# Workshop report
# The science policy nexus: assessing climate policy in an imperfect world

Roger Bodman, Celeste Young and Roger Jones

January 2014

VICTORIA UNIVERSITY
MELBOURNE AUSTRALIA

This workshop report contributes to the 2013 Victoria University Research Development Grant project *Exploring science–policy links for the new generation of climate change scenarios.* It reports on a workshop held on 22 November 2013 in Melbourne.

## Suggested citation

Bodman, R.W., Young, C. and Jones, R.N. (2014) *Workshop report – The science policy nexus: assessing climate policy in an imperfect world.* A report for the VU RDG project *Exploring science–policy links for the new generation of climate change scenarios*, Victoria Institute of Strategic Economic Studies, Victoria University, Melbourne, Australia.

## Acknowledgements

Cover photo: *courtesy* NASA, 'Earthrise', William Anders. Cartoon courtesy of John Ditchburn, Inkcinct Cartoons.

Thank you to all of the workshop participants and outside speakers for their time and active engagement with the workshop. A special thanks to Ian Carruthers for discussions on the workshop concept, commentary on the day and follow up afterwards. Thanks also to Brian O'Neill for his role in the RDG project, including hosting Roger Bodman at NCAR in May 2013 and then travelling out to Australia and participating in a series of discussions and presentations. Erwin Jackson for his talk and participation on the day. Thank you to George Pappas for opening the workshop and introductory remarks. Thanks to the additional table hosts and science advisors: Simon Batterbury, Penny Whetton, Scott Power and Peter Rayner. Also to our facilitator, John Crofts.



Victoria Institute of Strategic Economic Studies
Victoria University
PO Box 14428
Melbourne Vic 8001
Ph. 03 9919 1047
Email contact: roger.bodman@vu.edu.au

# Contents

## Introduction

This report provides a description and discussion of a Victoria University workshop entitled *The science policy nexus: assessing climate policy in an imperfect world.* The workshop took place on 22 November 2013 at the Quay West Suites, 26 Southgate Avenue, Melbourne. It was organised by Dr Roger Bodman, Ms Celeste Young and Prof Roger Jones from the Victoria Institute of Strategic Economic Studies (VISES). Alison Welsh and Margarita Kumnick provided additional organisational assistance. The event was funded as part of a Victoria University (VU) Research Development Grant (RDG).

The workshop is part of a research project *Exploring science-policy links for the new generation of climate scenarios,* which aimed to gain a better understanding of the policy relevance for the research outputs derived from new pathways of future climate emissions, the Representative Concentration Pathways (RCPs), developed for the IPCC's Fifth Assessment Report (AR5).

## Workshop background

A context paper was prepared in advance of the workshop to provide background reading (Bodman et al., 2013a). Accordingly, only a brief summary is presented here.

The four Representative Concentration Pathways (RCPs) describe future greenhouse gas concentrations and radiation changes in the atmosphere. The RCPs were largely constructed to support the climate research work of the IPCC AR5 Working Group I by providing a standard set of inputs for climate and integrated assessment modelling (Moss et al., 2010). The objective of the RDG research project was to better understand the role for policy in using the research outputs derived from these new scenario tools.

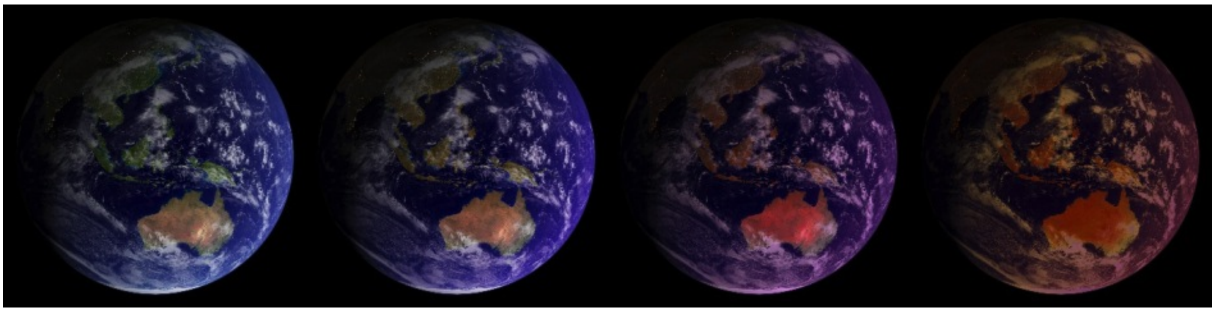
The RCPs were produced as part of an extensive process of building a new generation of climate scenarios, a process that that remains to be completed (Ebi et al., 2013). The main building blocks within that process are the Representative Concentration Pathways, but there is also an ongoing parallel process to develop the Shared Socioeconomic Pathways (SSPs).

Our research project was guided by an overarching question:

**The key research question: To what extent does the next generation of scenarios, as represented by the RCPs, meet the needs of climate policy and decision makers?**

The research then sought to:

- Assess how the RCPs are being applied and evaluate their appropriateness for translation into policy-relevant findings;
- Distinguish the 'science-for-policy' research agenda as distinct from the 'science-for-science' research agenda.



## Workshop aims

The overall aim of the workshop was to understand how users outside the climate modelling community understand the results from climate modelling research work reported by the IPCC's Fifth Assessment Report (AR5). The RCPs were developed to provide a standard set of inputs for a range of modelling experiments covering climate change, climate impacts and integrated assessment, with a timetable that allowed climate change projections to be prepared for the AR5. This can be considered as addressing the 'science for science' agenda because their overall construction was designed to meet scientific modelling needs even though their timing was designed to meet 'science for policy' needs.

The workshop was designed with the aim of gaining insight into how the 'science for policy' agenda is being addressed by the RCPs. This was achieved by considering:

- How the uncertainties associated with projecting future climate, as represented by the RCPs, are understood;
- Whether the RCPs meet the information needs of policy and decision makers or, if not, what are the information and knowledge gaps that need to be addressed;
- What 'science-for-policy' research would assist climate policy and decision makers to address the demands of climate change mitigation and adaptation.

Addressing the future is a challenge when dealing with climate change. Our context paper (Bodman et al., 2013a) provides a discussion about uncertainty and projections of global warming, both as background for the workshop and as an accessible introduction to the RCPs and the climate science-policy interface.

## Workshop design

The workshop was structured to ascertain and encourage understanding about the RCPs and climate modelling uncertainty in relation to climate policy. This was initiated through a framing exercise that used four short presentations to frame the day's conversation. These talks provided different perspectives on current climate science policy and are summarised in the next section. This framing exercise was followed by a series of interactive activities using scenarios designed to explore understandings and responses to the RCP scenarios and their application in decision making. These understandings and responses were consolidated in the final exercise using a 'critical friend', Mr Ian Carruthers, who provided a review of the day's proceedings. Ian is a former Division Head in the Commonwealth Department of Climate Change and Energy Efficiency and was a lead negotiator for Australia with the UNFCCC.

The workshop was based on a format developed by Celeste Young and supported by Professor Roger Jones (refer Appendix A for the workshop timetable). It was facilitated by Mr John Crofts who also contributed to the planning process.

The invitation-only workshop involved participants from both the public and private sectors to ensure a balanced representation of decision makers who would use the RCPs. The workshop participants were organised into tables of 6 or 7 people. Each table had a designated table host and a science advisor/provocateur to support the activities. The table hosts facilitated the table activities and the science advisor was there to help with specific science questions and also to provoke conversation into uncomfortable areas.

VISES Director Prof Bruce Rasmussen started off the workshop by introducing Mr George Pappas, Chancellor of Victoria University, who officially commenced the day's proceedings. Mr Pappas provided a welcome to country and a personal commentary, sketching the nature of the workshop and its relevance to VU's research program and strategic direction.

## Presentations

### Presentation one: The policy environment

Mr Erwin Jackson, Deputy CEO, The Climate Institute, described developments within the UNFCCC in establishing new international agreements for the post Kyoto Protocol process. Progress has been made since the $15^{th}$ Council of Parties (COP15) held in Copenhagen during 2009, with countries representing some 80% of global emissions committing to action and accepting the target to avoid a global-mean temperature increase of 2°C above pre-industrial.

Subsequent meetings have seen ongoing negotiations aimed at a new international agreement in 2015. Details for this are emerging and involve countries advancing self-selected contributions. At present there are different proposals and positions held by individual nations or groups (such as: a prescriptive legally binding instrument; a legally binding instrument with negotiated targets; a facilitative legally binding instrument with negotiated commitments; and a facilitative legally binding instrument with domestic contributions).

To date, international action is significant but insufficient to meet the 2°C goal. The international framework is being built on the success (or failure) of domestic actions (with both positive and negative examples). The outcome from Paris (COP21 in 2015) will likely involve new post-2020 goals with review mechanisms against the 2°C goal. Additional short-term actions outside the UNFCCC are making patchy progress (e.g., reducing HFCs, no new coal builds supported by Multi-lateral Development Banks).

