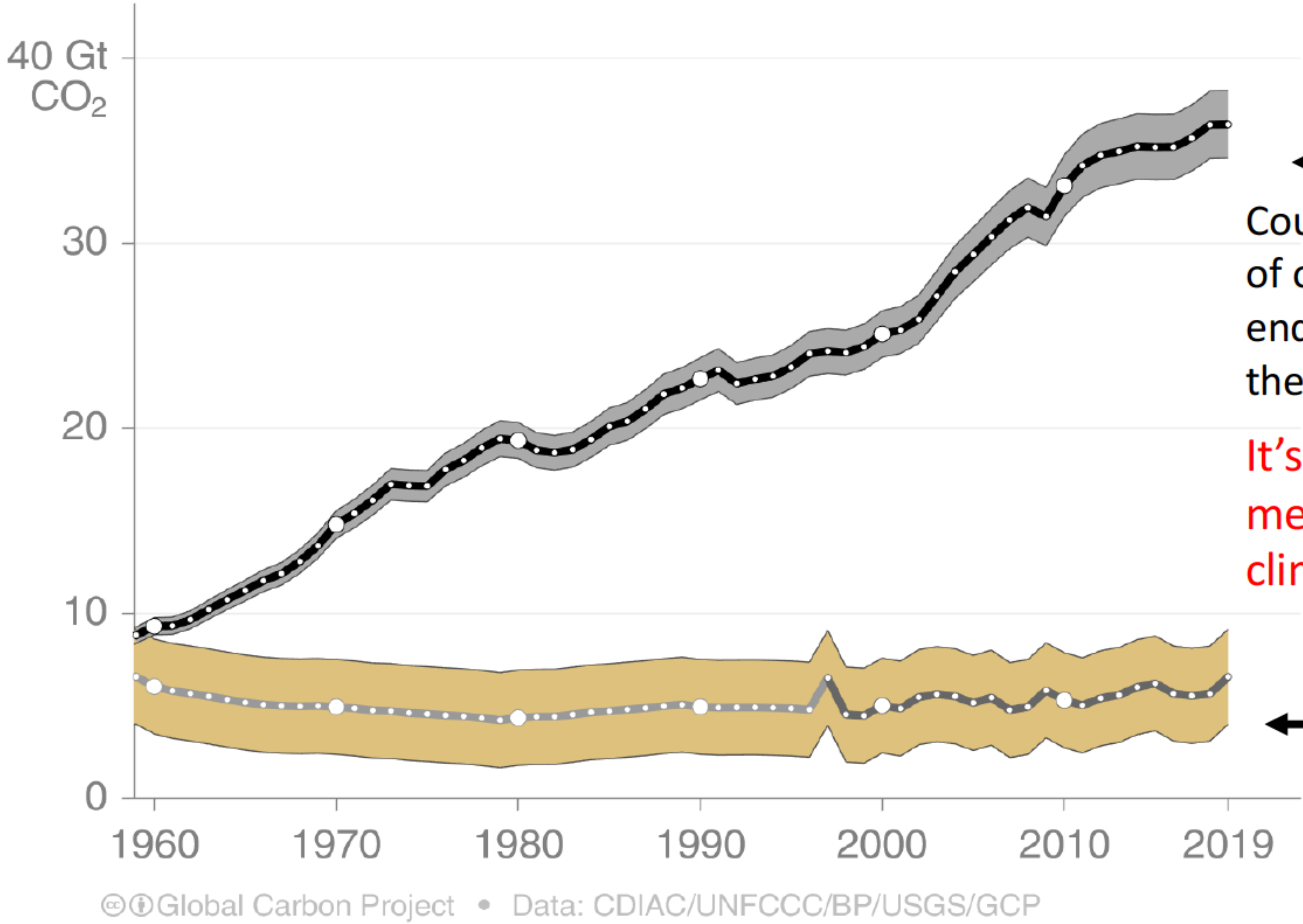
1.2°C: (now) Record Drought, Black Summer Fires, Record Floods in NSW
47% of local extinctions in world caused by climate change.

1.5°C: (virtually inevitable by ~2035) Once-in-30-year heatwaves happen every 3 years, NSW summer temps of 2019/20 = an `average summer.'

2.0°C: 50°C summer days in Sydney, 99% of all world's coral reefs gone, Complete ecosystem transformation on 13% of Earth's surface.

3.0°C+: (where world – including Australian – inaction is taking us)
NSW runoff water reduced by 45 to 60% in many areas.
Most world ecosystems destroyed or heavily damaged.
Large areas of world uninhabitable. Entire global economy damaged.

Global Annual CO_2 Emissions



Count emissions by country of origin, by sector, or by end user. In the end, its all the same.

It's fossil carbon (and methane) that is driving climate change.

But what about the Paris Agreement?

