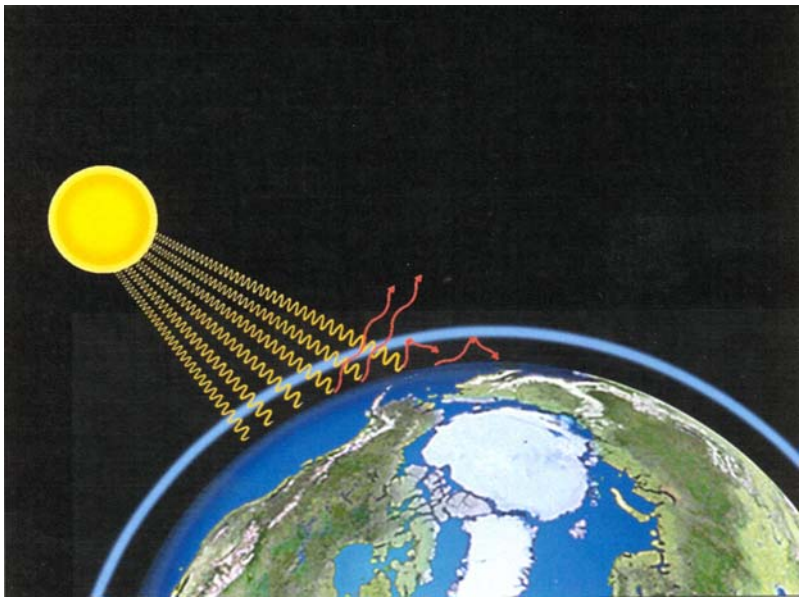
A brief summary of the science of global warming and climate change



Report prepared for an objections hearing in the Land Court of Queensland regarding the proposed Wandoan Coal Mine

Mining tenement numbers ML 50229, ML 50230 and ML 50231 and draft environmental authority (mining lease) number MIN100550607

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INTRODUCTION

1. I have been asked by the Friends of the Earth – Brisbane Co-Op Ltd to provide an expert report explaining what are global warming and climate change, how serious these problems are, and how does the mining, transport and use of coal contribute to these processes. I have also been asked to consider whether the predicted total emission from this mine is likely to contribute to climate change. Climate change and ocean acidification are inter-related but another expert, Professor Ove Hoegh-Guldberg has been asked to address the latter and I will, therefore, not address it in this report.

2. The science of global warming and climate change is very complex but there is now a broad scientific consensus about much of it. I have, therefore, deliberately chosen to keep the explanations of the concepts as simple as possible in this report and not over-burden the text with copious citations and complex diagrams or graphs. I also note that other eminent experts, including Dr Malte Meinshausen and Professor Ove Hoegh-Guldberg, are addressing several specific issues such as the resilience of the climate system and the likely impacts of global warming on the Great Barrier Reef Area. It is, therefore, not necessary for me to go into great detail on the topics they are addressing or about the likely severe impacts of global warming and climate change on the environment.

3. This report has been prepared in response to that request for use in an objection hearing in the Land Court concerning a large open-cut coal mine. The mine is the Wandoan Coal Mine, an open-cut coal mine proposed to operate for 30 years west of the township of Wandoan, approximately 350 km northwest of Brisbane and 60 km south of Taroom in the Surat Basin, Queensland (the mine).

4. The thermal coal deposits for the mine are estimated to be in excess of 1.2 billion tonnes, and are located within three Mining Lease Applications (MLAs 50229, 50230 and 50231), which comprise approximately 32,000 hectares. The coal from the mine is proposed to be crushed, processed and blended on site before being transported by rail to port for export or, possibly, for domestic use. The thermal coal produced by the mine is intended to be sold to other companies to be burnt in coal-fired power stations to generate electricity.

5. The Wandoan Coal Project environmental impact statement and an accompanying technical report on greenhouse gas emissions calculated that the emissions from the mining and use of the coal from the mine would be over 41 million tonnes of carbon dioxide equivalents annually and 1.3 billion tonnes of carbon dioxide equivalents over the life of the mine.[1]

6. As a final introductory matter, I note that I understand my duty as an expert witness before the Court based on rule 426 of the Uniform Civil Procedure Rules is to assist the Court. While I appear pro bono to assist the Court in these proceedings, I note also that my duty to assist the Court would override any

[1] Xstrata Coal (2008), Wandoan Coal Project Environmental Impact Statement , Parsons Brinckerhoff Australia Pty, Brisbane, Vol 1, Book 2, Ch 14 (Greenhouse gases and climate change); and Clarke S (2008), Technical Report – Wandoan Coal Project greenhouse gas assessment, URS, Brisbane.

obligation I may have to any party to the proceeding or to any person who is liable for my fees or expenses.

