Uncertainty and Climate Change:

The Challenge for Policy

John W Zillman AO FTSE
Warwick J McKibbin FASSA
Aynsley Kellow

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FOREWORD

The Academy of the Social Sciences in Australia engaged with the issues of climate change ten years ago, when it joined forces with the Australian Academy of Science and the Australian Academy of Technological Sciences and Engineering to guide a national evaluation of climate change science as it was known at the time. The issues surrounding the greenhouse effect and global warming, climate change and its potential consequences, have been vigorously debated among scientists and the general public in Australia and around the world since the 1980s. The challenge has been to identify (and attempt to measure) the elements of climate change, examine the possible, and/or likely results of such change in the short and long term, and to agree on policies that attempt to reduce the potentially serious global problem of climate change.

The Kyoto Protocol represents an attempt to meet this challenge, but it is already, after much modification to accommodate the various concerns of the many countries who have agreed to ratify the Protocol, somewhat under siege by its critics. A critical problem is the uncertainties which abound, in all the frames we bring to our understanding of climate change issues. The scientific uncertainties include our understanding of climate itself, the degree and form of anthropogenic induced climate change, the actual and potential impacts on the human and natural environments/ecosystems, the likely consequences and costs of mitigation or adaptation tactics. In addition, there are major economic and political (or diplomatic) uncertainties.

The compromise and cooperation among national governments, transnational corporations, environmentalists and other lobbying interests of many descriptions has been partially successful through the Kyoto Protocol, and this is to be applauded. But is the Protocol the best we can do with the knowledge we have so far? Are there alternative models which better 'fit' the uncertainties involved? Are the uncertainties so great that establishing some kinds of policy at this stage is premature, and may in fact make future cooperation more problematic?

The Academy invited three scholars, from different disciplines, to examine how uncertainty affects policy making, using climate change as a case study. John Zillman discusses the *science* of climate change; the uncertainty concerning the extent of climate sensitivity and the nature and magnitude of the impact on natural and human systems from continued emissions of greenhouse gases. Warwick McKibbin considers how the *economics* underpinning policy responses can best respond to the uncertainties associated with climate change. McKibbin makes a strong critique of the climate change policy response in the Kyoto Protocol. He proposes instead an alternative model – the McKibbin-Wilcoxen Blueprint – that relies less on controls which may have unknown costs, and more on clear incentives for national governments, firms and households to manage the risks from climate change. Aynsley Kellow explores the *politics* of climate change and how this can affect the policy making process. Some uncertainties can be down-played (or fostered) by particular interest groups to influence the construction of the climate change problem – its definition, the selection and assessment of evidence, for example – and thus limit the choice of policy options.

The prospect of climate change, although the exact nature and scale of both the change and its consequences are uncertain, means that prudential action will be taken by governments to lessen the possible negative impacts. The Academy takes no official position on the views presented by the authors in this volume, but hopes that these views will contribute to an informed debate on how Australia could best respond to and manage uncertainty in the quest for an effective domestic and international approach to policy on climate change.

The *Occasional Paper Series* devoted to policy issues is part of the Academy's program that demonstrates the contribution that social science research can make to public policy. This initiative was encouraged and funded by the Department of Education, Science and Technology (DEST) Higher Education Innovation Programme (HEIP) to strengthen the role of the social sciences in developing policy issues and providing advice to government.

Dr Michael Keating AC, FASSA
Chair, Policy and Advocacy Committee

UNCERTAINTY IN THE SCIENCE OF CLIMATE CHANGE

John W Zillman

Introduction

There was a time, in the first half of the twentieth century, when the earth's climate was regarded as pretty well known[1] and well understood and all that remained for the science of climatology was to build up the length of the record and fill in the remaining geographic detail. Over the past fifty years, however, we have come to realise that uncertainty pervades almost every aspect of our understanding of the global climate system[2] and of our use of that understanding in decision-making by governments, industry and the community at large. Indeed, it was only in the mid-1980s, a few years after the establishment of the World Climate Programme by the World Meteorological Organization (WMO) that the then President of the WMO Commission for Climatology coined the term 'the uncertainty business' for the study and exploitation of risks and opportunities in weather and climate.[3]

It was also in the mid-1980s that the prospect of dangerous human interference with the working of the global climate system, through mechanisms that had been reasonably well understood for almost a century[4] but for which clear warnings had only emerged from within the scientific community some three decades earlier,[5] eventually surfaced on the international political scene as a potentially serious threat to the future of humanity.[6] It took a few more years before the pressures for resolution of the many initially identified scientific uncertainties in the determination of global warming from an enhanced greenhouse effect led to the establishment, by the WMO and the United Nations Environment Programme (UNEP), of their joint Intergovernmental Panel on Climate Change (IPCC)[7] with the task (in summary) of assessing the available scientific information on climate change; and formulating response strategies for addressing the climate change issue.

The uncertainties surrounding climate (and especially climate change) are not limited to what will happen in the future but span the complete spectrum from our knowledge of past climate; and our understanding of the mechanisms of present-day climate; to our ability to predict future climate.

An in-depth understanding of the nature and significance of these uncertainties is essential for the formulation of properly informed national and international action on the greenhouse issue. Unfortunately, however, neither governments, stakeholder groups nor the community at large have found it easy to come to grips with the uncertainties of greenhouse science. To only slightly oversimplify:

- governments tend to look to the scientific community for clear and simple answers and become frustrated with equivocation and the fact that, as fast as scientific research resolves key uncertainties, new uncertainties are identified;
- those in the key stakeholder communities (especially the fossil fuel industry and the environmental movement at the extremes) tend to overstate either the uncertainties or the certainties to try to get government and community acceptance of the message that they want the science to deliver; and
- the community at large, who have learnt that science can predict the exact time of eclipses centuries ahead and technology can land a man on the moon, do not understand what is preventing the scientific community from doing just as well with climate change.

For their part, the expert scientific community have tended to split into two groups: the large majority who see the intergovernmentally-supervised, scientific-peer-review, consensus-based assessment process of the IPCC as the best way of communicating the contemporary state of the science in policy-relevant but policy-neutral terms[8] and who agree with, or are prepared to accept the scientific integrity of, the IPCC conclusions; and a much smaller group who, for whatever reason, take exception to the concept of consensus in science, disagree with one or more of the IPCC conclusions and seek to talk up the various sources of uncertainty identified in the IPCC assessments[9].

In these circumstances, a significant part of the contemporary challenge of the climate change issue is that of achieving a much more widely shared understanding of both the certainties and the uncertainties of climate change science and of better factoring them into the policy response process. Ten years ago, the Australian Academy of Science (AAS), the Academy of Social Sciences in Australia (ASSA) and the Australian Academy of Technological Sciences and Engineering (ATSE) joined forces to guide a national evaluation of climate change science focusing on current understanding and uncertainties[10.] This was updated in 2002[11] following the release of the IPCC's Third Assessment Report.[12] The present paper attempts to summarise and further update the earlier Academies' assessment in respect of the uncertainties of climate change science, drawing particularly on some recent summaries of the work of the IPCC.[13, 14, 15]

Certainty and uncertainty in science

One of the factors that has complicated the public and political response to the climate change issue has been a widespread misunderstanding of uncertainty in science. It may be useful, therefore, before homing in on the specifics of climate change, to look, more generally, at the nature and significance of certainty and uncertainty in science.

As characterised by Casti (1991),[16] the growth of scientific knowledge proceeds through the continued interplay of experiment and theory, with the analysis of experimental observations leading to 'empirical laws' which, if never disproven by further observations, may progress to the status of 'laws of nature' which, in turn, may be integrated into, or form the basis for, development of a theory. The quintessential illustration of this final step is the way in which Kepler's empirical laws of planetary motion were eventually explained by Newton's theory of mechanics. But unfortunately, at least in one sense, because Newtonian mechanics proved so successful in providing the basis for very accurate prediction of the movement of the planets, it led to the widespread misapprehension that all science is certain.

In fact, as pointed out by Pollock (2003)[17], the progress of science is about identifying, and seeking to reduce, uncertainty while recognising that some uncertainties may never be eliminated. It is fairly generally agreed that, in science, it is only possible to prove the falsehood of a proposition, not its truth and that there is no such thing as absolute certainty. While Newton's laws of motion may have seemed like the next best thing, Einstein's work buried, once and for all, the concepts of absolute space and time and Heisenberg shot down the belief in absolutely precise measurement in space and time. The discovery of the concept of chaos in natural systems in the 1960s[18] served to further emphasise that uncertainty is woven into the fabric of the scientific enterprise.

One of the great challenges for science is the quantification of uncertainty. This is most effectively done through the tools of mathematics and probabilities and especially through the well-known techniques of statistical significance testing and the like. The level of certainty in a particular scientific conclusion can be expressed in terms of the percentage likelihood (or probability) that the stated conclusion is true or, alternatively, as the level of confidence in the scientific community in the validity of the statement.

An important element of the process of establishing the level of confidence in, or certainty of, a stated scientific result is the peer review mechanism. Pollock[19] describes the methodology of peer review of scientific research findings in terms of a concept of science as a process of 'separating the demonstrably false from the probably true' and the way in which its consideration by the researcher's peers leads to the usual recognition of flawed research but allows research that meets a certain standard to be published for others to read, evaluate, contest or replicate. As Pollock points out, the peer review process is not infallible but the success of peer review in filtering out weak or flawed science far outweighs the occasional failure. Sometimes peer review will give the benefit of the doubt to a particularly important claim that later proves incorrect but the process allows for self-correction. Most research that has contributed to the significant progress of science over the past century has passed through the peer review processes of the relevant scientific journals but the recent trend for self-publication of research findings on the Internet has removed one of the important guarantees of the quality of publicly accessible research and hence the level of confidence to be attached to its conclusions.

Pollock goes on to describe and further discuss some of the dilemmas surrounding uncertainty in science[20] in terms of what he refers to as 'sowers of uncertainty' – people who do not like what science is telling them who then mount subtle and not-so-subtle assaults on the science - as 'unsound science', 'poor science', 'junk science' and the like – and argue that, had the research been properly conceived and executed, a different result (implicitly one more to their liking) would have emerged.

While such criticism normally takes place outside the usual for a for scientific discourse (and especially through radio and television talk shows, letters to the editor and so on), its impact on public understanding of the boundary between certainty and uncertainty on scientific issues can be substantial.

There is, of course, a very fine line between the ideologically motivated discrediting of a particular scientific conclusion, which does great disservice to the integrity of the scientific process, and the intellectually motivated challenging of the conventional wisdom on a particularly scientific issue which is, in essence, the source of scientific progress. It is probably fair to say that no scientific issue in recent times has been more subject to the dilemma of distinguishing the one from the other than that of greenhouse warming and climate change.

The science of climate change

The natural processes that determine the nature and behaviour of the earth's climate are extremely complex and there is no easy way of summarising everything about the mechanisms of climate that is necessary to come to grips with all the uncertainties in the science of climate change. There are, however, a few simple concepts from the climate change literature [21-23] that may help a little.

Planetary temperature

The overall climatic regime of planet earth is determined by the strength of the incident shortwave radiation from the sun and the reflectivity of the planet to the solar radiation. The absorbed solar energy maintains the earth-atmosphere system at an overall temperature (the 'planetary temperature', presently around 255K or -18^{o}C) at which the earth's 'longwave' emission back to space (which is proportional to the fourth power of its temperature) just balances the solar heating.

The things that can change this planetary temperature, and hence the overall climate regime of planet earth, include fluctuations in the radiant energy output from the sun, changes in the distance from the sun associated with changes in the earth's orbit (which are known to occur on time scales of tens to hundreds of thousands of years), as well as changes in the reflectivity of the earth resulting, inter alia, from changes in average cloudiness and the like.