Domestically, individual nations' actions are building towards reducing greenhouse gas emissions from a variety of efforts, including renewable energy targets, carbon pricing expanding, increased regulations to cut pollution and a gradually growing awareness amongst investors that the physics of climate science require carbon budgets that must leave vast fossil fuel resources unused.

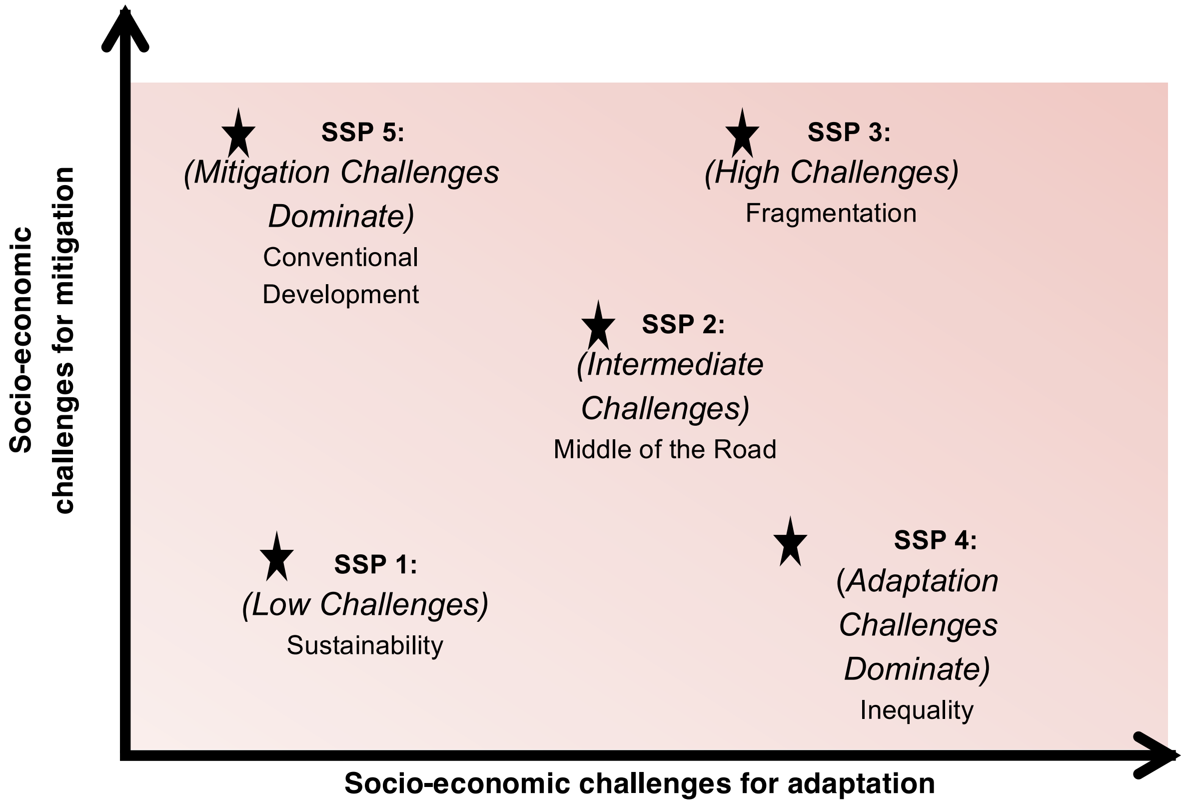
It is also in Australia's national interest to tackle climate change as we are one of the countries that will likely be more adversely impacted by climate change than other comparable countries. This implies that Australia has a stronger interest than most in arguing for deeper and more rapid cuts in global emissions.

Erwin concluded by saying that there remains a fundamental policy disconnect between our collective interest in avoiding 2°C and the proposed commitments (i.e., agreements are too slow in forming and are inadequate for the purpose).

## Presentation two: The science environment

Dr Brian O'Neill's presentation *The new scenario process for climate change research: Status, open questions, and next steps*, described the thinking behind the new scenario development process that has produced the Representative Concentration Pathways (RCPs) and the Shared Socioeconomic Pathways (SSPs). Brian briefly outlined the RCPs and then went into more detail about the SSPs as these are still very much a recent and ongoing development process.

SSPs are a mix of narrative and quantitative elements. The narratives are similar to the storylines associated with the earlier Special Report on Emission Scenarios (SRES; Nakicenovic and Swart, 2000), combining qualitative descriptions of broad patterns of development with an underlying logic that connects the narrative elements to each other. Quantitative elements include population, age structure and spatial population distribution, education, urbanization, income and income distribution. The SSPs are being framed as describing challenges for mitigation and adaptation to assist policy decisions in a world where both strategies are needed (see diagram below).




*(Source: O'Neill et al 2012)*

At the time of the workshop, the SSP conceptual framework was due to be reported and discussed in a special issue of *Climatic Change* (subsequently published in Volume 122, Issue 3, February 2014). The narratives and quantification of key drivers have also been completed and will be detailed in a forthcoming special issue of *Global Environmental*

*Change*.

The RCPs and SSPs are connected by a scenario matrix architecture, in which RCPs can be mapped to SSPs. Where an SSP, as modelled by an integrated assessment model (IAM), does or does not map to a particular RCP, then the links between specific socio-economic pathways and climate futures can be assessed and further understood. For example, what are the socio-economic conditions that lead to a high capacity to both mitigate and adapt to climate change?

Although work on the RCPs has been completed, work on the SSPs is still in progress. Emissions and land use scenarios based on SSPs are yet to be completed, research is looking for ways to carry out regional extensions, work is continuing to re-evaluate current SSPs, and possibly develop new versions (or variants of existing ones).

Remaining open questions related to the SSPs include:

- How will climate model information relate to the SSPs in practice?
- What extensions to the SSPs might be needed for linking global scenarios to regional or local analyses?
- What additional quantitative indicators for impacts, adaptation and vulnerability analysis need to be developed?

Dr O'Neill outlined the next steps in the SSP development process:

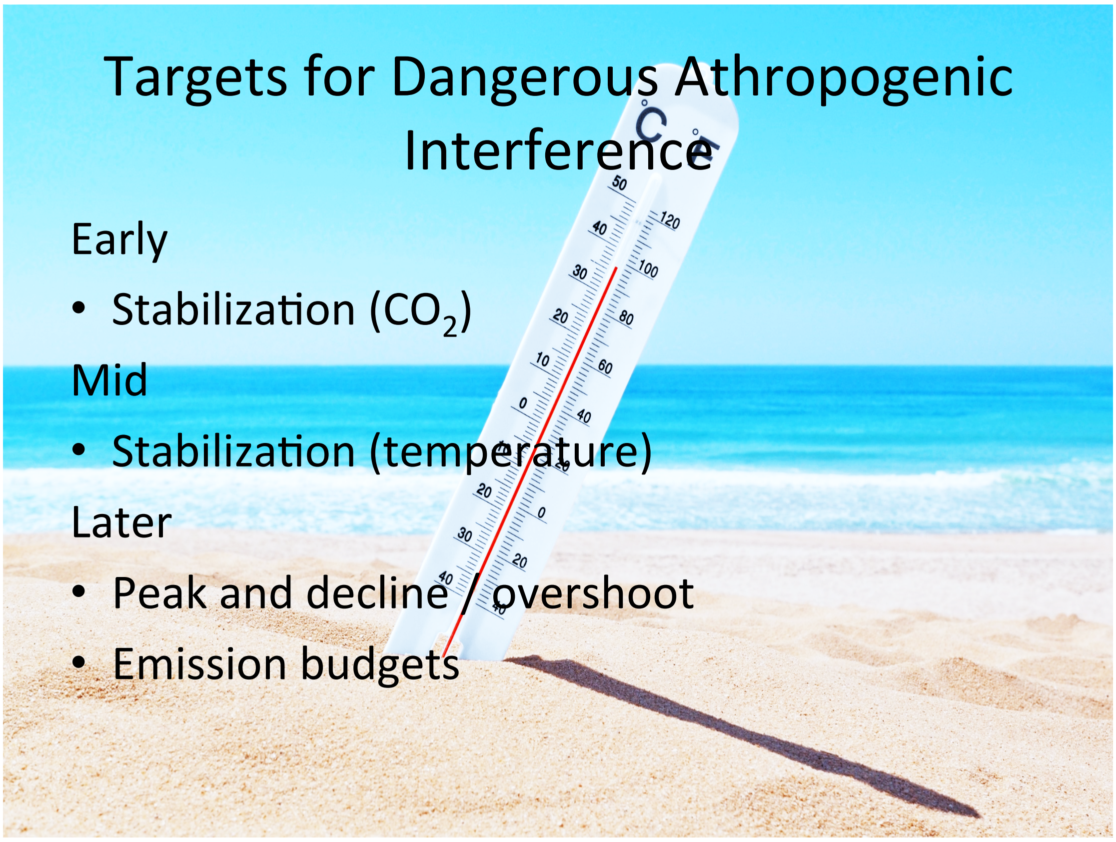
- IAM scenarios to be completed;
- Additional quantitative SSP elements being developed;
- Pattern scaling meeting, 23–25 April 2014, at NCAR;
- Design of a "Scenarios Modelling Intercomparison Project (MIP)" as part of the Sixth Climate MIP (CMIP6);
- Looking for ways to carry out regional extensions;
- Research based on the RCP/SSP framework;
- Continue to re-evaluate current SSPs, possibly develop new versions (or variants of existing ones);

## Presentation three: History of climate policy

In *Milestones in the 'Science for Policy' Research Agenda*, Professor Roger Jones stepped through some of the prominent developments in climate policy, showing how climate policy targets have changed and evolved.

