Expert Report on the Greenhouse Gas and Climate Implications of the

Narrabri Gas Project (SSD-6456)

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Advice Provided: 9 August 2020

I Context

1. This report is a response to an expert brief provided to me by Environmental Defenders Office (EDO) acting on behalf of North West Alliance, dated 10 July 2020. I have reviewed Part 31 Division 2 of the *Uniform Civil Procedure Rules 2005* (NSW) and the Expert Witness Code of Conduct which govern the use of expert evidence in NSW Courts, and I agree to be bound by their terms.

2. A brief list of my relevant qualifications includes:

Current:

- Honorary Professor, Climate Change Institute, Australian National University
- Chair, ACT Government Climate Change Council
- Member, Business Advisory Board, ACT Renewable Energy Innovation Fund
- Strategic Scientific Advisor and Principal, *Penny D Sackett Strategic Advisory Services*
- Author of over 135 scientific publications, 65 in refereed journals, together garnering more than 4,300 citations

Previous:

- Member, Scientific Advisory Board, Potsdam Institute for Climate Impact Research
- Chair, Memorandum Team, Nobel Laureate Symposium: *Climate Change,Changing Cities*
- Chief Scientist for Australia (2008-2011)
- Director, Research School of Astronomy and Astrophysics, ANU
- Board of Directors, Association of Universities for Research in Astronomy (AURA)
- Board of Directors, Giant Magellan Telescope Organization (GMTO)
- J Seward Johnson Fellow, Institute of Advanced Study, Princeton, NJ, USA
- PhD in Physics, University of Pittsburgh, USA

II Executive Summary

3. This submission concludes that the Narrabri Gas Project must not proceed on grounds of environmental and climate considerations, responsible stewardship, and social equity for and safety of future generations. Specifically,

   a. Current global warming of 1.1°C is changing the Earth's climate, with negative outcomes for human and environmental health. Warming of more than 2°C would result in even more dangerous adverse impacts, including the possibility of crossing so-called 'tipping points' that would accelerate climate change, perhaps irreversibly.

   b. Australia is a signatory to the UNFCCC Paris Agreement (UN 2015)[1], and thus committed 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."

   c. We now live in a world in which Northern Hemisphere permafrost, frozen for centuries, is melting. A world in which Siberia records temperatures of 38°C. A world in which Australia suffered its hottest and driest year, and a catastrophic bushfire season that killed over a billion animals, 800 million in NSW alone. Even the Paris accord range of 1.5°C to well-below 2.0°C is not 'safe.'

   d. Atmospheric concentration of carbon dioxide (CO_2), the main contributor to climate change, is now higher than any other time that the human species walked the Earth. If current accelerating trends in CO_2 and other greenhouse gases continue over the coming decade, the Earth's mean global temperature is likely to warm by 3°C to 4°C in the next 80 years.

   e. At 4°C of warming, the world's ecosystems would be heavily damaged or destroyed, large areas of the world become uninhabitable, the entire global economy would be damaged, and a sizeable risk would ensue that the Earth system is tipped into a state not seen for millions of years, and beyond humanity's ability to substantially influence.

   f. Fossil fuels are the largest contributor to global warming. Australia exports 7% of fossil fuels by CO_2 potential (CO_2-e) in the world,[2] a remarkable responsibility for a country with only 0.33% of the world's population. Any single source of greenhouse gas emissions is a small fraction of the total, yet the cumulative, shared problem of climate change is enormous and quite possibly existential.

g. About 50% of Australian gas reserves must remain in the ground to achieve a 2°C scenario. Thus, approval of *new* fossil fuel development or expansion is incompatible with keeping global warming to 2°C, and will `lock in' emissions and warming far beyond the end of mining operations. The Paris Agreement commits Australia 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."

h. The Scope 3 emissions from the Narrabri Gas Project will result in direct emissions for Australia, since any gas from the Project will be combusted in Australia. Whilst it is unclear how much of these Scope 3 emissions will be attributed to NSW, the jurisdiction of New South Wales is the only entity that can definitely stop all emissions, direct and indirect, associated with the Narrabri Gas Project from occurring. Thus, from both a local and global environmental protection point of view, NSW is the responsible jurisdiction.

i. At current rates, Australia's and NSW's notional 2°C emission budgets may be expended in 1.5–9 years (Australia), and 2–12 years (NSW), before or just after 2030. This time scale will be shortened by the approval of the Narrabri Gas Project.

j. The Narrabri Gas Project substantially works against achieving Australian and NSW 2030 emission reduction targets. In particular, the Project will *add* about 5 $MtCO_2$ annually to Australia's direct emissions at a time when Australia needs to find about 7.5 $MtCO_2$ *new reduction* every year to meet its 2030 goal, as well as maintaining the reductions found in previous years.

k. Gas is not a transition fuel to a future world that stays well below 2°C of warming[3]. It has only modest GHG gains over coal, and perhaps very little at all when methane emissions are fully and realistically accounted. Its benefits lie predominately in helping to ensure supply security in the short to medium term for a system focused on wind, solar and hydro[4]. New fossil fuel development is not required.

l. The large "production gap" between the intended future production of fossil fuels and the commitment to reduce emissions to keep global warming well-below 2°C means that approving the Narrabri Gas Project is inconsistent with the Paris Agreement.

m. Given that any future emissions "lock in" extra warming, there is no possibility for true "remediation" to current or future generations of the climate damages caused by emissions from Narrabri Gas Project.

III Anthropogenic climate change and its impacts

Greenhouse gases and climate change

4. Greenhouse gases (GHGs) trap some of the heat from the Sun that would otherwise escape from Earth's upper atmosphere; this heat warms the lower atmosphere and the surface of the Earth.

5. Anthropogenic climate change is change in the Earth's climate caused by human activities that release additional greenhouse gases into the atmosphere or alter the natural land and ocean sinks for these gases.

6. **Human activities are** upsetting a long-standing balance, **adding energy that fuels current changes in the global climate** (Intergovernmental Panel on Climate Change, or IPCC, 2013)[5]. **The primary greenhouse gases** driving current anthropogenic (human-caused) climate change **are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O)**.

7. According to a World Meteorology Organisation (WMO) analysis[6] based on five global datasets, **the global mean temperature for 2019 was 1.1°C above pre-industrial levels**. The past five years are the five warmest on record, and the past decade, 2010–2019, is also the warmest on record. Since the 1980s, each successive decade has been warmer than any preceding one since 1850. **Since 1978, no year has had a global mean temperature below the 1961–1990 average**[7].

8. Since 1970, the global average surface temperature has been rising at a rate of 2.0°C per century (NOAA 2016, IPCC SR 1.5, 2018)[8,9]. This is about 200 times faster than the average rate of change of about 0.01°C per century for the last 7,000 years (Marcott et al. 2013)[10].

9. Excess amounts of CH_4 and N_2O persist in the atmosphere for about 12 and 120 years, respectively. The life cycle of atmospheric CO_2 is more complex. **Carbon dioxide that is not absorbed quickly by ocean and land 'sinks' will remain in the atmosphere for thousands of years** (IPCC 2003)[11].

10. While 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 and present emissions is yet to be felt**.

11. **Even if world emissions dropped permanently to zero tomorrow, warming would continue to increase by a few tenths of a degree** due to the inertia in the Earth system responding to historical emissions (IPCC SR 1.5, 2018);[12] so that even with this extreme emissions

reduction, a drop in global temperatures might not be reliably detectable until 2035 to 2040 (Samset et al. 2020)[13].

Greenhouse gases and fossil fuels

12. Increased concentration of CO_2 in the atmosphere caused by human activity is the most important contributor to global warming and climate change (IPCC 2013, SPM)[14].

13. Atmospheric concentrations of CO_2, CH_4 and N_2O have risen since the industrial revolution, with a dramatic upward change of annual increase of CO_2 beginning around 1960 (Figure 1, below).

