CSIRO Submission 12/448

Productivity Commission *Draft Report*: Barriers to Effective Climate Change Adaptation

Productivity Commission, Australian Government

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Executive Summary

CSIRO considers that the Productivity Commission Draft Report on Barriers to Effective Climate Change Adaptation identifies a number of important general principles, including:

- there is a limited role for governments in adaptation;
- not all barriers warrant intervention;
- 'low regrets' actions should be prioritised; and,
- interventions and reforms should increase community well-being. On that basis most specific sectoral recommendations in the Draft Report are justified.

However, the Draft Report has a framing which CSIRO believes underestimates the challenges of adaptation policy and action by governments, industries and communities.

CSIRO considers that this framing overstates the degree of uncertainty about future climate change and the inability of people to make decisions in the face of this uncertainty. We also consider that the Draft Report overstates the inherent capacity of individuals, communities and industries to act, and act in a proactive way.

As a consequence of this framing CSIRO is of the view that the Draft Report underestimates the risks to Australia, resulting in a generally superficial analysis of the role of government in adaptation across the economy. This includes not undertaking a quantitative assessment of the economic costs and benefits of different interventions to support the recommendations.

In lieu of this more analytical approach the report relies on submissions to identify areas for action, which means it concentrates on areas where people are already active. CSIRO considers that this is a risky approach for Australia given the policy and societal implications of the recommendations as they stand. CSIRO suggests that the Draft Report's findings would be greatly strengthened by a rigorous analytical assessment of the net economic case for action or inaction across different sectors of the economy.

1. Introduction and background

CSIRO, through its Climate Adaptation Flagship, has significant research activities nationally and internationally and works closely with governments, industry and the community to develop practical and effective adaptation options. Our focus encompasses areas of relevance to policy, and our submission (Dec 2012) to the Productivity Commission's broad Issues Paper noted that "we would welcome the opportunity to discuss any areas in more depth with the appropriate subset of CSIRO scientists".

Many of the points that will be raised in this response to the Draft Report were raised in CSIRO's December 2011 submission to the Commission's Issues Paper. Now that the framing being used by the Commission is clearer we can recast these points in the context of that framing, which we consider underestimates the adaptation challenges facing Australia.

Adaptation to climate change is a complex systems topic that, like sustainable development, is not adequately analysed in a conventional economic framework that is implicitly constrained by equilibrium thinking. Issues such as non-stationarity in the operating environment, thresholds and non-linear change, and emergent properties across scales cannot be addressed from within this framing.

This submission focuses on a number of areas where CSIRO considers that the framing of the Draft Report understates the adaptation challenges, then turns to how this might be addressed.

2. Analytical framing that under-rates risks to Australia

CSIRO believes the framing of the Draft Report results in an under-rating of the risks facing Australia in adapting to climate change. This framing is illustrated by drawing on quotes from the Draft Report:

1. "*The timing and magnitude of future changes to the climate are uncertain…*" (p.3): Box 1 sets the direction for the report, which is that all aspects of the future are highly uncertain. CSIRO considers that this is a misreading of the science as far as decision-making is concerned, as noted in our original submission. Although Box 2 notes that 'some' change is locked in, the report continues as if there are no minimum levels of change and uncertainty is universal, and refers mainly to the IPCC AR4[1]. However, research over the past 3 years makes it increasingly clear that there is little chance of avoiding a minimum of +2°C rise in

[1] 'AR4' and 'AR5' in this submission refer to the IPCC's Fourth Assessment Report in 2007 and the forthcoming Fifth Assessment Report respectively.

average global temperatures (Anderson[2] and Bows 2008; Allen et al. 2009; Meinshausen et al. 2009; Rogelj et al. 2010; Anderson and Bows 2011). Furthermore, the AR4 projections indicate that this degree of warming is very likely to occur during 2050-2080[3]. CSIRO considers that this is a far more reliable prospect for planning than many other sources of uncertainty in public decision--making.

CSIRO also considers that the uncertainty of different climate related changes varies greatly, especially at a local scale – increases in maximum temperatures, heatwaves, fire weather conditions, minimum temperatures, ocean temperatures, ocean acidity, atmospheric CO_2 concentration, sea level and others all have an assured direction of change. It is possible to specify a minimum level of change that will occur during the 21st century for each of these variables, and a likely magnitude with some uncertainty in timing (AR4; Stafford Smith *et al.* 2011; IPCC 2012[4]). By contrast some other variables, including local rainfall, are genuinely uncertain, even in terms of direction in some locations (CSIRO and BoM 2007). But in the draft report uncertainty is all-encompassing.

Finally, p.45 perpetuates a related mis-framing – the so-called "cascade of uncertainty"; in fact this is only a cascade in a decision-making context where climate is the only driver (Jones 2000). Most adaptation decisions depend on many other factors and the significance of climate uncertainty may not increase and can often be diluted along a decision-centred pathway. Similarly, substantial and likely risks to various sectors and communities have been identified even after accounting for uncertainty (for example, DCC 2009[5]; Steffen *et al*. 2009). On the other hand, many aspects of good policy making can proceed with a more thoughtful analysis of uncertainty, as discussed at a different scale by Smith and Stern (2011)[6].

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[2] Any reference sources not footnoted in this submission may be found in our original submission to the Commission in Dec 2011 (CSIRO Submission 11/432). All of these were cited there, though publications continue to emerge to support this point.

[3] According to the A scenario projections reported in AR4.

[4] See p.11-13 in this recently released report: IPCC (2012). 'Managing the risks of extreme events and disasters to advance climate change adaptation - summary for policymakers. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change.' (World Meteorological Organisation: Geneva, Switzerland.) The full report is 582pp, published by Cambridge University Press.

[5] Department of Climate Change (2009). 'Climate change risks to Australia's coast: a first pass national assessment.' (Commonwealth of Australia: Canberra.)

[6] Smith, L. A. and Stern, N. (2011). Uncertainty in science and its role in climate policy. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* **369**, 4818-4841

2. "*Generally speaking, households, businesses and other organisations are capable of managing the climate variability and the risks they face*" (p.5): this statement is not supported by evidence or analysis in the Draft Report.
   CSIRO's assessment is that industries that depend on climate as an input, such as agriculture, have been somewhat successful at coping with climate variability, though the value of these responses will plateau over time (Howden et al 2007); but that there is weak evidence for many other sectors. Indeed, there is good contemporary evidence[7] of market failures in managing climate variability and extremes, with one major insurer embargoing new home and contents policies in Emerald and Roma in response to recurring floods; and insurance, particularly for strata title, becoming unaffordable in north Queensland, despite adherence to cyclone codes. So it is clear that efforts at managing current climate variability are still not adequate.

   CSIRO also notes that responses to current climate variability in the policy domain can take a long time to occur: the Draft Report (p.12 and 87-88) cites changes to drought policy in the light of the Commission's 2009 report as an example of successful adaptation. This neglects the history of drought policy reform in Australia: the 2009 recommendations largely paralleled those of the 1990 Drought Policy Review[8] – this apparently straightforward adaptation to climate variability in the most exposed and supposedly adapted sector in Australia actually took well over 20 years to implement due to political and policy difficulties. There remain unresolved perverse incentives in the tax system related to the same issue (Douglas 1995[9]; Stafford Smith 2003) which have long been noted to discourage the uptake of self-reliance technologies in the face of climate variability[10]. The example of drought preparedness highlights how long a lead time (decades) is actually needed for many policy changes, even when they appear obvious and in need of early action.

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[7] (http://insuranceandrisk.com.au/476a20bf/Suncorp%20urges%20better%20flood%20mitigation%20for%20Roma%20and%20Emerald; http://www.aph.gov.au/Parliamentary_Business/Committees/House_of_Representatives_Committees?url=spla/strata/report.htm; and recent Queensland Floods Commission of Inquiry 2012.