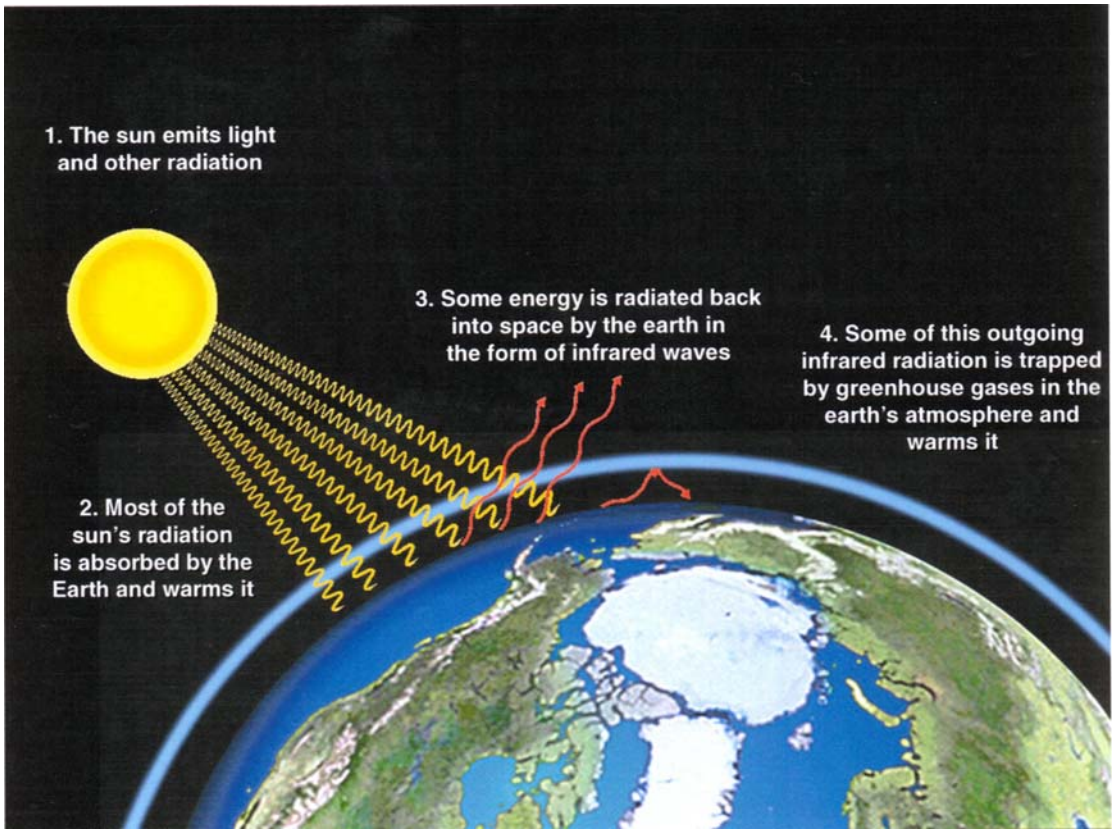
RELEVANT EXPERTISE

7. My brief biography is Appendix 1 to this report. In summary, I am emeritus professor of science, technology and society at Griffith University and adjunct professor at University of the Sunshine Coast and Flinders University. I am a recognised expert on the environmental aspects of energy supply and use. As well as having chaired the relevant committee of the national energy research body from 1983 to 1989, I have acted as a referee for the Inter-governmental Panel on Climate Change and three other global scientific reports on environmental issues. I wrote the first popular paperback book on the subject published in Australia, *Living in the Greenhouse* (1989), and published a follow-up book, *Living in the Hothouse* (2005). I was a member of The Australian Climate Group, which produced in 2004 the report *Climate Change Solutions for Australia*. I was a member of the National Greenhouse Advisory Panel for its entire duration, am deputy chair of the Queensland Sustainable Energy Advisory Council and a member of the Queensland Premier's Climate Change Council.

WHAT IS GLOBAL WARMING AND CLIMATE CHANGE?

8. We have known since the late nineteenth century that the Earth is kept warmer than it would otherwise be by the presence of trace gases in the atmosphere which trap heat. The "**greenhouse effect**" was given its name by the Swedish scientist Arrhenius in the 1890s because he recognised that it worked in the same way as the glass in a greenhouse, admitting the sunlight which warms the interior and blocking the infra-red radiation that would carry the heat away. The natural greenhouse effect is a great benefit and is the fundamental reason why the average Earth temperature, of 15^0C, is about 33°C higher than the temperature on our Moon (which does not have an atmosphere). The following diagram provides a simple pictorial explanation of the greenhouse effect.

Figure 1: Diagram of the greenhouse effect[2]



9. Most people are familiar with one example of the greenhouse effect: the difference in temperature between a cloudy or clear night. After a hot day, a cloudless night is usually considerably cooler than a cloudy night – the difference being that the water vapour in the clouds traps the Earth's heat in and prevents it being radiated to Space. Water vapour is the major greenhouse gas in the atmosphere. This provides a simple example of the greenhouse effect that is a matter of common experience rather than complex science.

[2] Adapted from Gore A (2006), *An Inconvenient Truth*, Bloomsbury, London.

10. There are three key terms that require brief definition and explanation to clarify the concepts associated with the enhanced greenhouse effect:[3]

(a) **Greenhouse gases** are gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere and clouds. This property causes the greenhouse effect. Water vapour (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and ozone (O_3) are the primary greenhouse gases in the earth's atmosphere. Moreover there are a number of entirely human-made greenhouse gases in the atmosphere, such as hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs).

(b) **Climate change** refers to a significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer). Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use. The *United Nations Framework Convention on Climate Change* (UNFCCC), in Article 1, defines climate change as, "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods". The UNFCCC thus makes a distinction between "climate change", attributable to human activities altering the atmospheric composition, and "natural climate variability", attributable to natural causes.

(c) **Global warming** is the common term for climate change due to anthropogenic emissions of greenhouse gases leading to increased global temperatures and other climatic effects such as changes in rainfall patterns and the frequency of severe storms.

11. Since the Industrial Revolution, humans have been burning **fossil fuels** – coal, oil and gas – that were stored over the geological time of the Earth's history. Burning these fuels essentially combines the carbon within them with oxygen from the air to produce CO_2. This process has now produced a dramatic increase in the amount of CO_2 in the air. Measurements from laboratories over the last fifty years have been supplemented by assessments of polar ice cores dating back 650,000 years.[4] These studies show that the natural variation of CO_2 levels has been from about 180 to 280 parts per million (ppm) and that global mean temperatures are directly and closely linked to the amount of CO_2 in the atmosphere. The present level of