The climate system

The earth's atmosphere, ocean, land, water, ice and biosphere form an internally coupled 'climate system' whose behaviour is determined by a range of physical, chemical, dynamical and biological processes which are ultimately driven by the energy from the sun. The most important weather- and climate-forming physical processes within the system can be described via a set of mathematical equations which express the laws of conservation of mass, momentum and energy in a form that enables the future to be determined on the basis of a knowledge of the present.

The greenhouse effect

One of the most important physical processes operating in the climate system is what is known universally, but somewhat inaccurately, as the greenhouse effect. It is the primary mechanism which keeps the temperature of the earth's surface some 70^{o}C or more warmer than 10-15km up in the atmosphere where jet aircraft fly.

The detailed physics of the greenhouse effect is extremely complex and difficult to explain in a rigorous way but the overall mechanism is well understood (Figure 1). In essence, it results from the fact that, even though the major constituent gases of the atmosphere are almost completely transparent to both shortwave (solar) and longwave (terrestrial) radiation, a number of atmospheric trace gases such as water vapour, carbon dioxide, methane and ozone (the 'greenhouse gases') absorb longwave radiation in certain spectral bands and re-emit radiant energy at a rate that is determined by the absorptivity/emissivity of the gas and the fourth power of the temperature.

This means that, with longwave energy radiating downward to the ground from the greenhouse gases in the atmosphere and adding to the shortwave energy coming in from the sun, the earth's surface must heat up to a higher temperature than it would be if only the sun's energy were heating the surface. In fact, the higher surface temperature that results (33^{o}C warmer, on average, than the planetary temperature), and the overall shape of the vertical temperature profile through the atmosphere, are the product of a balance between the radiative (shortwave plus longwave) heating of the surface and a combination of radiative, convective and latent heat transfer upward from the surface. This is the greenhouse effect. When the amount of greenhouse gases in the atmosphere increases, the atmosphere emits more radiation downward, the greenhouse effect is enhanced and the earth's surface warms up further.

Patterns of weather and climate

While the sun-earth geometry and the presence of greenhouse gases in the atmosphere determine the overall temperature level of the earth's surface, the detailed patterns of weather and climate over the earth result from the additional influence of two key features of the planet - the fact that it is round and rotating. Because it is round, the equatorial regions, where the sun is almost overhead, are heated much more than the poles, thus forcing a north-south overturning of the atmosphere with warm air rising in the tropics, flowing polewards aloft and sinking in the middle and high latitudes. Because the earth is rotating, the poleward-flowing air tries to maintain the eastward angular momentum it has gained from its earlier contact with the ground in the tropics and so accelerates rapidly eastward relative to the earth's surface, becomes unstable and breaks down into waves and vortices which are the familiar high level jet streams and surface highs and lows of the daily weather map. These, of course, interact with the mountain ranges and patterns of land and sea and, averaged over time, produce the well-known patterns of climate. By long-standing international convention, the 'normal' climate at any place on the earth's surface is regarded as defined by the averages of the relevant climate variables (temperature, rainfall, humidity, cloudiness, pressure, wind speed etc) over an agreed recent 30-year period.

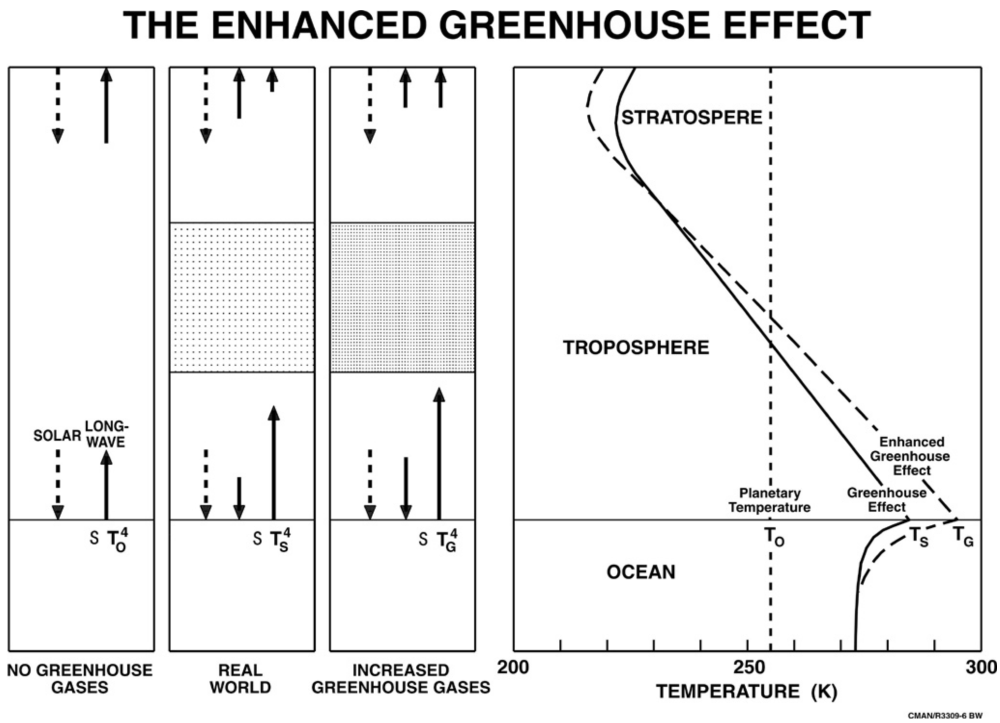

Figure 1: A schematic representation of the natural greenhouse effect and its enhancement through increased concentrations of radiatively active trace gases in the atmosphere. In a hypothetical world with no radiation-absorbing gases in the atmosphere (left panel) the shortwave radiant energy from the sun (broken arrows) which is absorbed by the earth's surface is re-radiated directly back to space at infrared wavelengths (solid arrows) with the average surface temperature (the planetary temperature T_o) stabilising at a level (255K or -18^{o}C) at which the infrared (longwave) radiation, which is proportional to the fourth power of the surface temperature (the multiplier S is known as the Stefan Boltzmann constant) just balances the incoming radiation. In the real world, with infrared absorbing and emitting gases present in the atmosphere, the atmosphere itself radiates infrared energy downward to the surface (second panel from the left) so that the surface must heat up by several tens of degrees in order to radiate sufficient additional energy upwards to restore balance. Although many other physical processes are called into play, this leads ultimately to an equilibrium vertical temperature profile in the atmosphere and ocean such as shown by the solid line in the right panel. With increased greenhouse gas concentrations (third panel from left) both physical reasoning and model results suggest an increase in downward radiation from the atmosphere (shown as a longer solid downward arrow), an enhanced greenhouse effect and a vertical temperature profile up to altitude 10km or so, such as that shown by the broken curve on the right.

Natural and human-induced change

While the 30-year 'normals' provide a useful guide to what to expect in the future, the interaction between the atmosphere and ocean, with their different densities, heat contents and characteristic time scales, leads to fluctuations of climate over a wide range of time scales, such that the climate patterns for one year will be different from those of the year before, those for one 30 year 'normal' period will be different from those of the previous 30 years and so on. This is referred to as the natural internal variability of climate which, there is reason to believe, can even include major shifts from one particular climate 'regime' to another associated with relatively sudden major rearrangements of the circulation of the atmosphere and ocean.

Climate change can also occur naturally as a result of influences external to the earth-atmosphere-ocean climate system. The most significant of these are changes in the incident radiation from the sun including, for example, from changes in the 11-year sunspot cycle or, on much longer time scales, changes in the earth's orbit. Another important source of 'natural' change which is conventionally regarded as external to the climate system is the injection of large amounts of dust and aerosol into the stratosphere from volcanic eruptions, leading to a reduction of the incoming solar radiation which can sometimes last for several years.

In addition to the natural changes resulting from both internal and external influences, it has become clear, over the past century, that human activities must be expected to lead to significant changes of climate. The most important mechanism through which this can occur is by modification of the vertical distribution of radiative heating of the atmosphere - either through enhancement of the natural greenhouse effect as a result of the build-up of carbon dioxide and other greenhouse gases from fossil fuel burning and the like or through changing the reflectivity of the atmosphere as a result of increased cloudiness (eg, from aircraft contrails) or the build-up of haze layers (eg, sulphate aerosol from coal burning). In general, increased greenhouse gas concentrations lead to surface warming and increased aerosol concentrations lead to surface cooling. The combined effect can conveniently be represented in terms of a quantity known as 'radiative forcing' which is usually defined as the change in the net (shortwave plus longwave) downward radiation flux at the tropopause (the top of the troposphere, the well-mixed lowest 10 km or so of the atmosphere) that results from the changed concentrations of greenhouse gases, or from some other cause.

Modelling climate change

It is possible to simulate the behaviour of the climate system, including its change over time as a result of human-induced radiative forcing, by numerically solving the set of mathematical equations which describe the physical laws of conservation of mass, momentum and energy for the various components (atmosphere, ocean etc) of the system (Figure 2). The simplest models involve the formulation of the key equations in 'one dimensional' form by integrating over the surface of the globe and calculating the 'equilibrium' global average surface temperature that results from different amounts of radiative forcing. The most sophisticated models simulate the evolution of the day-by-day weather patterns around the globe over decades or centuries, as the greenhouse gas (or other) forcing is changed, by carrying out the calculations on a three-dimensional grid over the earth's surface and upward through the atmosphere and downward into the ocean.

The methodology of such studies involves first checking that the model can realistically simulate the present patterns of global and regional climate by performing the calculations with the historical patterns of greenhouse gas (and aerosol) concentrations and radiative forcing and then running the model for a century or so into the future for any of a number of possible scenarios of greenhouse gas increases (Figure 3).

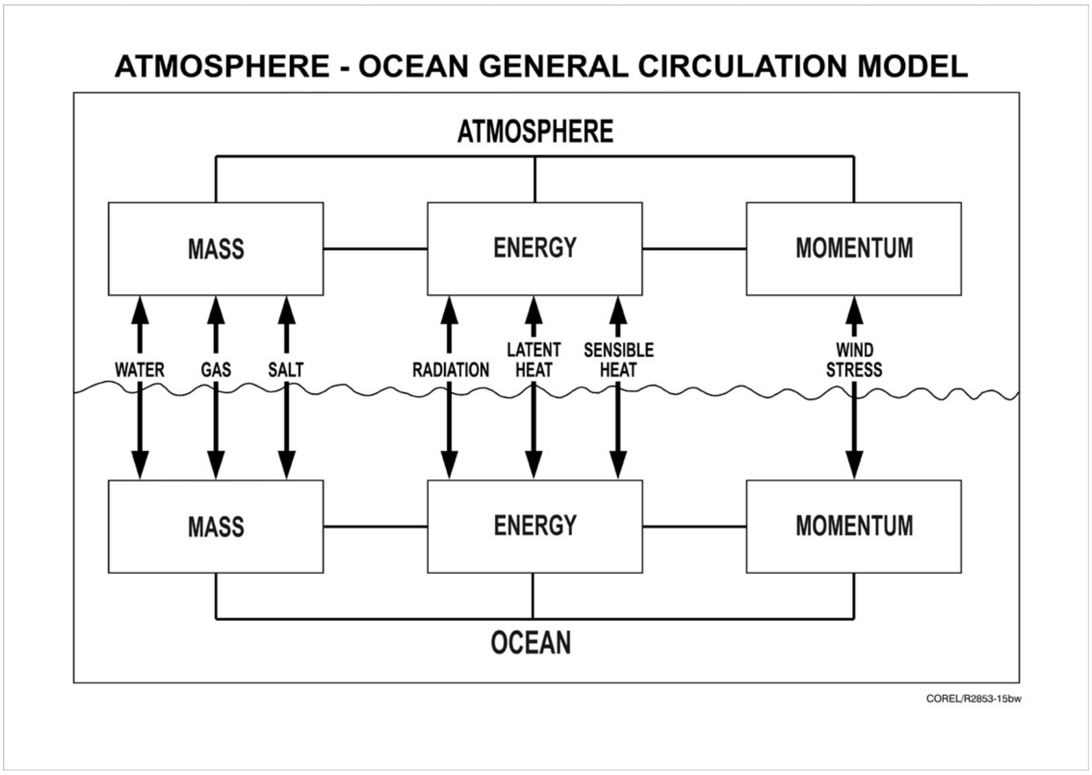

Figure 2: A schematic representation of a climate model. The laws of conservation of mass, momentum and energy for the atmosphere and ocean (including the effects of the earth's rotation) are formulated as mathematical equations, with the coupling between them through the transfer of properties across the sea-air (and land-air) interface allowed for, and the equations run forward in time, in predictive mode, for each of a large number of points on a three-dimensional grid over the earth. The averages over time (say 30 model years) of the various properties (temperature, pressure etc) of the atmosphere at the grid points then represent the model's simulation of the climate.