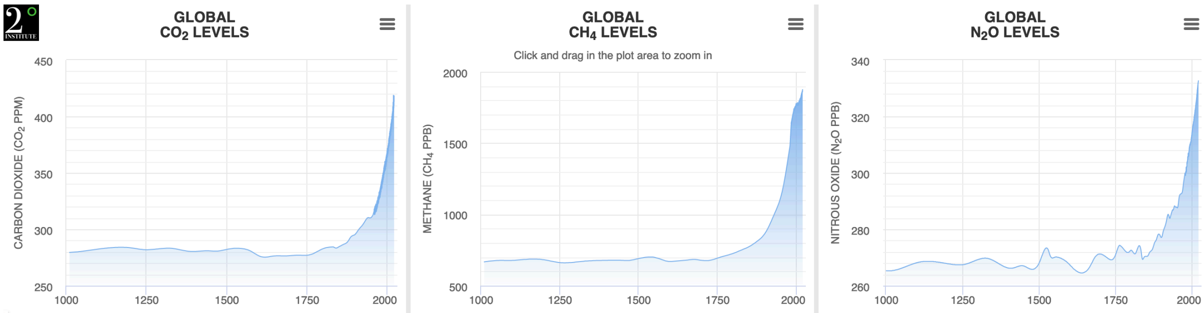

Figure 1: The rise of GHGs in the atmosphere from 1000AD to present is shown. Graph prepared by the Two Degree Institute, based on ice core records (CSIRO) and in situ measurements (Scripps Institute of Oceanography).

14. **Current levels of CO_2, CH_4 and N_2O in the atmosphere are 146%, 257% and 122%, respectively, of their pre-industrial levels** around 1850 (WMO 2019)[15].

15. 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 3 million years ago (Fedorov et al, 2013)[16]. For perspective, the species *Homo sapiens* (modern human) is believed to have arisen only 300,000 to 600,000 years ago. In other words, **carbon dioxide levels are higher now than any other time our species has inhabited the Earth**.

16. The growing trend in emissions continues: year-on-year CO_2 emissions from fossil fuels are now more than 300% of their value in the 1960s (Friedlingstein et al. 2019, their Table 6)[17].

17. **At present, 85-90% of the additional CO_2 emitted per year is from the burning of fossil fuels: coal, gas, and oil** (Le Quéré, C et al. 2018, their Table 6, Friedlingstein et al. 2019, their Table 6)[18,19].

18. CO_2 emissions from fossil fuel sources all continue to rise, despite what was thought to have been a peak for coal around 2013 (WMO 2019).[20] (Figure 2 below, provided by GCP 2019)[21]. **CO_2 emissions from gas are growing faster than from coal or oil.**

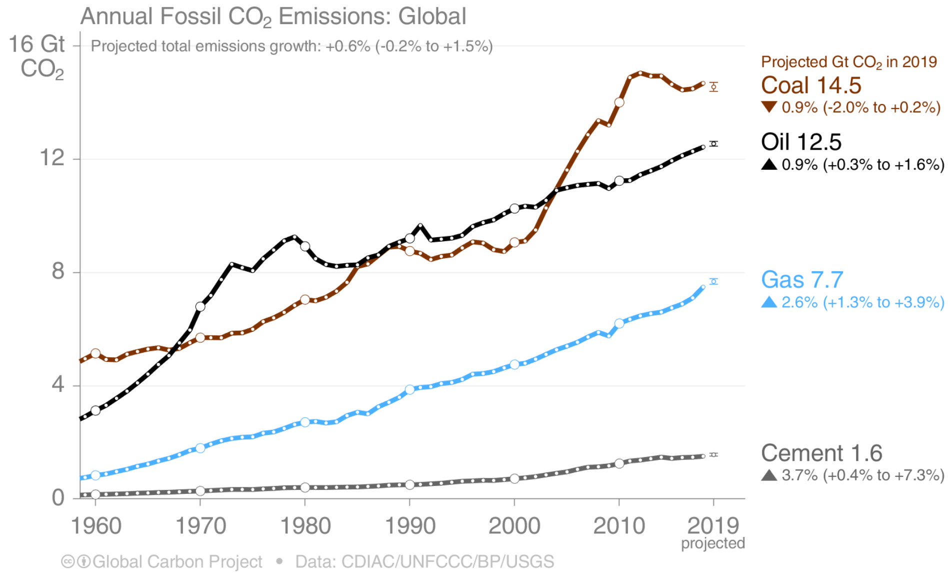

Figure 2: Global annual CO2 emissions from fossil fuels and cement production.

19. The **production, delivery and combustion of fossil fuels are also associated with the release of CH_4** (WMO 2019)[22].

20. Due to their different chemical properties and residency times in the atmosphere, GHGs have different global warming potentials (GWP), that is, they differ in the amount of heat they trap over a given period of time after they are emitted. **Over a 20-year period, methane is 84 times more effective than CO_2 in trapping heat, and 28 times more effective over 100 years** (IPCC 2015)[23].

Current impacts of climate change

21. **The current effects of climate change worldwide are substantial and costly**. These include (IPCC 2014)[24]: increased severity of storms and heat waves, species extinction, wild fires, coastal inundation from rising sea levels and increased storm surge, and the **possibility of crossing so-called 'tipping points' that would accelerate climate change** and greatly intensify its impacts (Schellnhuber et al 2016)[25], **perhaps irreversibly.**

22. Global effects of climate change are already occurring (WMO 2019[26], IPCC SPM 2013[27]):

    a. **Accelerating sea-level rise**, with the observed global rate increasing 25% over the last decade, from 3.04 millimeters 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**, affecting 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 Australia, the 2019/20 bushfires were the worst on record on many measures (Hughes et al 2020)[28], causing over one billion animals to perish[29]. A first analysis[30] suggests that the fire weather associated with the Australian fires has increased at least 30% since 1900 due to climate change, and that similar weather would be at least four times more likely if global warming reaches 2°C.

d. **Hotter days and warmer nights** over most land areas. Globally, July 2019 was the hottest month on record.

e. **Intensification of the hydrological cycle**: increases in the frequency, intensity and amount of heavy precipitation in many areas, and increases in the intensity and duration of drought in other regions (especially since 1970).

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

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

23. **Australia is witnessing serious climate-related impacts now**. The CSIRO and the Australian Bureau of Meteorology report (CSIRO/BOM 2018, and BOM 2020)[31,32] that:

a. **All years since 2013 have been amongst the ten warmest on record** for Australia.

b. Very warm day- and night-time temperatures that occurred only 2% of the time in past (1951-1980), now occur six times more frequently (2003-2017). As a result, the frequency of extreme heat events is increasing. (See Figure 3 below, from CSIRO/BOM 2018.)[33]