[8] Drought Policy Review Task Force (1990). 'Managing for Drought.' (Australian Government Publishing Service: Canberra, Australia.)

[9] Douglas, R.A., 1995. Improving the efficiency of livestock taxation in Australia. In Peterson, D. and Warren, N. (eds.), Rural Income Taxation, Australian Tax Research Foundation, Conference Series 15, 58-71.

[10] e.g. p.147 in Stafford Smith 2003

Thus the sense that adaptation to current conditions by individuals or government is well in hand is overstated, as is the implication that responses will be swift once a new problem is identified. This all contributes to an overly rosy sense that the problem is easy to solve.

3. "*In most cases, autonomous management of climate risks by households, businesses and communities will lead to outcomes that improve the wellbeing of the community as a whole*" (p.5).

   CSIRO considers that this statement is not supported by rigorous evidence, which is important since the achievement of better outcomes through collective action is one of the key roles of government. Indeed, the example provided by the Commission on the same page – that "households will make decisions…[such as] …buying cooling appliances…" is one where there are several potential collective outcome failures that illustrate maladaptation rather than adaptation (Scheraga and Grambsch 1998)[11]. This may result in higher CO_2 emissions, greater and disproportionate demands on power grids on hot summer days and a pricing of poorer people out of the energy market, among other egregious outcomes.

   CSIRO's view is that, whilst there are certainly circumstances in which collective good outcomes may emerge from individual actions, a more robust analysis of the cases in which these do not is needed, as discussed below. This is part of an apparent gap in the report's appreciation of the nature of emergent outcomes in complex systems, notwithstanding acknowledging their potential (p.55).

4. "*Individuals, businesses and governments are already adapting to climate change*" (box 4, p.7)

   CSIRO considers that this statement is provided with little supporting data other than some anecdotal examples of infrastructure projects, local government concerns and agriculture. Indeed, the only systematic (albeit modest) assessment of organisational responses that we are aware of in Australia is that of Gardner *et al*. (2010)[12]. These surveys included state and local government groups, infrastructure management organisations and a variety of industry representatives and individual businesses, oriented towards sectors that CSIRO is engaged with, and found that 59% had performed some form of vulnerability assessment, but less than 40% had proceeded to plan or otherwise act on adaptation. Even among the latter

[11] Scheraga, J. D. and Grambsch, A. E. (1998). Risks, opportunities, and adaptation to climate change. *Climate Research* **10**, 85–95.

[12] This source was cited in our original submission; a second survey, showing similar results from 2 years later, is not yet published but is also available on request.

there were few examples of actual adaptation actions and continued confusion between adaptation and mitigation activities. The surveys do highlight the *types* of organisations that are more likely to be taking action, data which could be used to prioritise investigation into areas where there is little action but a potential need. There are more specific assessments within sectors: for example, within the Superannuation Funds investment sector only 35% had recognised the impact that climate change might have on their investments (The Australian Institute of Superannuation Trustees/The Climate Institute). There is evidence that adaptation is not receiving a high priority in business because their focus has been on how to respond to carbon policies (e.g. see Price Waterhouse Coopers 2009, '*A survey of Australian business leaders' preparedness for the carbon-constrained economy and the Carbon Pollution Reduction Scheme'*).

CSIRO notes that there is also limited work overseas, for example in the UK's 2011 report and other European sources (Adaptation Sub-Committee 2011[13]; Berrang-Ford et al 2011; Ford et al 2011; Hoffman et al 2011), but all of this consistently shows some amount of planning activity with very little actual implementation of adaptation. The lack of action may or may not be rational, in fact, but does not support this assertion of the Draft Report, which then flavours the remainder of the report with a false sense that action is well underway.

5. "*One tool that can help to identify reforms that are likely to deliver net benefits is the 'real options' approach*" (p.9)

   CSIRO considers that the Draft Report relies heavily on 'real options', almost as an adaptation option in its own right rather than a valuation method for better assessing the value (or otherwise) of deferring action whilst information improves. The real options method is useful but it cannot 'identify' reform options, it can only help with the task of appraising whether (or when) they are worth pursuing. In the Summary, this tool is used to imply that all decisions in the face of uncertainty should be delayed until there is better knowledge. CSIRO is of the view that this is an error of framing since the appropriate analysis as generally described within Chapter 4 of the Draft Report is to appraise the expected costs and benefits of action, using real options to include the value of when to act and by how much. Then actions with modest benefit:cost outcomes but high certainty today can be reasonably legitimately compared with actions with high but uncertain returns in the future. This framing is outlined well in Chapter 4, except for an inappropriate treatment of non-linear or threshold changes (see below).

[13] Adaptation Sub-Committee (2011). Adapting to Climate Change in the UK: Measuring Progress, Committee on Climate Change, London. The other citations in our submission show similar outcomes in Europe more generally.

6. "*Some reforms … would only have benefits under certain climate change scenarios.*" (p.10) CSIRO considers that whilst it is often true that "Net benefits are more likely if reforms would deliver benefits under a range of climate scenarios" (p.65), this contributes to the sense that it is difficult to act in the face of uncertainty. There is a growing literature (Dessai and van de Sluijs 2007; Dessai et al. 2008; Hallegatte 2009; Stafford Smith et al. 2011) on robust decision making which looks for options that satisfice across many future possibilities instead of optimising to one; where even this is impossible there are other risk mitigation options such as risk hedging. This shift to framing risk better in adaptation decision-making seems challenging to many decision-makers even though it is widespread in other walks of life. CSIRO suggests that It would be useful if Chapter 4 addressed these issues.

7. "*Within limits, the impacts of gradual climate change should be manageable*" (p.2) CSIRO considers that, despite the mention of limits here, the Draft Report has not considered the potential implications of well-documented non-linear changes and thresholds, whether in the climate system (e.g. Keller *et al*. 2007; Lenton *et al*. 2008)[14], in adaptation responses (e.g. Lempert and Collins 2007; Boer 2010; Howden et al 2010; Benzie *et al*. 2011;)[15], or in our social constructs (e.g. Adger *et al.* 2008,2009; Marshall 2010; Craig 2010)[16], with positive potential (e.g. Westley *et al*. 2011; Park *et al*. 2012)[17] as well as negative.

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[14] Overpeck, J. T. and Cole, J. E. (2006). Abrupt Change in Earth's Climate System. *Annual Review of Environment and Resources* **31**, 1-31
Keller, K. Yohe, G. and Schlesinger, M. (2007). Managing the risks of climate thresholds: uncertainties and information needs. *Climatic Change*: DOI 10.1007/s10584-006-9114-6.
Lenton, T. M., Held, H., Kriegler, E., Hall, J. W., Lucht, W., Rahmstorf, S., and Schellnhuber, H. J. (2008). Tipping elements in the Earth's climate system. *Proceedings of the National Academy of Sciences* **105**, 1786-1793.

[15] Lempert, R. J. and Collins, M. T. (2007). Managing the risk of uncertain threshold responses: Comparison of robust, optimum, and precautionary approaches. *Risk Analysis* **27**, 1009-1026.
Boer, H. (2010). Policy options for, and constraints on, effective adaptation for rivers and wetlands in northeast Queensland. Australasian Journal of Environmental Management 17, 154-164.
Benzie, M., Harvey, A., and Miller, K. (2011). Adaptation in UK Cities: Heading in the Right Direction? In: 'Resilient Cities: Cities and Adaptation to Climate Change - Proceedings of the Global Forum 2010'. Vol. 1 pp. 231-242

[16] Adger, W.N., Lorenzoni, I. and O'Brien, K. L. eds (2008) 'Adapting to climate change: thresholds, values, governance'. (Cambridge University Press: Cambridge.)
Adger, W. N., Dessai, S., Goulden, M., Hulme, M., Lorenzoni, I., Nelson, D. R., Naess, L. O., Wolf, J., and Wreford, A. (2009). Are there social limits to adaptation to climate change? *Climatic Change* **93**, 335-354.
Marshall, N. A. (2010). Understanding social resilience to climate variability in primary enterprises and industries. *Global Environmental Change* **20**, 36-43
Craig, R. K. (2010). "Stationarity Is Dead" - Long Live Transformation: Five Principles for Climate Change Adaptation Law. *Harvard Environmental Law Review* **34**, 9-73.

