Submission to:
Senate Select Committee on Climate Policy

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Summary

1. The mitigation of global climate change due to emissions of radiatively active gases is a matter of extreme urgency. In the years since 1996 when the IPCC identified a 'discernible human influence on climate', the human influence on climate has become increasingly apparent in an increasing number of places, and the rate of change is currently tracking near the high end of earlier projections.

2. The effect of greenhouse gases on the climate system is commonly expressed in terms of CO_2-equivalent concentrations. If only long-lived gases are considered then current CO_2 equivalent concentration is 455 ppm (c.f. 280 ppm pre-industrial) and about 381 ppm CO_2-equiv if aerosols and tropospheric ozone are considered.

   - the 455 ppm from the long-lived gases gives a measure of the amount of change implied by emissions to date;
   - the lower amount represents the driver for the climate change that has already occurred;
   - the difference gives a measure of the extent to which the committed climate change from the long-lived gases is currently masked by the cooling effects of aerosols.

3. Of the long lived greenhouse gases carbon dioxide is the largest contributor to anthropogenic global warming. It is also *different* from the other greenhouse gases, as it has an extremely long atmospheric lifetime, with some of the added CO_2 remaining in the atmosphere for millennia [19]. Hence, decisions made now regarding emissions of carbon dioxide will have consequences for decades, centuries, and possibly millennia. It is necessary, in the very long term, for there to be *zero* net anthropogenic emissions of CO_2.

   In addition, continuing net CO_2 emissions are leading to increased acidification of the oceans, with consequent threats to marine life.

4. The Garnaut review [6, p 194] discusses CO_2 targets in terms of a 'budget' that represents the total amount of CO_2 that can be released ever, for a given atmospheric concentration. The 'budget' concept is a rough but useful approximation for CO_2. CASPI modelling [2, Table 4] indicates that the allowable budget, expressed as cumulative emissions from 2005 to 2150 would be about 550 GtC (gigatonnes of Carbon) for a 420 ppm CO_2 target, 715 GtC for 450 ppm, 960 GtC for 500 ppm and 1150 GtC for 550 ppm.

   The budget concept is a poor approximation for other gases, especially methane, due to their short atmospheric lifetime.

5. Both the ‘budget’ concept and more precise modelling imply that there will be a trade-off involved in specifying targets. For a given target concentration, delays in commencing reductions will imply a need for more rapid cuts later.

6. Delaying climate mitigation for reasons of scientific uncertainty was unjustified a decade ago. It is even less justified now. The degree of scientific uncertainty in climate science is less than the uncertainty involved in many other government decisions with wide ranging consequences.

   Even the low end of the range of uncertainty is sufficiently serious to justify concerted international action. However the high end of possible change represents involves such serious impacts that action to reduce the risk is justified even if the probability is (currently) assessed as relatively low.

   In particular, the risk of additional ‘unexpected’ warming is increased by various types of threshold phenomena where climate change triggers the release of additional greenhouse gases from natural systems.

7. The policy adopted by the European Union (see e.g. [3]) is that globally averaged anthropogenic warming should be limited to 2°C (relative to pre-industrial levels) to avoid dangerous climate change.

   Adopting this value, together with the IPCC estimate [9] of the climate sensitivity of 3°C, this suggests that the maximum ‘safe’ concentration of greenhouse gases in the atmosphere is 441 ppm CO_2-equiv. This is the mean estimate only, and there is a significant risk that warming could be as high as 3°C with a 441 ppm CO_2-equiv target.

   In any international agreement to limit emissions of greenhouse gases (and consequently, regulations by individual nations), it important that it is possible to adapt global targets to levels which are suggested to be ‘safe’ by the best available science of the day.

   An aggressive global target is in Australia’s national interest, as we are likely to suffer significant adverse impacts, including

   - Significant rainfall reduction, and even greater reductions in runoff, in agricultural regions in southern mainland Australia.
   - Increased rate of coral bleaching episodes of the Great Barrier Reef, and likely consequent destruction of reefs.

8. Australian action needs to be taken in the context of international agreements. The predominant aims must be:
   — to argue for strongest possible targets in order to protect the Australian environment;
   — to prepare the Australian economy to operate in a low-carbon global economy.

Submission

Overview

In order to address the threat of human-induced climate change, plans for Australian Emissions Trading Schemes for Australia have been developed by both the present Australian government and the previous government. In March 2009, draft legislation to establish such a scheme was released for comment. In addition, the Garnaut Review [6] endorsed such a cap-and-trade scheme as an appropriate approach for greenhouse mitigation by Australia, subject to ensuring the integrity of such a scheme.