The IPCC treatment of uncertainty

From the time of its establishment in 1988, all those who have been centrally involved in the IPCC process have been acutely conscious of their responsibility to provide a balanced and objective assessment of the state of knowledge of the science of climate change - focusing both on what is known and what is not known, on the certainties and the uncertainties.

This has not been easy to achieve. In addition to the wide range of research results and expert opinions emerging from the peer-reviewed scientific literature, those preparing the IPCC assessments - both the Lead Author scientists and the government representatives who guide the assessment process and 'approve' the SPM (Summary for Policy Makers) components of the Assessment Reports in intergovernmental 'sessions' of the IPCC or its

Working Groups - have been under substantial pressure, through the review mechanism, (over-) confidence in their own or their colleagues' published work, stakeholder participation in IPCC sessions, direct lobbying and, in some cases, direct politically-motivated argument, to overstate or understate the level of certainty, as the case may be.[24]

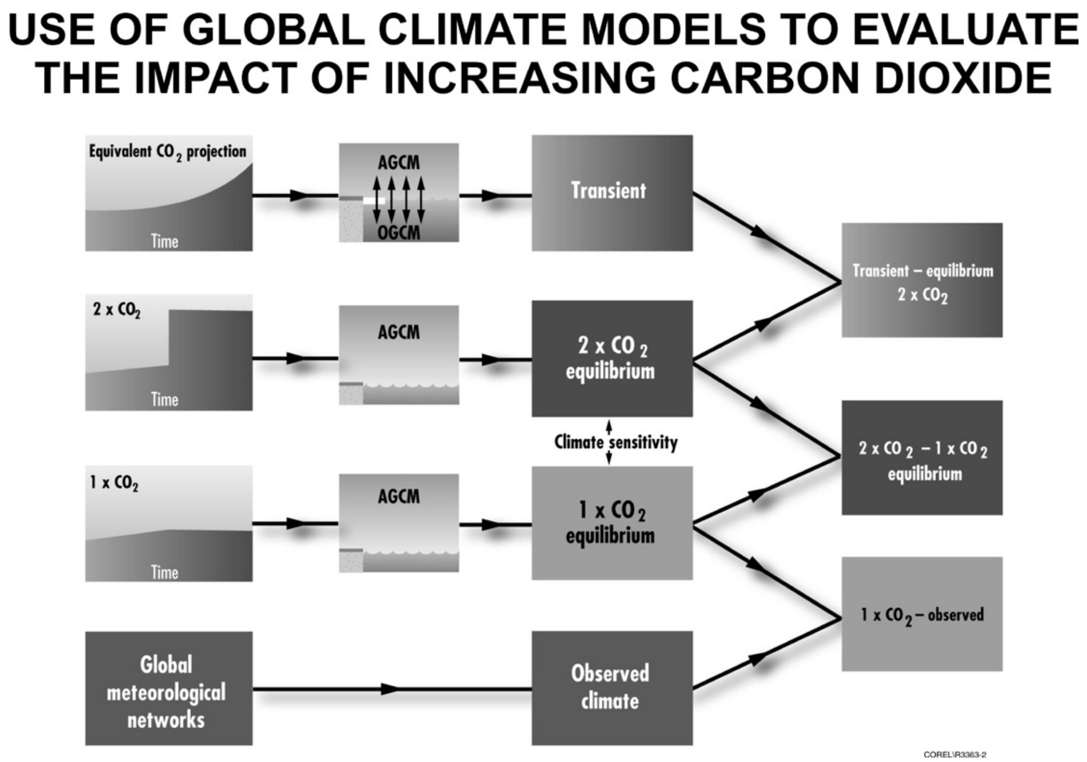

Figure 3: The methodology for using global climate models to explore the implications of increasing greenhouse gases on global climate. First, the model (cf Figure 2) is run forward in time for present day greenhouse gas concentrations (1 x CO_2) and the patterns of climate it produces after (say) a century compared with the observed climate from global meteorological networks to determine if the model is good enough for use in climate change studies. If the answer is yes, the model is then run out to equilibrium for a hypothetical doubling of greenhouse gases (2 x CO_2) and the difference between the global mean temperature for doubled CO_2 and present day CO_2 (known as the 'climate sensitivity') determined. Or, with more sophisticated models, the model may be used to simulate the (transient) changes of climate that result from a gradually increasing level of greenhouse gases (top panel).

First Assessment Report

The Working Group I (Science) component of the First Assessment Report (FAR) finalised in May 1990 before the industry and environmental lobbying processes were as sophisticated and subtle as they were soon to become, addressed the dilemma of uncertainty head on.[25]

> Uncertainties attach to almost every aspect of the issue, yet policymakers are looking for clear guidance from scientists; hence authors have been asked to provide their best estimates wherever possible, together with an assessment of the uncertainties.

After one of the most vigorous and rigorous scientific debates that I have ever witnessed among world leaders in any field,[26] the Working Group I Lead Authors for the FAR chose to cast the Executive Summary of their SPM in the following blunt, but very carefully worded, terms:[27]

- We are certain of the following: ....
- We calculate with confidence that: ....
- Based on current model results we predict: ....
- There are many uncertainties in our predictions, particularly with regard to the timing, magnitude and regional patterns of climate change, due to our incomplete understanding of:
  - sources and sinks of greenhouse gases, which affect predictions of future concentrations;
  - clouds, which strongly influence the magnitude of climate change;
  - oceans, which influence the timing and patterns of climate change;
  - polar ice sheets, which affect predictions of sea level rise.

  These processes are already partially understood and we are confident that the uncertainties can be reduced by further research. However, the complexity of the system means that we cannot rule out surprises.

The first attempt at an international political response to the IPCC's scientific statement of uncertainties came in the November 1990 Ministerial Declaration of the Second World Climate Conference. In the words of the Declaration:[28]

> ‘We note that, while climate has varied in the past and there is still a large degree of scientific uncertainty, the rate of climate change predicted by the IPCC to occur over the next century is unprecedented;'
>
> 'Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing cost-effective measures ..... ;' and
>
> 'The potentially serious consequences of climate change .... give sufficient reasons to begin by adopting response strategies even in the face of significant uncertainties;' and, from there to:
>
> 'We agree that the ultimate global objective should be to stabilise greenhouse gas concentrations at a level that would prevent dangerous anthropogenic interference with climate;'

….along with a lot of other words that were subsequently to be set in concrete with the May 1992 conclusion of negotiations on the text of the Framework Convention on Climate Change (FCCC) and its signature, by 155 nations, at the June 1992 Rio Earth Summit.[29]

But already by the time of the January 1992 session of the IPCC Working Group I that finalised an updated 'Supplement' to the FAR to inform the final stages of negotiations of the FCCC, some in the IPCC science community had become uncomfortable at the extent to which the nature of climate and the language of scientific uncertainty were being misunderstood in the policy process. There were two particular concerns. Firstly, the decision of the negotiators to set aside the naturally changing component of climate and reserve the term 'climate change' for only that part that is due to change in the composition of the atmosphere as a result of human activities was already beginning to set the stage for the massive confusion and misunderstanding of the uncertainties in climate prediction that have dogged the public and political debate ever since. Secondly, it started to dawn on the scientific community that the Convention negotiators (and the media) were interpreting the word 'prediction', as traditionally used by the atmospheric modelling community to describe the output of a model, far too literally and that some other word ('projection') had to be found to describe the output of a climate model forced by a particular 'scenario' of greenhouse gas concentrations. The 1992 Supplementary Report[30] did its best to register some important messages:

> 'Climate varies naturally on all timescales due to both external and internal features. To distinguish man-made climate variations from those natural changes, it is necessary to identify the man-made 'signal' against the background 'noise' of natural climate variability.'
>
> 'The prediction of future climate change is critically dependent on scenarios of future anthropogenic emissions of greenhouse gases and other climate forcing agents such as aerosols. These depend not only on factors which can be addressed by the natural sciences but also on factors such as population and economic growth and energy policy where there is much uncertainty and which are the concern of the social sciences. Natural and social scientists need to cooperate closely in the development of scenarios of future emissions.'
>
> 'Scenario outputs are not predictions of the future and should not be used as such.'

Second Assessment Report

By the time of completion of the 1995 Second Assessment Report (SAR), the science had made a lot of progress on addressing the uncertainties identified in the FAR, and the IPCC Working Group I community had become much more conscious of the need to clearly explain the importance of a balanced consideration of the sources and significance of the remaining uncertainties.[31] It is worth quoting in context, and (for the relevant parts) in full, the SPM of the SAR.

- Greenhouse gas concentrations have continued to increase;
- Anthropogenic aerosols tend to produce negative radiative forcing;
- Climate has changed over the past century;
- The balance of evidence suggests a discernable human influence on global climate;
- Climate is expected to continue to change in the future;
- There are still many uncertainties. Many factors currently limit our ability to project and detect future climate change. In particular, to reduce uncertainties, further work is needed on the following priority topics:
  - o estimation of future emissions and biogeochemical cycling of greenhouse gases, aerosols and aerosol precursors and projections of future concentrations and radiative properties;

- representation of climate processes in models, especially feedbacks associated with clouds, oceans, sea ice and vegetation in order to improve projections of rates and regional patterns of climate change;
- systematic collection of long-term instrumental and proxy observations of climate system variables (eg solar output, atmospheric energy balance components, hydrological cycles, ocean characteristics and ecosystem changes) for the purposes of model testing, assessment of temporal and regional variability and for detection and attribution studies.

Future unexpected, large and rapid climate system changes (as have occurred in the past) are, by their nature, difficult to predict. This implies that future climate change may also involve 'surprises'. In particular, these arise from the non-linear nature of the climate system. When rapidly forced, non-linear systems are especially subject to unexpected behaviour. Progress can be made by investigating non-linear processes and sub-components of the climate system. Examples of such non-linear behaviour include rapid circulation changes in the North Atlantic and feedbacks associated with terrestrial ecosystem changes.'

Third Assessment Report

The public and political response to the SAR (including its Working Group II (Impacts, Adaptations and Mitigation of Climate Change) and Working Group III (Economic and Social Dimensions of Climate Change) components) and especially the way in which the Working Groups' qualitative representation of uncertainties was interpreted and used by the various stakeholder communities, left the IPCC with a clear message that, for the Third Assessment Report (TAR), a much more quantitative and disciplined approach would have to be adopted for the characterisation of uncertainty.

This led to the preparation of a special cross-cutting Guidance Paper by Dr Richard Moss and Professor Stephen Schneider[31] on 'Uncertainties in the IPCC TAR' for use by the Lead Authors of all three Working Groups. This surveyed the various sources of uncertainty that could be expected to arise in the TAR, reviewed the available approaches for characterisation of uncertainty and offered a set of guidelines to be applied by Lead Authors. It included one particularly simple, but insightful, diagram (Figure 4) to illustrate the concept of the 'uncertainty explosion' as one progresses through the sequence from greenhouse gas emissions to the impacts of the resulting climate change.