[17] Westley, F., Olsson, P., Folke, C., Homer-Dixon, T., Vredenburg, H., Loorbach, D., Thompson, J., Nilsson, M., Lambin, E., Sendzimir, J., Banerjee, B., Galaz, V., and van der Leeuw, S. (2011). Tipping

As discussed in CSIRO's submission to the Issues Paper, incremental responses to incremental change are those that are most likely to be achieved through autonomous responses; whilst these need some attention by government, they will mostly occur through actions by individuals and industries. Instead, it is primarily transformative responses (Park et al 2012) and discontinuous change that CSIRO considers should be the focus of analysis. CSIRO suggests that the Draft Report would benefit from more consideration of these issues. In a short reference on p.50, the Draft Report acknowledges that "thresholds may limit the range of adaptation options available" (and non-linear climate change and impacts are acknowledged on p.43 and 45), but this point is never elaborated.

Impact thresholds are mentioned on p.75 where the Draft Report writes "scientists have hypothesised that there could be 'threshold' effects in the way ecosystems adapt to climate change": in fact these are extremely well-known and not just in ecosystems (e.g. Arnell 2000; Walker & Meyers 2007; and sources above)[18]. However, on the basis of describing this as only a hypothesis and putting the term thresholds in quotes, the paragraph goes on to imply that a real options approach will show that no response is required. CSIRO considers that the report would benefit from a deeper consideration of the issue of thresholds and their implications for adaptation responses across a range of sectors e.g. capacity of dams, protective effects of sea walls, non-linear damage associated with extreme events such as wind. This does not necessarily mean that there are policy barriers nor that government should necessarily act in response to thresholds and non-linear change, but since these are all areas of complexity where action is least likely to be socially optimal and where government is most likely to end up as the insurer of last resort, they should at least be a focus for analysis.

The section on precautionary principles on p. 75 also implies that thresholds (and in fact the precautionary principle more generally) are only a concern in environmental issues, and then rather dismisses them there. While there are indeed many well-documented thresholds in ecology, thresholds (or at least, very non-linear responses) are also common

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Toward Sustainability: Emerging Pathways of Transformation. *Ambio* **40**, 762-780.
Park, S. E., Marshall, N. A., Jakku, E., Dowd, A. M., Howden, S. M., Mendham, E., and Fleming, A. (2012). Informing adaptation responses to climate change through theories of transformation. *Global Environmental Change* **22**, 115-126 [*Note: this was cited in our original submission as 2011 but final publication was delayed to 2012*]

[18] Arnell, N.W. (2000). Thresholds and response to climate change forcing: the water sector. *Climatic Change* **46**: 305-316.
Walker, B. H. and Meyers, J. A. (2004). Thresholds in ecological and social–ecological systems: a developing database. *Ecology and Society* **9**, 3.

in many other walks of life, whether in relation to the capacity of dams, the protective effects of sea walls, the non-linear damage functions experienced in relation to most extreme events, in diverse social processes including preparedness to acknowledge that there may be a problem, and so on (see sources already cited). This does not necessarily mean that there are policy barriers nor that government should necessarily act, but since these are all areas of complexity where action is least likely to be socially optimal and where government is most likely to end up as the insurer of last resort, CSIRO considers that they should at least be a focus for analysis; instead, the draft report is silent on their implications.

Notwithstanding the critique above, CSIRO notes that we agree with some important aspects of the Commission's framing. In particular, governments should have limited roles; as much adaptation as possible should be facilitated to happen autonomously using local information; over-investment in early adaptation *is* ill-advised; and the existence of barriers does not mean that it is necessarily worth government acting on them.

3. Limits to the resulting analysis

CSIRO considers that the result of understating the risks and over-stating the preparedness of society for these is that a quantitative analysis of the economic costs and benefits of different interventions was not undertaken to support the recommendations. This is a risky approach given the potential policy and societal implications of the recommendations as they stand.

CSIRO notes that the Commission has relied heavily on key issues being raised by submissions. This approach has limitations because those areas of society that are not aware of adaptation needs would have not been motivated to make a submission. Submissions are therefore dominated by areas that are engaged; in the absence of a comprehensive and quantitative analysis, this simply serves to reinforce the sense that society is engaged in the issue, a classic example of 'confirmation bias'. CSIRO's questions whether there has been a resultant reliance on these submissions to identify the areas where action is needed (e.g. local government, insurance, planning and emergency management). Sectors that did not provide submissions have not been considered to the same extent: an equally viable proposition is that those other areas have not yet thought deeply about adaptation.

At a high level we identify at least two resulting areas of analytical gaps in the Draft Report:

(a) Roles and concerns of government

The Draft Report argues that: "governments…role in facilitating effective adaptation…might include:

- Managing climate risks effectively in their own activities
- Ensuring regulatory and policy frameworks do not unnecessarily impede private risk management…
- Correcting market failures…where the benefits to the community exceed the costs
- Managing the distributional impacts…for disadvantaged and vulnerable groups." (p.8)

CSIRO considers that the analysis would greatly benefit from a more authoritative and comprehensive statement about the potential role of government in lifting barriers to adaptation, *i.e*. beyond "role *might* include". For example, many activities can be included under 'correcting market failures' but the report goes on to identify only a few, without a comprehensive analysis. Not all these issues are particularly within the expertise of CSIRO, but at least some examples of areas not considered do emerge from our research activities:

- *The high level role of government* in maintaining a secure and stable economy in the face of change: while the Draft Report asserts the importance of a strong economic environment, it does not address whether this environment might be affected in systematic and holistic ways by climate change. For example, in the absence of convincing proactive adaptations to current and likely near-future climate extremes, insurance companies are showing signs of not offering coverage to new customers in high risk areas or increasing premiums to much higher levels for existing customers (see footnote 7). With at least some aspects of climate variability *likely* to increase in the future (IPCC 2012)[19], there is a growing prospect of more people being left uninsured under current approaches.

  Similarly, around two-thirds of Australia's large superannuation funds are currently invested within Australia. If increasing occurrence of extreme events without proactive adaptation results in an unstable investment environment these investments may seek more stable investment environments overseas, a concern that is being raised by

[19] Op.cit, footnote 4.

investors[20].Whether this is plausible therefore requires further analysis.

If either of these effects is plausible, then CSIRO considers that the assessment of individual adaptation actions needs to account not only for their individual value but also for their collective outcome – having (or not having) a better prepared Australia with a more stable economy that is attractive to investment and insurance. This analysis – and potentially a higher resulting level of facilitatory action than would be justified on the basis of individual assessments – is a core role for government. It is an example of emergent properties that the report does not analyse.

- *Emergent effects of coincident impacts*: another emergent (and emerging) concern for governments is the holistic risk faced due to coincident events – whether literally coincident in space and time (e.g. terrestrial flooding combined with storm surge), coincident in time (e.g. floods in Queensland at the same time as fires in Victoria as occurred in 2009, which may stretch the nation's total simultaneous emergency response capability) or just coincident within a jurisdiction within a financial year (as with floods and storms across the continent in 2010-11, which may stretch the budgetary capacity of governments even through taxes on the community to deal with restoration).