The present submission concentrates on the issue of appropriate ‘caps’, i.e. the targets for levels of reduction. It works from the possible choices in the form and timing of a global cap, and the ways in which such global caps might translate to Australian targets.

The submission draws on the work of the IPCC [9], the Stern Review [18], the Garnaut Review [6] and on work done at The University of Melbourne in the course of preparing a report on emission targets for the Garnaut Climate Change Review [2], building on earlier work undertaken at CSIRO [4].

1 Urgency

The mitigation of global climate change due to emissions of radiatively active gases is a matter of extreme urgency. In the years since 1996 when the IPCC identified a ‘discernible human influence on climate’, the human influence on climate has become increasingly apparent in an increasing number of places, and the rate of change is currently tracking near the high end of earlier projections.

In particular:

- human-induced climate change is happening now with negative effects;
- both human systems and the climate system both react slowly — further climate change is already effectively ‘locked in’ and each further delay ‘locks in’ additional change.

Many of the observed aspects of on-going climate change are well-known [9, chapters 3, 4, 5]. These include global warming, reduced rain in southern Australia, reduction of Arctic sea ice. As the warming progresses, there is an ever-increasing risk that some of these changes will be permanent. For some changes, the point at which change is irreversible is either extremely close or may already have been passed.

2 The human influence

Much of the warming effect of long lived greenhouse gases has been masked by accompanying emissions of aerosols, which only remain in the atmosphere for a short time, and are believed to contribute negatively to radiative forcing. However, as emissions from burning fossil fuels decrease in the future, so will atmospheric concentrations of aerosols and tropospheric ozone.

Including the effect of short lived constituents, we estimate that the CO_2-equiv concentration in 2008 was 381 ppm, while the level without aerosols (a large negative contribution) and tropospheric ozone (a significant positive contribution) was 455 ppm.

- the 455ppm from the long-lived gases gives a measure of the amount of change implied by emissions to date;
- the lower amount represents the driver for the climate change that has already occurred;
- the difference gives a measure of the extent to which the committed climate change from the long-lived gases is currently masked by the cooling effects of aerosols.

Taking the 'safe' level of globally averaged anthropogenically induced warming as 2°C, assuming climate sensitivity of 3°C, and taking the pre-industrial CO_2 concentration as 280 ppm, one obtains the estimate of 441 ppm CO_2-equiv. Excluding short lived atmospheric constituents, this threshold has already been crossed.

3 Carbon dioxide

Of the long lived greenhouse gases carbon dioxide is the largest contributor to anthropogenic global warming, approximately 2/3 of the total. It is also *different* from the other greenhouse gases, as it has an extremely long atmospheric lifetime, with some of the added CO_2 remaining in the atmosphere for millennia [19]. Hence, decisions made now regarding emissions of carbon dioxide will have consequences for decades, centuries, and possibly millennia. It is necessary, in the very long term, for there to be *zero* net anthropogenic emissions of CO_2.

The large natural exchanges of CO_2 between atmosphere and oceans have been in close balance over many millennia and have responded to increased atmospheric concentration by taking up about half of the human emissions. However the natural processes involved are sensitive to climate change and a small proportional effect could release significant additional CO_2 to the atmosphere.

In addition, continuing CO_2 emissions are leading to increased acidification of the oceans, with consequent threats to marine life [17]. Recent Australian research appears to have identified such an impact [1, 14].

4 The budget concept

The Garnaut review [6, p 194] uses the concept of a 'carbon budget'. This represents the total additional CO_2 emissions that are consistent with a given concentration target.

This 'budget' notionally represents the total amount of CO_2 that can be released, ever, for a given atmospheric concentration. The 'budget' concept is a rough but useful approximation for CO_2. CASPI modelling [2, Table 4] indicates that the allowable budget, expressed as cumulative emissions from 2005 to 2150 would be about 550 GtC (gigatonnes of Carbon) for a 420 ppm CO_2 target, 715 GtC for 450 ppm, 960 GtC for 500 ppm and 1150 GtC for 550 ppm.

For other long lived greenhouse gases, notably methane and nitrous oxide, the budget concept is far less useful. Due to the short atmospheric lifetime of methane (approximately 10 years), one can stabilise atmospheric concentrations of methane by stabilising emissions, i.e. a fixed amount can be emitted per year, in contrast to CO_2 for which a fixed total amount can be emitted. For nitrous oxide, the situation is less clear cut due to its relatively long lifetime (approximately 100 years). In order to make steep cuts in atmospheric concentration of nitrous oxide in 2100, then action needs to be taken now to reduce anthropogenic emissions.