The IPCC First Assessment Report (IPCC, 1990) asked the question, if climate change was a problem, what its impacts might be and how could we manage it, while the first official set of emission scenarios, IS92a–f (Pepper et al., 1992) appeared in 1992. At the same time the United Nations Framework Convention on Climate Change (UNFCCC) was formed, following an international environmental treaty negotiated at the United Nations Conference on Environment and Development (UNCED), informally known as the Earth Summit, held in Rio de Janeiro. The objective of the treaty was to prevent dangerous anthropogenic interference with the climate system by stabilizing greenhouse gas concentrations through adaptation and mitigation.

From the IPCC's Second Assessment Report (SAR; IPCC, 1996), Professor Jones highlighted the use of cost-benefit models and the assessment of stabilization targets, in particular the very real difficulties of achieving stabilization at a $CO_2$ concentration of 450ppm. The issue of stabilization continued into the Third Assessment Report (TAR; IPCC, 2001) along with an appreciation of the approximately linear relationship between radiative forcing and $CO_2$ concentrations. Targets for 'dangerous anthropogenic interference' became more of a feature at that time. A new set of scenarios, the SRES (Nakicenovic and Swart, 2000) series also came in with the TAR.




The emphasis on stabilizing atmospheric $CO_2$ concentrations as the goal of climate negotiations then shifted towards a focus on temperature change. In particular, the 2°C above pre-industrial goal became a dominant theme. Emissions scenarios for peak and decline/overshoot were introduced as it was realised how difficult this target is to achieve given continuing upward trends in emissions. From 2009 the cumulative carbon emissions budget concept appeared in the literature and began to gain traction.

## Presentation four: Climate change uncertainty

Dr Roger Bodman discussed the need for climate modelling to guide understanding of how the Earth's climate may change in the future. Model results are generated based on greenhouse gas emission scenarios, but projections of global-mean temperature (GMT) change and associated variables have a degree of uncertainty (see also our context paper, Bodman et al., 2013a).

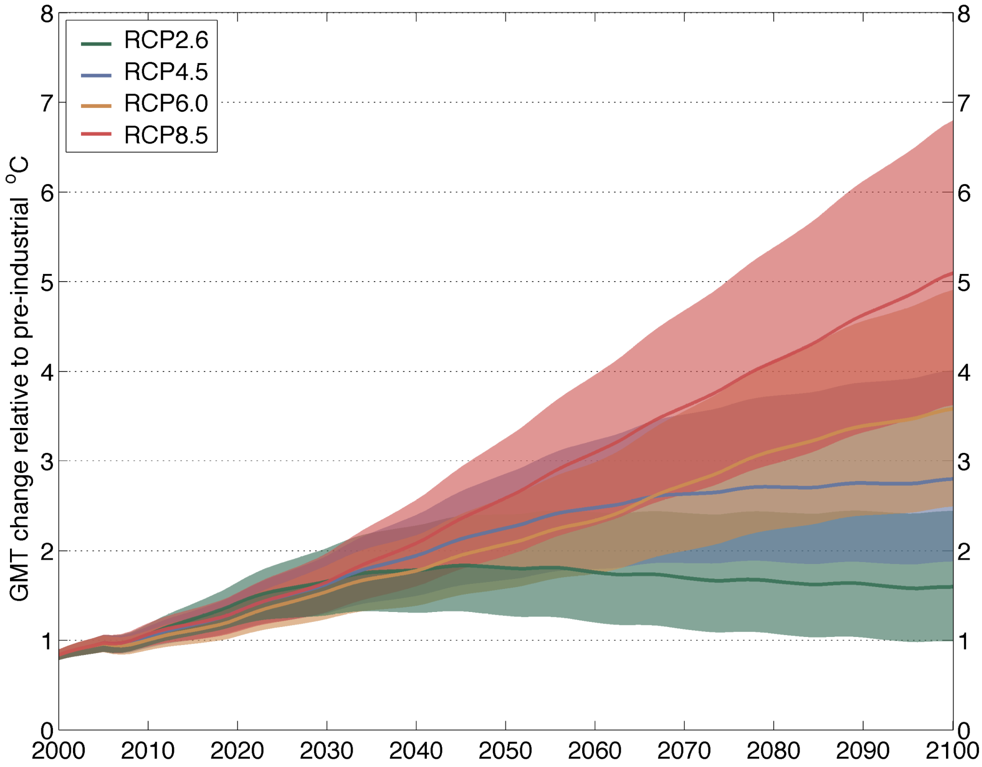
Uncertainties in temperature change arise from two main categories: 1) model or scientific uncertainty and 2) emissions or socioeconomic uncertainty. Model uncertainty stems from issues with observations, climate processes and the response of the climate system. Socioeconomic uncertainties arise from factors such as estimates of population changes, economic growth and energy demand along with the related sources and technologies. Scenarios are an attempt to capture these factors.

The most recent projections presented in the IPCC's Working Group I Fifth Assessment Report (WGI, AR5; IPCC, 2013) provides results based on the new RCPs, with uncertainties based on a multi-model mean from a suite of complex coupled climate models. The numbers for GMT change allow for model differences and natural variability, but they do not provide for uncertainties associated with the carbon cycle.

The simple climate model MAGICC (Bodman et al., 2013b) provides a useful tool to generate probabilistic GMT change projections that account for the carbon cycle. Comparison to the WGI AR5 results show slightly more warming and a wider range of uncertainty, particularly for the higher forcing scenarios.

**Characteristics of the RCPs (Moss et al., 2008). $Wm^{-2}$ is Watts per square metre and concentrations are in $CO_2$ equivalents.**

| Name | Radiative Forcing | Concentration | Pathway shape |
|---|---|---|---|
| **RCP8.5** | >8.5 $Wm^{-2}$ | >1,370 $CO_2$-eq in 2100 | Rising |
| **RCP6.0** | 6 $Wm^{-2}$ at stabilisation after 2100 | 850 $CO_2$-eq (at stabilisation after 2100) | Stablilisation without overshoot |
| **RCP4.5** | 4.5 $Wm^{-2}$ at stabilisation after 2100 | 650 $CO_2$-eq (at stabilisation after 2100) | Stablilisation without overshoot |
| **RCP2.6** | Peak at 3 $Wm^{-2}$ before 2100 and then decline | Peak at 490 $CO_2$-eq before 2100 and then decline | Peak and decline |




**RCP temperature change projections. Shaded regions represent 67% confidence intervals. Based on MAGICC (Bodman et al., 2013b).**

## Scenario exercises

1. The first workshop exercise, ‘Our understanding of uncertainty’ allowed participants to bring their own understandings of uncertainty, especially climate-related uncertainty, to the table.

2. In the second exercise, each group was assigned a range of warming associated with a single RCP and asked to explore the resulting implications, and potential policy options.

3. In the third exercise, each group adopted the role of one level of government (local, state, federal or international), and was faced with developing climate policy through 2015 to 2030 by accounting for all four RCPs.

4. The final exercise asked participants to list their thoughts, based on the previous exercises, as to what was needed to promote a wider understanding of the science and to support decision making.

## Exercise one: Our understanding of uncertainty

Each table was asked to explore how they interpreted uncertainty in the context of climate change projections. The issues to be addressed were broadly given as:

- The different types of uncertainty (e.g., biogeophysical, socioeconomic, policy);
- How uncertainty is expressed (e.g., expected outcomes, range of outcomes, probabilities);
- Implications of uncertainty (act, delay, precautionary principle, more knowledge, risks to be managed);
- Uncertainty in their situation at different temporal and spatial scales.

Each group recorded their primary uncertainties after which the notes where then collated and displayed, ready for subsequent discussion. The notes from each table are recorded in Appendix B.

The main messages and the post activity discussion gave an overall sense that people were well aware of uncertainty being a problem in the communication and understanding of climate change. The key message was that uncertainty is a factor in many different spheres, but it is something that we are capable of managing.