  CSIRO considers that it would be useful to have an analysis of how the implications of the thresholds of response capacity that each of these types of coincident events represents would affect the assessment of benefits from investing in individual proactive adaptation projects due to their emergent benefit. To our knowledge this analysis is not available, so it is not possible to say quantitatively how much additional impetus it would provide for policy change in the disaster risk reduction area, otherwise addressed in Chapter 10; even now it would be possible to perform a first pass analysis of this nature.

- *Timing of investments*: notwithstanding a clear statement of methodology from Fankhauser in Chapter 4, CSIRO considers that the Draft Report would benefit from an application of this methodology to a stronger analysis of timing issues in investments. Issues which may result from conceptualising adaptation decisions as individual and disaggregated include several dimensions, such as that of coincident investments.

  CSIRO's view is that organisations (including government) with a large asset base that

[20] By the Investor Group on Climate Change at the ANU/NCCARF/DCCEE Policy workshop, Canberra, 3-4 May 2012, report available from Bob Webb, ANU.

may be widely exposed to climate change need to ensure that an incremental and disaggregated view on adaptive asset replacement does not result in all action being scheduled for the same short time period. For example, major utilities own infrastructure worth many billions of dollars (~$30bn in the case of Sydney Water). Many elements of these assets are likely to be significantly affected by climate change by around 2030 (12 high risk priority areas identified, Sydney Water 2008); assessed individually, replacement of these with climate change ready assets may not be worthwhile until close to 2030. But to replace much of the portfolio at once would clearly make impossible demands on liquidity, so a holistic view will promote earlier replacements to spread the investment load. Government regulation of public/private utility investments and their resulting pricing structures often does not encourage such a long-term view view (e.g. Grafton and Kompas 2007)[21].

The Draft Report emphasises the potential for delaying decisions (justified by a real options analysis); after noting the analytical method in Chapter 4, it does not consider the potential benefits or costs of bringing decision-making forward, to spread the investment load or for other reasons. As a consequence the role of government in facilitating earlier action, through the provision of smartly-targeted seed funding programmes and other means is not addressed.

- *Emergent community benefits from collective action*: the Draft Report highlights the issue of net community benefits – a good focus for assessing adaptation success, but one that is not greatly followed up with a keen eye on where individual responses do not result in the best community level outcome, at least in a timely manner, often with consequences for governments as the unwilling insurer of last resort. CSIRO considers that a much more critical assessment of this across sectors would be desirable.

- *Contested institutions*: government has a vital role to play in resolving issues where institutions are contested and no one player has legitimacy, even when this applies to government itself. This point was discussed in our original submission (Gorddard et al,) as a case where lead times are long, change may need to be transformative, and a considerable proactive investment in the engagement of multiple stakeholders including the public often pays off with much lower eventual costs to the community. Whilst Chapters 7-9 touch on issues of importance in coastal planning, the role of government

[21] Grafton, R. Q. and Kompas, T. (2007). Pricing Sydney water. Australian Journal of Agricultural and Resource Economics 51, 227-241.

as early facilitator is not addressed. Water reform and the Murray-Darling Basin is another case in point: the current Basin Plan does not yet take account of climate change, and the process of including such issues has a very long leadtime.

(b) Systematic analysis across the economy

The Draft Report notes that "The first step in setting reform priorities was to identify areas where the case for reform was likely to be strongest" (p.76) then outlines sensible criteria for so doing (p.77). However, it then asserts that "Based on research, consultation with stakeholders and evidence received in submissions, the Commission identified a number of areas where reforms to address barriers could have broad effects." No detail is provided on these interactions or the methodology so it is difficult to assess whether all important issues have been identified, either cross-sectorally or in individual sectors, nor is there a synoptic qualitative analysis to ensure that all areas of potential high impact have been identified and examined.

Australia currently lacks a comprehensive synoptic analysis of this nature, although Nelson et al. (2011)[22] provided a methodology which could be implemented at a variety of levels of detail, from a quick first overview, through to a detailed economic appraisal (see Appendix 1); it also made an initial qualitative analysis by sector of what transformational adaptation might be important and at least potentially require policy consideration (Appendix 2). CSIRO considers that the Report would have benefited from building on these initial efforts at systematisation to ensure that there is a strong case for *inaction* in the sectors which are omitted.

High levels of exposure to climate change in a particular sector does not mean that there will necessarily be useful actions open to government on barriers: but these sectors should at least be identified and looked at closely. Conversely, modest exposure in a sector does not mean that if there is at least one important barrier amenable to government action then this should not be pursued. Thus both a framing analysis and a sector-by-sector discussion would be desirable in CSIRO's view.

Sectors with high exposure: In the absence of an holistic analysis (see Appendix 1), one high level indicator of sectors with potentially high exposure is provided by the typical asset lifetime of different sectors. Such data is available (e.g. see Taxpayers Australia 2010)[23] but has not been analysed in this way as yet.

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[22] Nelson, Byron and Stafford Smith (2011). *Adaptation as a public policy agenda*. DCCEE Discussion paper 4. Sections are reproduced in Appendices 1 and 2 herewith.

[23] Taxpayers Australia (2010). *Effective life tables for depreciating assets: From 1 July 2010*. Online resource (http://www.taxpayer.com.au/assets).

Sector by sector appraisal: Nelson *et al.* (2011), reproduced in Appendix 2, drew on a wide consultation to address the following sectors as an initial appraisal of potential policy issues, particularly considering transformative levels of climate change: government, coastal settlements, infrastructure, financial institutions, water, natural ecosystems, health, emergency management and agriculture. In order to confidently dismiss the need for action, CSIRO considers there are a series of other sectors that could receive the same treatment (with some examples of issues where there may be barriers amenable to government action):

- Mining (although the larger companies have high capacity for autonomous adaptation, there are emergent impacts on the national economy that warrant analysis, and there is also a large number of smaller miners with low capacity)
- Roads and transport (although transport is dismissed in the Draft Report [p.77] and is included under infrastructure in Appendix 2, it is worth noting that roads regularly attract 80%+ of disaster recovery emergency funding; there is therefore an emergent issue of whole-of-stock scheduling for adaptation preparedness.)
- Aging (although health is considered in Appendix 2, the specific implications of changing demographics and an aging population in the face of climate change warrant consideration, as many responses have long lead times.)
- Social services (this under-considered area contains some known issues such as the lack of incentives for tenants in low income housing[24] to act on adaptation or mitigation.)
- Education (skills in systems thinking and understanding probabilities and risk management are becoming increasingly important as no regrets improvements in adaptive capacity for climate change but also many other issues[25].)
- Tourism (there may well be no material barriers that are specific to this sector [p.77], strong regional dependence on tourism may lead to the needs for critical structural adjustment, that has a long lead time. For example, the Draft Report repeatedly mentions the potentially catastrophic impacts on the Great Barrier Reef [e.g. p.50] but draws no conclusions, cross-sectoral or otherwise, from this.)
- Energy (energy ratings policy will be invalidated by a non-stationary climate (Wang et al. 2010a), and a new approach will be required which does not require continual updating;

[24] CSIRO is carrying out a project exploring this particular issue, available for discussion on request.

[25] See CSIRO submission to Senate Enquiry on climate change, skills and employment, 2008 for more details.

to avoid maladaptation, this should be available soon for new infrastructure that has multi-decadal lifetimes)

- Immigration (there are considerable possible implications for Australia due to the impacts of climate change on our neighbours, near and far; these could trigger environmental refugee movements, increased demands for emergency aid, conflicts over resources. Where international policy dimensions are involved, there are likely to be long lead times involved.)
- Quarantine, shifting fisheries stocks (natural movement of species will test our quarantine laws and definitions of weeds [is an invading species from Papua New Guinea a weed or a successful adaptor (Dunlop & Brown 2008)?] and may challenge international fisheries interactions: international negotiations to resolve such issues will have a long lead time.)