The role of non-CO_2 gases is often quantified in terms of CO_2-equivalence. The IPCC has defined two forms of equivalence (see glossary):
— *concentration equivalence* which reflects the effect of a mixture of gases on the radiative balance of the earth; and
— *emission equivalence* which looks at the cumulative effect of emissions over a specified time period, commonly taken as 100 years.

5 Tradeoffs

Both the 'budget' concept and more precise modelling imply that there will be a trade-off involved in specifying targets. For a given target concentration, delays in commencing reductions will imply a need for more rapid cuts later.

This trade-off is discussed in the Stern Report [18] and in some detail in the CASPI stabilisation report [2, Figs 16,17]. The CASPI report [2, Fig16] shows families of alternative emissions histories, leading to stabilising CO_2 at 450, 500 and 550 ppm. The tradeoff is made explicit [2, fig 17] (reproduced here as Figure 1), by plotting the maximum allowed emissions against the peak in the percentage rate of reduction that would be required. Similar comparisons are made in the Stern report [18, Table 8.2], giving slightly higher reduction rates. The difference is that the analysis used by Stern allowed more abrupt initial changes than are considered in the CASPI analysis.

6 Risk and uncertainty

The level of uncertainty described below (table 1) does not represent a reason for not taking action. Even at the less serious end of the possible range, the consequences of climate change are sufficient to justify concerted international action. As has been cogently argued by Pollack in *Uncertain Science – Uncertain World*, [16] the level of uncertainty surrounding human-induced climate change is much less than the uncertainty for many other decisions made regularly by governments, corporations and individuals.

In considering the level of uncertainty, it is important to separate:

- uncertainty about future human decisions
- uncertainty about the behaviour of the climate system

Planning measures for adaptation to climate change need to consider both forms of uncertainty.

However for making decisions about setting emission targets, only the second form of uncertainty is relevant. Those who cite (often implicitly) uncertainty about possible decisions as a reason for not making decisions are being mischievously misleading.

While even the low end of the range of possible climate change is serious enough to justify action, there is a need to consider high end of possibilities. Adopting targets that further reduce the

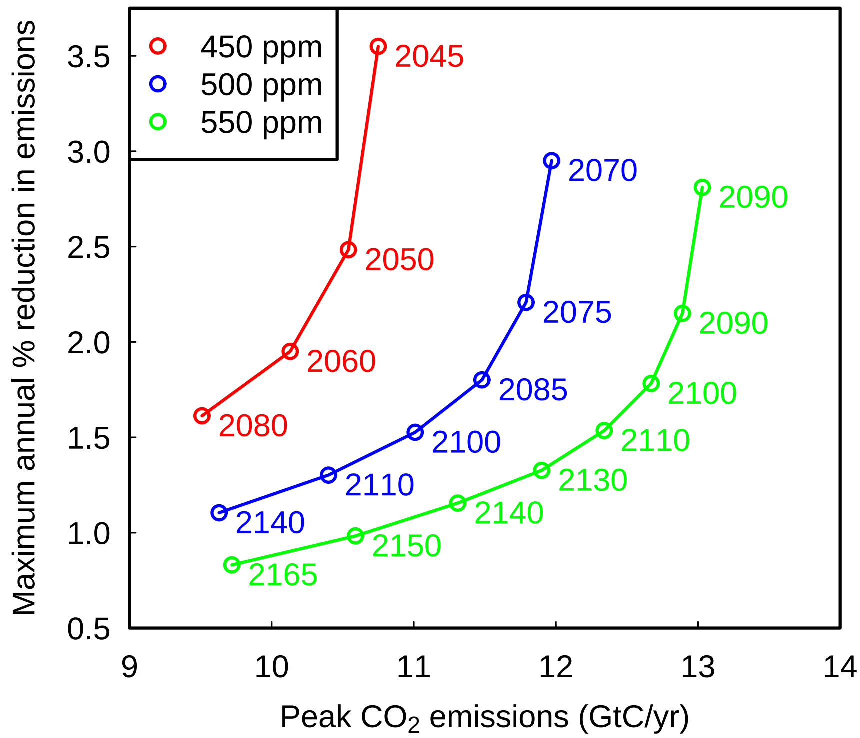

Figure 1: Trade-off between peak global emissions and subsequent reduction rate, for various target concentrations of CO_2. Reproduced from [2, fig 17]. These calculations assume that the amount of additional CO_2 from climate to carbon feedbacks will be small.

probability of these ‘low-probability’ cases is similar to incurring costs to avoid many other events that would have low-probability, but which would be highly damaging if they occurred.