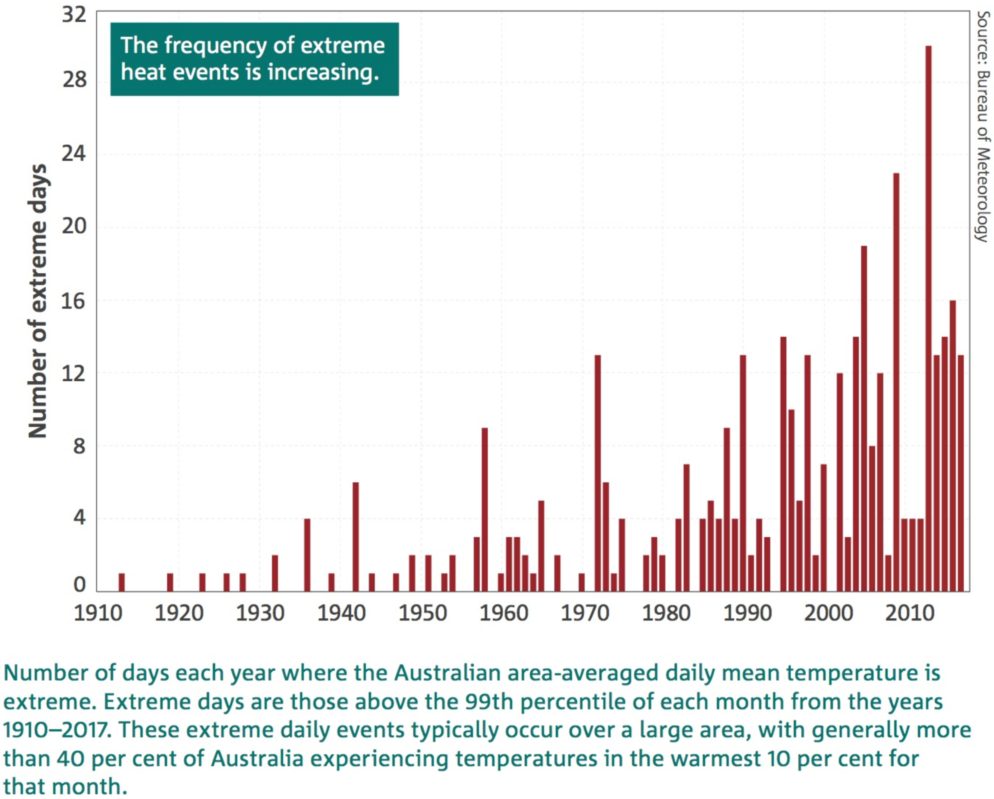

Figure 3: Number of extreme (at 99th percentile) heat days from 1910 to 2017.

c. April to October rainfall has decreased in the southwest of Australia. May–July rainfall has seen the largest decrease, by around 20% since 1970.

d. **Cool-season rainfall has declined in southeast** and southwest Australia, while it has increased in northern Australia.

e. The observed long-term **reduction in rainfall across southern Australia has led to even greater reductions in stream flows**, with four major drainage divisions (**including the Murray–Darling Basin, which contains Narrabri**) showing a declining trend since the 1970s.

f. More of the total annual rainfall in recent decades has come from heavy rain days.

g. **2019 was Australia's warmest year on record**, with the annual national mean temperature 1.52°C above the 1961-1990 average, above the old record of +1.33°C in 2013. **It was also the driest on record**; nationally-averaged rainfall for 2019 was 40% below the 1961–1990 average. (See Figure 4 below.) **These extreme areas include the Narrabri region**.

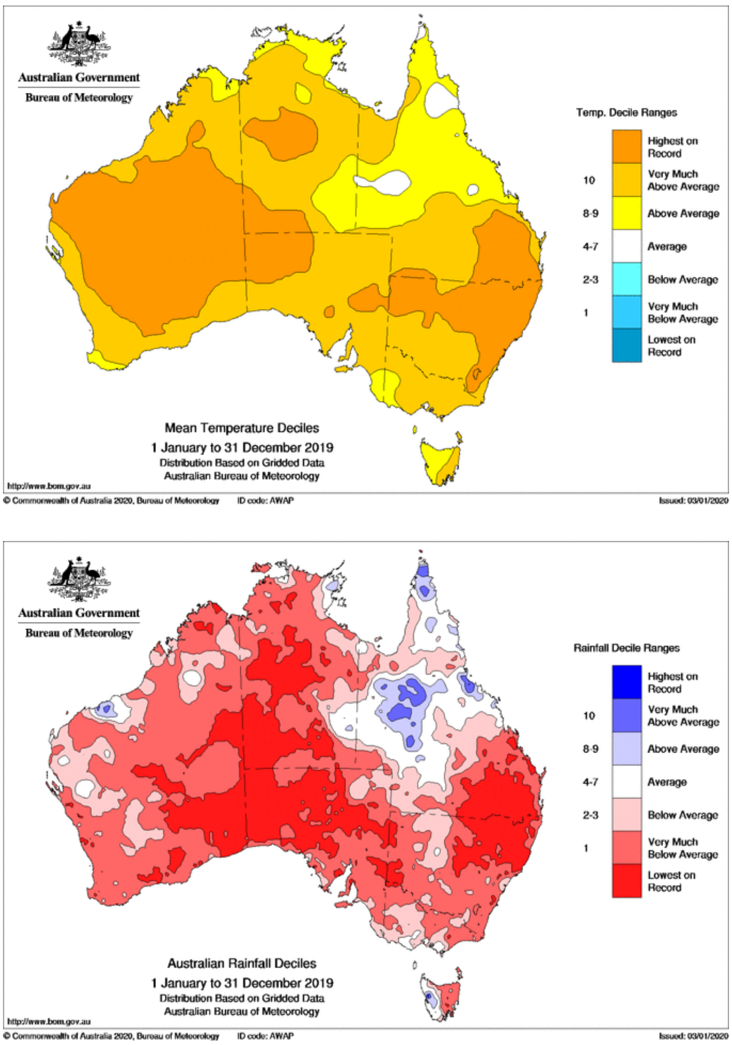

Figure 4: Areas in Australia that experienced their highest ever recorded temperatures (bright orange, top) and lowest ever recorded rainfall (dark red, bottom) in 2019.

h. The **severity of the long and intense marine heat waves** in the Tasman Sea and around southeast Australia and Tasmania from September 2015 to May 2016 and from November 2017 to March 2018, can be attributed to anthropogenic climate change and are **linked to coral bleaching in the Great Barrier Reef**.

i. A **long-term increase in extreme fire weather**, and fire season length, has occurred across large parts of Australia. **In 2019, the national annual accumulated Forest Fire Danger Index (FFDI) was its highest since 1950**, when national records began.

j. The average pH (a measure of alkalinity) of surface waters around Australia has decreased since the 1880s by about 0.1, corresponding to **a more than 30% increase in ocean acidity, which impacts the entire marine ecosystem. The current rate of change is ten times faster than at any time in the past 300 million years**.

24. Most all of these **climate change impacts are being felt in New South Wales, many to an even larger degree than the national average.**[34,35] In particular:

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.

b. The five warmest years on record for NSW are 2019, 2018, 2014, 2017 and 2009.

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

d. **Total rainfall for NSW was the lowest on record in 2019 at 55% below average**; well below the previous driest year of 1944.

e. **Rainfall** on the most recent 2- to 3-year timescales **in northern inland New South Wales, containing the Narrabri region, has been near or below previous record low values**[36], many of them set during the Federation Drought in 1900–1902. The extent and timing of the dry conditions meant **that agriculture was particularly affected with the top 100cm of soil at record moisture lows at** many locations, including **Narrabri** (see Fig. 5).

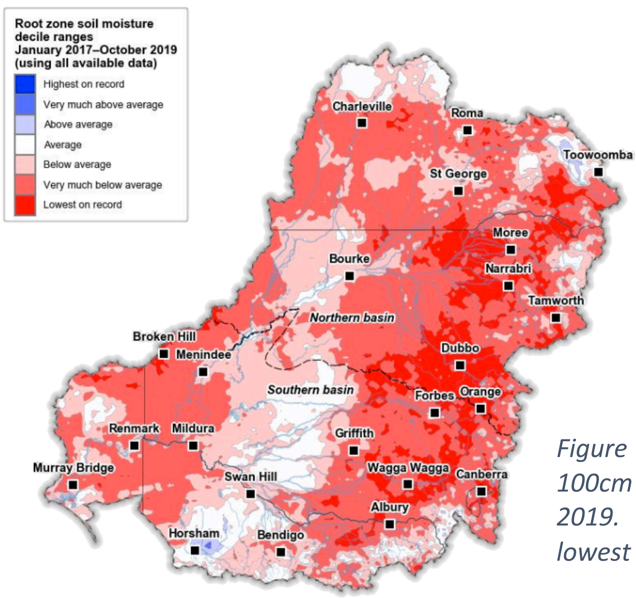

Figure 5: Root zone soil moisture in top 100cm of soil for period Jan 2017 – Oct 2019. The Narrabri region experienced lowest on record levels in this time frame.