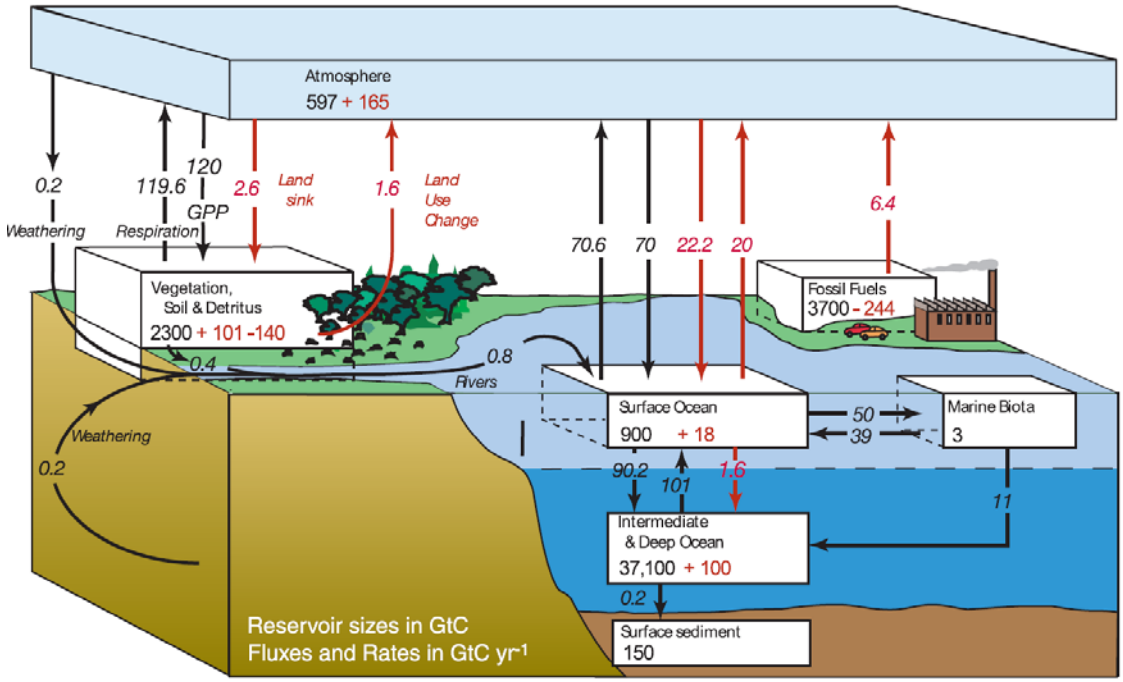
[3] I have referred to my own publications and the Australian Bureau of Meteorology (2003), *The Greenhouse Effect and Climate Change*, BOM, Canberra, for these definitions.

[4] See in particular, Petit JR, Jouzel J, Raynaud D, Barkov NI, Barnola JM, Basile I, Bender M, Chappellaz J, Davis M, Dalaygue G, Delmotte M, Kotlyakov VM, Legrand M, Lipenkov VY, Lorius C, Péplin L, Ritz C, Saltzman E, and Stievenard M, (1999) "Climate and atmosphere history of the past 420,000 years from the Vostok ice core, Antarctica" *Nature* 399: 429-436; and Siegenthaler U, Stocker TF, Monnin E, Lüthi D, Schwander J, Stauffer DR, Barnola JM, Fisher H, Masson-Delmotte V, and Jouzel J, (2005) "Stable Carbon Cycle – Climate Relationship During the Late Pleistocene" *Science* 210: 1313-1317.

CO_2 in the atmosphere is about 390 ppm and increasing steadily by a further 2 ppm each year.[5]

12. Once carbon dioxide is emitted from the burning of fossil fuels such as coal, it enters the global carbon cycle in which the carbon moves in different forms through the atmosphere, oceans and land biota over centuries to millennia (Figure 2).

Figure 2: The global carbon cycle for the 1990s, showing the main annual fluxes in GtC yr^{-1}: pre-industrial 'natural' fluxes in black and 'anthropogenic' fluxes in red.[6]



13. This is a simple explanation of the main concepts and processes relevant to the issues facing the Court. The Earth's climate and the science of global warming and climate change is far more complex than this but, unless I am requested to by the Court to assist its understanding, I will not go into more detail about these matters, except to add that there is a growing concern in the climate science literature about the risk of exceeding a critical threshold and precipitating rapid and essentially irreversible changes to the climate, as discussed further in paragraph 20.[7]

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[5] Tans P and Keeling R, U.S. Department of Commerce - National Oceanic & Atmospheric Administration – Earth System Research Laboratory – Trends in Atmospheric Carbon Dioxide at http://www.esrl.noaa.gov/gmd/ccgg/trends/ (viewed 13 April 2011).

[6] Intergovernmental Panel on Climate Change (IPCC) (2007), *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, p 515.

[7] A further, reasonably simple, explanation of the science of the greenhouse effect and climate change is Australian Bureau of Meteorology (2003), *The Greenhouse Effect and Climate Change*, available at http://www.bom.gov.au/info/GreenhouseEffectAndClimateChange.pdf.

HOW SERIOUS A PROBLEM IS GLOBAL WARMING AND CLIMATE CHANGE?

14. The average temperature of the Earth is now warmer than at any time since human records began and it is clear that much of this increase is due to human activities releasing greenhouse gases to the atmosphere.

15. The Intergovernmental Panel on Climate Change (IPCC), the leading international body on climate change science, concluded in its Fourth Assessment Report (AR4) in 2007 that mean global temperatures increased by 0.74°C between 1906 and 2005 and most of the observed increase over the 20th century is very likely (i.e. >90%) due to anthropogenic emissions of greenhouse gases from the combustion of fossil fuels, agriculture, and land-use changes.[8] This finding is based on an extensive body of science. The main reports of the AR4 are nearly 3,000 pages long and published in three volumes. To assist the Court in understanding the full context of the causes and impacts of climate change I have attached the body of the, much shorter, Synthesis Report produced by the IPCC as Appendix 2 to this report.[9]

16. The IPCC projected likely future temperature changes using different scenarios of emissions set out in its *Special Report on Emissions Scenarios* (SRES), with projected concentration of CO_2 in the year 2100 from 540 to 970 ppm, compared to about 280 ppm in the pre-industrial era and about 368 ppm in the year 2000. Further calculations summarised in Section 5.4 of the attached Synthesis Report give the IPCC conclusion that mean global temperatures will increase from 1990 levels by between about 1°C for a low-emissions scenario and about 5°C for a projection of present trends, the future which will eventuate if current proposals for new fossil-fuel production are approved.

17. The levels of reduction in anthropogenic greenhouse gas emissions that are required to stabilise global temperatures at less than a mean 2-3°C rise are uncertain. It will probably require stabilisation of equivalent greenhouse gas concentration of 450 ppm or lower, with further reductions after 2100.[10] The recent summary by the Australian Academy of Science concluded *"To have a better than even chance of preventing the global average temperature from eventually rising more than 2^0C above pre-industrial temperatures, the world would need to be emitting less than half the amount of CO_2 by 2050 than it did in*

[8] Intergovernmental Panel on Climate Change (IPCC) (2007), *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge.

[9] IPCC (2007) *Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, 104 pp.