The Guidance Paper identified some examples of sources of uncertainty as follows:

- Problems with data
  - missing components or errors in the data
  - noise in the data associated with biased or incomplete observations
  - random sampling errors and biases in a sample
- Problems with models
  - known processes but unknown functional relationships or errors in the structure of the model
  - known structure but unknown or erroneous values of some important parameters
  - known historical data and model structure but reason to believe parameters or model structure will change over time

  - uncertainty regarding the predictability (eg chaotic or stochastic behaviour) of the system or effect
  - uncertainties introduced by approximation techniques used to solve a set of equations that characterise the model
- Other sources of uncertainty
  - ambiguously defined concepts and terminology
  - inappropriate spatial/temporal units
  - inappropriateness of/lack of confidence in underlying assumptions
  - uncertainty due to projections of human behaviour (eg future consumption patterns, or technological change) which is distinct from uncertainty due to 'natural' sources (eg climate sensitivity, chaos).

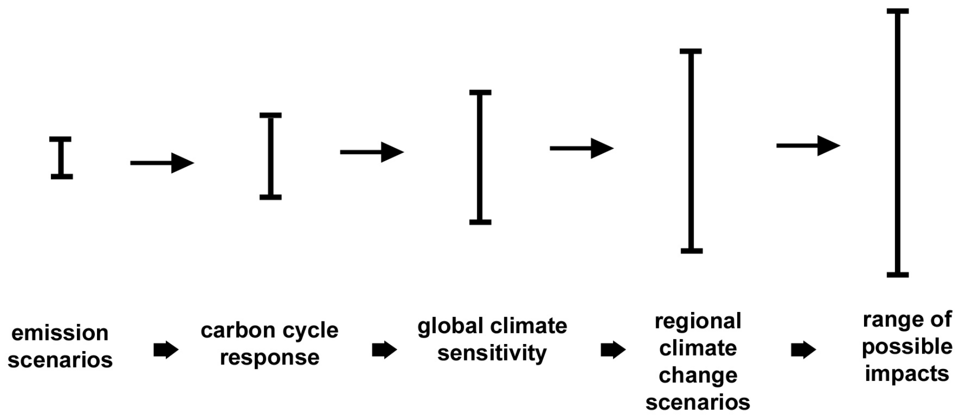

Figure 4: The range of major uncertainties typical in climate impact assessments showing the 'uncertainty explosion' as these ranges are multiplied to encompass a comprehensive range of future consequences, including physical, economic, social and political impacts and policy responses (*Moss and Schneider, 2000*).

It recommended the following seven steps (in summary) for assessing uncertainty in the TAR:

- For each major finding, identify the most important factors and uncertainties that are likely to affect the conclusions;
- Document ranges and distributions in the literature;
- Given the nature of the uncertainties and state of science, make an initial determination of the appropriate level of precision;
- Quantitatively or qualitatively characterise the distribution of values that a parameter, variable or outcome may take;
- Rate and describe the state of scientific information on which the conclusions and/or estimates are based using the following scale to characterise the probability estimates of confidence that the judgement is correct;
  - very high confidence (95-100%)

  - high confidence (67-95%)
  - medium confidence (33-67%)
  - low confidence (5-33%)
  - very low confidence (0-5%)
- Prepare a traceable account of how the estimates were constructed;
- Use formal probabilistic frameworks for assessing expert judgement.

As it turned out, this attempt at cross-Working Group consistency and quantification of uncertainty in the TAR proved only partly successful. In the case of Working Group I, some of the Chapter Lead Authors found great difficulty with the terminology and assignment of numbers to their subjective level of confidence. The TAR Working Group I SPM[33] finished up using a terminology for representation of judgmental estimates of confidence as follows:

- virtually certain (greater than 99% chance that a result is true)
- very likely (90-99% chance)
- likely (66-90% chance)
- medium likelihood (33-66% chance)
- unlikely (10-33% chance)
- very unlikely (1-10% chance)]
- exceptionally unlikely (less than 1% chance).

The IPCC endorsed the Moss-Schneider Guidelines[34] and also fixed on a definition of 'uncertainty' for use in the characterisation of climate change as follows:[35]

> 'An expression of the degree to which a value (eg the future state of the climate system) is unknown. Uncertainty can result from lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from quantifiable errors in the data to ambiguously defined concepts or terminology or uncertain projections of human behaviour. Uncertainty can therefore be represented by quantitative measures (eg a range of values calculated by various models) or by qualitative statements (eg reflecting the judgement of a team of experts).'

Against this background, it is important to note the cautious wording of some of the statements in the TAR SPM[36] which, despite the care taken by the IPCC Lead Authors to avoid overstatement of their level of confidence, subsequently led to outspoken dissent from a number of the more sceptical members of the climate science community[37, 38] - especially in response to their being quoted without the careful qualifiers in the original IPCC formulation, eg:

- 'globally it is <u>very likely</u> that the 1990s was the warmest decade and 1998 the warmest year in the instrumental record since 1861
- new analyses of proxy data for the northern hemisphere indicate that the increase in temperature in the 20th century is <u>likely</u> to have been the largest of any century during the past 1000 years
- the warming over the last 50 years due to anthropogenic greenhouse gases can be identified despite uncertainties in forcing due to anthropogenic sulphate aerosol and natural factors. Changes in natural forcing during this period are estimated to be negative and are <u>unlikely</u> to explain the warming

- the warming over the past 100 years is very unlikely to be due to internal variability alone, as estimated by current models
- anthropogenic warming is likely to lie in the range 0.1 to 0.2^{o}C per decade over the next few decades *under the IS92a scenario*.'

The TAR also attempted to quantify the contemporary scientific confidence in the evidence for both observed and projected climate extremes as follows:[39]

Change	Confidence in observed changes during the latter half of the 20th century	Confidence in projected changes during the 21st century
Higher maximum temperatures and more hot days over nearly all areas	Likely	Very likely
Increased summer continental drying and associated risk of drought	Likely in a few areas	Likely over most mid-latitude continental areas
Increase in tropical cyclone peak wind intensities	Not observed in the few analyses available	Likely over some areas

Following these and a number of other statements which attempted to convey a quantitative sense of certainty and uncertainty in the judgements emanating from the science assessment in the TAR, the TAR SPM concluded 'Further research is required to improve the ability to detect, attribute and understand climate change, to reduce uncertainties and to project future climate change'. It then went on to identify a long list of high priority areas for action.

In its assessment of the literature on possible future rates and patterns of climate change, the TAR went to special lengths to distinguish between uncertainties about future climate resulting from uncertainties in the science and uncertainties about future climate resulting from the fact that we do not know how greenhouse gas emissions will evolve over the next century. It therefore presented such things as possible future rates of global warming in terms of scientific uncertainty bands for each of a number of (essentially arbitrarily chosen) scenarios of future emissions based on an earlier IPCC assessment of the scenarios literature (the so-called SRES scenarios), while making clear that these were 'what if?' scenarios, that they should not in any sense be interpreted as predictions, that the IPCC was not in a position to attach probabilities to their occurrence and that their only purpose was to show how the climate system might be expected to respond to any of the wide range of emissions futures that had been suggested as possible in the published literature. Unfortunately, the IPCC's critically important distinction between scenarios, projections and prediction was all but ignored by most of those who proceeded to use the TAR for public information and public policy purposes, leading to massive confusion in the community as to the sources and level of uncertainty about future climate.

Fourth Assessment Report

The preparation of the IPCC's Fourth Assessment Report (AR4) is now underway with a target of 2007 for completion. The basic framework within which the IPCC assessment of program in the literature since the TAR is being carried out (Figure 5) remains unchanged. But, given the limited success of the TAR approach to the quantification of uncertainty – or at least the limited public and political understanding of the significance of the uncertainties that resulted from the TAR approach – consideration was again directed, in the AR4 scoping process,[40] to the development of more rigorous and more readily understandable ways of characterising the uncertainty of the scientific conclusions on each key aspect of the report. It remains to be seen how successful this will be.

Areas and sources of uncertainty

There are many different, but comparably useful, ways of viewing the total picture of uncertainties in the science of climate change. There is also, of course, a wide range of levels of uncertainty attached to various components of the total problem; and many different causes of the current levels of uncertainty ranging from inadequate data and limited theoretical understanding of key processes to the fundamental dilemma that results from our inability to predict a future which depends on collective human behaviour when that behaviour will itself be influenced by the prediction.

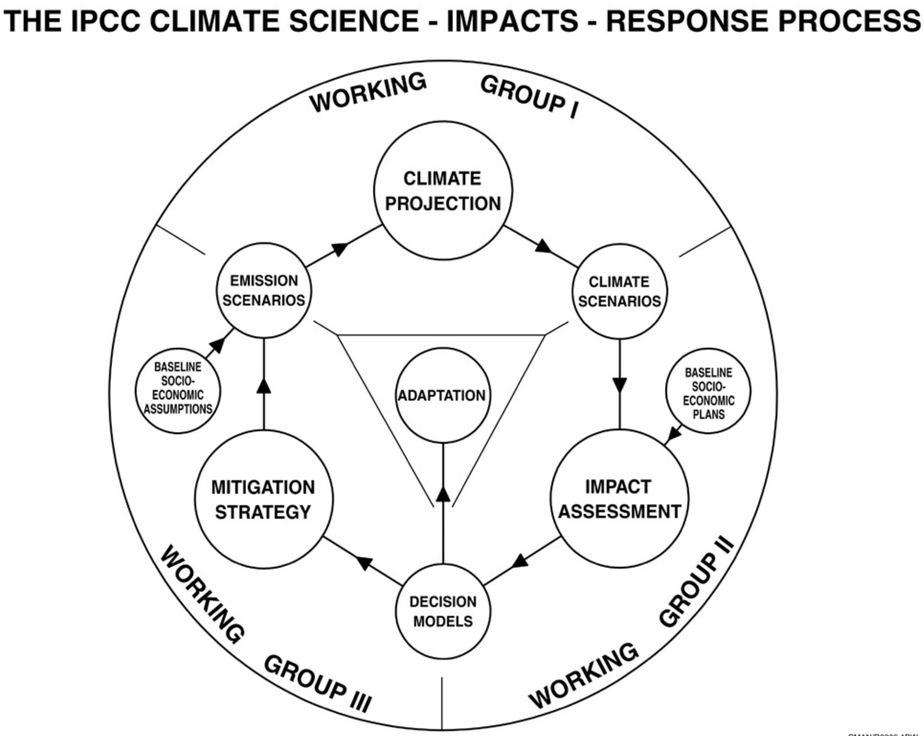

Figure 5: The conceptual structure of the climate change issue as used by the IPCC in assessing the literature on climate change science (Working Group I), impacts and adaptation (Working Group II) and mitigation strategy (Working Group III). The process begins with a set of baseline socio-economic assumptions which are used to develop a set of emission scenarios for use in generating concentration scenarios as input to climate models whose 'projections' for each of the scenarios are used to guide the development of climate change scenarios. These, in turn, are then used for climate impact studies, the results of which are then, in turn, used as input to policy decisions on the balance of adaptation and mitigation in the response process.

Two of the more useful ways of viewing the uncertainties of the climate change issue flow from the following two different formulations of the problem:

- Testing theory
  - formulate a theoretical basis for simulating the behaviour of the climate system;
  - test the theory with observations of past and present climate;
  - if successful, use the theory to 'predict' future climate
- Explaining observations
  - observe past changes of climate
  - develop an explanation for the observed changes;
  - use the explanation to formulate a model for predicting future climate.

The first is closer to the usual concept of the 'scientific method' and probably the more intellectually rigorous, but the second fits more closely with the public perception of the issue. As a matter of practical convenience, therefore, the following summary will cover in turn the uncertainty (both the areas and sources of uncertainty) associated with:

- our knowledge of how climate has changed in the past;
- our understanding of the mechanisms of climate and climate change; and
- our ability to predict how climate will change in the future.