- **Nations** that **have committed to reducing emissions by 2030** have done so on average by only **7.5%** (on 2010 levels).
- But what is needed:
  - **30% reduction** by 2030 to limit warming to **2°C** and
  - **55% reduction** by 2030 to limit warming to **1.5°C**.
- Based on current policies as opposed to Paris Agreement pledges, warming could go as high as **3.6°C**.

International Energy Agency's Net Zero Roadmap: No new or extended coal mines from 2021

IEA 2021. Roadmap for the Global Energy Sector, https://www.iea.org/reports/net-zero-by-2050

Regardless of when net zero is reached, the world has a fixed carbon budget for limiting global heating.

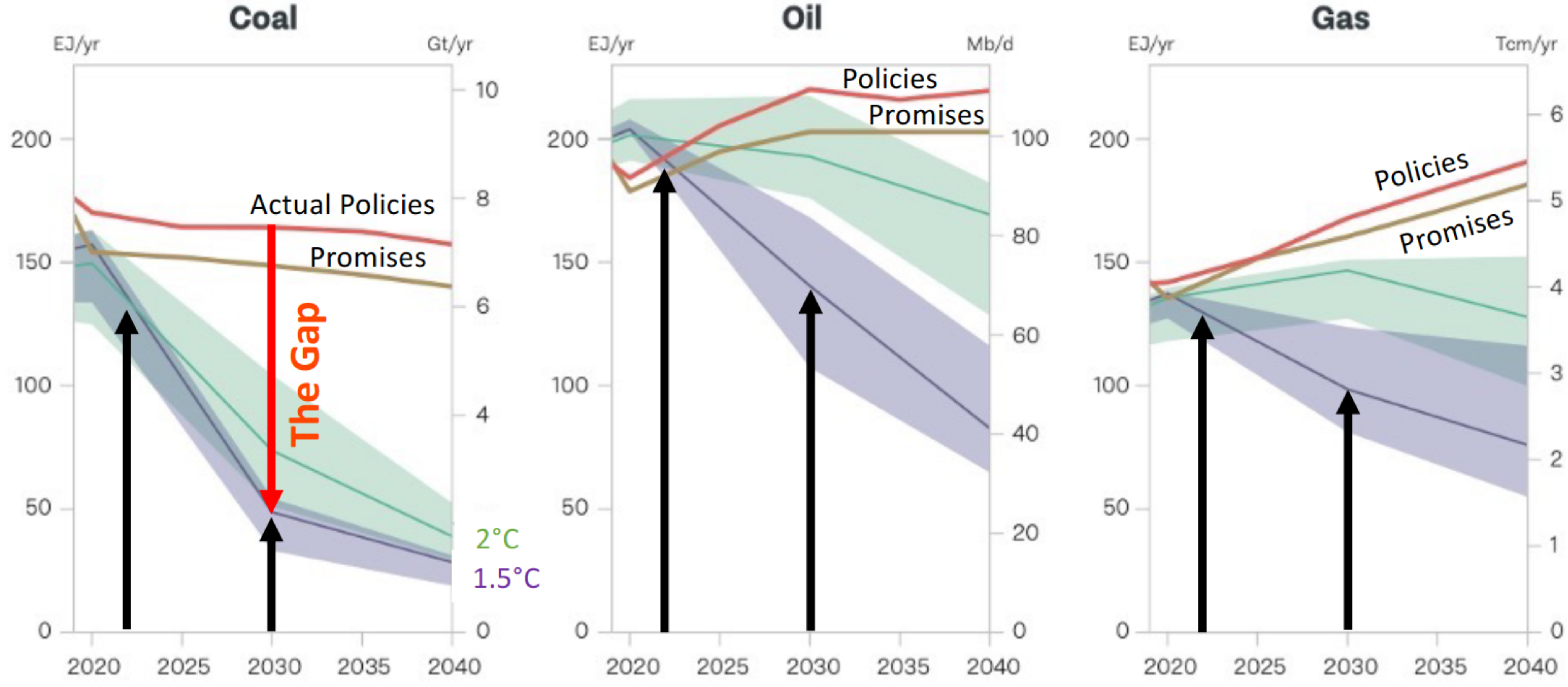
About 8 years remain at current emission levels before the remaining global carbon budget to hold warming to 1.5°C with at least a 67% chance is exhausted.

That's one reason why what we do between now and 2030 is so important.