[10] See generally, Houghton J (2004), *Global Warming: The Complete Briefing*, 3rd ed, Cambridge University Press, Cambridge, pp 257-261; and Pittock AB (2005), *Climate Change: Turning Up the Heat*, CSIRO Publishing, Melbourne, pp 152-155.

2000. To do this on a smooth pathway, global emissions (which are still rising) would need to peak within the next ten years and then decline rapidly."[11]

18. Australia has warmed by 0.9°C since 1910, rather more than the increase in global average temperature. Globally, the period since 1990 has seen all of the ten hottest years since reliable instrumental records began (about 140 years ago). The last decade is the warmest ever recorded and the last year is the warmest year ever recorded. A range of studies collated by the IPCC all agree that the current temperatures are the highest for at least 2000 years. While there is some indirect evidence that there may have been warm periods for small regions in the northern hemisphere in the Middle Ages, all reliable studies show that the recent global and northern hemisphere average temperatures are higher than at any time in at least 2000 years.

19. For Australia, the consequences of anthropogenic global warming and climate change have been: an increase in average temperature of 0.9°C since 1910; an increase in the frequency of very hot days; a decrease in the frequency of very cold nights; more frequent, persistent and intense droughts; more frequent heavy rainfall events; decreased winter rainfall, especially in southern Australia; sea levels increasing about 2 cm per decade; and increasingly frequent extreme events such as category five tropical cyclones, severe east coast low pressure systems and intense bushfires. To assist the Court in understanding the impacts of climate change on Australia, I have attached as Appendix 3 to this report the executive summary of a technical report on climate change in Australia published by the CSIRO.[12]

20. When I wrote *Living in the Greenhouse* in 1989, it was clear that human activity was changing the composition of the atmosphere and clear that the climate was changing, but most scientists felt it was not provable that the climate change was being caused by the enhanced greenhouse effect. Since then, there has been an immense scientific effort to analyse climate change and develop sophisticated computer models which test theories about the link between greenhouse gas levels and climate. The IPCC has now released four assessments in 1990, 1996, 2001 and 2007, with the Fifth Assessment Report due to be released 2014. The IPCC is made up of hundreds of the world's most distinguished atmospheric chemists, physicists and climatologists. Its work is overseen by the United Nations and the World Meteorological Organisation. The assessments show the steady strengthening of scientific confidence that we are seeing real changes in the Earth's climate driven by human activity, principally the release of carbon dioxide and other greenhouse gases (especially methane) as a consequence of energy use.

21. As the attached CSIRO report shows, climate change is already imposing significant economic, social and environmental costs on Australia and the rest of the world. In the specific case of Australia, the most obvious economic costs are the impact of reduced agricultural production, the increased cost of water supply and the increasing costs of severe weather events.

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[11] The report by the Australian Academy of Science, *The Science of Climate Change*, is available at www.science.org.au/policy/climatechange2010.html

[12] CSIRO (2007) *Climate Change in Australia – Technical Report 2007*, CSIRO, Melbourne.

22. In terms of primary production, Treasury estimates that the 2002-03 drought reduced farm output by 24 per cent, cut agricultural income by 46 per cent, reduced employment by about 100,000 jobs and decreased overall national GDP by almost 1 per cent[13].

23. The more recent prolonged drought had a greater impact.[14] All mainland State capitals were forced to implement water restrictions as a result of reduced rainfall and run-off to reservoirs. Since 1977, inflows to water supply systems of Adelaide and Melbourne have been two-thirds of the previous average, while Sydney, Brisbane and Perth figures have been less than half the previous average, WA spent $140 million on a desalination plant to augment its reduced water supply and is now commissioning a second, but there are still concerns about the reliability of its water supply in the dry period that is still continuing as this report is written. Several other States, including Queensland, are committed to desalination technology to augment water supplies.

24. In terms of natural disasters, only one of the twenty largest causes of insured losses (the Newcastle earthquake) has not been weather-related; the world's second-largest re-insurer, Swiss Re, has warned that the global cost of natural disasters could double in the next ten years, as small changes in such climate variables as temperature lead to disproportionate increases in storm intensity, drought severity, probability of flooding or risk of severe bushfires.[15]

25. In social terms, intensified summer heatwaves will cause more deaths from heat stress, as happened in Europe in August 2003. While it understandably attracted much less attention than the catastrophic "Black Saturday" bushfires, the February 2009 heatwave is estimated by the Victorian Department of Health to have caused about twice as many deaths as the fires.[16] Rates of food poisoning and diarrhoeal disease usually increase in hotter conditions (especially in poorer rural communities), while a 2005 report supported by the Australian Medical Association and the Australian Conservation Foundation concluded that vector-borne diseases like dengue fever and Ross River virus will spread as the changing climate increases the areas suitable for the mosquitoes that carry these contagions.[17] This was confirmed by a 2009 outbreak of dengue fever in the Cairns area, with more than 350 cases reported.

26. Finally, climate change is already having a significant impact on Australia's unique natural systems, decreasing the extent of mountain rainforests, causing coral bleaching, moving snow-lines higher with impacts for alpine species, being

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[13] L.Lu & D.Hedley, The impact of the 2002-03 drought on the economy and agricultural employment, Economic Roundup Autumn 2004, Treasury, Canberra
http://www.treasury.gov.au/documents/817/HTML/docshell.asp?URL=03_article_2.asp

[14] See, for example, Dept of Climate Change and energy Efficiency, Water Resources, Canberra 2011, http://www.climatechange.gov.au/climate-change/impacts/water-resources.aspx

[15] Swiss Re (2004) Global Climate Change: Swiss Re's Perspective
http://chge.med.harvard.edu/programs/policy/briefings/documents/simon.pdf

[16] Victorian Government, January 2009 Heatwave in Victoria: an Assessment of Health Impacts. http://www.health.vic.gov.au/chiefhealthofficer/downloads/heat_impact_rpt.pdf

[17] R Woodruff et al (2005) *Climate Change Health Impacts in Australia*, http://ama.com.au/node/2120

associated with the increased frequency of severe fire events and being linked with "thickening" of woody vegetation in savannas and bushland.[18]

27. There is also the risk that climate change could exceed a critical threshold and cause abrupt changes. As an example of the sort of change which could occur, the average rainfall in the Perth area has reduced by about 20 per cent, but the warmer and drier conditions mean the average annual run-off into the water supply reservoirs since 1997 is only **one-third** of the figure before 1975.[19] Evidence is emerging that the changes to the atmosphere can alter the working of such important global systems as ocean circulation patterns and the stability of polar ice sheets. The deep ocean circulation of the north Atlantic appears to be slowing now; if this were to accelerate, as some fear, it could affect both the regional climate of western Europe and the capacity of the oceans to support life. The increasing level of carbon dioxide in the air is causing more of the gas to dissolve in the oceans and measurably changing the average acidity, with potentially serious implications for shellfish and corals. There is concern that the large ice sheets of Greenland and West Antarctica could be destabilised, leading to sea level increases of several metres. The scale of these potential risks underlines the need for caution in the way we change the natural systems of the Earth.