Core themes that emerged from the discussion were:

- Policy uncertainty is a greater problem than climate uncertainty: it is policies that enable or inhibit changes in decisions and actions, not science. Science can inform, but it is not an agent;
- Understanding and communicating uncertainty is a challenge;
- There is a balance to be struck between waiting for more information and the need for action to address climate change;
- Some degree of uncertainty will always remain and have to be dealt with;
- Acting and making decisions will reduce policy uncertainty;

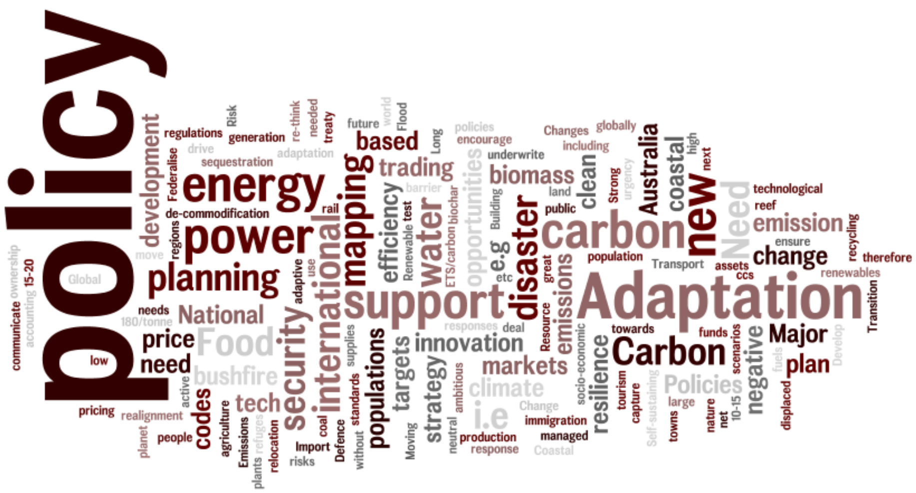
- Framing climate change as a risk management problem will be more useful than remaining focussed on uncertainty;
- Simple, single value targets and best estimates may well be more conducive to action than numbers given ranges, even if expressed as probabilities.

## Exercise two: Dealing with uncertainty

For the second group activity, each table was assigned one of the four RCP scenarios, which describe one aspect of the world of the future, with its global-mean temperature (GMT) change (refer to the figures below). This assumed that policy uncertainty was fixed but scientific uncertainty needed to be managed. The groups were asked to:

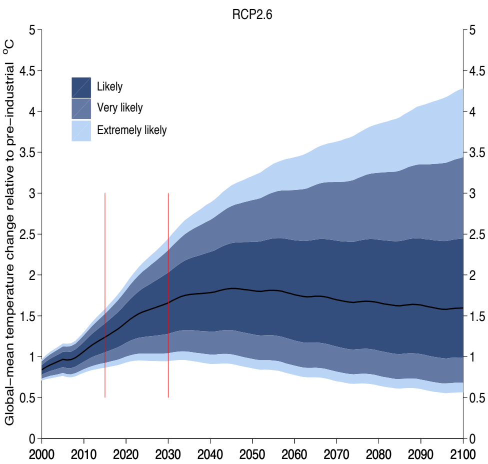
1. Highlight the significant features of the given scenario (with help from a table science advisor);
2. Discuss what the scenario implies as far as the path the world must have chosen to follow (energy technologies, information exchange, GDP, population etc.), making note of key assumptions;
3. Work out policy options for 2015 to 2030, identifying at least three and up to five policies that Australia should/could/must implement given the climate outcomes implied by the scenario and the graph of temperature change;
4. Make notes ready for display and present a brief summary and comment on your policies.

Notes from each of the groups are included in Appendix C.

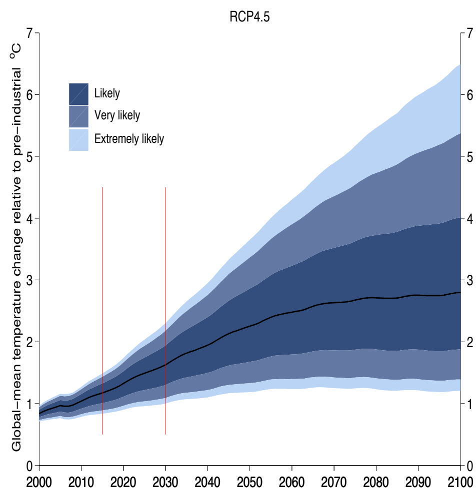



The outer scenarios, RCP2.6 and RCP8.5, appear to have been the most challenging for the table groups judging by the number of recorded comments. An RCP2.6 world implies drastic cuts in greenhouse gas emissions, with some form of carbon pricing applied across most countries. Policies that drive investment in renewable energy and massive technological change would be needed, with international agreement and commitment essential for this scenario to be achieved. The high emissions, high temperature change outcome for RCP8.5 posed particular problems, effectively requiring planning for ‘the end of the world as we know it’, with limited future options.

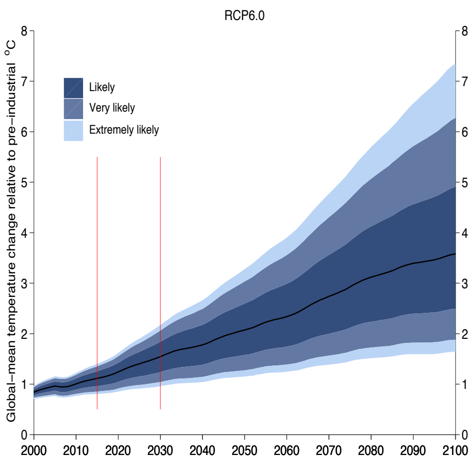
These scenarios require strong policies to either effect change (RCP2.6) or deal with the consequences of a radically different climate (RCP8.5). RCP2.6 is almost entirely about mitigation, while RCP8.5 is concerned with adaptation. Scientific uncertainty is also largely a non-issue in this context; it disappears as a barrier to decision-making and taking action to deal with these alternate future worlds.



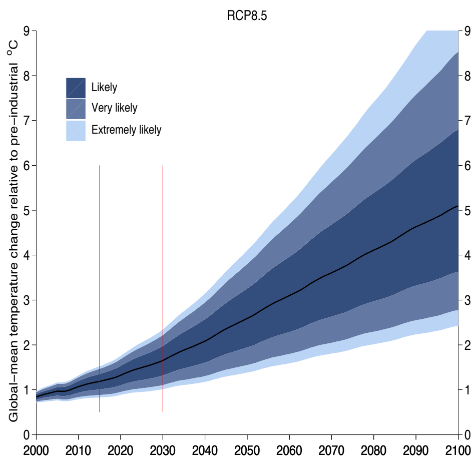

(a) RCP2.6




(b)RCP4.5




(c) RCP6.0




(d) RCP8.5

**RCP scenarios: Probabilistic global-mean temperature change projections. Red lines indicate the decision making period.**

The intermediate scenarios, RCP4.5 and 6.0 require more nuance or hedging, with a much wider variety of policies to address both mitigation and adaptation challenges. The comments indicate there are multiple, interconnected solutions, yet many of these have been given limited attention in policy settings.

## Exercise three: Making policy choices

For the third group exercise, each table was presented with all four scenarios to consider as equal possibilities and assigned a role as one tier of government (The Asia-Pacific region, the Federal Government, a state government, and a local council).

Each group was asked to select three policies from the previous exercise to manage climate change, selecting on the basis that they will be implemented during 2015–2030 and to discuss:

- What 2 or 3 policies are most relevant to each level of government?
- What is needed to enable these policies?
- What are the uncertainties that will impact these policies?

Notes were recorded as before and findings reported back to the room. The groups' notes are reproduced in Appendix D.


Interestingly, these group discussions showed a lack of concern about particular scientific uncertainties and the particular emission scenario the world actually followed, focusing more on the big issue. Responding to specific predictions was therefore seen as less important than managing the overall risk of climate change.

Every group suggested that all levels of government address energy policy at the appropriate scale. Such policies ranged across approaches to pricing (emission trading schemes, market mechanisms, removing perverse subsidies, regulations, incentives) and innovation (new technologies, knowledge and information, technology transfer). Policies were also proposed for adaptation, vulnerability and resilience. Governance at all levels emerged as a key theme, in particular governance structures and time frames for planning.

Key needs identified for enabling policies were:

- Leadership and continuity;
- Communication along with access to and sharing of information;
- Collaboration across all different types of government and organisations.

A diverse set of uncertainties that would impact on climate policies emerged, reflecting the roles of the different levels of government. At a higher policy level, the connections between global and regional activities become more important. At the state and local level, specific concerns, such as financial constraints and uncertainties about climate impacts and adaptation were more prominent.

## Consolidation and reflection exercise

The participants were invited to write down one question that they would like to see addressed. The aim was to gain some insight as to what people had learnt through the day and what their outstanding issues were. In addition, these questions were elicited to inform possible future research priorities. They have been collated and organised into four categories: science, costs, communications and general comments, and are listed in Appendix E. Answers to some of these questions may be used in follow-up exercises.

Some of these questions could be answered with existing knowledge, but others are more speculative and difficult to answer. However, the participants generally agreed that they don't want to experience a world in which climate change has progressed so far that the extreme circumstances raised are realised.

Communication emerged as a concern on a number of different and sometimes contradictory levels. For example, a number of the questions request detailed information, yet participants also highlighted the benefit of simple, single-value targets. Some of the questions appear to expect straightforward short answers, yet the complexities of the real world mean that this can be very difficult to achieve.

# Closing session

## Summary of the days findings

To conclude the workshop, Mr Ian Carruthers summarised the day's findings. A major theme across Ian's comments was the relevance and utility of science as a basis for policy and decision making.