IV Future climate change and climate risk

25. 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** (WMO 2019).[37]

26. On a simplified level, future climate change can be projected on the basis of different scenarios for future anthropogenic GHG emission trajectories. Greenhouse gas emissions **targets are useful in estimating future climate change only to the extent that the targets are achieved, year after year**.

27. **Other determinants 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. This is a risk of the highest order, and is discussed in its own subsection.

Projections of future climate change and its effects

28. The CSIRO and BOM (CSIRO/BOM 2018)[38] report that **Australia will experience climate effects more extreme than those currently at play**, including:

    a. Further increase in temperatures, with **more hot days and fewer cool days**.

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

    c. More frequent, extensive, intense and longer-lasting marine heat waves, increasing bleaching of the Great Barrier Reef (GBR). **At 2°C warming, global coral reefs, including the GBR, are very likely to be eliminated** (IPCC SR1.5)[39].

    d. A decrease in cool-season rainfall across many regions of southern Australia, with **more time spent in drought**.

    e. More intense heavy rainfall throughout Australia, particularly for **short-duration extreme rainfall events**.

    f. An **increase in the number of high fire weather danger days and a longer fire season for southern and eastern Australia**.

    g. Fewer tropical cyclones, but a greater proportion of high-intensity storms, with ongoing large variations from year to year.

29. **The regional area of the proposed Narrabri Gas Project** is situated in the Central Slopes cluster region[40] used to project more local future effects of climate change. Based on work by the CSIRO and BoM, **future climate projections** for this region include:

a. Average **temperatures will continue to increase in all seasons** (*very high confidence*).

b. **More hot days and warm spells** are projected with *very high confidence*. **Fewer frosts** are projected with *high confidence*.

c. Average **winter rainfall is projected to decrease** with *high confidence*.

d. **Increased intensity of extreme rainfall events** is projected, with *high confidence*.

e. A **harsher fire-weather climate** in the future (*high confidence*).

30. Climate projections depend on the speed with which global emissions (predominately from fossil fuels) evolve. **If the trend of rising emissions is continued**, the world will be on a pathway similar to the scenarios[41] labeled RCP6.0 and RCP8.5 by the IPCC (Collins et al. 2013[42], based on extrapolation of observed emissions trend in Le Quéré et al. 2018[43], and consistent with Climate Action Tracker, 2019[44]). In this case, **global warming can be expected to be +4°C in just 80 years**. The current average warming is about 1.1C.

31. **Climate impacts are hitting harder and sooner than previous scientific assessments have expected.** Over two decades, the IPCC has published a series of science-based risk assessments for people, ecosystems and economies worldwide. **A comparison of these "Reasons for Concern"** (see Figure 6 below, based on WMO 2019)[45] **shows that the level of risk has increased with each subsequent analysis from 2001 to 2018**.

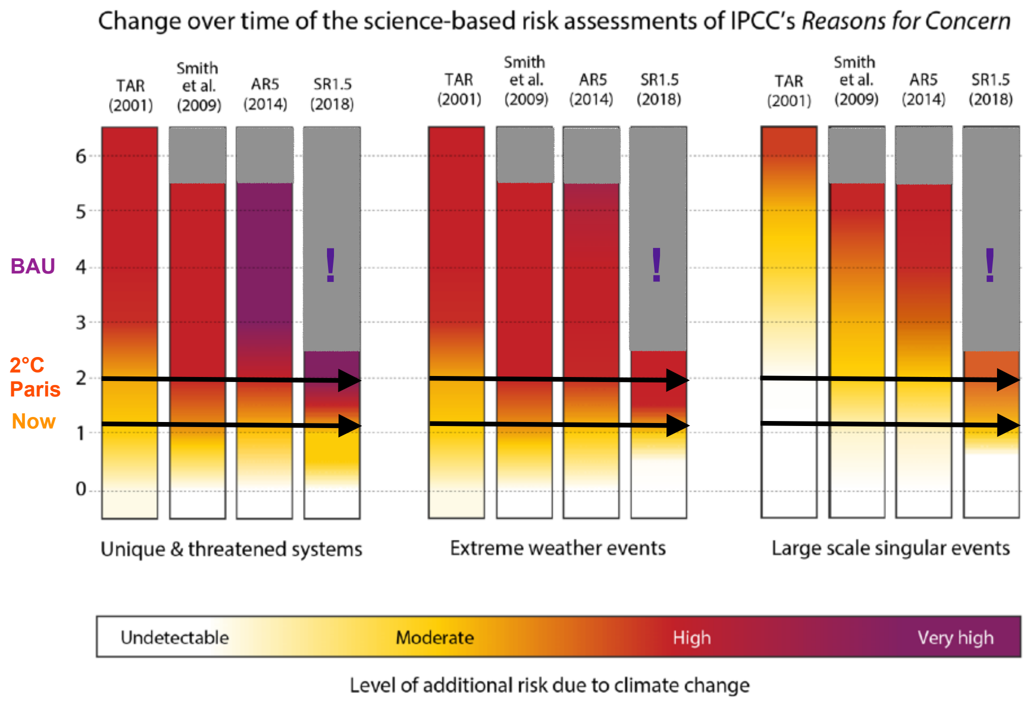

Figure 6: Global warming above pre-industrial temperatures climbs moving vertically upward. Indicated are the present (marked as "now" at 1.1°C), a 2°C scenario, and "business as usual" at about 4°C. Time of publication increases as the arrows move from left to right in each of the three impact regimes. Later IPCC reports (up to 2018) indicate higher risks (deeper, dark colours) than did earlier reports at the same temperature. (Areas marked in grey have not been formally assessed by the indicated IPCC report, but clearly lie in the high to very high risk regime.)

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

33. Already we know that **even the Paris accord range of 1.5°C to well below 2.0°C is not 'safe.'** 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 Figure 6 shows.

34. **At 4°C of warming (a consequence of continuing on our current path), today's world would be nearly unrecognisable**, with high to very high risk that (IPCC 2014 SPM)[46]:

    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. There is a huge increase in the size and distribution of climate-vulnerable populations, as large areas of the world become uninhabitable, causing migration and conflict to escalate;

    d. Aggregated global impacts significantly damage the entire global economy; and

    e. A moderately high risk of a cascade of intrinsic 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[47].

The greatest climate risk of all: crossing Earth system tipping points

35. The stability of the Earth system is influenced by feedbacks between the climate system and carbon-regulating processes such as frozen permafrost soils or carbon uptake by forests. Many biosphere feedback processes are losing strength, increasing the **risk that self-reinforcing mechanisms will counter efforts to mitigate further climate change, and instead accelerate it** (WMO 2019)[48].

36. **Tipping points[49] in the Earth System refer to thresholds that, if crossed, would lead to far-reaching, and, in some cases, abrupt and/or irreversible changes.** Examples[50] range from the release of CH_4 from ocean methane hydrates, which is likely to take place slowly over millennia, to the total loss of Arctic sea ice in summer, which on current trends is likely to happen between 2040 and 2050.

37. **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"**[51]. In this future, average

temperatures will rise to match those not seen since the beginning of the Stone Age, millions of years ago, with devastating consequences.

38. **It is uncertain precisely where this "Hothouse" threshold lies, but it could be as close as a few decades away,** that is, at or just beyond 2°C of warming[52].

Global, national and state-level emission targets

39. **Australia** is a signatory to the UNFCCC Paris Agreement (UN 2015)[53], and thus **committed 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**."

40. Individual signatory nations have made separate Nationally Determined Contributions (NDCs) to meet the Paris goals.

41. At present, it is estimated that the **current NDCs, if achieved, would result in global warming between 2.9°C and 3.4°C** by 2100 relative to pre-industrial levels, and continuing thereafter (WMO 2019)[54]. That is, **current commitments are not sufficient to hold warming to 2°C, let alone well below 2°C. Current levels of NDC ambition must be roughly tripled for global emission reduction to be in line with even a 2°C scenario**(WMO 2019)[55].