Such ‘risk-avoidance’ is normal behaviour in many contexts such as insurance, military preparedness etc. These considerations adopted in various ways in the Stern Report [18] and the Garnaut Review [6].

In particular, the risk of various high-warming cases is increased by various threshold phenomena where climate change affects natural processes in a way that leads to the release of additional greenhouse gases [12].

A worst case would involve triggering a sequence of ‘cascading failures’. The 2007 IPCC assessment [9] noted such coupling between carbon and climate as contributing a large poorly quantified uncertainty in projections of future climate change.

Such feedbacks can be considered as either increasing the warming resulting from a given emissions target or increasing the extent of reduction required in order to reach a desired concentration target [11, 13].

CO_2 concentration	CO_2-equiv concentration	Peaking year CO_2 emissions	Changes in global emissions in 2050 (% of 2000 emissions)	Equilibrium Warming 2.9°C	Equilibrium Warming 4.5°C
ppm	ppm	year	%	°C	°C
350–400	445–490	2000–2015	-85 to -50	1.9–2.3	3.0–3.6
400–440	490–535	2000–2020	-60 to -30	2.3–2.7	3.6–4.2
440–485	535–590	2010–2030	-30 to +5	2.7–3.1	4.2–4.8
485–570	590–710	2020–2060	+10 to +60	3.1–3.9	4.8–6.0
570–660	710–855	2050–2080	+25 to +85	3.9–4.7	6.0–7.2
660–790	855–1130	2060–2090	+90 to +140	4.7–5.8	7.2–9.1

Table 1: Stabilisation levels, cuts in emissions, and equilibrium climate response for two values (2.9°C and 4.5°C) of the climate sensitivity. Adapted from [41: Table 3.5, Ch. 3]. This represents a variety of studies and so the ranges reflect a combination of scientific uncertainty and choices of stabilisation pathway.

7 Global targets

Global targets for CO_2-equiv atmospheric concentration must be determined on the basis of the best available science, economic modelling of the costs associated with mitigation, adaptation, and impacts, and normative judgments about the impact of changing climate upon ecosystems and communities.

Economic impacts can be either positive, e.g. enhanced primary production via CO_2 fertilisation, or negative, such as decreased rainfall and runoff in agricultural regions in southern Australia. It is widely believed that net impacts will be adverse for anything other than modest increases of CO_2 and consequent warming.

The impacts of climate change occur on a variety of timescales, and will be geographically heterogeneous, complicating the issue further still. There are significant uncertainties in modelling the environmental impacts of climate change, particularly in terms of regional phenomena, and their are even larger uncertainties in the economic modelling of the costs of mitigation and adaptation.

The setting of a target concentration is thus a difficult task, subject to high levels of uncertainty, normative judgments, and competing national interests.

The policy adopted by the European Union (see e.g. [3]) is that globally averaged anthropogenic warming should be limited to 2°C (relative to pre-industrial levels) to avoid dangerous climate change; Hansen et al. [7] argued in 2006 that warming should be limited to 1°C relative to the year 2000 (in addition to warming of 0.7°C from the late 19^{th} Century). More recently, Hansen et al. argued strongly for more stringent targets of 350 ppm for carbon dioxide [8].

We believe that the European value for the threshold of dangerous anthropogenic interference in climate is the most widely used and accepted value (it is a normative judgment, and so there is no ‘correct’ value), and hence adopt 2°C as the threshold for dangerous warming.

To calculate the CO_2-equiv concentration of long lived greenhouse gases which would give 2°C of warming, we take the IPCC estimate [9] of the climate sensitivity of 3°C, and determine that the maximum ‘safe’ concentration of greenhouse gases in the atmosphere is 441 ppm CO_2-equiv. There is significant uncertainty in the value of the climate sensitivity, and the IPCC reports a likely range of 2°C to 4.5°C. If the higher end of the range happens to be correct, then 441 ppm

CO_2-equiv would result in 3°C of warming, which is far into the regime of 'dangerous' climate change.