Main points:

- Aggregate emissions are what count (i.e., the global total) and therefore policy requires international agreements;
- There is a slow evolution towards long term agreements on mitigation;
- Communication issues around the science are a problem;
- Need approaches to mitigation;
- Adaptation is treated as the poor cousin;
- Simple metrics are needed around the task to be performed; e.g., cumulative budget and how we are tracking towards it;
- How to sell the findings and keep it before the politicians and community.

Ian Carruthers also provided a summary of observations following the workshop, as shown below:

- Noted evolution of international climate change response over past 25 years, since agreement in 1992 UN Climate Convention to stabilise atmospheric concentrations at a safe level. However a great deal more still needs to be done, and the pace of global response must accelerate if safe levels to be preserved. There are some positive recent signs.
- Climate modelling work through simple models scenarios serve two purposes:
    - Advancing quality science understanding
    - Simplified science outputs to guide policy action on:
        - Global and national emissions reductions
        - Implementing climate adaptation strategies - where do the greatest risks lie and their timing.
- Uncertainty - a term interpreted very differently in parlance of science world and of policy/community/media.
    - The science community needs to focus on choice of language when

communicating science findings outside the internal science world of journals etc.

    - When communicating science distinguish between the uncertainty pertaining to scientific understanding of physics of climate system and those uncertainties that pertain to human decisions and behaviours affecting future pathways of emissions trends and coping capacity to deal with impacts.

- The workshop identified a need for continuing climate modelling analysis of:
    - Emissions reduction strategies at different scales (global and national)
    - Adaptation strategies - noting, so far little practical experience in application of adaptation strategies.
- Vital to continue to build community support for action on climate change:
    - Without a constant and building community groundswell it is difficult for governments to continue out in front and difficult for business to maintain as a priority. Science community has critical role in explaining to community in clear messaging why action needed.
    - As one idea, simple climate model analyses could be used to communicate on a regular basis the progressive draw down of the available carbon budget allowed into atmosphere if safe climate to be preserved (2°C) – analogous to the atomic scientists 'minutes to midnight' announcements on degree of risk of nuclear catastrophe.

Observing at arm's length over a long period, has led Ian to conclude that introducing economic costs alongside the physical science risks is a very complex business, requiring large project budgets to assemble the economic data needed. For example, the work of ABARES (formerly ABARE) over many years was regarded as among the world leaders in this space, but it is problematic in whole variety of ways.

## Closing remarks

Professor Peter Sheehan, Research Director of the Centre for Strategic Economic Studies closed the workshop with the following observations:

- There is a disconnect between the RCP8.5 pathway, which we are on, and RCP2.6, the path we want to be on. How do we switch?
- RCPs and SSPs have a model start year of 2010. Scenarios need to be continually updated so as to connect science and policy together, reflecting the actual emission trajectory the world is on;
- Interactions occur on different time frames (climate change occurs over long timeframes, but policy decisions that affect emissions occur over the next decade or so);

- RCPs are for decadal to century time scales; they don't capture what happens in the short term but RCP2.6 demands action on a shorter time scale for it to be achieved (transition from high to low pathway)
- What else could we do within this framework?
- Model sensitivity to achieving RCP2.6 (test to see what factors most affect the ability to achieve this pathway, associated temperature outcomes and carbon budget).

## Workshop summary

Climate science has developed increasingly sophisticated tools for assessing the uncertainties associated with climate change projections. Exercise one sought to gain insights into how people with a policy orientation understood these uncertainties. Rather than being focused on the specific details, participants' overwhelming orientation was towards actively seeking solutions and not letting uncertainty act as an obstacle to effective action. A focus on best estimates and simple targets was thought to be a useful strategy, since getting bogged down in particular nuances only leads to more discussion and confusion. Uncertainty then becomes a barrier to change. Possibly more useful would be attention to the risks of climate change, seeking policies to manage a range of outcomes, maybe framed on 'no-regrets' or precautionary principles.

The second exercise tested what happened when future emission emissions were fixed, with just one scenario to consider, thereby eliminating a degree of socio-economic and policy uncertainty. A wide variety of policies were thrown up in this process. The high emissions/high temperature change scenario RCP8.5 and the low emissions/low temperature change scenario RCP2.6 were, in some respects, the most problematic to deal with. The policies and technological changes needed for RCP2.6 can be envisaged readily, but realisation of those policies is a huge challenge. RCP8.5 is difficult because it represents the end of the world as we know it. These two scenarios represent opposite extremes; they are easier to imagine than the more middle-of-the-road scenarios, but more challenging to respond to realistically.

Across the restricted set of possibilities represented by the RCPs, RCP8.5 is a world where recent patterns of growth continue (mitigation efforts by the EU, USA and China suggest that some reduction in GHG emissions below this will be achieved). Addressing RCP8.5 requires policies that present significant challenges in dealing with climate impacts in a world that will be very different to that of the recent past. The main challenges revolve around adaptation.

RCP2.6 is desirable in that a global-mean temperature outcome of less than 2°C is likely. The major policy challenges require very high levels of mitigation associated with a radical transformation of energy sources towards zero carbon emissions. The intermediate scenarios, RCP6.0 and 4.5 still require mitigation but also some degree of adaptation.

Whatever path the world follows, climate change poses challenges across many different dimensions. The workshop comments indicate there are multiple, interconnecting solutions yet many of these have seen little real attention paid to them in a policy sense.

The third group activity, in which all four RCP scenarios were equally likely to apply, was a very policy-oriented discussion, with almost no attention paid to scientific and socioeconomic uncertainties. More pertinent were uncertainties about future policy directions and the interactions between different spheres of governance.  Comments indicated the need for a comprehensive range of climate policies to address a wide variety of potential problems largely independent of the scenario specifics. Mitigation and adaptation polices are required in each case, it is only the extent to which they are needed that varies. This weighting can be adjusted over time. More important, is putting into place well thought-out policies and sticking with them over the long term, making adjustments according to the necessities of evolving climatic changes and socioeconomic circumstances.

Reflecting on the workshop aims through a question and answer process reveals the following points:

*How are the uncertainties associated with projecting future climate, as represented by the RCPs, understood?*

- Understanding of the uncertainties associated with global-mean temperature projections varied, but were considered to be of secondary importance. People were content to accept best estimates as a guide and work from there. More significant were uncertainties related to the policies needed to address climate change.

*Do the RCPs meet the information needs of policy and decision makers or, if not, what are the information and knowledge gaps that need to be addressed?*

- The RCPs and the presentation of climate change projections in the IPCC's AR5 WGI report largely address the science of climate change, which is the WGI mandate. Less clear is the relevance of this work to climate policy, which, under the auspices of UNFCCC, has focussed on the 2°C target and the cumulative carbon emissions budget. From the workshop, the interest of policy makers appears to lie more with policies that can be negotiated within an environment that involves the many different and often competing issues that governments at all levels have to deal with.

*What 'science-for-policy' research would assist climate policy and decision makers to address the demands of climate change mitigation and adaptation?*

- Perhaps one of the most useful lines of research would be looking at the changes needed to move away from our present emission trajectory (a future world with the temperature change outcome of up to RCP8.5) towards a much lower emission level (such as RCP2.6). What types of transformations are needed to achieve this? Another related avenue of research would be to consider a suite of complementary climate policies that would encourage and enable these transformations.

One of the striking features of the group discussions was a lack of concern about scientific uncertainties and the particular emission scenario the world actually followed. This suggests that, rather than trying to improve techniques for estimating uncertainties associated with GMT change projections, research could more usefully be focussed on measures to reduce emissions and manage the risks of climate change.

## Future tasks

In the context of addressing the changes needed to move away from our present emission trajectory towards a much lower emission level, we are developing a research program that will address this issue. This work will also be used to inform a proposed ARC Discovery Project application for a combined climate/economic model that allows for rapid updating to recent emissions and shows the gap between that and preferred emission pathways. The transformations and rate of change needed to close this gap will be examined as part of this project.