42. Despite this, **most nations are not on-track to meet their current commitments**, which if not corrected immediately, would result in even more warming.

43. As a nation, Australia's NDC is to reduce its emissions by 26%–28% (on 2005 levels) by 2030 (Commonwealth of Australia Factsheet)[56], which according to Government documents translates to a 2030 target of 440–452 MtCO_2-e.[1] **Australia's 2030 target has been rated "Insufficient" to hold global warming to below 2°C** (Climate Action Tracker, 2019)[57].

44. Australia's **current emissions *policy trajectory* has been rated "Highly Insufficient,"** as it is estimated that **if all nations were to follow its lead, global warming would lie in the range 3°C to 4°C above pre-industrial times** in 80 years (Climate Action Tracker, 2019)[58].

45. Expert analysis by Australia's Climate Change Authority (CCA 2015)[59] also judged Australia's 2030 target inadequate to meet the nation's obligations under the Paris accord.

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

46. **Moreover, Australia is not on track to meet its 2030 Paris commitment**. The Government's own 2018 projections (Australian Government 2018)[60] indicate emissions of 563 MtCO_2-e in 2030, a reduction of only 7–8% on 2005 levels, with most of that reduction coming from projected changes in land use, a sector highly vulnerable to sequestration reversal through wildfires.

47. In its more recent projections (Australian Government 2019),[61] the **Government relies on an "over-achievement" of its 2020 target to reduce its task to 2030. This has no basis in science**, as the carbon budget (see Section IV) at any given time is already reduced by past emissions. **Discounting this leaves a total abatement task for the Australian 2030 target**, on the Government's own projections, of between 395 Mt CO_2-e (26% reduction) and 462 Mt CO_2-e (28% reduction) over the period 2021 to 2030, or **about 40 to 46 Mt CO_2-e annually over this period**.

48. **Notable is that every state and territory in Australia has now set a net zero emissions target of 2050 or earlier,[62] resulting in a *de facto* national target** at this level.

49. In particular, **New South Wales has set an objective[63] of reducing its greenhouse gas emissions by 35% on 2005 levels by 2030**, and to reach net zero emissions by 2050. Reaching net zero emissions by 2050 will only be consistent with the Paris Agreement if rapid reductions in emissions are begun now, as will become clearer in the next section on so-called 'carbon budgets.'

V The 'carbon budget approach' to stabilising the climate

50. So how does one estimate the change needed to limit global warming fast enough to meet the Paris targets and stabilise the climate? 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**, for example the Paris Accord target range of 1.5°C to "well below" 2°C of warming. (Collins et al 2013)[64]. This approach was adopted by the Climate Change Authority to form its 2015 recommendations (CCA 2015)[65].

51. It is **reasonable to assume that human actions may have already committed the world to global warming above the aspirational Paris goal of 1.5°C**. A few tenths of a degree of additional warming from the present 1.1°C are already locked in from GHG gases already emitted (SR1.5 2018, Fig 1.5)[66].

52. Work led by the UK Met Office shows **there is a 20% chance that the world will see global average +1.5°C warming (at least temporarily) in the next 5 years** (WMO 2020[67]). As land temperatures rise faster than ocean temperatures, many land locations will record 1.5°C warming first, as in fact Australia experienced just this last year. For these reasons, **the carbon budget for 2.0°C is primarily considered here**. **The Paris Agreement 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**.

The Global Carbon Budget until Net Zero Emissions Reached to hold warming to 2°C

53. 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 between (see Figure 7, taken from IPCC SPM 2013.)[68]

    a. The **'carbon budget':** that is, the cumulative amount of carbon[69] emitted 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.

54. **The budget is not annual, but cumulative: for all time—past, present and future. Once the carbon budget has been 'spent' (emitted as greenhouse gases), emissions must be held to net zero[70]** from that point onward in order to avoid exceeding the target temperature.

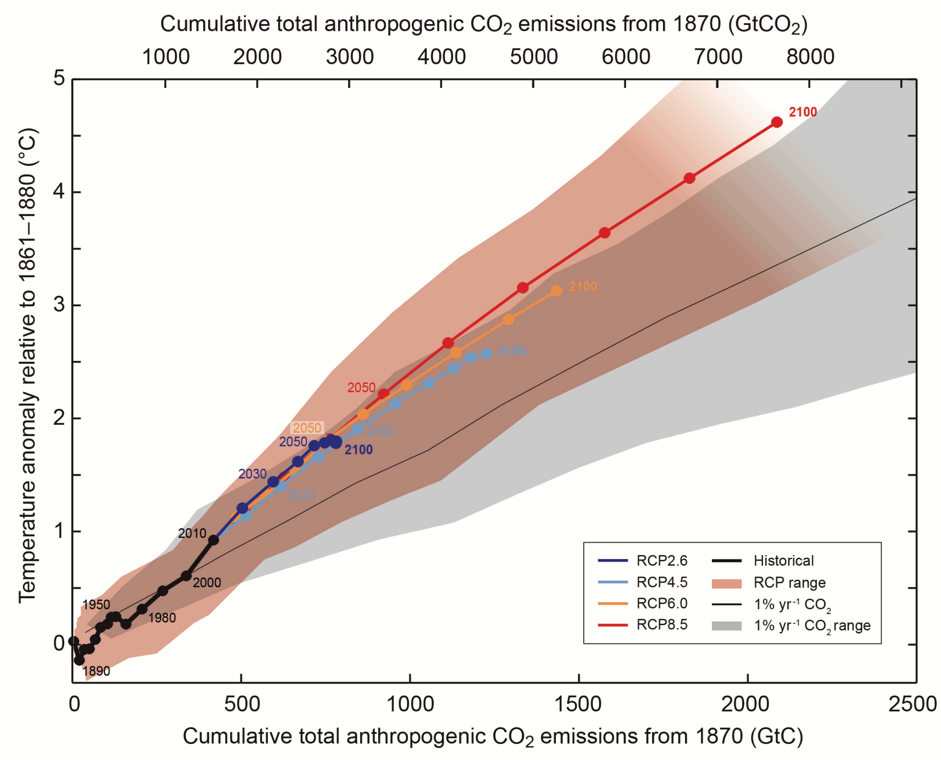

Figure 7: Relationship between warming (vertical axis) and total carbon emitted (in billions of tonnes, GtC) since 1970 by humans (horizontal axis). The black line shows historical emissions, and coloured lines show projections based on different scenarios of future human emissions.

55. 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,

    e. Accounting for feedbacks in the climate system, that is, how warming causes the Earth system to release some of its own sequestered CO_2.

56. **Here, a conservative, precautionary application of these assumptions is used to determine a carbon budget for a 2°C scenario**. Temporary overshoot is disallowed, feedbacks are included, and a 66% probability of meeting the target is required. Two different estimates are given, one based on the most recent full IPCC report, and another on a more recent, but less comprehensive IPCC report.

57. **First, the IPCC AR5 Report** (IPCC SPM 2013)[71] estimates that **in order to have a greater than 66% probability (2 out of 3 chance) of limiting global average temperature rise to no more**

than 2°C, the total human carbon budget since 1870 must not exceed about 1,000 billion tonnes of carbon (1,000 Gt C), emitted as CO_2.