The Fossil Fuel Gap

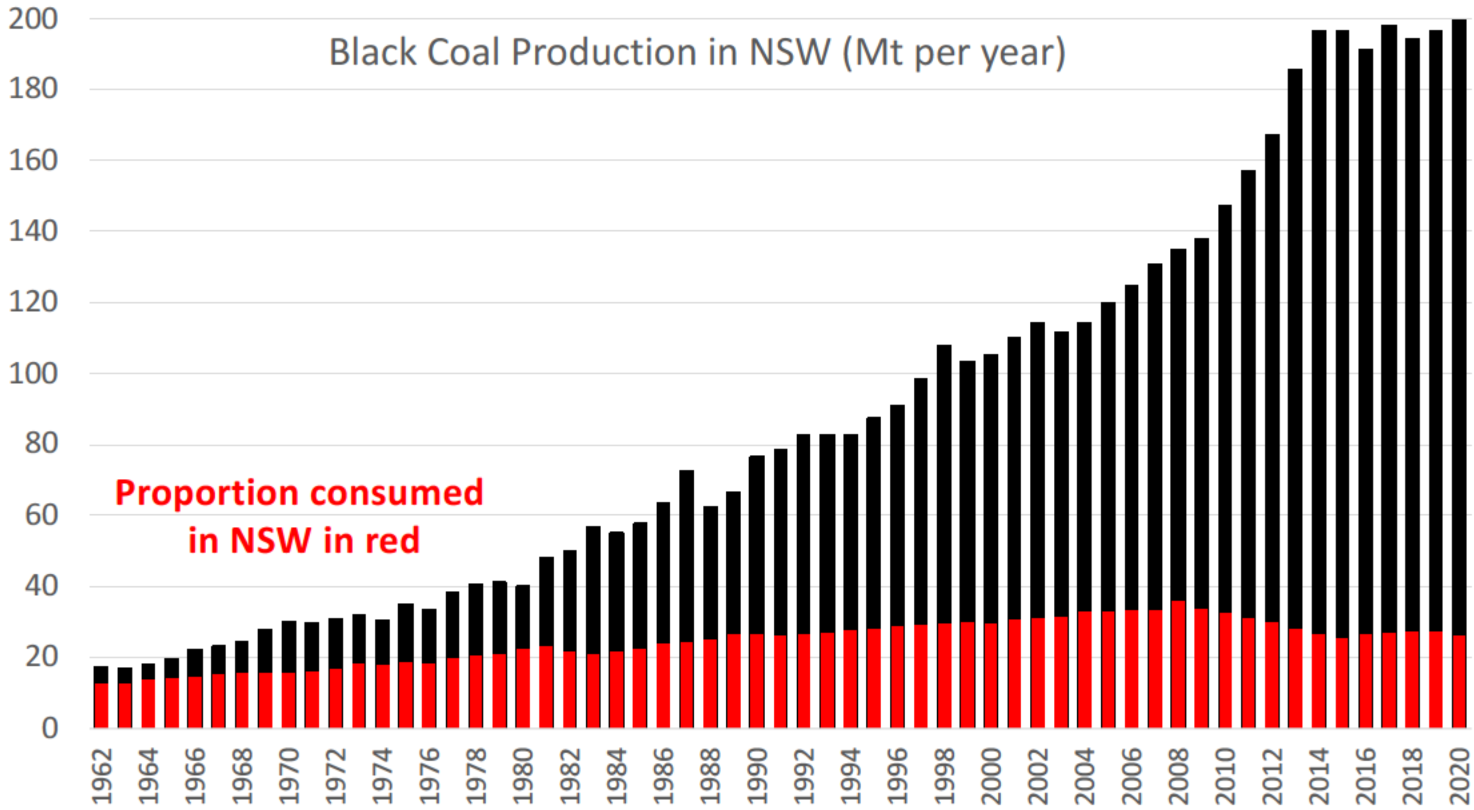
Joint 2021 Report from:
Stockholm Environment Institute, International Institute for Sustainable Development, ODI, E3G, and UN Environment Programme
https://productiongap.org/2021report

50% Chance of Holding Global Warming to 1.5°C
66% Chance of Holding Global Warming to 2°C



Data from Australia Energy Statistics 2021

This trend must reverse starting now in order to be consistent with a future of 1.5°C to 2.0°C global warming