A target of 450 ppm CO_2-equiv would perhaps allow for 420 ppm of CO_2, with some additional forcing due to other long lived greenhouse gases (principally methane and nitrous oxide). As discussed in Section 4, this leads to an (approximate) global budget for the cumulative emission of 550 GtC between 2005 and 2150.

As scientific understanding of climate sensitivity (affecting the temperature increase for a given CO_2-equiv concentration) and carbon-climate feedbacks (affecting the amount of CO_2 remaining in the atmosphere for fixed emissions) improve, the best estimate of the 'safe' level of emissions will change with time. It must be possible to adapt global targets to levels which are suggested to be 'safe' by the best available science of the day. In particular, it must be possible to revise downwards global targets if the science suggests that it is prudent to do so.

An aggressive global target is in Australia's national interest, as we are likely to suffer significant adverse impacts, including

- Significant rainfall reduction, and even greater reductions in runoff, in agricultural regions in southern mainland Australia.

- Increased rate of coral bleaching episodes of the Great Barrier Reef, and likely consequent destruction of reefs.

8 The need for emissions cuts by Australia

Australian action needs to be taken in the context of international agreements. The predominant aims must be:
— to argue for strongest possible targets in order to protect the Australian environment;
— to prepare the Australian economy to operate in a low-carbon global economy.

In these contexts, early introduction of emission cuts by Australia should be set so as to serve the role of convincing other nations of our bona fides and in providing as gradual as possible transition to the deep cuts that will by required to reduce the threats of global climate change.

In convincing the rest of world of our bona fides, there would seem to be a need for 'catch up'. Even setting aside the claims of Guy Pearse [15] (suggesting that Australia's role in the Kyoto process consisted of trying to undermine it from within), arguing for special conditions at Kyoto and then refusing to ratify leaves Australia with a credibility gap in international climate negotiations.

In terms of preparing the Australian economy for a low-carbon world (since our preparations lag behind many comparable nations), important criteria are:
— ensure that economic recovery does not lock in bad decisions that are expensive to reverse;
— ensure that forward guarantees of future caps and/or permit allocations allow for moving to stronger targets.

An important point to note in assessing how Australia might fit into a future international framework is that some variation on equal per capita emissions may well be incorporated on equity grounds — in per capita terms Australian emissions are particularly high.

The Authors

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Ian Enting was one of the lead authors of the chapter "CO_2 and the Carbon Cycle" in the 1994 IPCC report on *Radiative Forcing of Climate Change* [10]. Part of this contribution involved coordinating modelling groups world-wide to calculate the degree of emission reduction required to stabilise atmospheric CO_2 concentrations [4]. He was part of an experts group, working under the auspices of the UNFCCC Subsidiary Body for Scientific and Technical Advice, analysing the Brazilian Proposal for setting emission reduction targets on the basis of historical responsibility for warming. Ian Enting produced number of contract reports for the Australian Greenhouse Office and over 2007-8 he played a leading role in the preparing the report *The Science of Stabilising Greenhouse Gas Concentrations* [2] for the Garnaut Review on Climate Change.

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Glossary

(see also glossaries in IPCC reports).

CASPI Climate Adaptation — Science and Policy Initiative — The University of Melbourne.

climate sensitivity A measure of the extent to which greenhouse gases affect climate at equilibrium. Conventionally defined as the amount of warming arising from doubling CO_2 (or CO_2-equiv) concentrations. (In this context equilibrium means atmosphere-ocean equilibrium but not necessarily equilibrium of ice sheets).

CO_2-equivalent concentrations A measure of the influence on climate from a mixture of greenhouse gases. It is the amount of CO_2 which,on its own, would have the same effect as the mixture of gases. Thus CO_2-equivalence is the property of the **mixture** and cannot be fully decomposed into a sum of individual CO_2-equivalent contributions for individual gases. It reflects the instantaneous state of the atmosphere.

CO_2-equivalent emissions This is a measure of the climatic influence of emissions of greenhouse gases. It is defined in terms of cumulative influence over a period that is usually taken as 100 years. This definition is used in the Kyoto Protocol and for the reporting of national emission inventories as required by the UNFCCC.

committed warming This has been defined in various ways but the IPCC [9, Glossary entry for 'climate change commitment] defines it as the amount of additional warming that would occur if the atmospheric composition was held constant.

transient climate sensitivity This is a measure of the amount of warming under conditions of increasing greenhouse gases (often referenced to double CO_2). This will be less than the amount of warming at equilibrium because of the time taken to warm the oceans. The difference is the 'committed warming'.

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