# Appendix A: Workshop agenda

## VU Workshop -The Science Policy Nexus

Venue: Quay West Suites, 26 Southgate Avenue, Melbourne

Time: Friday 22nd of November, 9:00am – 5:00pm

| | | |
|---|---|---|
| 9:00am | Open | Registration, tea and coffee |
| 9:30am | Welcome | Mr George Pappas, Chancellor, Victoria University |
| 9:40am | Workshop introduction | Mr John Crofts, Workshop Facilitator |
| 9:45am | The policy environment | Mr Erwin Jackson, Deputy CEO, The Climate Institute |
| 10:05am | The science environment | Dr Brian O'Neill, Scientist III, National Center for Atmospheric Research, Boulder, USA. |
| 10:25am | Q & A | Discussion |
| 10:45am | Morning break | |
| 11:15am | History of climate policy | Professor Roger Jones, Professorial Research Fellow, Centre for Strategic Economics, Victoria University |
| 11:30am | Climate change uncertainty | Dr Roger Bodman, Postdoctoral Research Fellow, Centre for Strategic Economics, Victoria University |
| 11:45am | Q & A | Discussion |
| 12:05am | Our understanding of uncertainty | Group Activity |
| 12:30pm | Lunch break | |
| 1:15pm | Review understanding of uncertainty | Group Discussion |
| 1:30pm | Dealing with uncertainty | Group Activity |
| 2:00pm | Summary | Brief summary from each group |
| 2:15pm | Making policy choices | Group Activity |
| 2:45pm | Summary | Brief summary from each group by table host |
| 3:00pm | Afternoon break | |
| 3:20pm | Review | Group discussion, comments and questions |
| 4:00pm | Summary of the days findings | Mr Ian Carruthers, Former Division Head in the Department of Climate Change and Energy Efficiency |
| 4:15pm | Close | Professor Peter Sheehan, Research Director, Centre for Strategic Economics, Victoria University |
| 4:20pm | Finish | |

## Appendix B: Group exercise one

The notes from each table, identified by colour, are recorded here:

**1) Red Table**

- Meaning of uncertainty varies in different communities – scientific/public/policy
- Wait until it becomes clearer
- Uncertainty around technological pathway
- Uncertainty around impacts
- Adaptation is long term – mismatched timeframes
- Can spend too much time on uncertainty
- Need to always tell the story in the same way
- How best to communicate
- Can lead to inaction, ignoring tails
- Need for simplified conclusions
- Actual uncertainty surprisingly large versus narrative of growing certainty over time
- Policy timeframe is 5–10 years, uncertainties are less important over that time, more important post 2050
- Adaptation policy may have longer time frame; e.g., building desalination plants needs to account for climate change & important to get it right
- Scientists might be concerned about 'perfect' representation of uncertainty but for what issues/sectors does the uncertainty in climate really matter? Probably where lifetime of decision consequences is very long.
- Need to identify sectors where near-term decisions on adaptive response will have long-term consequences; e.g., at the city level, and focus on understanding uncertainty that affects those decisions.

Key messages:

- Policy is constantly under review (perhaps maximum timeframe of 10 years before changes).
- How does the science communication become sophisticated enough to influence the short-term decision making outlooks that drive our politicians?
- Scientists know the uncertainties best therefore they need their best advice on what to do now given possibilities
- In public mind: uncertainty maps to 'we don't know'
- There is considerable value in simplified targets e.g., 2°C, 1,000 Gt C
- Lots of uncertainty – get over it and simplify

**2) Green Table**

- Problem of irreducible uncertainty when people think uncertainty is an excuse to do nothing until we have 'certainty'
- Economic uncertainty – IAMs are 'real' models but with no financial system yet the financial system is a wild card; e.g., GFC. Carbon bubble – ability of fossil fuel projects to obtain funding, coastal property values, investment decisions of huge pension funds etc.

- Technological developments; e.g., solar PV, renewables storage, wind, already disrupting utilities' business models.
- Improve the language when communicating about what the models are telling us, what does it mean to have likelihood scenarios and how does that translate into aiding decision making
- Change behaviour with uncertainty, be more aware of the consequences if changing from scenarios A to B
- Challenges for decision makers (making decisions based on likelihoods/uncertainty ranges)
- Risk management
- Influence of psychological/behavioural aspects in how people react to probabilities or range of outcomes
- Rebuilding after floods – myopia/risk understanding problem? Or externality/institutional problem (subsidised flood insurance)
- Social psychology – voting intentions not about 'facts' but more about tribe, and sense of identity
- Vested interests – fossil fuel companies, news outlets
- What thresholds are there that will galvanise policy change
- Non-linear processes
- Uncertainties communicated as indecision
- Problem of communicating uncertainty
- Making conscious decision to reduce uncertainties by acting now

**3) Yellow Table**

- Disaster management – will the insurance industry cope?
- Policy makers and politicians respond more to change in votes than to scientific uncertainty
- Policy uncertainty versus scientific uncertainty
- Start using best guess
- When science intersects with policy in particular contexts then some uncertainties will be less relevant and others more relevant. This can simplify communication.
- Uncertainty is key for some kinds of policy, but is simplified out for other purposes.
- Determination of risk in insurance sector is on an annual basis for insurance – however longer term climate changes are considered e.g. for bushfire risk and floods
- 2°C target is a boiled-down target suitable for policy makers (for good or ill!)
- Price on carbon – did focus the mind in Australia but insufficient focus on incentives to corporations and government to respond to pricing.
- Uncertainty is a problem word for policy makers
- Interest groups understand uncertainty by focusing on the mean

**4) Blue Table**

- Some lack of clarity due to different baselines, modelling frameworks etc.
- Risks around different assessments not being consistent which allows for misrepresentation

- Uncertainties = lack of evidence, leads to lack of policy action
- Better to frame as risk not uncertainty
- Risk management framing
- Carbon budget framing useful as provides a strong link to early actions, which in turn links to the 2°C outcome
- Costs (economic) are more immediate and clear whereas the cost of inaction is not clear or very uncertain
- Costs of adaptation on high and low emission scenarios (disconnect between mitigation and adaptation)
- Uncertainty/vulnerability is in eye of the beholder

Key messages:

- How to 'sell' uncertainty to the community?
- Pricing compared to uncertainty?
- Policy makers especially decision makers don't necessarily understand uncertainty – should we communicate in terms of risk or certainty?
- Changes in presentation of the science (baseline years, assumptions e.g. carbon cycle) make it hard to compare things overtime.
- Are uncertainties in future impacts (location and timing) preventing attempts to estimate costs of impacts?
- From a policy perspective, it would be great to compare costs of mitigation with costs of impacts (a cost-benefit analysis could provide a stronger case for action – maybe!)

**5) Yellow/Green Table**

- Uncertainty – so many different perspectives – language creates a certain understanding but can create confusion.
- Different measurements used
- Scientific literacy – the consistency of measurement – creates uncertainty
- Communication – creating certainty
- Scientific uncertainty – data outcomes – models
- Innovation of this – uncertain – diffusion/uptake of solar good example
- Perception of change e.g. power station used by large utilities and not accounting for technological change
- Investment → uncertainty / innovation → uncertainty
- Policy – uncertainty convenient excuse for lack of actualization e.g. lots of money going into certain areas – driven by politics of the day – cyclical
- Engagement – need to be able to communicate with community
- Siloed approaches, etc. make it very difficult to put into action long term policy
- Budgets uncertain – need consistent funding
- Uncertainty – needs to be an enabler – need to be prepared. People want solutions.
- What is an acceptable level of risk?
- Sustainability funding e.g. fire services levy (lack of understanding as to how it should be spent)
- Politics are uncertain

- Changing government department name – confuses purpose
- Is the science good enough and how do we navigate this with policy dictates
- Industry lobbying against change with energy efficiency and appliance – so uncertainty of how industry reacts to policy
- Media big uncertainty – different ways of communicating, no control

Key messages:

- Policy uncertainty stymies long-term investment
- Uncertainty fuelled by media and short-term events
- Australia has particularly bad political culture for certainty and long-term policy
- Consistency in use of language when communicating uncertainty in science
- Uncertainty about what projections mean in reality
- Governments already make decisions with some degree of uncertainty
- Uncertainty – ones we can reduce, irreducible, partially reducible
- Used as an excuse not to act
- Uncertainty in future government policy
- Innovation highly uncertain
- Developing and implementing policy impacted by numerous factors and difficult to predict influence of these factors.

## Appendix C: Group exercise two

1) **Red table**: **RCP2.6**

Assuming we are not being a free rider:

- Australia needs 15–20% emissions cut by 2020, more than 100% by 2050, net negative globally by about 2070
- ETS/carbon pricing policy – mix of regulation and price policy e.g., no new coal plants without CCS
- Need international carbon trading policy – buy permits
- Adopt most ambitious renewables policy in the world
- Policies to encourage energy efficiency
- Consumption based accounting
- R&D budget and policy for negative emissions (how to achieve?). Afforestation, pumping water to interior. Massive technological change needed
- Carbon policy
- Import biomass and carbon capture technologies
- Transport policy
- Need a transformation/groundswell of support from the population and therefore need to communicate the urgency of the issue

**2) Green table: RCP8.5**

- Food security – local production, refuges to support
- Energy security – will need small footprint, hi tech energy or domes
- Think new planet, i.e. re-think how to live as 'extremeophiles'
- Need next 10–15 years to plan extreme pathways/scenarios, high tech innovation
- Develop and test scenarios for the future (socio-economic responses)

**3) Yellow table: RCP6.0**

- Moving towards relocation of large populations so as to deal with incoming migrants
- Food security policy
- Water policy
- Resource management policy to move to clean energy
- Keep fossil fuels in the ground
- Change sources of power generation
- Carbon sequestration (biochar etc.)
- Building codes for more heat
- Coastal retreat (managed realignment)
- Flood and bushfire protection
- Tax on carbon
- Food sourcing
- Tolerant immigration policy

- Long term de-industrialization and de-commodification
- Financial markets for adaptive costs and opportunities
- Policies for location and resilience of people
- Stronger building codes
- Changes to land use policy including development approvals and ownership
- Strategic development of climate change opportunities
- Innovation targets
- Risk mapping e.g., coastal mapping and decision making tools, mapping of climate risks, assets
- Adaptation planning for regions across Australia
- Self-sustaining towns i.e., own power and water supplies
- National disaster resilience strategy
- Renewable energy targets of 50%
- Emissions trading

**4) Blue table: RCP4.5**

- Carbon price linked to international markets at say $180/tonne
- Strong power sector and vehicle emission and efficiency standards
- Policy to ensure all new power investment is low emission
- National 30-40% target by 2050 in international treaty
- Transition plan to support nature based tourism i.e., no great barrier reef
- Defence planning active in disaster response at home and in region
- Federalise adaptation – major funds, disaster pool underwrite insurers
- Global cooperation on displaced populations
- Adaptation policies for agriculture
- R&D clean technology
- Adaptation – water recycling
- Adaptation – planning regulations: coastal policy, bushfire, flood
- All new investments to be carbon neutral
- Large fund to support innovation
- Major R&D program to drive biomass and ccs
- Major public transport and interstate rail strategy
- Adaptation fires

Note that the Yellow/Green table was disbanded and amalgamated into other tables, as some people were unable to stay for the afternoon.