28. For Queensland a recent report by the State Government[20] states that:
    - by 2050, projected temperature increases are 1 to 1.4^{o}C for the low emissions scenario and 1.7 to 2.2^{o}C for the high emissions future (approving new large coal mines would be consistent with the high emissions future);[21]
    - the best estimates (of both high and low emission scenarios for 2050) are for decreasing stable rainfall,[22] but more severe rainfall events;[23]
    - sea levels have been projected to rise by 0.8 metres by 2100, but indications are that the rise could be significantly more;[24]
    - increasing number of very hot days, e.g. by 2050 Longreach is projected to have 156 days over 35 degrees compared with 112 days now;[25]
    - frequency of severe tropical cyclones increasing by as much as 56 per cent by 2050;[26] and

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[18] See, for example, M Howden, L Hughes, M Dunlop, I Zethoven, D Hilbert & C Chilcott [eds], Climate cgange impacts on biodiversity, CSIRO Canberra 2003, available at http://www.environment.gov.au/biodiversity/publications/greenhouse/pubs/greenhouse.pdf

[19] Figure 4.1 in WA Department of Premier and Cabinet (2006) *Options for bringing water to Perth from the Kimberley, An Independent Review* http://www.water.wa.gov.au/PublicationStore/first/64772.pdf,.

[20] State of Queensland (Department of Environment and Resource Management) (2010), *Climate Change in Queensland - What the Science is Telling Us*, available at http://www.climatechange.qld.gov.au/pdf/climate-change-in-queensland-2010.pdf

[21] Ibid at page 27.

[22] Ibid at page 27.

[23] Ibid at page 30.

[24] Ibid at pages 3 and 42. Also note that recent science has indicated that, at the current rate of acceleration in ice sheet loss, the contribution of ice sheets alone would result in an additional 56 cm of sea level rise by 2100: see Rignot, E., I. Velicogna, M. R. van den Broeke, A. Monaghan, and J. Lenaerts, Acceleration of the contribution of the Greenland and Antarctic ice sheets to sea level rise, *Geophys. Res. Lett.* 38, L05503, doi:10.1029/2011GL046583 .

[25] Ibid at page 29.

[26] Ibid at page 30.

- *"Queensland can expect to experience: increases in increases in heat-related illnesses, difficulty in supplying urban and agricultural water needs due to decreasing rainfall, and increasing temperature and evaporation. Greater numbers of severe tropical cyclones, combined with storm surges, will increase erosion and coastal flooding and cause more damage".*[27]

29. In terms of specific impacts, the report sets out useful "Key messages" boxes on pages 38, 44, 48, 54, 60 and 71.

30. The Stern report in the UK[28] and the report of the Australian Business Leaders Roundtable on Climate Change[29] both concluded that climate change is already having significant economic impacts and that these will worsen dramatically if the problem is not controlled. The IPCC estimates that global release of carbon dioxide needs to be reduced by at least 60 per cent to stabilise the atmospheric concentrations and thus stop the enhancement of the natural greenhouse effect. As noted above, in paragraph 15 and footnote 8, the more recent science has caused these targets to be reviewed downward. Both the Garnaut Report and the more recent summary by the Australian Academy of Science demand more urgent action, with the AAS report leading to the conclusion that global emissions must peak before 2020 and then decline rapidly to have a better-than-even chance of avoiding alarming consequences.

HOW WOULD THE MINING, TRANSPORT AND USE OF COAL FROM THE MINE CONTRIBUTE TO GLOBAL WARMING AND CLIMATE CHANGE?

31. The Wandoan Coal Project environmental impact statement and an accompanying technical report on greenhouse gas emissions calculated that the emissions from the mining and use of the coal from the mine would be 1.3 billion tonnes of carbon dioxide equivalents.[30]

32. An initial point to understand in assessing the contribution that these emissions will make to climate change and global warming is that greenhouse gas emissions are additive, i.e. any emissions add to the amount of greenhouse gases already in the atmosphere.[31] While different greenhouse gases persist in the atmosphere for

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[27] Ibid at page 27.
[28] Stern N (2006), *Stern Review on the Economics of Climate Change*, HM Treasury, London, available at http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/stern_review_report.cfm.
[29] Australian Business Leaders Roundtable on Climate Change (2006), *The Business Case for Early Action*, available at http://www.businessroundtable.com.au/.
[30] Note that "carbon dioxide equivalents" (CO_2-e), is a standard for measuring the effect of different greenhouse gases. One CO_2-e is equal to the amount of greenhouse gas that has the effect of 1 kilogram CO_2 emitted. The emission of 1 kilogram of N_2O equals 310 CO_2-e and the emission of 1 kilogram of CH_4 equals 21 CO_2-e. The major greenhouse gas emitted from the use of coal is CO_2 itself, which is equal to CO_2-e by definition but the standard term is used here because mining coal also releases other greenhouse gases, especially methane.
[31] In the past 200 years, more than 2.3 trillion tons of CO_2 have been released into the atmosphere due to human activities relating to fossil fuel consumption and land-use changes: Baumert KA, Herzog T,

different lengths of time, CO_2 affects the atmosphere for very long periods. While it has been accepted that significant amounts will still be affecting the atmosphere after 200 years, the most recent science finds that as much as 35 per cent could still be affecting the atmosphere for thousands of years.[32] As a consequence of this, we have to accept that CO_2 emitted into the atmosphere from the mine could influence the atmospheric concentrations of CO_2 for centuries or even longer. It is not possible to link these emissions to any particular impact on a specific part of the environment in Queensland, Australia or globally, other than to contribute to greenhouse gases in the atmosphere and thereby contribute to global warming and climate change. The impacts of greenhouse gas emissions from this mine should, therefore, be understood as contributing to the cumulative impacts of global warming and climate change.