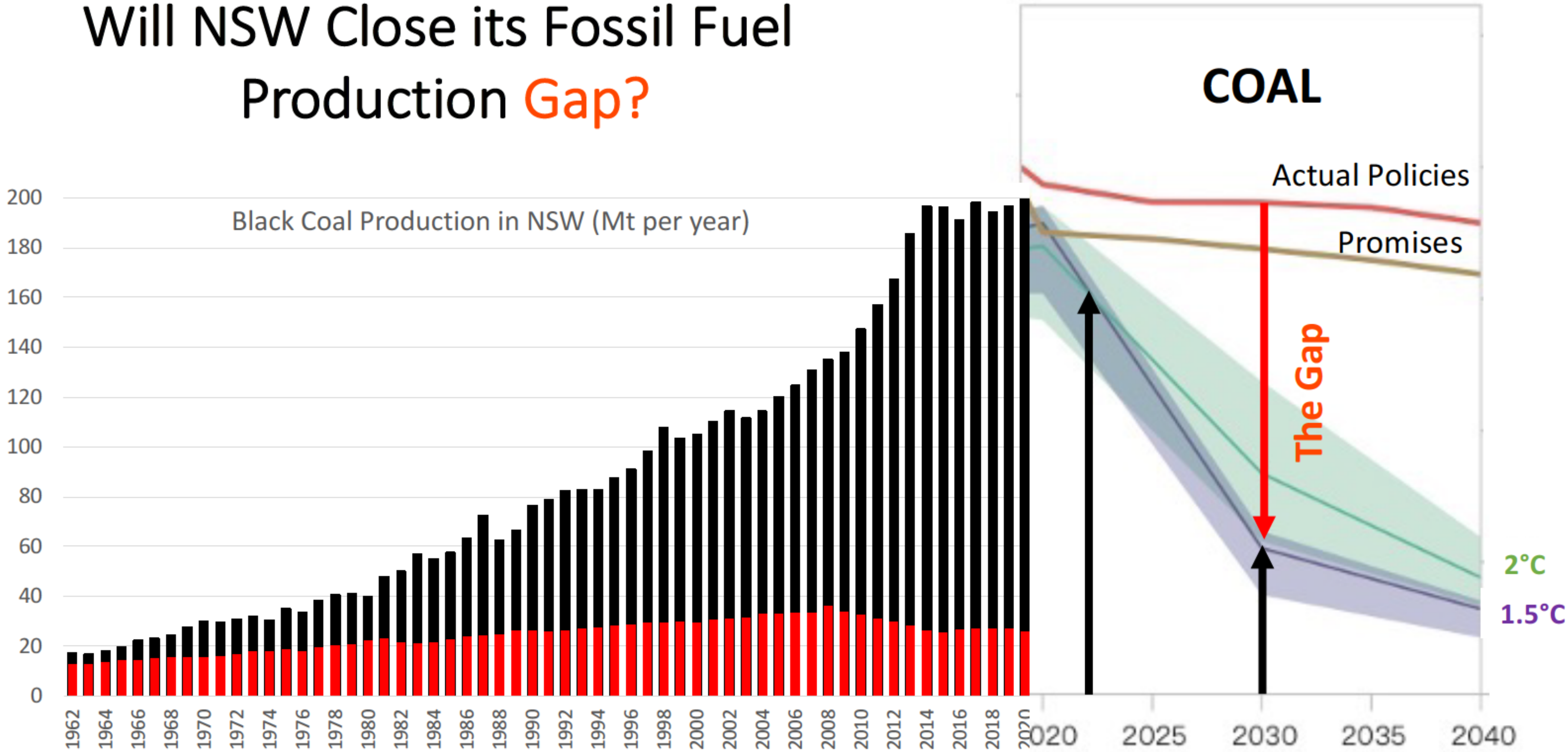


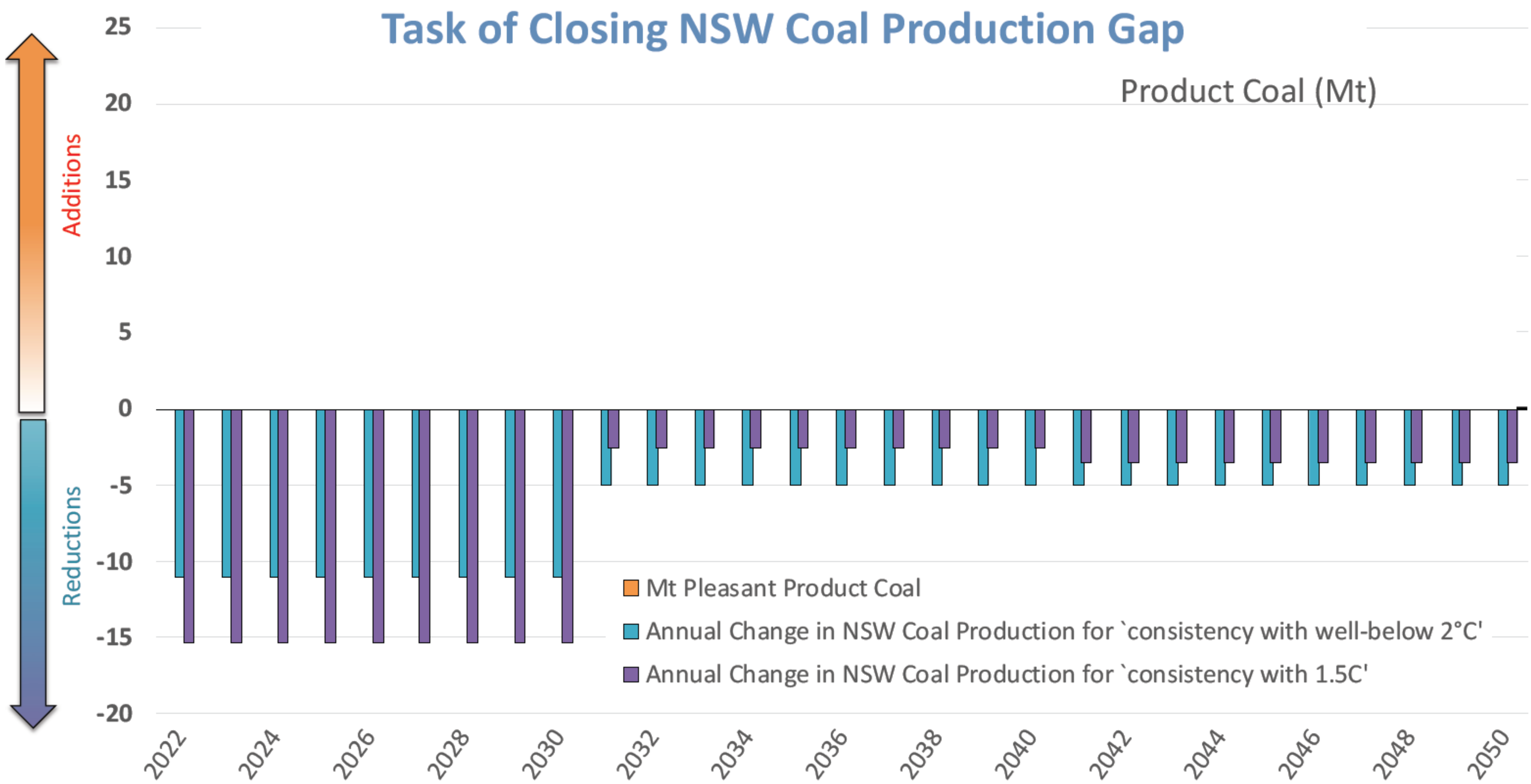
GHG emissions from the combustion of NSW coal (Scope 3)