How climate has changed in the past

The global instrumental meteorological networks that have gradually built up over the past century and a half under the auspices of the WMO and its non-governmental predecessor, the International Meteorological Organization (IMO), including, of course, the routine observations from ships at sea, have provided a reasonably sound basis for describing the overall long-term average patterns of the main climate variables (temperature, rainfall, humidity, cloudiness, pressure, wind speed etc) over the globe.[41] But these observations suffer from quite a few deficiencies which limit the accuracy and detail of the description of present day climate and how it has changed over the period of the instrumental record.

There are still major limitations in our knowledge of the spatial patterns of both the average and extreme values of many important climate variables and phenomena over both land and sea as a result of:

- variable and, in many cases, inadequate network density, especially over the mountains, deserts and oceans;
- inhomogeneous, and sometimes non-standard, instrumentation and instrument exposure (including the lumping together of observations collected for such different purposes as supporting aviation safety and research into local atmospheric processes);
- different levels of quality control of data, different approaches to the derivation of key variables (eg, different ways of calculating the daily average temperature for a particular location) and use of different periods of years for determining 'normals'; and
- lack of a consistent methodology for recording weather and climate extremes.

Given these limitations in describing the spatial patterns of climate for any individual year, decade or 30-year 'normal' period, there are clearly further sources of uncertainty when we seek to use the data to describe the trends over time in climatic means or extremes for individual observing stations, countries, regions or the globe as a whole. In addition to those elaborated above, we now have to deal with the following sources of uncertainty:

- changes in network structure, density and representativeness over time;
- changes in instrumentation, exposure (eg through the 'urban heat island' phenomenon as cities build up around long-term observation sites), calibration and processing methods;
- introduction of new methods of observation (eg satellite detection of upper air temperature in lieu of conventional radiosondes) with the inherent uncertainty[42] as to whether the different methods are 'measuring the same thing'; and
- changes of observer and observing practice over time;
- different statistical techniques for identifying trends or discontinuities in time series data.[43]

The determination of climate change over time back beyond the instrumental period is subject to even higher levels and different sources of uncertainty since much of the work on reconstruction of temperature and rainfall trends and other climate parameters must be based on the interpretation of 'proxy' data such as tree rings, coral cores, pollen records, ice cores and the like. The major sources of uncertainty derive from:

- the validity and uniqueness of the transfer function from proxy to climate variable;
- the quality, reliability and intercomparability of the different proxy records; and
- the temporal and spatial resolution of the proxy records.

Taken together, these various sources of uncertainty in the historical record and its interpretation lead to such vigorous debates as to whether there really was a globally coherent 'Little Ice Age' from the 14th to the 19th centuries and whether the 1990s really was the warmest decade in the last thousand years.[44, 45] Given the high level of confidence of several of the key research groups in the validity of their work and the equally strong conviction of their critics that they have misused and misinterpreted the basic data, this debate will, almost certainly, continue for some years yet. It will, almost certainly, be a focus of particularly careful analysis in the IPCC's Fourth Assessment Report.

The mechanisms of climate and climate change

While it is fair to say that the past half century or so of research into the workings of the climate system, including through such focused international efforts as the Global Atmospheric Research Programme (GARP), the World Climate Research Programme (WCRP) and the International Geosphere-Biosphere Programme (IGBP) have provided us with a remarkably comprehensive big-picture understanding of the mechanisms of climate and climate change, at the more detailed process level the science of climate and climate change is still full of uncertainties. From the long list of scientific questions for which answers are needed, one can identify as the presently most problematic:

- the mechanisms of internal natural variability in the atmosphere and ocean;
- the cycling of carbon dioxide between the atmosphere, oceans and terrestrial biosphere;
- the interpretation and expansion of the concept of radiative forcing;[46]
- the radiative forcing properties of the various natural and anthropogenic greenhouse gases;
- the role of the direct, and the many indirect mechanisms of, radiative forcing by aerosols;

- the role of 'feedbacks' due to water vapour, cloud, snow and sea ice on the radiation budget;
- the transfer of heat, water vapour and trace gases across the sea-air, ice-air and land-air interface;
- the role of land cover and land use changes in forcing local and global climate;
- the respective roles of the meridional circulation and eddies and of the ocean and the atmosphere, in transferring heat from the equator to the poles;
- the susceptibility of the climate system to thresholds and regime changes;
- the impact of changing large scale patterns of climate on the frequency and intensity of weather and climate extremes.

Most of these, and many others, continue as the focus of a wide range of national and international research programs and projects under the general auspices of the WCRP and the IGBP.

Predicting future climate

The prediction of future climate on decade to century time scales and the assessment of the impacts of whatever changes occur is, of course, the most important scientific challenge of the climate change issue and the area of greatest uncertainty. But it is especially important, here, to distinguish sharply between three different components of the prediction problem:

- the determination of what might happen to global, regional and local climate as a result of the natural (internal or externally forced) variability of climate, irrespective of any human interference with the climate system;
- the determination of future emissions of greenhouse gases and aerosols and their future concentrations in the atmosphere so that we can determine what will be the nature of the radiative forcing of climate change; and
- the use of climate models to calculate ('project') how the climate system would be likely to respond to the expected greenhouse gas and aerosol concentrations and radiative forcing.

The first of these, the prediction of the natural changes of climate over the coming century, is fraught with difficulties and uncertainties and must be regarded as essentially impossible in any deterministic sense. While we have some feel, both from observations and from models, for the likely range of natural variability of climate on decade to century timescales, we can say little about the prospect of major switches in climate regime (associated, say, with shutdown of the 'conveyor belt' transfer of warm surface water to the north Atlantic[47]) or changes that might result from external forcing such as could come from (essentially unpredictable) volcanic eruptions. All we can say, with some measure of confidence, is that natural processes over the next century could well be large enough to negate or dangerously amplify such changes as might result from human interference with the climate system.

The second component of the climate prediction problem is even more problematical. In essence, it requires that we be able to predict future greenhouse gas and aerosol emissions and concentrations as input to the climate models. At this stage, the IPCC community have taken it as a given that meaningful *prediction* of future emissions is impossible. They have, therefore, adopted the concept of using a range of emission *scenarios* as a 'what if' device and have resisted the pressure from some in the scientific community to attempt to attach probabilities to the emission scenarios. While this approach means that there is no basis for actually *predicting* the anthropogenic component of future climate change, the emission scenarios, properly used and regardless of the socio-economic assumptions on which they are based, provide a useful framework for demonstrating the sensitivity of climate to different levels of greenhouse gas emissions; and hence, importantly, a basis for determining future emission profiles that would not be likely to lead to global warming (or other forms of climate change) beyond particular threshold levels.

While the first two components of the climate prediction problem effectively rule out any immediate prospect of climate prediction on decade to century timescales, the third component is much more promising and much more useful. In summary, global climate models have now been developed to a stage of sophistication where, for any greenhouse gas emission (or concentration) scenario, it is possible to say quite a lot about how the climate could be expected to evolve. It is important, therefore, to take stock of the uncertainties involved in the use of climate models, in conjunction with emission *scenarios*, to produce *projections* (*not predictions*) of the anthropogenic component of possible future climate change.

The three most important characteristics of anthropogenic climate change which we need to quantify in order to assess potential impacts, the capacity for adaptation and the urgency of mitigation action are:

- the overall rate of warming and sea level rise;
- the regional patterns of climate change; and
- the changing occurrence of extremes.

While the first of these is the most soundly based, there are nevertheless many uncertainties resulting from:

- inadequacies in our understanding of the global carbon cycle and other biogeochemical processes which introduce substantial uncertainties into the determination of greenhouse gas concentrations for any given pattern of future emissions;
- uncertainties in the determination of radiative forcing for any particular concentration of greenhouse gases;
- limitations in the capacity of the models to simulate the response of the atmosphere, ocean and land surface to the imposed radiative forcing; and, as a result:
- uncertainties in the overall sensitivity of the climate system to increased greenhouse gas concentrations as measured, for example, by the 'climate sensitivity', the warming that would occur for hypothetically doubled carbon dioxide; and
- in the case of sea level rise, both the processes related to heat transfer to the deep ocean and the extent of glacier melt.

The current state of knowledge of these in 2001, as illustrated in the detailed charts included in the IPCC TAR, can be summarised in terms of the envelope of possibilities for global mean temperature and sea level rise shown in Figure 6. Figure 6 shows, in one emission scenario, the 'model range' of expected warming. The important next step in refining the information available from the science (quite apart from the non-climate-science issue of whether it will be possible to assign probabilities to particular emission scenarios) will be the use of 'ensemble forecasting' techniques to determine the probability distribution for the warming *for any nominated emission scenario*. For example, preliminary studies on the probability distribution for the climate sensitivity (the equilibrium warming for doubled carbon dioxide) from a dozen or so reputable models that are expected to be assessed in the IPCC's Fourth Assessment Report (Meehl, 2003) suggests a 5-95 per cent uncertainty range of 2.0-4.4^{o}C within a median of 3.1^{o}C.

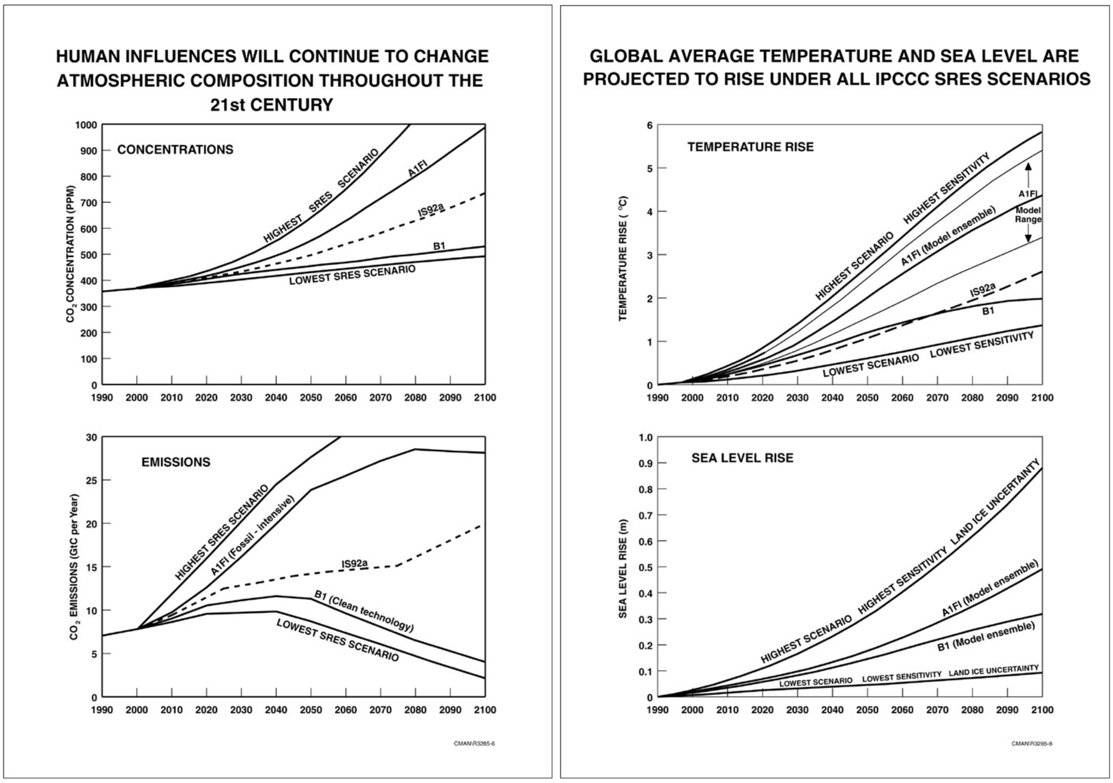

Figure 6: A schematic representation of the IPCC's use of emission scenarios (bottom left) spanning the range of scenarios in the published literature to provide a consistent set of greenhouse gas concentration scenarios (top left) as input to climate models which then 'project' a range of global mean temperature increases (top right) and sea level rise (bottom left). The level of uncertainty in global mean temperature rise resulting from the range of climate sensitivities emerging from the different climate models is shown for one emission scenario (the A1FI 'model ensemble' and 'model range') from which it is clear that the main 'uncertainty' in predicting future greenhouse gas warming at this stage results not so much from scientific uncertainties as from our lack of knowledge of future greenhouse gas emissions and concentrations.