Whilst this is a partial and qualitative appraisal, CSIRO suggests that a developed version would provide a more comprehensive basis to assess (or justifiably dismiss) where a closer analysis of policy might be most warranted.

Environment sector: regarding section 11.1 in the Draft Report, CSIRO notes that there is extensive documentation of clear thresholds in responses in biological systems (see sources cited above, and Steffen *et al*. 2009), and a growing body of literature on responses (Dunlop & Brown 2008; Steffen *et al.* 2009; Williams *et al.* 2009; Dunlop *et al.* 2012; Williams *et al*. 2012)[26]. A number of policy issues arise from these that have not been considered by the Draft Report. The most notable example documented in these reports, which is unequivocally a public policy issue and clearly a barrier to timely action, is the question of re-framing policy objectives for conservation (Prober and Dunlop 2011)[27]. This is an example of a transformative issue with a long lead time, since it will require awareness in governments, considerable public consultation and changes in attitude before it can be achieved. And there are many other areas of related policy barriers, including the

[26] As noted in our original submission, not all of these are public yet but could be made available to the Commission on request; the others are referenced therein, except: Williams, R. J., Bradstock, R. A., Cary, G. J., Enright, N. J., Gill, A. M., Liedloff, A. C., Lucas, C., Whelan, R. J., Andersen, A. N., Bowman, D. M. J. S., Clarke, P. J., Cook, G. D., Hennessy, K. J., and York, A. (2009). 'Interactions between climate change, fire regimes and biodiversity in Australia - a preliminary assessment.' (CSIRO: Canberra.).

[27] Prober, S. M. and Dunlop, M. (2011). Climate change: a cause for new biodiversity conservation objectives but let's not throw the baby out with the bathwater. *Ecological Management and Restoration* **12**, 2-3

legislative definition of invasive species (Webber and Scott 2012)[28], various issues related to the EPBC Act[29], and parallels at State government levels.

4. Implications

A more systematic and comprehensive analysis would almost certainly concur with the Draft Report that the issues of local government, planning, emergency management and insurance are important. CSIRO also agrees with the report that the existence of a potential issue does not necessarily mean that there is a barrier to action that is amenable to government intervention, nor that government should be involved in 'everything'. However, this submission has shown that there are other areas of government endeavour which are worth considering and that the evidence is not provided in the Draft Report that these have been systematically dismissed for good reason. Further, notwithstanding some excellent discussion in the fine text of the Draft Report, the Chapter summaries and particularly the overall summary give a strong sense that relatively little action is required of government. CSIRO suggests that this case has not been made and examining the following issues would address this gap:

- The role of government needs stronger and more comprehensive analysis, with better quantification of areas that need closer attention
- Whilst a line-by-line analysis of legislation is not warranted as argued by the Draft Report, clear and systematic qualitative analysis of all major sectors in government is required (and the basis for this exists, and could easily be built upon); ideally this would be accompanied by some degree of quantitative analysis though it is recognised that this is not a trivial undertaking
- An improved analysis is required of specific emergent impacts and timing issues, particularly assessing the value (or otherwise) of speeding up proactive action beyond what would be suggested by separate analyses of individual adaptation actions; it may be beyond the scope or resources of the Commission to undertake this assessment but it is needed.
- A more robust analysis of the environment sector is highly desirable, particularly focusing on government roles in setting objectives and consequent legislative definitions across various sub-sectors including conservation, invasives, offsets, etc.

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[28] Webber, B. L. and Scott, J. K. (2012). Rapid global change: implications for defining natives and aliens. *Global Ecology and Biogeography* **21**, 305-311.

[29] Documented in CSIRO's public submission to the recent EPBC Act Review

- More considered assessment be given of supporting preparedness for transformational change in many areas (through actions beyond just providing information)
- More analysis be made of the role of government in community education about risk management and systems thinking

5. Conclusion

CSIRO is happy to engage further in discussion to expand on or provide more analytical detail beyond this submission.

Attachment 1 – Analysis methodology proposed by Nelson *et al*. (2011).[30]

Economic analysis of adaptation

Economic analysis of adaptation helps to explain why the adaptation we see happening across Australian society tends to be incremental responses once significant change has already occurred. As we will see below, it also suggests that foregoing opportunities for flexible and low cost adaptation is likely to impose significant efficiency losses on the Australian economy.

Unlike action that follows change, adaptation that anticipates future change is a form of insurance that can be undertaken by the private sector or governments or both. It involves making small, relatively certain (precautionary) investments to avoid or manage the consequences of uncertain and potentially much larger future costs.

Framing adaptation that anticipates change as a precautionary investment similar to insurance helps to explain the option value often associated with adaptation. In financial terms, a formal insurance contract is an example of a *put option*. An insurance contract specifies the right, but not obligation, to sell a damaged asset at a predefined price if uncertain adverse events occur.

However, framing adaptation that anticipates change as insurance or a form of precautionary investment does not imply that it can only be implemented through formal insurance markets. Local adaptation is implemented by individuals, households and businesses who can weigh the costs and benefits of taken action to pre-empt climate change and decide whether and how much to invest in self insurance. Self insurance can be financial, through setting aside funds to meet future adaptation expenses. Alternatively it can involve a raft of actions to manage risk (raising a house on piers), deal proactively with uncertainty (relocate) or build adaptive capacity (diversify income sources).

The economics of adaptation

There is a strong prima facie case for thinking that adaptation to anticipate future change is likely to be economically more efficient than reacting after significant change has occurred. This is because acting in advance of change is likely to increase opportunities for flexible and low cost adaptation, and enable adaptation responses with potentially adverse and irreversible consequences to be avoided.

This is demonstrated in figure 4. The marginal costs of adapting after significant change has occurred (C_R) are likely to start high and rise rapidly within a constrained set of adaptation

[30] reproduced from pp.9-13 in Nelson *et al*. 2011 – see footnote 22

options (C_R asymptotes at A_{limit}). The costs of adapting after change start high because many opportunities for low cost, anticipatory adaptation are precluded. Limited time for planning and innovation constrains the overall set of available adaptation options. Those that are available are likely to include a high proportion of crisis responses with unavoidable adverse and sometimes irreversible consequences.

In contrast, the marginal cost of proactive, adapting to anticipate significant change (C_p) start low, and are likely to include a high proportion of no-regrets options that can be undertaken for other purposes with little or no additional cost (marginal cost starts negative). The costs of adapting to anticipate change rise slowly across a broad set of adaptation options. Adequate time for planning and innovation mean that it is much less likely that adaptation options will be constrained over the relevant range (C_p does not reach a vertical asymptote).

The marginal benefits of adapting before or after significant change also differ significantly. The benefits of adapting after significant change has already occurred start high but diminish rapidly (B_R has a steep slope). Crisis management dictates immediate responses regardless of the cost. Consequently, the benefits of adapting reactively in response to significant change are immediate and certain, but small. The total benefits of adapting after change are small because this type of adaptation contributes little to longer term adaptive capacity (B_R is close to the y axis).

In contrast, the marginal benefits of adapting to anticipate significant future change start low, but diminish only gradually at higher levels of adaptation (B_P has a shallow slope). Marginal benefits start low because there is no pressing need to adapt. Action is taken well in advance of the adverse impacts of climate change. This makes it difficult to evaluate immediate and very tangible investments in adaptation against the uncertain and relative intangible future benefits of adapting.

Uncertainty also means that the full value of any single investment in anticipatory adaptation may never be fully realised. Each investment creates the option of a better future outcome – whether or not this benefit is realised depends on the future direction of change, and whether options are exercised. If this option value is accounted for, the total benefits of anticipatory adaptation are likely to be high because it contributes significantly to building longer term adaptive capacity (B_R is distant from the y axis).