33. In assessing the contribution of the emissions from the proposed mine, it is important to understand that geological structures now trap the carbon contained in the coal, so that the carbon is completely isolated from the atmosphere and will not contribute to global warming or climate change in its current form. It would, therefore, be wrong to say that "the mining of this coal will not make any difference to global warming because if this mine does not proceed the coal will just come from another mine somewhere in the World". It is true that there is a large amount of coal in the World and that the coal could be supplied from another mine.[33] However, that reasoning ignores the fact that coal is a finite resource, so the mining and use of the coal from this mine will release to the atmosphere fossil carbon that would otherwise be trapped in the ground. Such reasoning also ignores the growing recognition that reasonable and practicable measures should be required to avoid, reduce or offset the greenhouse gas emissions from all human activities, including the proposed mine. Global warming and climate change are massive problems for society that, ultimately, need to be addressed through action at the level of individual projects such as this proposed mine.

34. As the emissions of greenhouse gases from the mine will add to the amount of greenhouse gases already in the atmosphere, they need to be considered in the context of national and global emissions. The most recent available data on Australia's national direct greenhouse gas emissions are set out by the Commonwealth Department of Climate Change and Energy Efficiency in the

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and Pershing J (2005), *Navigating the Numbers: Greenhouse Gas Data and International Climate Policy*, World Resources Institute, available at http://www.wri.org/climate/pubs_description.cfm?pid=4093, p 4.

[32] Archer D (2005), "Fate of Fossil Fuel in Geologic Time" 110 Journal of Geophysical Research C09S05, doi: 10.1029/2004/2004JC002625; Archer D and Brovkin V (2008), "The millennial atmospheric lifetime of anthropogenic CO2" Climatic Change 90:283-297 DOI 10.1007/s10584-008-9413-1; Solomon et al (2009), "Irreversible climate change due to carbon dioxide emissions" PNAS 116 (6) 1704-1709, doi: 10.1073/pnas.0812721106: Archer D, et al, Atmospheric Lifetime of Fossil Fuel Carbon Dioxide, Ann.Rev.Earth & Planetary Sciences 37, 117134 (2009), doi: 10.1146/annurev.earth.031208.100206.

[33] Globally, coal reserves are significantly larger than other fuels. At current prices and consumption rates, present reserves of coal will not be depleted until the year 2168. Total global coal consumption, production, and reserves in 2004 are 2,778, 2,732, and 448,464 million tons of oil equivalent, respectively: Baumert, Herzog, and Pershing, n 31, pp 43 and 44.

National Greenhouse Gas Inventory.[34] The *National Greenhouse Gas Inventory* reports Australia's direct greenhouse gas emissions in 2009 as follows:

Sector	Emissions (Mt CO_2-e)
Energy	417.4
Fuel Combustion	377.7
Fugitive Emissions	39.7
Industrial Processes	29.6
Agriculture	84.7
Land Use, Land Use Change and Forestry	18.7
Waste	14.1
Australia's Net Emissions	564.5

35. Global greenhouse gas emissions in 2000 (excluding emissions from land use, land use change and forestry) were estimated to have been about 34 Gigatonnes of CO_2 equivalents (Gt CO_2-e), but the IPCC Fourth Assessment Report gave the 2004 figure as 49 Gt, so the current figure is likely to be even higher still.[35]

36. To put the potential release of CO_2 from the proposed mine extension into context:

    (a) the annual average emissions from the proposed mine (41.7 million tonnes) extension would be about 7.4 per cent of the national figure for a year or about 0.085 per cent of the current annual global release of greenhouse gases.

    (b) The average annual emissions from the proposed mine would be greater than the annual emissions of New Zealand (approximately 32.6 million tonnes in 2007) and, at peak production, greater than the annual emissions of Ireland (approximately 44.3 million tonnes in 2007).[36]

    (c) the lifetime emissions from the proposed mine would be equivalent to 2 years and 4 months of national emissions, or about 2.7 per cent of the current annual global release of greenhouse gases.

37. The IPCC data show that about 40 per cent of the carbon from fossil fuels released each year comes from coal, about 40 per cent from oil and about 20 per cent from gas. Since some of the oil is used to transport coal, the IPCC figure of about

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[34] National Greenhouse Gas Inventory – Kyoto Protocol Accounting Framework at www.ageis.greenhouse.gov.au/.
[35] World Resources Institute, Climate Analysis Indicators Tool (CAIT) Version 4.0. http://www.wri.org/climate/. 1 Gt equals 1,000 Mt.
[36] United Nations Statistics Division, Millennium Development Goals indicators: Carbon dioxide emissions (CO2), thousand metric tonnes of CO2 (collected by CDIAC) available at http://mdgs.un.org/unsd/mdg/SeriesDetail.aspx?srid=749&crid=.

10,000 Mt, or 10 Gt, of CO_2 released each year from the burning of coal should be seen as a conservative estimate that does not include the associated transport emissions. Because coal contains more carbon and less hydrogen than oil or gas, it produces proportionately more CO_2 per unit energy. In round figures, gas produces about 60 per cent of the CO_2 per unit energy of coal, while petroleum fuels produce about 80 per cent. Burning coal to generate electricity is extremely inefficient, so that coal-fired electricity releases about five times as much CO_2 per unit energy as directly burning gas.

38. The global problem of climate change stems from compounding of all the local decisions to burn fossil fuels and release carbon dioxide. Australia, like other OECD countries, agreed at the Kyoto conference to curb our greenhouse gas emissions. The consensus at Kyoto was that the global problem requires a global solution, to which all countries must contribute. Apart from the USA and China, every country accounts for a small fraction of the global greenhouse pollution, but all will have to play a role in reducing the burden on the atmosphere. The more recent Copenhagen Accord, negotiated at COP15 in 2009, and the 2010 Cancun Agreement are directed toward a legally binding global agreement to curb greenhouse gas emissions.