The experience so far with the use of climate models to delineate the possible future regional patterns of climate change for any particular radiative forcing scenario suggests that little can yet be said with confidence about future regional climate change. The various models handle the detailed evolution of weather systems in quite different ways and generally do not cope with the combined influence of orography and surface transfer processes very well. Although some in the modelling community believe that their models capture enough of the detailed behaviour of the atmosphere to provide potentially useful guidance, my own assessment is that there is little or no skill yet in the projection of regional climate change beyond a finding, from most models, that the continents can be expected to warm faster than the oceans.

While some modellers have also developed an enviable level of confidence in the capacity of their models to simulate the impact of greenhouse gas increases on the occurrence of extremes (extreme temperatures and rainfall rates, tropical cyclones, severe storms and the like) the consensus assessment, within the IPCC climate science community, is that the levels of confidence are low, except for the expectation of more frequent hot days under sustained greenhouse warming.

In summary, therefore, while it is, at present, completely impossible to *predict* future climate on the decade to century timescale in other than probabilistic terms, there is increasing confidence that, for any given greenhouse gas emission scenario, it *is possible* to *project* the trends in global mean temperature and rainfall that would result from the enhanced greenhouse warming - but little, if any, of the spatial or temporal detail.

Conclusion

After three years of study of the climate change literature, the author of the popular recent techno-thriller *State of Fear*, Michael Crichton, proclaimed his certainty that there is too much certainty in the world.[48] Lest this brief survey here give the impression that there is, in fact, so much *uncertainty* in the world of climate change science that nothing can be said with sufficient confidence to usefully inform the policy process, I hasten to stress that I believe this would be a completely wrong impression. Because, despite all the uncertainties identified in the IPCC assessments, which greenhouse sceptics tend to highlight and greenhouse zealots tend to discount, the body of scientific knowledge summarised in the IPCC reports makes clear that there is a great deal about which we are now virtually certain.

For my part, I am virtually certain (ie, I believe there is more than 99 per cent chance that it is true) that:

- The earth's climate is naturally variable across a wide range of timescales and amplitudes;
- The trace amounts of carbon dioxide and other radiation-absorbing gases in the atmosphere are producing a natural greenhouse effect that is keeping the earth's surface considerably warmer than it would otherwise be;
- Increasing greenhouse gas concentrations superimpose a gradual warming trend on top of the natural variability of climate with the rate of warming determinable, within reasonably narrow confidence limits, for any given rate of increase of greenhouse gases;
- Both greenhouse gas concentrations and global mean temperature have increased over the past century and at least some of the observed warming is due to the enhanced greenhouse effect; and
- Unless offset by natural cooling larger than any that has been observed over the past few centuries, continuing increases in greenhouse gas concentrations will lead to further global warming and other significant changes of climate over the next century.

I also, however, consider it very likely (ie, I believe that there is a 90-99 per cent chance that it is true) that:

- We cannot yet say how greenhouse warming will influence the patterns of climate change at the regional level beyond a general expectation of greater warming over the continents than over the oceans;

- We cannot yet say how greenhouse warming will affect the occurrence of extreme weather and climate events beyond a general expectation for more hot days; and
- We will not, for the foreseeable future, be able to actually *predict* climate change to the end of the century, in other than a general probabilistic sense, because:
  - we do not yet understand the natural variability of climate well enough to predict the natural component of change; and
  - we do not yet have a sufficient basis for knowing how greenhouse gas emissions will change in the future to enable us to estimate the greenhouse component of the change.
- We do not yet understand enough about the processes involved in forcing the climate system beyond the thresholds that might lead to rapid non-linear change to go much beyond drawing attention to the possibility of sudden regime changes or other surprises.

There is little doubt, in my mind, that the scientific community now know enough about the certainties and uncertainties of climate science to provide more effective input than has been achieved so far to the formulation of policy for the mitigation of anthropogenic climate change as well as to national and sectoral planning for adaptation to unmitigated climate change. The continuing challenge for the scientific community will be to provide that input in ways that are both rigorous and understandable/useful to those involved in policy formulation and statecraft[49, 50] and especially to the community at large. As may well have become evident from this paper, I believe we still have some way to go.

Dr John Zillman AO FTSE is President of the Australian Academy of Technological Sciences and Engineering (ATSE) and President of the International Council of Academies of Engineering and Technological Sciences (CAETS). He was Director of the Australian Bureau of Meteorology from 1978-2003 and President of the World Meteorological Organization from 1995-2003. He has authored many scientific papers and reports on Australian, southern hemisphere and global climate and served from 1994 to 2004 as Principal Delegate of Australia to the Intergovernmental Panel on Climate Change (IPCC).

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SENSIBLE CLIMATE POLICY

Warwick J McKibbin

Introduction

The Kyoto Protocol entered into force on 16 February 2005. This should be a landmark day for climate policy because it is the culmination of an enormous amount of political negotiation since the Rio Earth Summit in 1992, on what the world should do about the possibility of climate change. The sad irony about the entering into force of the Kyoto Protocol is that it will likely achieve very little in the quest to address the problem of climate change. For a number of reasons outlined below the Kyoto Protocol is so badly constructed that it has set back the search for sensible and effective policy responses by at least a decade.

Probably the best argument for countries outside the small group who have adopted effective targets, to adopt the Kyoto Protocol now that is has entered into force, is that 'it is the only game in town'. This is a very weak argument in favour of the Kyoto Protocol. It also demonstrates why the Kyoto approach is unlikely to work over the time periods required for effective climate policy actions. The detailed critiques of the Kyoto Protocol are many and are briefly summarised in this paper but the main problem is that the Protocol fails to address the fundamental policy problem that is climate change – uncertainty about the future and our understanding of the future. Should countries outside the Kyoto targets, such as Australia, jump on the Kyoto ship – the only game in town – as it sails into the unknown, or pursue independent courses of action? The problem that Australia faces is that even if it followed its own course of action, most of the costs that the Australian economy faces in tackling climate change in a Kyoto framework are caused by the actions of other nations, as economic modeling in an often misquoted study has shown.[1] As a major fossil fuel exporter and major exporter of fossil fuel intensive products, the actions of other countries within the Kyoto Protocol have a major impact on Australia. Whether Australia should or should not ratify was dwarfed by the question of whether Australia should be pushing for a different approach altogether.

Australia and all major emitting countries need to cooperate in the design of an alternative global regime to that of the Kyoto Protocol. The 'command and control' approach to environmental policy is inappropriate; what is needed is an alternative which focuses on trading off explicitly the short run costs and long run benefits of environmental policy within a well designed institutional framework that establishes clear long term incentives for action. That approach must be decentralised to countries, but with those countries acting cooperatively in their own interests rather than dominated by a large global bureaucracy. Reports by Institutes and committees who are populated by those former designers or supporters of the Kyoto Protocol, such as the recent report[2] of The International Climate Change Taskforce (2005), base their well meaning policy proposals on the same fundamental flaw as those of Kyoto. The strategies rely on a 'targets and timetable' approach with unbounded costs, hoping (or in some cases confidently predicting) that technological breakthroughs will solve the problem easily and cheaply. It is not the unwillingness of countries to take action that is the problem – but the unwillingness to take action at any cost it takes. Whatever people believe, the evidence is clear that the uncertainties that abound in climate policy do not warrant action at unbounded costs.

There is a lot of confusion and misinformation in the climate policy debate. For example it is often argued that because Australian carbon emissions per capita are the highest in the world (outside the Middle East) that most cuts in carbon should be undertaken in Australia. In fact the reason carbon emissions are highest in Australia is because of plentiful and low cost coal. If the goal were to reduce global carbon emissions at lowest cost, it would clearly be best for the most efficient and low cost carbon producers to produce all the carbon, and the rest of the world with high cost energy or low output per unit of energy to stop emitting. This outcome is not easily generated in a targets and timetables world with some arbitrary cap on carbon emissions by each country. In a carbon constrained world, common sense argues that Australia would likely be one of the largest carbon emitters simply because carbon is cheap and efficiently used. Yet it is easy for vested interests to fund advocates to argue the line that emissions in Australia must fall no matter what. McKibbin and Stegman[3] show that there is no evidence historically for convergence of per capita carbon emissions and indeed emissions per capita are dominated by the endowments of fossil fuels. It hardly seems sensible to target something which is very different to the natural endowments the planet provides unless the cost of achieving sensible global carbon reduction are irrelevant or dominated by some other domestic agenda. If global carbon emissions must fall there is no reason to expect that they should fall in all countries or in a uniform way. If global costs are a consideration then any reduction in fossil fuel emission should be taken from the most inefficient emitters.

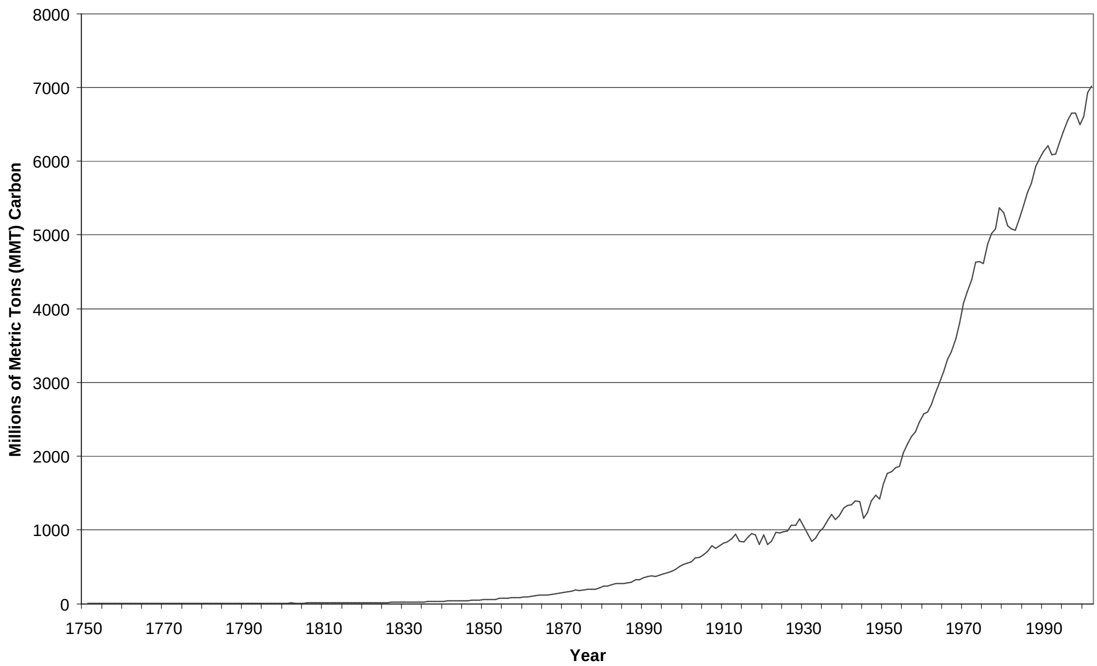
This paper re-examines the debate on what a sensible climate change policy would look like, making the case that costs relative to expected benefits should dominate precise targets *and timetables* in any sensible regime. It does not take the Kyoto Protocol as given, but steps back from this particular debate to explore the issues of what should be done in an ideal world without lobbyists (both for fossil fuels and alternative energy sources), politicians and evangelical environmentalists, who by assumption rule out tradeoffs between costs and benefits. Given the ideals of what should be in a system that deals with equity, efficiency and political feasibility the paper then summarises what has been done so far. It is natural to compare the Kyoto Protocol to the ideal features of such a system and point to the benefits and flaws. An alternative approach called the McKibbin-Wilcoxen Blueprint is then outlined and its strengths relative to Kyoto are explored. The paper also considers how it is possible to move the current state of negotiations under the Kyoto Protocol to the Blueprint approach without discarding much of what has been negotiated under the Kyoto banner. Finally, it considers the issue of what Australia can and should do. Australia exports AUS$28 billion of energy related exports and these exports are highly vulnerable to actions taken in destination countries. Australia has a national interest in developing a global climate policy regime that makes more sense than the Kyoto approach. It has little to gain from making its goal to achieve Kyoto targets outside the Kyoto system and be satisfied with that.