is 3 times more damaging to the NSW environment

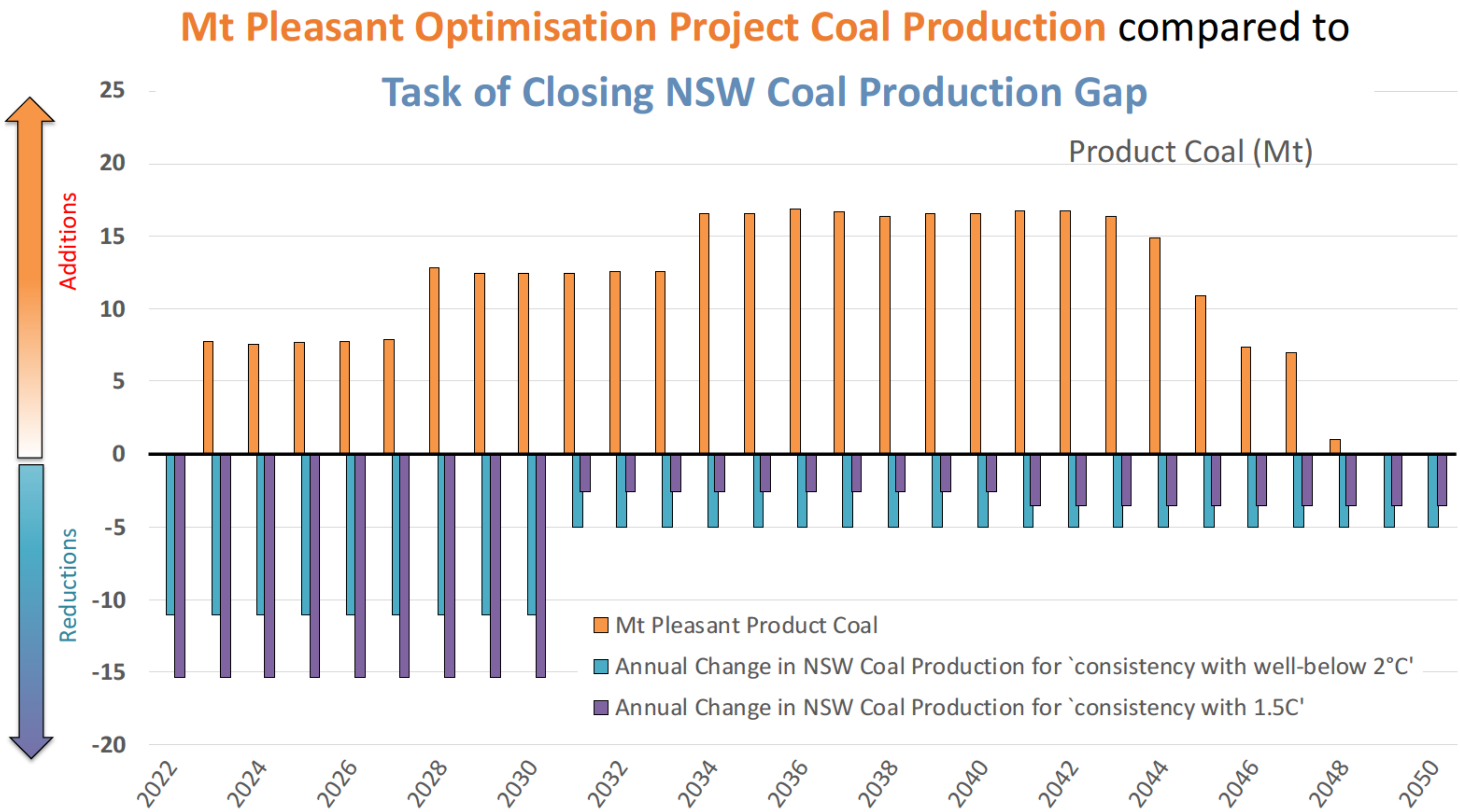
than all of the State's direct emissions (Scope 1) combined

Will NSW Close its Fossil Fuel Production Gap?