39. The Stern report in the UK and the report of the Australian Business Leaders Roundtable on Climate Change both concluded that the most effective way to slow down the release of greenhouse gases is to build a clear price signal into our economic system. The present political debate about a proposal to introduce a very modest carbon tax shows how difficult this will be to implement. So the most obvious solution is to apply stringent conditions to any large project that would release significant amounts of carbon dioxide or methane, making the project greenhouse-neutral. Even then, since the basic purpose of mining steaming coal is to allow it to be burned and therefore release carbon dioxide in vast quantities, a responsible approach would be defer any such proposal until there exists a proven technology for capturing and storing the resulting emissions.

CLEAN COAL AND GEO-SEQUESTRATION

40. There is a strong emphasis at the present time in the Australian and Queensland Governments and the coal industry on “clean coal” and geo-sequestration (basically, capturing and pumping greenhouse gas emissions underground rather than emitting them to the atmosphere).[37] The Xstrata group of companies, of which the main proponent of the mine is part, is the world’s largest exporter of thermal coal. In 2004, it noted on its website that:[38]

> Xstrata Coal recognises that coal is also a carbon liability and that climate change is a real international and community issue. Furthermore, the company believes that emission reductions resulting from the use of coal are required and achievable within a sustainable development framework.

[37] See generally, Metz, B., O.Davidson, H. C. de Coninck, M. Loos, and L.A. Meyer (eds) (2005) *IPCC special report on Carbon Dioxide Capture and Storage*, prepared by working group III of the IPCC, Cambridge University Press, Cambridge. Available at www.ipcc.ch.

[38] http://www.xstrata.com/reports/doc/x_hsec_climate_change_2004.pdf.

Through its approach to climate change, Xstrata Coal:

- acknowledges that any action taken to address climate change has a delay, so planning for the future is needed now;
- is committed to playing a part in identifying and implementing solutions to the challenge of climate change;
- recognises that the future will be a "carbon-constrained world";
- is working together with governments, researchers and industry in Australia through the COAL21 programme to develop a portfolio of options for reducing greenhouse gas emissions from the use of coal in electricity generation;
- collaborates in research and development programmes and provides both technical and financial support to dedicated Cooperative Research Centres focused on near zero emission technologies;
- supports additional research into CO_2 capture and storage;
- assesses its products for utilisation in new, near-zero emission future technologies, such as gasification;
- has developed a close working relationship with the power generation industry to help expand the implementation of higher efficiency, low emission power plants;
- strives continually for the more efficient use of energy and reduction of greenhouse gas emissions at its operations;
- looks to collaborate with its customers, both domestic and international, towards the sustainable use of coal through new power generation technologies;
- seeks to enter into joint ventures with power generation companies in capturing and using methane to generate electricity, thereby preventing further greenhouse gas emissions from its operations; and
- monitors and explores opportunities for the use of emission reduction mechanisms proposed in the Kyoto Protocol.

Xstrata Coal plans to spend in excess of US$9 million over the next five years on research into clean coal technology, methane utilisation, and carbon sequestration.

41. More recently, Xstrata Coal put the following comment on its web site:[39]

> The projected growth in demand for fossil fuels underpins Xstrata's strategy to continue to grow our thermal coal business. However, it also highlights the urgent need to find ways to reduce the CO2 emissions that result from using coal as an energy source.
>
> Xstrata mines about 1.5% of the world's annual thermal coal production, and is the largest exporter of the fuel. There are three main sources of greenhouse gas emissions associated with our coal products. The most significant is the use of coal as an energy source by our customers. Greenhouse gas emissions are also generated from the extraction and production of coal. A third source of greenhouse gas emissions is the transportation of coal to our customers.
>
> In 2009, combustion of the coal we produced by our customers accounted for approximately 227 million tonnes of CO2e, or approximately 10 times the Scope 1 and Scope 2 emissions generated by our operations. The transportation of coal from our ports to our customers accounted for approximately 11.6 million tonnes of CO2e.

42. There are many ways in which the use of coal can be made more efficient, thereby reducing overall emissions, but the potential for commercial, industrial-scale CO_2

[39] http://www.xstrata.com/sustainability/environment/climatechange/reducingemissionsfromcoal/

currently a matter of speculation. While CO_2 has been injected into declining oil fields for more than 30 years to increase oil recovery and the technology for capturing of CO_2 is already commercially available for large CO_2 emitters, such as power stations, storage of CO_2, is a relatively untried concept. At this time, no power station anywhere in the world operates with a full carbon capture and storage system.

43. The research that is currently being conducted on geo-sequestration is not expected to produce viable, commercial applications for at least 15 years. Even on the most optimistic view, there would then be major economic and practical issues of retro-fitting existing power stations and other coal burning facilities to capture CO_2 emissions and pump them underground. The potential for geo-sequestration also depends upon locating suitable geological formations into which the gas or liquid form of the emissions can be injected with complete confidence that the carbon would not escape. This is certainly problematic, and very probably costly.

44. Based on currently available technology it can be assumed that none of the CO_2 emissions from the use of the coal from this mine will be captured and stored underground. Consequently, it should be assumed for the purposes of assessing the potential impacts of the mine that all of the greenhouse gas emissions from the mining, transport and use of the coal will be emitted to the atmosphere and contribute to global warming and climate change.

ALTERNATIVES

45. It is sometimes asserted that there is no realistic alternative to fossil fuels for electricity generation. A 1992 report by the national energy research body[40] found we could get all our electricity from a mix of renewables by 2030, with storage to allow for periods of little wind and no sunlight. More recently, the 2010 report by Beyond Zero Emissions and the Institute of Energy at the University of Melbourne[41] showed that we could move to supply Australia's power needs completely from a mix of renewables by 2020: roughly 50 per cent wind power, 40 per cent solar with storage and 10 per cent hydroelectricity. The 1992 report concluded, on the basis of the technology available nearly twenty years ago, that moving completely to renewables would increase power prices by about 50 per cent. The BZE report found that the overall cost of providing electricity from now to 2050 would not be significantly more if Australia adopted their approach, because the extra capital investment in the next ten to twenty years would be offset by the dramatic reduction in replacement of fossil-fuel capacity and the total elimination of fuel costs. Adopting this approach would require a significant investment in the next decade or two, but it is a practical scheme for meeting our needs without releasing carbon dioxide into the atmosphere by burning fossil fuels.