58. However, **the amount humans have 'left to spend' is much less, for three reason**s, described below and presented numerically in Table 1 below, rounded to nearest 5 Gt.

    a. First, **historical emissions** from 1870 through 2018 total about 625 Gt C (Le Quéré et al. 2018)[72]. Subtracting this, and the about 10 Gt C emitted in 2019, **leaves 365 Gt C in the budget for 2020 onwards**.

    b. Second, implicit in simple budget estimates is the assumption that future non-CO_2 emissions will be reduced to zero at the same rate that CO_2 is diminished. This will be difficult to achieve, since most anthropogenic CH_4 and N_2O emissions arise from the agricultural sector, where emission reductions are generally considered to be more difficult and expensive than those in other sectors. If these **non-CO_2 gases** are not reduced to zero as quickly as CO_2, their **effects could consume up to 210 Gt C** (IPCC SPM 2013,[73] page 27) **from the carbon budget, leaving 165 Gt C**.

    c. Third, some carbon cycle feedbacks, such as permafrost melting and the abrupt shift of the Amazon rainforest to a savanna, are not accounted for in the standard carbon budget approach, and require the budget to be reduced further (Ciais et al. 2013)[74]. Quantitative estimates suggest that a 2°C temperature rise would release about 110GtC of additional CO_2 emissions to the atmosphere (Steffen et al. 2018)[75]. These **feedback processes** have already begun. If allowed to run through a warming of 2°C, **would reduce the forward carbon budget to 45 Gt C, beginning at the start of 2020**.

Table 1: Carbon budget for 66% chance of limiting warming to 2°C, based on IPCC 2013

Budget Item	**Global (Gt C)**	**Australia (Mt C)**	**NSW (Mt C)**
Base Budget beginning in 1870	1,000		
Historical emissions through 2019	-635		
All non-CO_2 greenhouse gases	-210		
Carbon feedbacks in Earth system	-110		
Remaining Budget to Net Zero Emissions	**45**	**150**	**50**

59. Humans currently emit about 11.5 Gt C every year (including land use changes), with no signs of slowing[76]. **If this continues, the carbon budget analysis presented in Table 1 indicates that the 2°C budget may be expended in about 4 years** (i.e., a budget of 45 Gt C divided by 11.5 Gt C per year in annual global emissions).

60. **In a later report** (IPCC SR1.5)[77], **the IPCC provided an updated carbon budget analysis.** Estimates of climate sensitivity, pre-industrial temperature levels and treatment of aerosol emissions, which lead to a net cooling effect, were revised. Subsequently, an analysis that

takes into account non-linearity in the carbon budget-warming relationship indicated that the carbon budget may need to be revised upward (Nicholls et al 2020)[78]. Accounting based on these newer results is shown in Table 2, rounded to nearest 5 Gt.

Table 2: Carbon budget for 66% chance of limiting warming to 2°C, based on IPCC SR1.5

Budget Item	**Global (Gt C)**	**Australia (Mt C)**	**NSW (Mt C)**
Base Budget (now beginning 1 Jan 2011; historical emissions pre-2011 have already been deducted)	435		
Historical emissions for 2011 through 2019	-100		
Non-CO_2 greenhouse gases allowance (conservative estimate based on Saunois et al. 2020[79,80])	-50		
Correction due to non-linearity (see Nicholls et al. 2020)	+70		
Carbon feedbacks in Earth system not included[81] in Nicholls et al. 2020	-65		
Remaining Budget to Net Zero Emissions	**290**	**950**	**300**

61. The **range provided by these two separate carbon budget analyses leads to the conclusion** that most of the total 2°C carbon budget has already been spent, and **that without immediate, dramatic action, humanity's remaining 2°C carbon budget may be consumed in about 4 – 25 years**, that is, sometime between about 2023 and 2044.

62. **If greenhouse gases (especially CO_2 and CH_4) can be reduced quickly and continuously, this budget could last longer. Unfortunately, both CO_2 and CH_4 emissions are going in the *opposite* direction, they are rising, year on year.** For that reason, the timescale to bring the world to net zero emissions may actually be shorter than estimated above.

63. In order to extend the deadline to reach net zero emissions whilst simultaneously staying within the 2°C carbon budget, greenhouse gas emissions must be reduced sharply now. The sooner we start and the more sharply we drop emissions, the better chance we have of staying below 2°C.

64. **In order to reach carbon neutrality by 2050** (a commitment all Australian states and territories have made) **on a steady, linear path, world emissions need to peak in 2020, and then decrease by 3.3% of their 2019 level every year,** year-on-year until 2050. This is an annual reduction of about 0.4 GtC (or 1.4Gt CO_2-e) every year. Achieving a steady reduction of this magnitude is not impossible, but is quite challenging. **For comparison, the decrease**

in emissions in 2020 due to COVID-19 range are estimated at 4-7% on 2019 levels (Le Quéré et al 2020[82]).

65. Delaying the date of peak emissions past 2020 will require *even higher* annual reductions down track or acquiescence to losing even a 66% chance of avoiding the dangers of a climate warmer by 2°C or more.

66. It is important to note that these carbon budgets are for 2°C of warming. The Paris agreement is to limit **"global temperature rise** this century **well below 2°C** above pre-industrial levels" and to pursue efforts to limit the rise to 1.5°C.

67. **In order to keep warming to *well below 2°C* with 66% probability, the carbon budgets are smaller and timescales to reach net zero emissions shorter** (SR1.5 2018[83]).

What about a carbon budget for holding warming to 1.5°C?

68. Using an analysis similar to that used to create *the more optimistic* of the two preceding 2°C carbon budgets (i.e., Table 2), it is possible to estimate a 1.5°C carbon budget. Those results are shown in Table 3 below. With current global human emissions at 11.5 GtC every year, Table 3 indicates that **the global 1.5°C budget may be expended in about 3 years**. Unfortunately, it appears that Paris Agreement signatories may have not succeeded in limiting the global temperature rise to 1.5°C.

Table 3: Carbon budget for 66% chance of limiting warming to 1.5°C, based on IPCC SR1.5

Budget Item	**Global (Gt C)**	**Australia (Mt C)**	**NSW (Mt C)**
Base Budget (now beginning 1 Jan 2011; historical emissions pre-2011 have already been deducted)	235		
Historical emissions for 2011 through 2019	-100		
Non-CO_2 greenhouse gases allowance (conservative estimate based on Saunois et al. 2020[84,85])	-50		
Correction due to non-linearity (see Nicholls et al. 2020)	+15		
Carbon feedbacks in Earth system not included[86] in Nicholls et al. 2020	-65		
Remaining Budget to Net Zero Emissions	**35**	**114**	**36**

Carbon budgets for Australia and New South Wales

69. These **global numbers can be translated into approximate remaining 'carbon budgets' for Australia and for NSW**. Arguments can be made as to how much a region can or should be allowed to emit, based on history, industrial base, international trade, or ethics. Nature is blind to these distinctions. In this context, however, it is worth noting that **Australia, the USA, and top-oil-producers such as Saudi Arabia, have the highest per capita emissions of greenhouse gases in the world** (WMO 2019)[87].

70. **Here, the remaining 2°C carbon budget is simply apportioned equally among the world's population to arrive at notional values for Australia and NSW**, which yields the numbers in the rightmost columns of Tables 1 and 2. Note that the budget numbers for Australia and QLD are in *millions* of tonnes of carbon (Mt C), not *billions* of tonnes of carbon (Gt C).

71. In order to put these local carbon budgets in perspective using the most recent National Greenhouse Gas Inventory[88] data (Scope 1 only), Australia emits about 380 million tonnes of CO_2 per year, which contains about 105 million tonnes of carbon (105 Mt C). New South Wales emits 90 million tonnes of CO_2 annually, containing about 25 Mt C. Thus, using the estimates in Tables 1 and 2, **on current emission rates, Australia will have 'spent' its per capita share of the 2°C carbon budget in about 1.5–9 years, and NSW's share will be exhausted in about 2–12 years**, before or just after 2030**.** Using the estimates from Table 3 of notional regional shares of a 1.5°C carbon budget, **on current emission rates, Australia and NSW will have exhausted their shares of the 1.5°C carbon budget in 2021**, which is to say, next year.

VI The Narrabri Gas Project in a Climate Change Context

72. Placing the emissions from the Narrabri Gas Project, (NGP) or any other activity, in a social and environment context can be done in different ways, depending on the framing of the overall goal. **A key component of the framing is whether or not the emissions are seen as a local output**, divorced from other global social and environmental issues, or whether they are seen **in an inextricably connected global context that, in turn, influences local outcomes**.