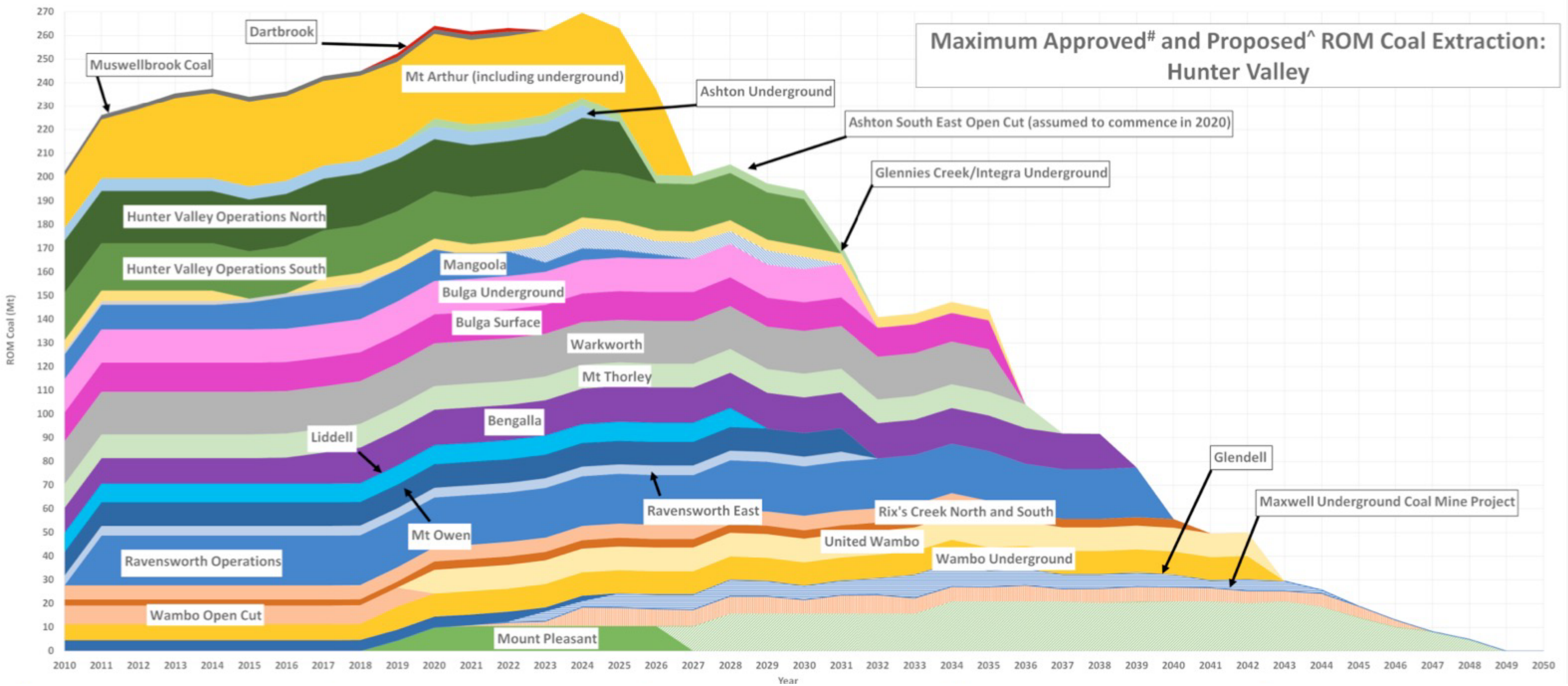
Task of Closing NSW Coal Production Gap
Product Coal (Mt)
Additions
Reductions
25
20
15
10
5
0
-5
-10
-15
-20
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
2042
2044
2046
2048
2050
Mt Pleasant Product Coal
Annual Change in NSW Coal Production for `consistency with well-below 2°C'
Annual Change in NSW Coal Production for `consistency with 1.5C'