Uncertainty and climate change

At the heart of the climate change debate are two key facts. The first is the familiar and undisputed observation that human activity is rapidly increasing the concentration of greenhouse gases in the atmosphere. A shown in Figure 1, each year, worldwide fossil fuel use adds about six to seven billion metric tons of carbon to the atmosphere, and the concentration of carbon dioxide is now about 35 per cent higher than it was at the dawn of the Industrial Revolution.

The second fact, however, is that no one fully understands how the climate will respond.[4] The increase in greenhouse gases could lead to a sharp rise in global temperatures with severe consequences for ecosystems and human societies. On the other hand, it’s possible that the temperature rise could be modest, easy to mitigate or adapt to, and far in the future. The most likely outcome is probably somewhere between the two, but the intrinsic complexity of the climate makes it impossible to know precisely what will happen, with any degree of confidence. Even if we had complete confidence in the projection of climate outcomes, determining the costs and benefits of policies that would limit greenhouse gas emissions is even more difficult. Costs, for example, depend heavily on how fast emissions would grow in the absence of a climate policy: the more quickly emissions rise, the more expensive it will be to reduce them to any given level. The rate of emissions growth, however, depends on factors that are impossible to predict accurately over long spans of time: population growth, educational attainment, productivity growth within different industries, convergence (or lack thereof) in incomes between developing and developed countries, fossil fuel prices, and many others. Plausible alternative assumptions about these factors can lead to vastly different estimates of future emissions and therefore vastly different predictions of the extent of climate change.[5]

Figure 1: Global Carbon Dioxide Emissions from Fossil Fuels, 1751-2002

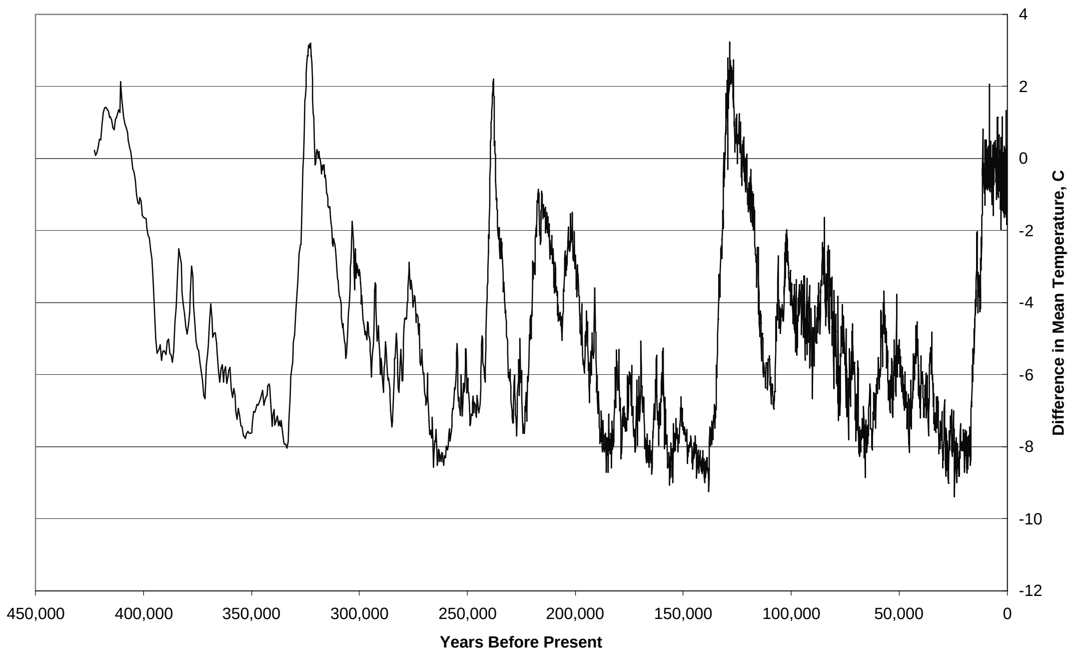


Source: Marland, G, TA Boden and RJ Andres (2003). Global, Regional, and National CO_2 Emissions, in Trends: A Compendium of Data on Global Change. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, US Department of Energy, Oak Ridge, Ten., USA for 1751-2000; and Energy Information Administration (2004) International Energy Annual. US Department of Energy, Washington DC for 2001-2002.

Some of the uncertainties we face can be seen in the historical record of previous global temperature change shown in Figure 2. The temperature record shows large fluctuations in temperatures over the past 450,000 years.

It also shows a clustering of high temperatures in recent centuries. Scientists have a reasonably good understanding of what caused these fluctuations, but far less understanding of how to predict the future baseline temperatures. The predictions depend on predictions of human activity such as future carbon emissions. Some attempt to undertake these predictions are contained in the Intergovernmental Panel on Climate Change (IPCC) *Special Report on Emissions Scenarios* (SRES). The profiles of future emissions projected in the SRES have been heavily criticised by various authors including Castles and Henderson.[6] The essence of their argument is that economic growth rates are assumed to be far too high, compared with historical experience, because of mis-measurement of the relative size of countries in the SRES report. This critique of excessively high economic growth rates and resulting high emission profiles has been supported in modelling work by McKibbin, Pearce and Stegman.[7] Despite the importance of this particular critique, it is just one of many problems that point to the inability to project the future with much certainty.

Figure 2: Global Temperature Record, Vostok Ice Core Data

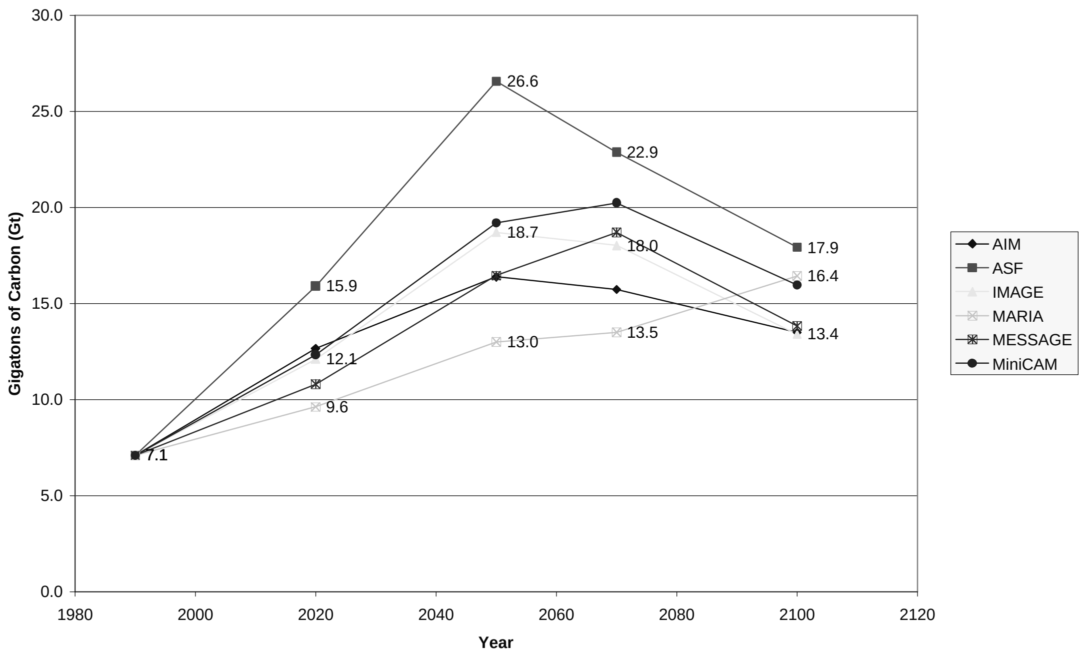


Source: McKibbin and Wilcoxen (2002a) Figure 2.7 from data in Petit, JR, D Raynaud, C Lorius, J Jouzel, G Delaygue, NI Barkov and VM Kotlyakov (2002), 'Historical isotopic temperature record from the Vostok ice core,' Trends Online: A Compendium of Data on Global Change, Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, US Department of Energy, Oak Ridge, Tenn. URL: http://cdiac.esd.ornl.gov/trends/temp/vostok/jouz_tem.htm.

Figure 3 shows one set of predictions under common assumptions from six models in the SRES. Twenty years into the future the range of estimates is large. But the fundamental issue is that it is inherently difficult to predict the future and dangerous to rely on the accuracy of predictions to determine the success of policy choices.

It is not only the underlying science and future projections of the world economy that are uncertain. Figure 4 shows the various estimates of the costs of mitigation generated by the leading economic models used as inputs into the IPCC process.[8]

Figure 3: Emissions of Carbon Under IPCC Scenario A1B

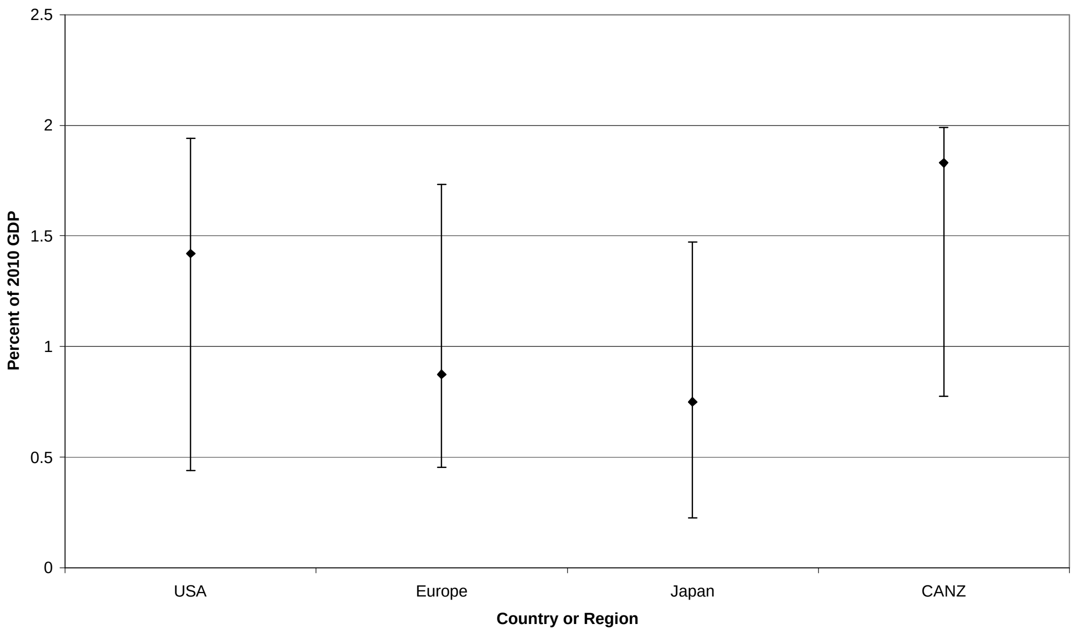


Source: Figure 2.6 in McKibbin and Wilcoxen (2002b) from Intergovernmental Panel on Climate Change (2000), Emissions Scenarios, Cambridge: Cambridge University Press.