73. The former approach is likely to focus on "regional accounting," excluding Scope 3 emissions from consideration, whereas the latter "global influence" framing will include Scope 3 emissions as part of a larger collective issue that affects all. These two framings are examined in the following subsections.

Regional "Accounting" of Emissions

74. The greenhouse gas assessment of the Narrabri Gas Project (Appendix R, EIS)[89] provides estimates of Scope 1 (direct project emissions) and Scope 2 (indirect, via emission embedded in project's energy use) emissions for two different options for sourcing energy for the project. Scope 3 emissions (other indirect emissions arising from the project by an entity not controlled by the project) have also been estimated. Since Santos has pledged that "**all Narrabri gas will be sold and delivered into the domestic market"**,[90] **all Scope 3 emissions for the Narrabri Gas Project are presumed to be Scope 1 emissions for Australia**. Santos' estimates are reproduced in Table 4 below.

Table 4: Santos estimates of GHG emissions of Narrabri GP over 25-year project lifetime

Total Project Emissions (Mt CO_2-e)	**NGP Option 1** All project electricity sourced on site gas-fired plant	**NGP Option 2** All project electricity sourced from NSW grid
Scope 1 (Direct emissions)	26.3	15.5
Scope 2 (Indirect emissions from sourced electricity elsewhere in Australia)	–	18.0
Scope 3 emissions (from use of product downstream by customer)	94.3	94.3

Will the Narrabri Gas Project compromise meeting Australian and NSW GHG targets?

75. The proponent's Response to Submissions[91] (page 6-217) states: ". . .the project was found to generate less than 0.2 per cent of Australia's annual emissions. **Accordingly, the project is not expected to compromise the ability of the Australian Government to meet its commitments under the Paris Agreement."** This statement is refuted below.

76. **Comparisons to current emissions or to emissions targets set by governments are often used as a proxy for assessing climate change impact.** Such comparisons are an **imperfect, and often misleading measure for climate impact assessments** since:

    a. the targets may not reflect the actual speed, magnitude or risk of climate change,

    b. regional targets generally count only regional (Scope 1) emissions, thereby ignoring the real, but indirect consequences of local activities, and

    c. 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.

77. Table 5 is an attempt to provide a deeper "regional accounting" analysis, where comparisons are made in now megatonnes of CO_2-e (rather than Mt C) or as a percentage. This analysis indicates the extent to which the **Narrabri Gas Project will make meeting Australian and New South Wales 2030 emissions targets considerably more difficult**.

Table 5: Effect of Narrabri Gas Project on meeting 2030 emissions targets

Total Annual Emissions (all GHGs)	**$MtCO_2$-e**	**Narrabri Gas Project Expressed as %**
Narrabri Annual Emissions averaged over 25-year lifetime **(NGP scopes 1, 2, and 3, all attributable to Australia)**	4.8 – 5.1	Depending on NGP Option chosen
Narrabri Annual Emissions averaged over 25-year lifetime **(NGP Scope 1 only emitted in NSW)**	0.6 - 1.05	Depending on NGP Option chosen
Australia Direct Emissions in 2018	537	0.88% – 0.93%
Australia Direct Emissions 2030 Target (annual change in *new* emissions reductions starting from 2018 to meet Australia's 26% reduction target on 2005 levels by 2030)	-7.5 per year	**64% - 68% (in wrong direction)**
New South Wales Direct Emissions in 2018	132	0.5% - 0.8%
NSW Direct Emissions 2030 Target (annual change in *new* emissions reductions starting from 2018 meet 35% reduction target on 2005 levels by 2030)	-2.4 per year	**26% - 44% (in wrong direction)** (only Scope 1, ignoring emission from any NGP gas sold to NSW grid)

78. Table 5 shows that the average annual (scopes 1 + 2 +3, all emitted in Australia) **emissions** from the **Narrabri Gas Project** of 4.9 – 5.1 Mt CO_2-e **are nearly 1%** (0.88-0.93%) **of Australia's current direct emissions**. The project, through Scope 1 emissions directly attributable to NSW, **would add 0.5–0.8% to NSW's current annual emissions, a sum equivalent to the total current emissions of 50,000—80,000 individual residents of New South Wales**, when considering the State's emissions on a per capita basis.

79. A more relevant comparison, however, is not to current emissions, but to the magnitude of the emissions reductions required to meet stated emissions targets in the future. **Narrabri Gas Project emissions over its first 10 years of life would equal about 12% (in the opposite direction) of Australia's total abatement task[92] of 395—462 $MtCO_2$-e to meet its 2030 target. For NSW to meet its own declared 2030 target, a total abatement of 56 $MtCO_2$-e will need to be found in the next 10 years; the NGP would fight against this by *adding* a very significant 6 to 11 $MtCO_2$-e** (11% – 19% of the NSW abatement task) **over this period.**

80. Another measure is to consider the amount of *new, previously unaddressed* emissions that must be brought to zero every year to meet 2030 targets. The Australian 2030 target, if approached linearly, requires an average *new reduction* of 7.4 Mt CO_2-e per year, year on year, from 2018 to 2030. That is, **to meet its stated 2030 Paris commitment, Australia would need to – each year – not only maintain its reduction from the previous years, but find another *further* reduction of 7.4 $MtCO_2$-e each year to 2030. In comparison, the Narrabri Gas Project would *add* more 4.8 — 5.1 $MtCO_2$-e every year, and continue to add that annual amount for the years 2031 – 2045.**

81. Meeting the **NSW's own 2030 target will require an annual new *reduction* of about 2.4 $MtCO_2$-e per year, year on year, whereas the Narrabri Gas Project would *add* at least 0.6 $MtCO_2$-e every year, thus working in the *opposite direction* and nulling 26 – 44% of the intended reductions in all other areas of NSW industry and commerce every year.** This *excludes* emissions from any NGP gas used in gas plants within the State.

82. In summary, the implication of the analyses presented in this section is that, **if approved, the Narrabri Gas Project would make the Australian and NSW emissions targets for 2030 considerably more difficult to meet.** Furthermore, the project **would further shorten the timespan before Australia and NSW exceed their notional 2°C carbon budgets,** times that already lie within the next ten years or so (see point #71). Thereafter, these jurisdictions effectively take on world "debtor" status with respect to regional accounting of the 2°C global budget.

The True Global Influence of Emissions and the Role NSW can play

83. Although the *National Greenhouse and Energy Reporting Act 2007* (the NGER Act)[93] 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, **from an environmental perspective, all emissions, including Scope 3 emissions** released when gas is combusted by its end user, **must be included. To do otherwise is to assume that the gas is never used for its intended purpose.**

84. As Table 4 shows, **if the Narrabri Gas Project were to proceed**, it would cause (directly and indirectly) **the release of over 120 Mt CO_2-e** (about 33 MtC) into the atmosphere over its 25-year life. Comparison to Tables 1 and 2 show that this is ***at least*** **11% of the remaining NSW 2°C carbon budget** (if it were considered responsible for all of the NGP Scope 3 emissions).

85. From a climate perspective, these points are pivotal, because NSW is the only jurisdiction that that can definitely stop these additional emissions from occurring. **From an environmental protection point of view, NSW is the responsible jurisdiction**.

Is approving the Narrabri Gas Project consistent with the Paris Agreement?

86. The proponent's Response to Submissions[94] (page 6-217) states: ". . . ***The proponent supports limiting global temperature rises to less than two degrees Celsius in line with the Paris Agreement*** *- also known as the 450 Scenario . . . Under an International Energy Agency scenario consistent with 2 degrees (450 Scenario) global gas demand grows 14% by 2040 compared to 2014, and forms 22% of the global energy mix."*

87. Whereas the proponent may be applauded for supporting a 2°C warming limit, two points must be made about the **inappropriateness of using the International Energy Agency's (IEA) "450 Scenario" as a justification for proceeding with the Narrabri Gas Project.**

88. First, according to the IEA[95], its '450 Scenario' reflected polices "*that put the world on a pathway that is consistent with having around a* ***50% chance*** *of limiting the global increase in average temperature to 2°C in the long term, compared with pre-industrial levels*." Therefore, **the IEA '450 Scenario' reduces chances of a 2°C scenario to a coin-flip,** whereas the Paris pledge is to keep warming well-below 2°C, aiming for no more than 1.5°C.