The result is that adapting after significant change has occurred leads to smaller amounts of high cost adaptation (A_R, P_R), than adapting to anticipate future change (A_P, P_P). The net cost to the economy of relying on adaptation after significant change has occurred is the value of

foregoing opportunities to anticipate change. In the simple model presented here, this is equal to area B (the value of anticipating change) minus area A (the value of adapting after change).

Figure 4 – The economics of adaptation.

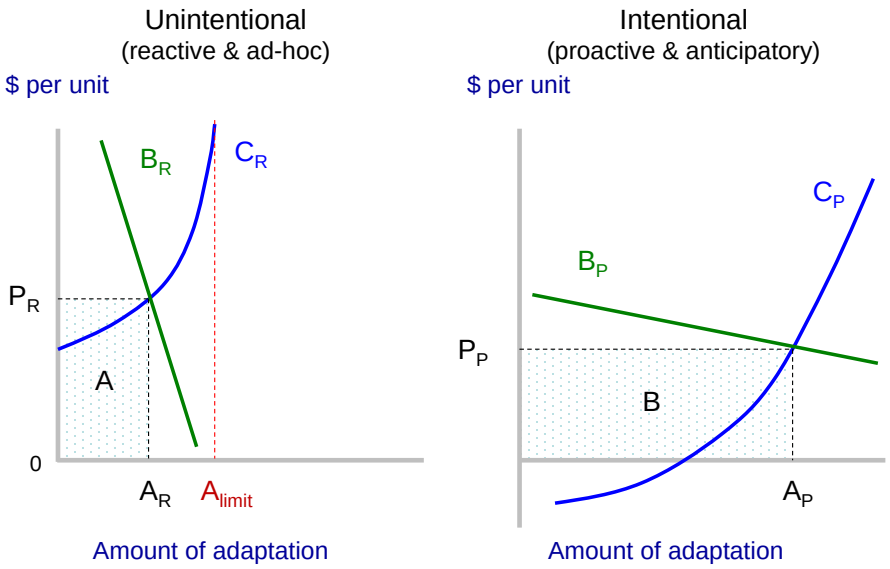
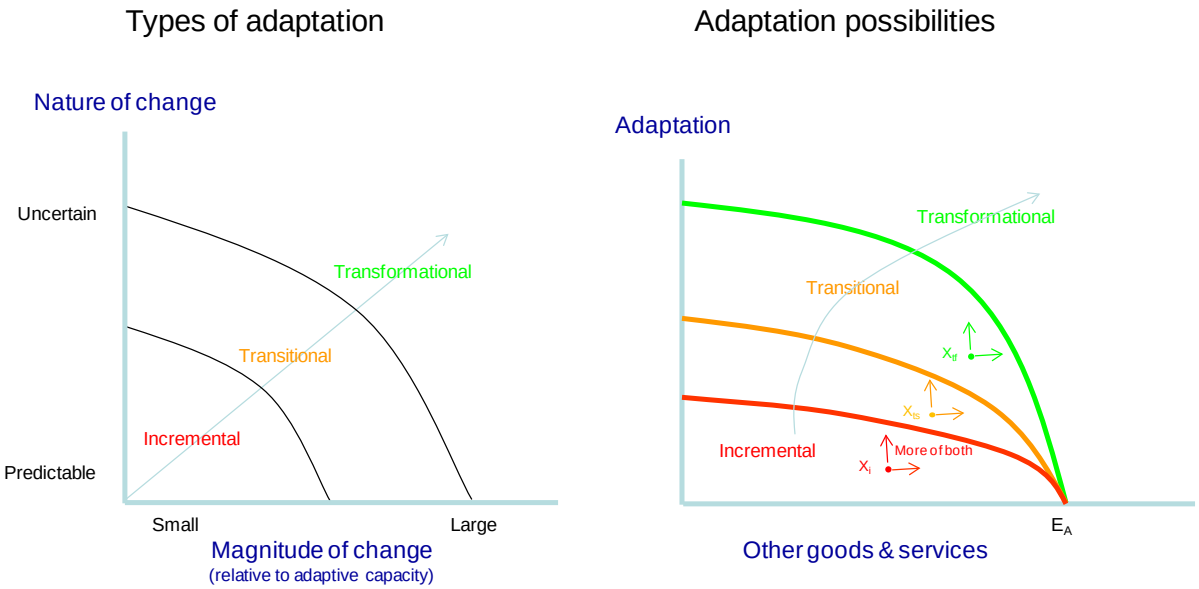


Figure 5 – Types of adaptation and production possibilities



In sectors adapting only after significant change occurs, it will be difficult to refocus adaptation on actions that anticipate future change. This is because adapting reactively once change has occurred may appear to be efficient within existing ways of doing business. If existing ways of doing things that assume a stationary climate have been established over many years, the benefits of taking more transformational action to anticipate a changing climate will seem intangible.

One way to address this challenge is to focus policy development on the adaptation possibilities enabled by the different types of adaptation described above in figure 1 (figure 5). The right hand side of figure 5 shows the different adaptation possibilities that can be achieved through trade-offs with the production of other goods and services. Incremental approaches enable only incremental improvements in adaptation (red curve). Transitional actions rely on getting the most out of current ways of doing things to increase adaptation for any level of effort (orange curve). Transformation increases adaptation even further by adopting completely new ways of doing things (green curve).

Within each of these different types of adaptation, any trade-offs that lies on the red, orange or green curves may appear to be locally efficient. Any point within the curves (such as X_i, X_{ts} and X_{tf}) is inefficient because more of both adaptation and other good/services can be achieved with the same level of effort. However, overall efficiency must consider foregone opportunities to adapt transformationally. For large and uncertain climate impacts, incremental or transitional efforts to adapt are inefficient because much more adaptation could have been by adopting new ways of doing things.

A challenge for economists is to empirically estimate the value of moving beyond incremental adaptation to anticipate significant future climate change.

Table 1 – Estimating the economic benefits of adaptation

Sector	Unintentional (Reactive, ad-hoc)			Intentional (Proactive, anticipatory)			Opportunity cost $
	P_R $	A_R Quantity	Value Area A (P_R x A_R)	P_P $	A_P Quantity	Value Area B (P_P x A_P)	(Area B – Area A)
Government							
Coastal settlements							
Infrastructure							
Water							
Natural ecosystems							
Health							
Water							
Emergency management							
Agriculture							
Total							$ Sum for all sectors

Valuing proactive adaptation

The analytical framework above provides a simple but robust foundation for estimating the economic benefits of proactively adapting to anticipatory future change relative to reacting once change has occurred. The costs (P_R, P_P) and amounts (A_R, A_P) of adaptation can be estimated using existing research across climate sensitive sectors and regions, and aggregated in a simple table (table 1). These costs and adaptation outcomes can be estimated and compared for incremental, transitional and transformation adaptation options. Increasing sectoral detail

can be added to the analysis overtime, supported by increasingly sophisticated economic modelling of the costs and likely future amounts of adaptation.

While beyond the scope of this paper, the analytical framework above raises the question of how to measure and compare adaptation outcomes (the x axis). This problem pre-exists and is not unique to the development of this analytical framework. Further development of this framework will help to guide the choice of methodologies used to value and prioritise adaptation options.

For example, cost-benefit analysis frames adaptation as a choice between well-defined alternatives with reasonably predictable outcomes. It is therefore appropriate for evaluating the benefits of incremental adaptation options. Other methodologies - such as real options analysis – have been developed to guide decision making under uncertainty. These may be more appropriate for evaluating transformational adaptation to anticipate future change.

Attachment 2 – Goals of adaptation vs current trends: Table from Nelson et al. (2011)[31].