## Appendix D: Group exercise three

### 1) Red table: Asia-Pacific

- Includes many vulnerable countries, many of which are not major emitters
- Region includes established industrial countries and newly developed/transitioning countries
- Three types of countries in region:
- Developing, vulnerable, not large emitters needing policies for reducing vulnerability
- Industrialised countries such as Japan, Australia, South Korea that need to reduce emissions
- China and India, working to improve living standards for a large populace, expanding their manufacturing and increasing demand for energy leading to becoming significant emitters of GHGs
- Need a coordinated response to energy policy – huge rollout of nuclear, focus on coal and CCS, shift to renewables
- Motivated by avoiding potential conflicts in energy interests
- Very free market type policy? ETS or very coordinated/strategic top down to decide on energy priorities jointly
- Remove perverse subsidies affecting fossil fuels
- To enable this: a governance framework for the region to carry this out, perhaps as an EU style region
- Regional disaster response including food security, with regional adaptation fund. Requires a governance structure to enable this
- Motivation: wide disparity among development levels
- Ability to set up regional initiatives
- Where would leadership come from? China?

Here, the uncertainties in climate projections were not the issue. It was just what policy tools do you have available and how would you get agreement to implement them across such a disparate region – too many unknowns. The scale of the problem is daunting.

*What 2-3 policies are most relevant to your region? Why did you select those and what makes these policies important?*

1. Coordinate regional energy policy/emissions
   - Could be free market ETS-style approach
   - Could be more strategic/regulatory
   - Include forests?
   - Remove perverse subsidies
2. Regional vulnerability reduction and adaptation strategy
   - Disaster relief
   - Food security
   - Regional adaptation fund, GEF-style?

Motivation:

1. For energy strategy:

- Reduce conflict within region
- Reduce climate change within the region

2. For vulnerability:
   - Wide variation in development levels and vulnerability in the region

*What do you to enable these policies?*

- Leadership – where would it come from for developing a regional governance structure – does not currently exist. Move to an EU style region?

*What are the uncertainties that will impact these policies?*

- Ability to set up governance structures
- Climate uncertainties – will world look more like RCP8.5 or RCP2.6?
- When does each policy area (energy, vulnerability) become more important?
- How effective is regional approach given global economy?

**2) Green table: National region, Australia**

*What 2-3 policies are most relevant to your region? Why did you select those and what makes these policies important?*

1. Energy policy
   - Price and technology
     - Reduce reliance on coal
     - Resource rent – internalize costs

2. Adaptation – Vulnerability
   - Long term planning
   - "Unpopular" – needs scientific backing
   - Finance – positive and negative drivers
   - Taxation and audit
   - "Build back better" policy
   - Potential large changes need to be accounted for
   - Limits to adaptation (as insurer)

3. Geoengineering
   - Policy position and understanding
   - Foreign policy
   - Aid assistance
   - Technology transfer

*What do you to enable these policies?*

- Knowledge and research
- Communicating and enabling
- COAG structures

- Sharing knowledge across departments
- Continuity – institutions and governance
- Climate knowledge (fit for purpose)
- Knowledge from those implementing adaptation

*What are the uncertainties that will impact these policies?*

- What will energy markets do?
- Conflict – intergenerational?
- Future uncertainty (socio-economic)

Additional recorded notes:

- Transition plan to support nature based tourism
- Federal adaptation fund to create a disaster pool
- Defence playing active role in disaster response in region
- Global agreement to deal with displaced populations
- Carbon pricing ETS
- Power sector standards
- Vehicle standards
- Policy to ensure new investment in low emission technologies
- 30-50% target by 2030

**3) Yellow table: State government**

*What 2-3 policies are most relevant to your region? Why did you select those and what makes these policies important?*

1. Education and information
    - Media, disaster education
    - People need to understand and own the risks
    - Diversify media
    - Regulations
    - Defence
    - Civil defence

2. Innovation
    - Set targets to drive investment and create environment for new technology and change
    - Investment in both soft and hard technologies
    - Market mechanisms e.g. ETS
    - (Money is reducing at government level but risks increasing – public purse cannot keep paying)

*What do you to enable these policies?*

- People and institutions to support this with government buy in across local/private/research/overseas
- Money from Commonwealth and private (super) investment

- Support people to use the information – education
- Strong interplay with other bodies – Commonwealth, private, international
- Supportive regulation and policies
- Collaborative systems
- (Annex Tasmania, Establish National Guard, Criminal Works Program!)

*What are the uncertainties that will impact these policies?*

- Politics
- Media
- People's response
- Money
- Climate events
- Social inequality
- Cascading climate events – social, environmental, fiscal impacts
- Resource shocks – sudden loss of a resource such as water
- Where are the thresholds?

### 4) Blue table: Local government

*What 2-3 policies are most relevant to your region? Why did you select those and what makes these policies important?*

1. Planning
2. Community resilience / communications / engagement
3. Low emission operations
   - Under own control
   - Would like to over adapt as risk stops with us
   - Interface with local community
   - Lead by example / showcase

*What do you to enable these policies?*

- Have a clear simple story to influence
- Planning:
  - Clarity and certainty i.e. legal settings (VCAT)
  - Open/green spaces
  - Appropriate building for 100 years
- Information
  - What are the effects at a local level and appropriate frameworks to understand and mitigate risks
  - Socio-economic data
- Money
- Risk transfer strategy

*What are the uncertainties that will impact these policies?*

- Lack of uncertainty i.e. actual adaptation needs
- Funding
- Timeframes - 0 to 50 years

- Liability
- Demographic changes

## Appendix E: Workshop questions

**A) Science**

1. What are the human impacts of warming at the 95% probability range (end of tail in a probability distribution)?
2. What is the likelihood that carbon cycle effects kick in once Arctic sea ice is gone to such an extent that there may not be an equilibrium average temperature between say ~1.5°C and a much higher temperature, like 5, 6°C?
3. How much will climate impacts differ for small reductions in the radiative forcing pathway?
4. What do we have to do by 2020 and 2030 to avoid ruling out a likely chance of meeting the below 2°C goal?
5. What are the parameters to the first globally catastrophic tipping point/irreversibility?
6. What do we need to do in the next 5-10 years (to make 2 degrees attainable)?
7. What are the total GHG emissions (GtCO2e) for the four RCPs?
8. Is there any way of measuring, for the four RCPs, the cooling effect (or their equivalence to GtCO2e) of SO2 and other cooling factors, that is, negative GtCO2e?

**B) Costs**

1. Could you please show me some horrendographs (an expression borrowed from Roger Jones) with $ on the Y-axis instead of some incomprehensible scientific acronym?
2. Determine the most cost-efficient emissions reduction scenario and report back on how we are tracking?
3. Quantify the impact in terms of cost.
4. Is it possible for a clear, simple statement on the absolute need for cuts in global emissions of xx GtC/y by 2020 or 2025 to avoid adverse impacts costing yy% of global GDP?

**C) Communications**

1. How can policy makers help scientists translate/communicate the science?
2. Why weren't these problems identified and addressed well before now? What could have been done (do you think) to prevent/minimize the situation we're in now?
3. More compelling communication of the science. Consider how it translates not only for the policy makers but also the community.

**D) Comments**

1. Why has social science taken such a back seat until now in IPCC and other key bodies?
2. How can science help with mitigation when the blockages to action are political and social? For example, how can the science community gain support for action?
3. What are your priorities for the research funds that you have?
4. Is there a way (pattern of investment) that would lead to more policy impact?

5. Does IPCC AR6 need a CMIP6?
6. What are the changes that we need to make as local government to minimize the risk of climate change scenario through long term planning and community management?
7. What are the small-scale changes local government can make to reduce risk and improve our capacity to adapt?