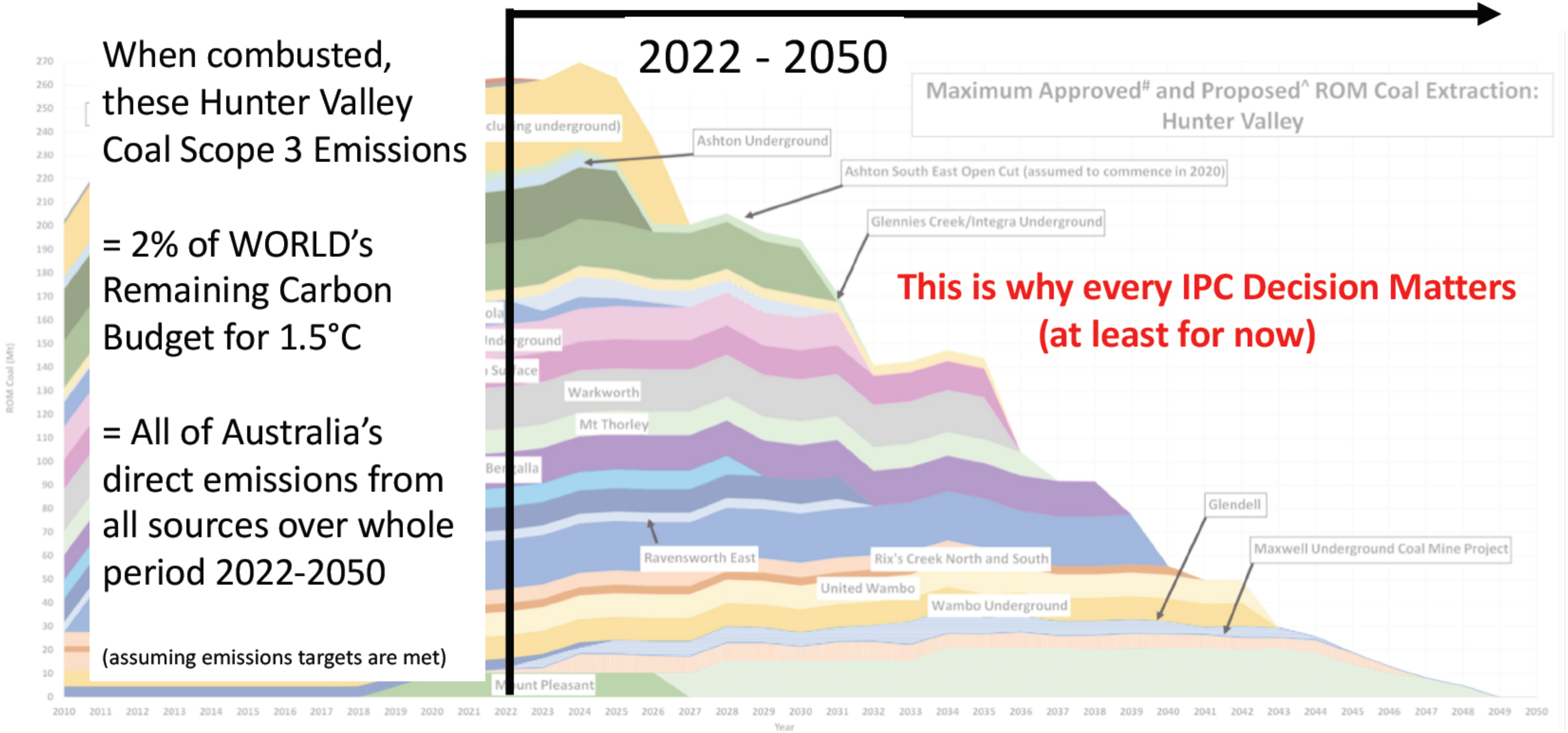
Mt Pleasant Optimisation Project Coal Production compared to
Task of Closing NSW Coal Production Gap
Product Coal (Mt)
Additions
Reductions
25
20
15
10
5
0
-5
-10
-15
-20
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
2042
2044
2046
2048
2050
Mt Pleasant Product Coal
Annual Change in NSW Coal Production for `consistency with well-below 2°C'
Annual Change in NSW Coal Production for `consistency with 1.5C'