Sector	**What adaptation do we currently see taking place?** Characteristics of observed adaptation	**What adaptation would we like to see happening in by 2030 if we are on a trajectory to 2°C?** Characteristics of (mainly) incremental/transitional adaptation and risk management	**What adaptation would we like to see happening by 2030 if we are on a trajectory to 4°C?** Characteristics of (mainly) transformational adaptation and robust decision making under uncertainty
Government	Government role mostly confined to providing information about climate change, with growing attention to adaptation options. Exploratory investigation of potential climate change impacts and adaptation solutions in some agencies. Embedding for many agencies has proven to be an unfunded commitment leading to little or no specific policy development or program commitment.	Adaptation to climate change routinely built into all policy development. Specific adaptation programs in Australian Government agencies with responsibility for climate sensitive sectors. Regulatory reform completed to facilitate proactive adaptation throughout the private sector. Significant coordination of adaptation efforts across sectors. Improved coordination between tiers of government (including the CMAs and Regional Development Australia committees) to permits the Federal Government to work more closely with state and local governments to support their adaptation efforts. Strong focus on development of knowledge products and tools for use by all sectors of the Australian community to support the necessary levels of adaptation. Develop a culture of discussion and debate in order to manage increasingly significant change processes. National standards are adopted for climate change scenarios to use in planning, with a process for regular review. Governance systems are established to negotiate preferred future scenarios in order to set common objectives for overlapping planning processes.	As for 2°C, but with additional emphasis on: Government provides a regulatory framework facilitating transformational change across the economy and society. Significant changes to the way Governments manage public assets and the delivery of services. Actively manage significant structural adjustment of industries made uncompetitive by climate change. Significant changes to social policy to manage changing expectations of living standards and way of life. Alternative governance arrangements in place as local governments become increasingly unable to cope, particularly in coastal areas. Social policy actively addressing equity issues arising from differential socioeconomic impacts of climate change and/or differences in capacity to pay adaptation costs.

[31] Reproduced from pp.22-28 in Nelson *et al.* (2011) – see footnote 22.

Sector	What adaptation do we currently see taking place? Characteristics of observed adaptation	What adaptation would we like to see happening in by 2030 if we are on a trajectory to 2°C? Characteristics of (mainly) incremental/transitional adaptation and risk management	What adaptation would we like to see happening by 2030 if we are on a trajectory to 4°C? Characteristics of (mainly) transformational adaptation and robust decision making under uncertainty
Coastal settlements	Limited knowledge of sea-level rise and increasing risk of inundation and erosion hazards Extremely limited awareness/knowledge of other climate change hazards such as saltwater intrusion of groundwater and accelerated fatigue of under-ground/above ground structures, acidification of marine waters, potential changes to extreme wind speeds. Unclear allocation of risk and responsibility between state and locals governments. Limited guidance on coastal adaptation policy (such as a sea-level rise benchmark) but often a lack of detailed guidance in how to apply on-ground. Lack of integration of coastal adaptation policy across government. For example, population pressures 'forces' development on land that will increasingly be at high risk. Some moves to address rigid planning controls that largely exclude adaptation from planning processes and restrict adaptation options. Unintended consequences of development on adjacent communities and future adaptation options not being considered	Public disclosure of risk (eg from sea-level rise) to enable households to make informed decisions into the future and be an active participant of adaptation response Access to consistent risk information across key government and private sectors – to enable appropriate risk management across government and to enable the private sector to participate in adaptation responses eg through financial and insurance sectors Adaptation planning across coastal decision makers is developed and used to guide spatial planning (minimise future risk and start to address existing assets at high risk) and to guide development of long lived/critical infrastructure. Some funding to address high priority issues National consistency to planning approach and allocation of roles, risk and responsibility. Integrated consideration of adaptation planning needs across government delivery. Adaptation to climate change built into planning in a manner similar to energy efficiency ratings and noise sheds around major airports. More flexible and nuanced planning controls designed to meet/exceed expected risks, within modified settlements and planning frameworks. National agreement on new setback rules/lines (based on probability) and arrangements for planned retreat. Also need national agreement on approaches to renewing coastal developments especially to ensure that these don't encroach on valued natural ecosystems and, therefore, reduce resilience of those systems.	As for 2°C, but with additional emphasis on: Policy and planning mechanisms in place necessary to redesign and/or relocate urban settlements as required in response to climate change threats, while maintaining/enhancing liveability. Put policies in place to manage a tendency by the private sector to withdraw from insuring risk, so that it is appropriately shared with the public sector. This could translate to more assertive policies to reduce risk and clarify responsibility. For example, a stronger emphasis could be placed on retreat. Criteria for areas to protect will need to be defined and implemented.. Likely to see more innovation in engineering responses from the private sector as new business opportunities are perceived. Greater focus on sustainable urban form, designed to minimise the heat island effect in larger cities. Significant regulatory reform to allow transformative change without excessive delays due to bureaucracy or as a result of litigation.

Sector	What adaptation do we currently see taking place? Characteristics of observed adaptation	What adaptation would we like to see happening in by 2030 if we are on a trajectory to 2°C? Characteristics of (mainly) incremental/transitional adaptation and risk management	What adaptation would we like to see happening by 2030 if we are on a trajectory to 4°C? Characteristics of (mainly) transformational adaptation and robust decision making under uncertainty
Infrastructure	Focus is almost exclusively on maintaining current infrastructure assuming stationary climate to meet rising demand – some investments recognise the costs of adaptation. Flexible and proactive adaptation is prevented by rigid engineering rules and protocols. Demand management and alternative means of supply are given minimal or last-resort consideration.	The design of infrastructure routinely considers the ways in which climate change will influence the services provided during its lifetime. Long-term adaptation measures are actively being installed as part of ongoing maintenance. Demand management routinely used to reframe questions of maintain service capacity. Adoption of revised Australian Rainfall & Runoff Handbook guidelines. Regulation of infrastructure investment leads to proactive adaptation. Design standards and tolerances are set to suit likely conditions over life of each component and these are regularly reviewed in light of new knowledge.	As for 2°C, but with additional emphasis on: Alternative means of providing the services provided by infrastructure are routinely or even preferentially considered. Significant reform of consumer expectations of the reliability of service delivery. Substantial re-alignment of major infrastructure such as roads, rail lines, bridges, urban drainage. Repositioning of facilities for dealing with waste water (sewage) to avoid pump outages due to flooding and consequent contamination of other water bodies & supplies. Regulation of infrastructure investment mandates proactive adaptation.
Financial Institutions	**Private Insurance** In response to recent extreme weather events, some insurance companies are withdrawing from 'high risk' areas. Reinsurers are re-evaluating risk frameworks in light of changing risk. Over time this will flow through to general insurers. **Lending/Investment** Seeking guidance on how to evaluate risk to assets. If climate change risk is considered, it is in an ad hoc way. Super funds are concerned that short-term investors are not taking appropriate account of long-term climate risks in infrastructure investment decisions, thereby establishing conditions for increased vulnerability and reduced life expectancy.	**Private Insurance** The insurance market works to set price signals that supports effective adaptation. The sector works closely with Government to identify and implement strategies that encourage strong take up of private cover. **Lending/Investment** Investment decision frameworks incorporate measures for appropriately assessing future risk from climate change. Lending/investment policies require proponents to have in place risk assessments and strategies for mitigating risk.	As for 2°C, but with additional emphasis on: **Private Insurance** Some level of private insurance is compulsory. Premiums are directly linked to the assessed risk of individual assets. Some residual risk resides with asset owners. Significant reform of consumer expectations regarding insurance coverage. **Lending/Investment** Investment decision frameworks are integrated with public sector contingency funding to coordinate appropriate investment responses to extreme events.