89. Second, according to the proponent, this '450 Scenario' is predicated on global gas demand growing by only 14% from 2014 to 2040. In fact, current information from the IEA[96] already shows 11% growth from 2014 to 2018, before considering demand from 2019 and 2020. This matches the IEA's conclusion that natural gas production has grown at an annually

compounded growth rate of 2.8%, implying a 14.8% rise from 2014 through 2019. In other words, **the world demand for gas *has already outpaced* that of the '450 Scenario' that yields only 50-50 odds of holding warming to 2°C**. Therefore, **approving** new fossil fuel projects, like **the Narrabri Gas Project, is inconsistent with the Paris Agreement intent to hold warming well-below 2°C.**

Gas is not a transition fuel to hold global warming below 2°C

90. **Australia is the world's leading exporter of coal** (IEA 2019)[97] **and the second largest producer and exporter of LNG** (IGU 2018)[98]. Under government projections analysed in a new international SEI report (SEI et al., 2019),[99] Australia's extraction-based emissions from fossil fuel production would nearly double by 2030 compared to 2005 levels, despite Australia's stated Paris NDC target of a reduction in territorial GHG emissions of 26–28% over the same period.

91. **Current levels of global national stated ambitions (NDCs) with respect to the Paris Agreement must be roughly tripled for global emission reduction to be in line with a 2°C temperature limit** (WMO 2019)[100]. Thus, not only must current targets be met, much more ambitious targets must be met quickly in order to hold global warming below 2°C.

92. The most common argument for **gas as a "transition fuel" or "bridge" to a zero-emissions future** is based on estimates of its lifetime emissions being 33-50% less than coal.[101] This argument is used by the NSW Department of Planning, Industry and Environment in its final assessment[102] of the Narrabri Gas Project. However, it is "**unclear to what extent such a bridge still exists**"[103] or is needed, given the rapid development and uptake of lower cost renewable plus storage options and the possibility of undetected or unreported methane emissions from gas production.

93. T**he high global warming potential of methane is particularly concerning with new gas development** (See point #20). A **recent, accelerating surge in atmospheric methane over the past decade is attributed in equal parts to agriculture and fossil fuels production/use** (Jackson et al. 2020)[104]. **High levels of unreported fugitive CH_4 emissions from gas operations in the U.S. are being revealed** by recent top-down studies[105,106,107].

94. Together with the **lack of a suitably long, detailed and statistically-significant studies of CH_4 emissions from Australian gas operations** similar to the proposed Narrabri Gas Project, there is **substantial reason for concern that the Project's CH_4 emissions may be underestimated**.

95. Even putting the unreported methane concern to one side, a recent economic analysis **based on only a 50% chance of achieving 2°C** (equivalent to flipping a coin) concluded that **half of all gas reserves must remain unused from 2010 to 2050 in order to meet a target of 2°C** (McGlade and Ekins, 2015),[108] specifically including reserves held by OEDC countries in the Pacific, of which Australia is the major player.

96. Underscoring this point is the SEI report (SEI et al., 2019)[109] that analyses the gap between different nations' expectations for the production of fossil fuels and the Paris warming targets that the same nations support. The analysis shows that **governments are planning to produce about 50% more fossil fuels by 2030 than would be consistent with a 2°C pathway and 120% more than would be consistent with a 1.5°C pathway. This means that plans *already on the table* must be shelved to hold warming to Paris limits.**

97. **The disconnect between the intention to produce more fossil fuels and the commitment to reduce emissions has been called the "Production Gap."** Australia is a major contributor to this gap[110] between global intended fossil fuel production and the Paris agreed warming target range, as shown in Figure 8 below, taken from the SEI report[111].

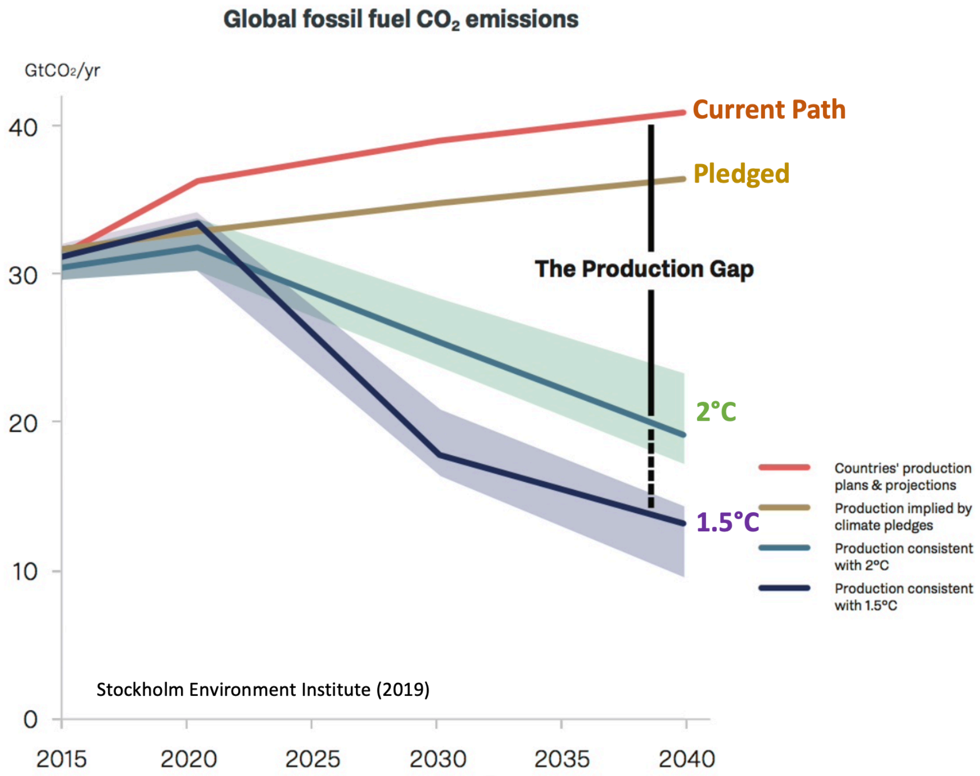

Figure 8: Possible trajectories of global CO_2 emissions from 2015 to 2040 in units of $GtCO_2$ emitted in each year. In red is the current trajectory, whilst the gold line indicates what would be achieved if all Paris Agreement pledges were met. Lavender and turquoise trajectories reflect world fossil fuel production consistent with a 66% chance of holding warming to 1.5°C and 2.0°C, respectively. Shaded regions indicate uncertainty ranges for the 1.5°C and 2.0°C trajectories.

98. Trajectories for gas may decline slower than oil or coal to achieve the overall trajectories shown in Figure 8, but **gas must still decline around 2020 (under a 1.5°C pathway) or around 2030 (under a 2°C pathway)**.[112]

99. **Redressing this fossil fuel production gap cannot be met by *adding* fossil fuel development,** even that which may have already planned. Instead, **new fossil fuel development and expansion must cease, and ageing facilities brought to rapid close**. For the reasons discussed in this section, in my view, **approving the Narrabri Gas Project is inconsistent with the Paris Agreement.**

VII Conclusion: The Narrabri Gas Project must not proceed

100. This submission concludes that the Narrabri Gas Project must not proceed on grounds of environmental and climate considerations, responsible stewardship, and social equity for and safety of future generations. A brief summary of the main points supporting this conclusion can be found in the Executive Summary.

Respectfully submitted on 9 August 2020,

Penny D. Sackett

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