Approved and Proposed ROM Hunter Valley Coal Extraction

From Project EIS, Appendix S



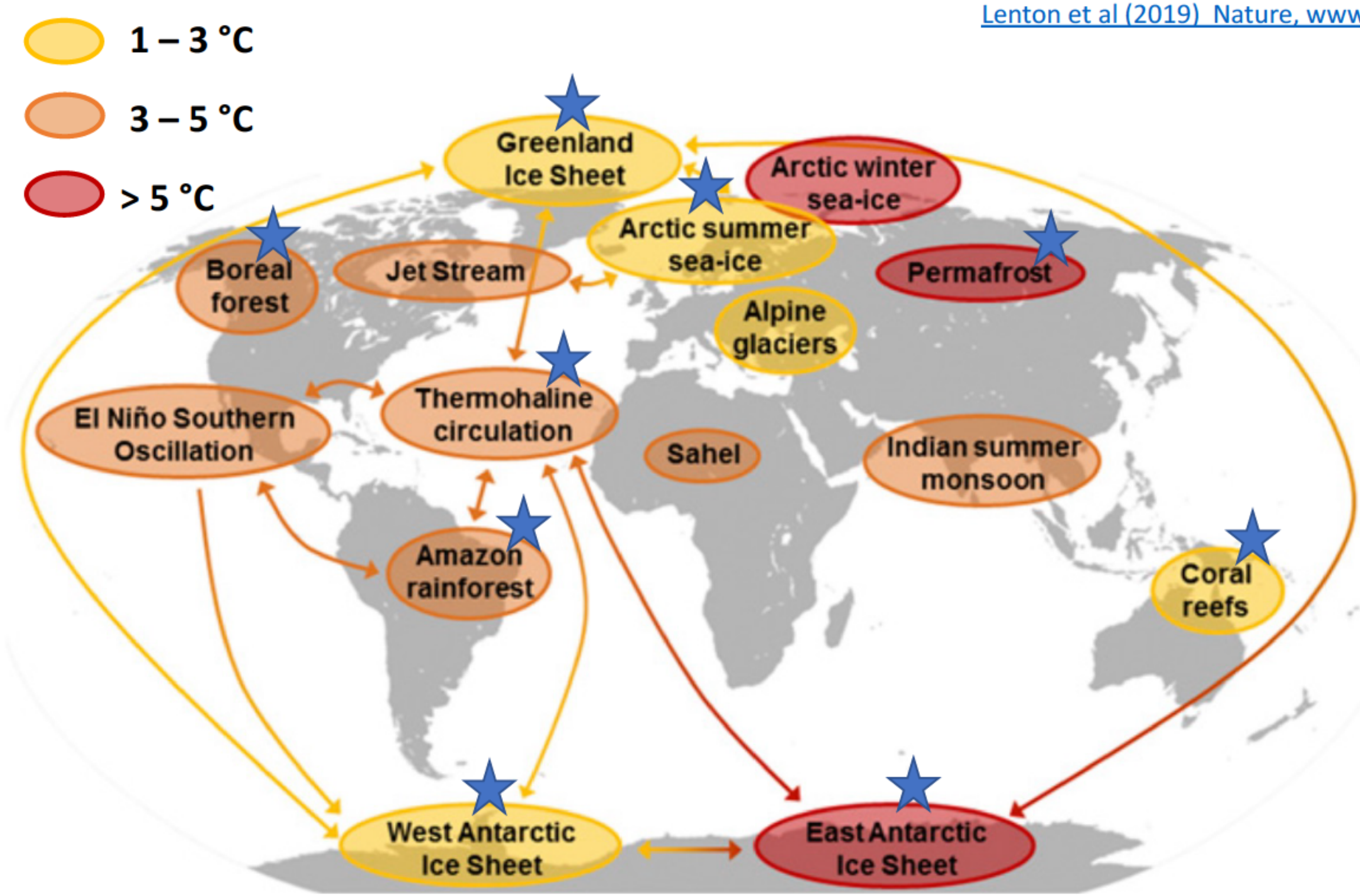
Approved and Proposed ROM Hunter Valley Coal Extraction



Earth System Elements at risk of `tipping:' 9 of 15 are `on the move'★

[Steffen et al (2018) PNAS, www.pnas.org/content/pnas/115/33/8252.full.pdf](http://www.pnas.org/content/pnas/115/33/8252.full.pdf)

[Lenton et al (2019) Nature, www.nature.com/articles/d41586-019-03595-0](http://www.nature.com/articles/d41586-019-03595-0)



If these elements tip and then cascade in a domino effect,

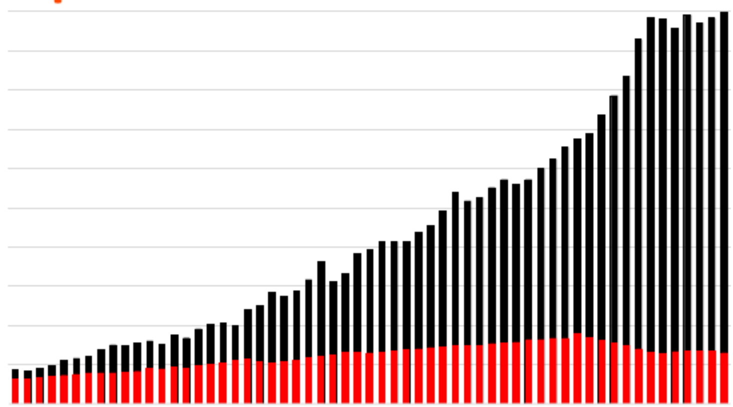
the result could be a `Hothouse Earth'

with temperatures and sea levels not seen since the Stone Age, millions of years ago.

At that point, our climate future would be out of our hands.

Mt Pleasant Optimisation Project:

Greenhouse Gas and Climate Implications



Professor Penny D Sackett
ANU Institute for Climate, Energy and Disaster Solutions
Presented to NSW Independent Planning Commission
8 July 2022