[40] M.Stevens, Renewable Electricity for Australia, NERDDC Discussion Paper no. 2, Department of Resources and Energy, Canberra 1992

[41] Beyond Zero Emissions, Zero Carbon Australia, BZE/University of Melbourne 2010

SUMMARY OF CONCLUSIONS

46. The burning of fossil fuels – coal, oil and gas – has dramatically increased the amount of carbon dioxide in the air and strengthened the natural "greenhouse effect".

47. The average temperature of Australia has increased by about 0.9 degrees in the last hundred years, more than the global average.

48. The Australian Academy of Science recently concluded that global emissions need to peak before 2020 and then decline rapidly to give a better-than-even chance of keeping the further increase in average temperatures to 1 degree. Present trends of increasing fossil fuel use could see average temperatures rise by as much as five degrees this century.

49. The climate changes of the last hundred years are already imposing serious economic, social and environmental costs on Australia and the rest of the world.

50. This project, if approved, would add about 1.3 billion tonnes of CO2 equivalent to the atmosphere. Its annual emissions would be greater than the total figure for New Zealand and about 7.4 per cent of Australia's national total.

51. Based on currently available technology, it must be assumed that none of the carbon dioxide emissions would be captured and stored; all of that carbon dioxide would affect the global atmosphere for centuries.

52. There are realistic alternatives to the burning of increasing quantities of coal.

DECLARATION

53. In accordance with rule 428 of the *Uniform Civil Procedure Rules* 1999 (Qld), I confirm that:

    (a) the factual matters stated in this report are, as far as I know, true; and

    (b) I have made all enquiries considered appropriate; and

    (c) there are no readily ascertainable additional facts that would assist me in reaching more reliable conclusions; and

    (d) the opinions stated in this report are genuinely held by me; and

    (e) this report contains reference to all matters I consider significant; and

    (f) I understand that my duty is to assist the Court and that it overrides any obligation I may have to any party to the proceeding or to any person who is liable for my fees or expenses; and

    (g) I have complied with my duty to assist the Court.

Signed: **Professor Ian Lowe**

Date: **.....5 August 2011.....**

Address: **5/2 Tamarindus Street, Marcoola 4564**

APPENDIX 1

BRIEF BIOGRAPHY: PROFESSOR IAN LOWE AO FTSE FQA

Professor Ian Lowe is an emeritus professor at Griffith University, where he was previously Head of the School of Science. He holds a Bachelor of Science with Honours in physics from the University of New South Wales, a D.Phil. from the University of York (UK) and was recently awarded a D.Univ. by Griffith University.

Professor Lowe is an internationally recognised expert on environmental issues, energy, science, technology and futures. He has held senior advisory roles for all three levels of government and consulted extensively for companies and peak organisations in the private sector. He is President of the Australian Conservation Foundation and a Fellow of the Australian Academy of Technological Sciences and Engineering.

Professor Lowe was made an Officer of the Order of Australia in 2001 for services to science and technology, especially in the area of environmental studies. In 2002, he was awarded a Centenary Medal for contributions to environmental science and won the Eureka Prize for promotion of science. He has also received the Prime Minister's Environment Award for Outstanding Individual Achievement and the Queensland Premier's Millennium Award for Excellence in Science. Professor Lowe is a member of the Environmental Health Council, the Radiation Health and Safety Advisory Council and the National Enabling Technologies Stakeholder Advisory Council. He is a past member of many senior advisory bodies, including the National Commission for UNESCO. He chaired the Queensland Government task force implementing the reform of science education and the Brisbane City Council task force on climate change and energy. He is deputy chair of the Queensland Sustainable Energy Innovation Group, which advises the state government on energy innovations, and a member of the Queensland Premier's Climate Change Council. He chaired the advisory council that produced in 1996 the first national report on the state of the environment. He was a member of the National Energy Research, Development and Demonstration Council from 1983 to 1989, chairing its standing committee on economic, social and environmental issues, and directed the Commission for the Future in 1988.

Professor Lowe has been a referee for the Inter-governmental Panel on Climate Change, the scientific body set up by the United Nations to advise on climate change. He attended the Geneva, Kyoto and Copenhagen conferences of the parties to the Framework Convention on Climate Change, and was a member of the Australian delegation to the 1999 UNESCO World Conference on Science. He was on the steering group for the UNEP project Global Environmental Outlook and an invited participant in the 2000 and 2003 workshops on Sustainability Science. He acted as a referee for both the International Geosphere-Biosphere Program's 2004 report, "Global Change and the Earth System", and the UN's Millennium Assessment Report, released in 2005.

Professor Lowe has made countless contributions to newspapers, radio, television and periodicals and gave the ABC's Boyer lectures in 1991.

APPENDIX 2 – IPCC SYNTHESIS REPORT

Extracted from: IPCC (2007) *Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, 104 pp

[this extract does not includes only the main body of the Synthesis Report and excludes the glossary and index].

Note: Due to the file size, this appendix was deleted from this file. It is available on the IPCC website.

APPENDIX 3 – CSIRO CLIMATE CHANGE IN AUSTRALIA TECHNICAL REPORT (AND UPDATES)

Executive summary extracted from: CSIRO (2007) *Climate Change in Australia – Technical Report 2007*, CSIRO, Melbourne

CSIRO (2009) *Climate Change in Australia – Science update 2009 issue one*, CSIRO, Melbourne

CSIRO (2009) *Climate Change in Australia – Science update 2009 issue two*, CSIRO, Melbourne

Note: Due to file size, this report was deleted.

It is available on the CSIRO website.

APPENDIX 4 – DERM AND QUEENSLAND CLIMATE CHANGE CENTRE OF EXCELLENCE –

CLIMATE CHANGE: WHAT THE SCIENCE IS TELLING US

Note: Due to file size, this appendix was deleted. It is available on the DERM website.

APPENDIX 5 – CLIMATE COMMISSION – THE CRITICAL DECADE

Note: To reduce the file size this appendix was deleted. It is available on the Climate Commission website.

APPENDIX 6 – BEYOND ZERO EMISSIONS –

ZERO CARBON AUSTRALIA STATIONARY ENERGY PLAN

Note: Due to file size, this appendix was deleted. It is available on the BZE website.

The total length of this report in the form presented to the court was 497 pages.