Sector	What adaptation do we currently see taking place? Characteristics of observed adaptation	What adaptation would we like to see happening in by 2030 if we are on a trajectory to 2°C? Characteristics of (mainly) incremental/transitional adaptation and risk management	What adaptation would we like to see happening by 2030 if we are on a trajectory to 4°C? Characteristics of (mainly) transformational adaptation and robust decision making under uncertainty
Water	Rural – Water reform has significant momentum and a mix of policy instruments is beginning to be implemented, some of which consider adaptation. However, changes to water allocation and pricing reform remain highly contested, and are to beneficially affect river flows. Urban – focus is on supply augmentation especially through desalination plants, but demand management is still weak. Water management corporations are required to meet annual dividend targets that drive them to ensure profitability through selling maximum quantities of water	Rural- Water management plans contain strategies for managing reductions in water availability due to climate change. Significant reallocation of water from productive to environmental uses. Pricing used to allocate water to its highest value irrigation entitlements uses. Urban – Significant demand management through pricing and allocation, supported by water-sensitive urban design. Consideration of regulations that limit the amount of water 'captured' on land to a proportion of what would have infiltrated prior to agricultural development . Major shift in irrigated agriculture from Murray Darling Basin to Tasmania and northern Australia. Substantial changes in technology starting with replacement of drains with pipes, drip irrigation instead of sprays to improve efficiency of water use as water increases in value/cost. Urban – Significant demand management through pricing and allocation, supported by water-sensitive urban design.(note that some work has been done already on water sensitive urban design) Increased reuse and recycling through more sophisticated treatment methods to makes water safe for human consumption.	As for 2°C, but with additional emphasis on: Rural - Water management plans contain strategies for managing significant reductions in water availability due to climate change. Transformation and relocation of agricultural production – different outputs using different farming systems, input mixes, and in different locations. Complete shift to high efficiency irrigation methods. Urban – Complete cultural change to urban water use reflecting increased scarcity and unreliability of supply. Demand managed effectively through pricing and allocation, support by water-efficient urban design. Double piping to new developments, some retrofitting into existing developments to provide drinking water separately to water for flushing toilets for example that could be treated recycled water. Heavy reliance on water reuse and recycling for human consumption. Implement policies to address the nexus between water supply and energy used for desalinisation.

Sector	What adaptation do we currently see taking place? Characteristics of observed adaptation	What adaptation would we like to see happening in by 2030 if we are on a trajectory to 2°C? Characteristics of (mainly) incremental/transitional adaptation and risk management	What adaptation would we like to see happening by 2030 if we are on a trajectory to 4°C? Characteristics of (mainly) transformational adaptation and robust decision making under uncertainty
Natural ecosystems	Incremental changes to current reserve systems. Over-reliance on individual conservation strategies, especially corridors (e.g. Great Eastern Ranges Initiative). Conservation objectives are not yet set in ways that consider the impact of climate change on ecosystems. New National Biodiversity Conservation Strategy does not address climate change in a manner that acknowledges the level of threat. Little action except for G B Reef and iconic sites within MDB; Kakadu etc are "of concern" but little action yet. Lack of integration across NRM policies eg revegetation policies often require replacing what is there – regardless of whether it will be viable in future climate – particularly issue for long lived forest species	Expansion of reserve boundaries to maintain suite of ecosystems, but recognition that some may be in irreversible decline (triage). Completion of the Comprehensive, Adequate, Representative and Replicated (CARR) National Reserve System to enhance resilience. Flexible approaches to establishing conservation systems across a range of private and public reserve systems that reflect geographical changes to ecological values. Whole of landscape planning and management Increased translocations - engineering approaches to relocating species Redesigned and renegotiated conservation goals incorporated in national and s/t legislation and reflected in regional strategies and plans. Well integrated fire management planning that recognises the needs of biodiversity conservation in a changing climate and that fire regimes to accomplish this are different from regimes for protection of life and property. Use of cost benefit analysis in overall fire management planning and implementation.	As for 2°C, but with additional emphasis on: Significant relocation of public reserve systems, negotiated alongside transformation to agricultural land use. Transformational change to the way conservation goals are set, and the management strategies used to protect specific ecological values. Strong focus on storage options such as seed banks, zoos and other methods of artificially maintaining gene pools. Strong focus on maintaining ecological function perhaps rather than species diversity. Risk hedging and options approaches used to manage the changing ecological value of conservation areas against alternative long-term futures.
Health	Some consideration – the Australian Health Minister's Conference may be developing a Climate Change and Health plan (TBC). Some states have developed heat wave management systems and national action is being discussed.	Few impacts on human health are likely by 2030, except possible increase in heat-related illnesses and mental health issues associated with drought. Develop heat wave warning systems. Better management of heat stress and related logistics e.g. involvement of emergency management staff rather than just relying on ambulance and hospital staff.	As for 2°C, but with additional emphasis on: Continue to monitor emerging health threats and develop capacity to deal with them. This may include improving monitoring of mosquito-borne diseases. New healthcare capacity and medical skills to deal with previously unforeseen diseases and climate related health problems. Increased emphasis on preventative measures in public health as the most cost-effective approach for maintaining a healthy and productive community. Comprehensive assessment of all the pathways by which climate change will adversely affect public health, including mental health, and indirectly via environmental and dietary changes. Fundamental changes to urban design to reduce urban heat island effects and equity implications for heat stress

Sector	What adaptation do we currently see taking place? Characteristics of observed adaptation	What adaptation would we like to see happening in by 2030 if we are on a trajectory to 2°C? Characteristics of (mainly) incremental/transitional adaptation and risk management	What adaptation would we like to see happening by 2030 if we are on a trajectory to 4°C? Characteristics of (mainly) transformational adaptation and robust decision making under uncertainty
Emergency management	A new National Disaster Resilience Strategy has a strong focus on increasing resilience to a range of hazards and notes the likely effects of climate change. Resourced and geared up to deal with occasional extreme events, with an implicit focus on restoration to pre-crisis condition – not transformational. Little or no consideration of the synergies and contradictions between adaptation policy and emergency response. Government relied on almost entirely as insurer of last resort.	Better equipped to respond to more frequent and more severe disasters, and recognition that remediation may not be possible or desirable. Implement measures to recruit additional volunteers as demand increases. Integrated approaches that balance emergency response with strategic activities to adapt to changing event frequency. Appropriate allocation of risk between governments and communities.	As for 2°C, but with additional emphasis on: Communities only minimally reliant on governments that are increasingly unable to provide restorative interventions for all climate events. Increased reliance on professionals as demand overwhelms volunteer-based response services. Responses to extreme events are dominated by flexible adaptation responses to reduce future vulnerability. Well-formed understanding of national capacity to respond to multiple simultaneous extreme events across the continent
Agriculture	Many examples of excellent short-term incremental adaptation to climate variability and climate change. Some preliminary consideration of longer-term or transformational adaptation such as relocation of industries. Drought policy questioned as undermining incentives to adapt.	Climate sensitive industries increasingly flexible and actively relocating to favourable climates. or other strategies such as with dairy that are increasingly buying in supplies of forage etc grown elsewhere rather than needing to produce abundant and high quality forage locally. Drought policy replaced with policies supporting drought preparedness and adaptation. Shift in irrigated agriculture to Tasmania and northern Australia. Policies and programs to deal with abandonment of marginal farming lands, possible revegetation for multiple benefits including carbon sequestration. Increased spatial diversification supported by flexible infrastructure. Development of whole of landscape planning and management approaches that integrate biodiversity conservation and agriculture, focus on sustainable agriculture that incorporates carbon sequestration, reduces land and water degradation (salinity, runoff of chemical residues e.g. into the GBR lagoon) By 2030 - review energy use in agriculture as availability of liquid fossil fuels declines.	Significant land use change supported by increasingly flexible transport and marketing infrastructure. Address the loss of high quality agricultural land to other uses such as urban expansion. Agricultural land use decisions integrated with flexible conservation reserve design. A significant cultural change in which farming goes from being a static, concentrated and location specific activity, to an opportunistic, diverse and mobile activity across large areas of land use. This will be complemented by intensification of core agricultural production areas. Diversification to products not previously produced in Australia.