# Appendix F: List of participants

| | |
|---|---|
| Mr Alan Pears | RMIT University |
| Ms Annabelle Butler | Suncorp |
| Mr Ben Honan | Suncorp |
| Dr Brantley Liddle | Victoria University |
| Dr Brett Parris | Monash University |
| Dr Brian O'Neill | National Centre for Atmospheric Research |
| Dr Carol Grossman | Commonwealth Department of Environment |
| Ms Celeste Young | Victoria University |
| MsChristeneKilmartin | Department of Transport Planning and Local Infrastructure, Victoria |
| Mr Corey Watts | Climate Institute |
| MsCynnamon Dobbs | City of Melbourne |
| Mr Daniel Voronoff | Department of Human Services, Victoria |
| Professor David Karoly | University of Melbourne |
| Mr Erwin Jackson | Climate Institute |
| Dr Holly Foster | Victorian Fire Services Commissioner |
| Mr John Crofts | Facilitator |
| Mr Ian Carruthers | Former Division Head, Department of Climate Change and Energy Efficiency |
| Ms Jasmine Neve | Department of Environment and Primary Industries, Victoria |
| Ms Judy Bush | Northern Alliance for Greenhouse Action |
| Dr Karl Braganza | Australian Bureau of Meteorology |
| Ms Kate Hancock | Commonwealth Department of Industry |
| Ms Kylie Goodwin | Department of Environment and Primary Industries, Victoria |
| Mr Owen Pascoe | Climate Change Authority |
| Dr Penny Whetton | CSIRO |
| Professor Peter Rayner | University of Melbourne |
| Professor Peter Sheehan | Victoria University |
| Mr Richard Smith | Lloyds Register Quality Assurance |
| Dr Roger Bodman | Victoria University |
| Professor Roger Jones | Victoria University |
| Dr Scott Power | Australian Bureau of Meteorology |
| Dr Scott Rawlings | Office of the Commissioner for Environmental Sustainability, Victoria |
| A/Prof Simon Batterbury | University of Melbourne |
| Ms Stephanie Metz | Climate Change Authority |
| Ms Yvonne Lynch | City of Melbourne |

## Appendix G: Key terms and acronyms

| | |
|---|---|
| ABARES | Australian Bureau of Agricultural and Resource Economics and Sciences |
| AOGCM | Atmosphere-Ocean General Circulation Model |
| AR4 | Fourth Assessment Report of the IPCC (2007) |
| AR5 | Fifth Assessment Report of the IPCC (2013) |
| BECCS | Bioenergy and Carbon Capture and Storage |
| CCS | Carbon Capture and Storage |
| $CH_4$ | Methane |
| CM | Climate Model or Climate Modelling |
| CMIP5 | Coupled Model Intercomparison Project Phase 5 |
| CMIP6 | Coupled Model Intercomparison Project Phase 6 |
| $CO_2$ | Carbon Dioxide |
| COP | Conference of the Parties |
| ESM | Earth System Model |
| GHG | Greenhouse Gas |
| GMT | Global-mean temperature |
| GtC | Gigatonne of Carbon (a billion tonnes) |
| IAM | Integrated Assessment Model |
| IAV | Impacts, Adaptation and Vulnerability |
| IPCC | Intergovernmental Panel on Climate Change |
| MAGICC | Model for the Assessment of Greenhouse gas Induced Climate Change |
| Median | Mid-point in a probability distribution; the 50$^{th}$ percentile |
| NCAR | National Center for Atmospheric Research (Boulder, Colorado) |

| | |
|---|---|
| $N_2O$ | Nitrous Oxide ($NO_x$ – nitrous oxides) |
| Overshoot | The term given when atmospheric concentrations of greenhouse gases peak and then decline, rather than rising towards a stable limit |
| Radiative forcing | Is the change in the net (incoming minus outgoing) energy at the top of the atmosphere due a change in the climate system. |
| RCP | Representative Concentration Pathway |
| SPM | Summary for Policy Makers (of the IPCC's WGI report) |
| SRES | Special Report on Emission Scenarios |
| SSP | Shared Socioeconomic Pathway |
| Storylines | Narrative elements of scenarios, often used to aid quantification of future changes |
| TS | Technical Summary (of the IPCC's WGI report) |
| UNFCCC | United Nations Framework Convention on Climate Change |
| WGI | Working Group I (of the IPCC, the first volume on the physical climate). |
| $Wm^{-2}$ | Watts per square metre, the measure of additional energy provided by *radiative forcing*. |

## References


Bodman, R.W., Jones, R.N. and Young, C.K. (2013a) *The science-policy nexus: Assessing climate policy in an imperfect world*, Working Paper No.18, available from the Centre for Strategic Economic Studies' website (http://www.cfses.com/publish/papers.htm#CCpapers).

Bodman, R.W., Karoly, D.J. and Rayner, P.J. (2013b)Uncertainty in temperature projections reduced using carbon cycle and climate observations, *Nature Climate Change,* doi:10.1038/NCLIMATE1903.

Ebi, K.L., Hallegatte, S., Kram, T., Arnell, N.W., Carter, T.R., Edmonds, J., Kriegler, E., Mathur, R., O'Neill, B.C., Riahi, K., Winkler, H., Vuuren, D. and Zwickel, T. (2013) A new scenario framework for climate change research: background, process, and future directions. *Climatic Change*, 1-10.

Garnaut, R. (2008) *The Garnaut Climate Change Review*, Cambridge University Press, Melbourne.

IPCC (1990) *Climate Change: The IPCC Scientific Assessment*. Cambridge University Press, Cambridge, UK.

IPCC (1996) *Climate Change 1995: The Science of Climate Change*. Cambridge University Press, Cambridge, UK.

IPCC (2001) *Climate Change 2001: The Scientific Basis. Contribution of Working Group I of the Third Assessment Report.*Cambridge University Press, Cambridge, UK, 2001.

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

IPCC (2013) *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.*Cambridge University Press, Cambridge, UK (in press).

Meinshausen, M., Smith, S.J., Calvin, K., Daniel, J.S., Kainuma, M.L.T., Lamarque, J.F., Matsumoto, K., Montzka, S.A., Raper, S.C.B., Riahi, K., Thomson, A., Velders, G.J.M. and Vuuren, D.P.P. (2011), The RCP greenhouse gas concentrations and their extensions from 1765 to 2300, *Climatic Change*, **109**,213–241, doi:10.1007/s10584-011-0156-z.

Moss, R., Babiker, W., Brinkman, S., Calvo, E., Carter, T., Edmonds, J., Elgizouli, I., Emori, S., Erda, L., Hibbard, K., Jones, R., Kainuma, M., Kelleher, J., Lamarque, J.F., Manning, M., Matthews, B., Meehl, J., Meyer, L., Mitchell, J., Nakicenovic, N., O'Neill, B., Pichs, R., Riahi, K., Rose, S., Runci, P., Stouffer, R., van Vuuren, D., Weyant, J., Wilbanks, T., van Ypersele, J.P. and Zurek, M. (2008)*Towards New Scenarios for Analysis of Emissions, Climate*

*Change, Impacts, and Response Strategies,* Intergovernmental Panel on Climate Change, Geneva, 132 pp.

Moss, R.H., Edmonds, J.A., Hibbard, K.A., Manning, M.R., Rose, S.K., van Vuuren, D.P., Carter, T.R., Emori, S., Kainuma, M., Kram, T., Meehl, G.A., Mitchell, J.F.B., Nakicenovic, N., Riahi, K., Smith, S.J., Stouffer, R.J., Thomson, A.M., Weyant, J.P. and Wilbanks, T.J. (2010), The next generation of scenarios for climate change research and assessment, *Nature, 463,* 747–756.

Nakicenovic, N., and Swart, R. (2000), *IPCC Special Report on Emissions Scenarios,* Cambridge University Press, Cambridge, UK.

O'Neill B. C., Carter T. R., Ebi K. L., Edmonds J., Hallegatte S., Kemp-Benedict E., Kriegler E., Mearns L., Moss R., Riahi K., van Ruijven B., van Vuuren D. (2012) Meeting Report of the Workshop on The Nature and Use of New Socioeconomic Pathways for Climate Change Research, Boulder, CO, November 2–4, 2011. Available at: http://www.isp.ucar.edu/socio-economic-pathways.

Pepper W., Leggett J., Swart R., Wasson J., Edmonds J., Mintzer I. (1992) Emission scenarios for the IPCC: an update, supplementary document to *Climate Change 1992*. Cambridge University Press, Cambridge.

Peters, G. P., Andrew, R. M., Boden,T., Canadell,J. G., Ciais, P., LeQuere, C., Marland, G., Raupach, M. R. and Wilson, C. (2013). The challenge to keep global warming below 2°C. *Nature Climate Change*, 3:4–6.

Riahi, K., Smith, S.J., Stouffer, R.J., Thomson, A.M., Weyant, J.P. and Wilbanks, T.J. (2010), The next generation of scenarios for climate change research and assessment, *Nature, 463,* 747–756.

Nakicenovic, N., and Swart, R. (2000), *IPCC Special Report on Emissions Scenarios,* Cambridge University Press, Cambridge, UK.

United Nations (1992) *United Nations Framework Convention on Climate Change*. United Nations, Geneva.

vanVuuren, D.P., Edmonds, J.A., Kainuma, M., Riahi, K. and Weyant, J. (2011a) Special Issue: The Representative Concentration Pathways in Climatic Change. *Climatic Change*, 109, 1-241