These estimates are based on the Kyoto Protocol of 1997 rather than the highly diluted Kyoto Protocol that has emerged subsequent to the Marrakech and Bonn negotiations.[9] For the United States the range of estimates by 2010 of the GDP loss is from 0.48 per cent to 1.95 per cent with a mean estimate of around 1.4 per cent per year. This is a large range and does not cover all possible scenarios since this is a common scenario across a range of models; what it indicates is the uncertainty of estimates even a decade into the future. This doesn't reflect a problem with the models *per se*, but reflects the extent of uncertainty in understanding the world economy, possible future scenarios and in estimating the costs or benefits of mitigation.

The standard reaction to this inherent uncertainty has been to generate two extreme responses. The first is to argue that nothing should be done because the problem might be small (or in extreme versions of this approach some people argue that the problem is nonexistent) and avoiding it might be expensive. The second approach is to argue that something drastic should be done, since the problem may be enormous and taking action might be cheap. Both approaches are likely to be wrong. A robust strategy would consider all the various combinations of alternatives. Suppose the problem is small but avoiding it is cheap, or suppose the problem is enormous and avoiding it is very expensive. A prudent policy would avoid both extremes and would be a combination of mitigation and adaptation strategies, where possible at low cost.

Figure 4: Median GDP Loss in 2010 Under 1997 Kyoto Targets, by Region
(Error bars show the range between the 20th and 80th percentiles)



Source: McKibbin and Wilcoxen (2002a) figure 2.12 using data from Weyant, J (ed) (1999). 'The Costs of the Kyoto Protocol: A Multi-model Evaluation,' The Energy Journal, Special Issue. *Weyant (1999).*

Features of a sustainable global system

Climate change policy must deal explicitly with the uncertainty outlined above as well as the uncertainties surrounding the reactions of other countries.[10] The free rider problem in any system involving the 'global commons' is a particularly acute problem for the design of climate change policy. Policy makers need to be concerned with the impact of their own actions as well as the likely reactions of other countries to a global agreement. The costs of addressing climate change are uncertain, the costs of climate change are uncertain and the future is inherently uncertain; so much uncertainty doesn't mean that doing nothing is the best policy. It is quite clear that human activity is raising global concentrations of carbon dioxide. While climatologists disagree about how much warming will occur and when it will happen, virtually no one seriously suggests that mankind can continue to emit increasing amounts of carbon dioxide into the atmosphere without consequences. At the other extreme, the idea that climate change is such an overwhelming problem that it must be stopped no matter what the costs of doing so, is also untenable given existing evidence. Too little is known about the net effects of climate change, the costs of reducing emissions, or the cost of adaptation, to draw this conclusion. To pretend that climate policy doesn't need to take costs into consideration is to guarantee that many governments will ultimately reject any climate change treaty.

There are both political and economic aspects to the issue of sustainability. A policy regime may collapse because of the extreme strain placed on economic adjustment or it may collapse because the incentives facing politicians change, even though economic sustainability is satisfied.

A sustainable climate change policy should meet four basic criteria. First, the policy should slow down carbon dioxide emissions where it is cost-effective to do so. Second, the policy should involve some mechanism for compensating those who will be hurt economically without requiring massive transfers of wealth that could undermine economic stability. Third, since climate change is a global problem, any solution will require a high degree of consensus both domestically and internationally. A system that does not ultimately include developing countries will do little to achieve the goals of the *United Nations Framework on Climate Change* (UNFCCC). It is not realistic to think that a rigid global centralised regulatory regime for greenhouse policy can ever be implemented. Few countries want to relinquish sovereignty over setting their own polices especially when the policies in question can have large economic effects. Fourth, the regime must allow new countries to enter with minimum disruption and also allow a core group of countries to continue to participate even if countries exit the system at certain times. A system involving many countries that doesn't survive changing composition over time is destined to fail, since the reality is that a country's commitment to that regime is a function of the commitment of political incumbents at any point of time.

Ultimately, to be sustainable over a significant number of years, a climate change treaty must be realistic.

In more general terms, economic logic gives some clear guidelines in how to design policies that let the appropriate mix[11] of mitigation and adaptation strategies emerge over time. The key is to design institutions, regulations and markets which deliver the appropriate incentives for governments, firms and households to respond in a way that reduces the impact of greenhouse gas emissions both through abatement as well as adaptation. This broad principle suggests that mandating fixed targets for carbon abatement by an arbitrary but fixed date, such as followed in the Kyoto Protocol and other targets and timetables approaches, will only give appropriate outcomes if by accident the extent of abatement chosen is consistent with the tradeoffs between effective abatement and adaptation activities. There is nothing in the design of the Kyoto targets that effectively deals with the balancing of costs and benefits of taking action.

What is required are clear regulations on what types of restrictions on greenhouse gas emissions will be imposed. Then property rights over those emissions need to be clearly defined over long time frames consistent with the types of long-term investment decisions that characterise energy generation activities. Thirdly, markets need to be created that allow price signals to be given to households and firms so that they can respond to incentives generated by the market which in their turn have responded to the restrictions imposed by government regulation. These price signals need to be both short term and long term in nature. We would argue that the short term price signals (ie, the short term costs) should be capped at roughly the perceived benefits of taking action, through government intervention in the short term market. Finally futures markets are required to enable individuals and companies to manage the risk of climate change and well as the risk of climate change policies.

The role for government in this approach is not to mandate an amount of abatement or an amount of adaptation at some point in the future, because it cannot possibly get this right except with an enormous amount of good luck. A simple cap and trade system overlaying a targets and timetables approach does not solve this problem; it only minimises the cost given the target and timetable. Government needs to concentrate on creating and preserving property rights and appropriately regulating markets. It should focus on where public goods exist and where markets may not produce the socially desirable outcomes; then too, on where there are serious coordination failures such as in federal and state relations, inconsistent regulatory frameworks within federal government and between federal and state governments. Addressing these issues alone has a potential for lowering the cost of effective action on climate change.

These broad concepts may seem somewhat esoteric to non-economists but in the next section, a practical way to implement these ideas is outlined.

Finally it is important that the system that is designed internalises the individual incentives of governments, firms and households (and voters) within countries to adhere to an international agreement and not 'free ride' on other countries. All these stakeholders should be encouraged to adhere to the agreement because it is in their own economic and environmental interest to sustain it. This can be achieved through the creation of assets whose value depends on the agreement and whose value collapses if the agreement is negated. A system that relies completely on severe (but ultimately not credible) compliance mechanisms that require complex monitoring and enforcement procedures as the only guard against free riding, is less likely to survive than an agreement that is designed in which individual incentives sustain the agreement through political and economic coalitions within countries.

What has been done so far?

International negotiations on climate change policy began in earnest in 1992 at the Rio Earth Summit organised by the United Nations. The result of the summit was the UNFCCC, a non-binding agreement aimed at reducing atmospheric concentrations of greenhouse gases so as to achieve the goal of 'preventing dangerous anthropogenic interference with the Earth's climate system'.[12] It was signed and ratified by most of the countries in the world, including the United States, and entered into force in 1994.

The Convention's intent was to stabilise emissions of greenhouse gases at 1990 levels by the year 2000 through voluntary measures taken by individual countries. Most of the burden was to be assumed by 40 industrialised countries listed in Annex I to the Convention. In particular, Article 4, Paragraph 2(a) required each of these countries to 'adopt national policies and take corresponding measures on the mitigation of climate change' in order to reduce its emissions. Annex I countries were also required to contribute to a financial fund (subsequently merged into the Global Environment Facility, or GEF) to be used to help pay for climate-friendly projects in developing countries.

In the subsequent decade, however, few substantive policies were implemented and global emissions of greenhouse gases rose considerably. From that perspective, the UNFCCC failed to achieve its goal. However, its real contribution was to set up a mechanism under which negotiations could continue as periodic 'Conference of the Parties' (COP) meetings.

The first Conference of the Parties, COP 1, was held in Berlin in March and April of 1995. The second Conference, COP 2, was held in Geneva in July of 1996. COP 3 was held in Kyoto in

December of 1997. The result of the meeting was document called the 'Kyoto Protocol,' a treaty that formalised the 'targets and timetables' approach that had been taking shape since COP 1. The Protocol set explicit emissions targets for the countries listed in its Annex B, which included essentially all industrialised countries who were signatories.[13] Each of these countries was to reduce its greenhouse gas emissions so that its total emissions, when converted to a carbon-equivalent basis, did not exceed a specified percentage of its 'base period' emissions. For most countries the base period was 1990 but countries having economies in transition were allowed to choose other base periods during COP 2.[14] Average emissions over the 'budget period' 2008-2012 were to be at or below the target.[15] The Annex B limits are shown in Table 1; countries designated as 'economies in transition' are marked with an asterisk.

Table 1: Kyoto Protocol Emissions Limits or Reduction Commitments

(Per cent of 1990 or base period emissions)

Country	Target	Country	Target
Australia	108	Liechtenstein	92
Austria	92	Lithuania*	92
Belgium	92	Luxembourg	92
Bulgaria*	92	Monaco	92
Canada	94	Netherlands	92
Croatia*	95	New Zealand	100
Czech Republic*	92	Norway	101
Denmark	92	Poland*	94
Estonia*	92	Portugal	92
European Community	92	Romania*	92
Finland	92	Russian Federation*	100
France	92	Slovakia*	92
Germany	92	Slovenia*	92
Greece	92	Spain	92
Hungary*	94	Sweden	92
Iceland	110	Switzerland	92
Ireland	92	Ukraine*	100
Italy	92	United Kingdom	92
Japan	94	United States	93
Latvia*	92		

* Country designated as an 'economy in transition.'

The commitments in Table 1 amount to about a 5 per cent reduction below 1990 emissions for the Annex B countries as a group, or about 245 million metric tons of carbon.[16] The Protocol was designed to allow Annex B countries flexibility in meeting their commitments. Some of the flexibility concerns the unilateral actions countries can take to comply with the Protocol. First, the specific policies to be used to reduce emissions were left completely to the discretion of each country. Second, compliance could be achieved by any mix of carbon-equivalent reductions in four individual gases and two classes of halocarbon: carbon dioxide, methane, nitrous oxide, sulphur hexafluoride, hydro fluorocarbons (HFCs) and perfluorocarbons (PFCs). Third, countries could offset some of their emissions by enhancing 'sinks' of carbon dioxide: forests or other mechanisms that remove carbon dioxide from the atmosphere. Fourth, reductions in excess of the Annex B commitments could be carried forward and used to count toward compliance in future periods.

The Protocol also provides three mechanisms that allow for flexibility on a multilateral basis. The most important is international emissions permit trading (IET), which is allowed among Annex B countries under the Protocol's Article 17. In addition, Article 6 of the Protocol allows for 'Joint Implementation' (JI), a project-based system under which one Annex B country can receive credit for emissions-reducing activities it finances in another Annex B country. The use of emissions trading and JI, however, must be 'supplemental to domestic actions,' a vague phrase that left open the possibility that quantitative limits could be imposed on the amount of trading and JI.[17]

For the Protocol to come into force it must be ratified by 55 per cent of its signatories, and they must jointly account for at least 55 per cent of total carbon dioxide emissions (at 1990 levels) from Annex I countries. Most of the operational details of the Protocol's international mechanisms – IET, JI and the Clean Development Mechanism (CDM) – were left for future COP meetings to resolve. There was no negotiation over issues of compliance, how institutional structures would work, or on how developing countries might be involved beyond the CDM. Meetings after COP 3 were devoted to working out the operational details of the Kyoto Protocol.[18] For the purposes of this paper, the key issues are the relaxation of targets through changes in allowed sinks.

When the second part of COP 6 was convened in Bonn in July 2001, it was intended to resolve all remaining implementation details of the Kyoto Protocol. The outcome was a package of proposals known as the 'Bonn Agreements' which included, among other things, an increase in the sink allowances for forestry and landuse changes that were granted to several countries.[19] The total increase in sink allowances was large, and reduced the overall stringency of the protocol by 54.5 million metric tons of carbon. Countries given sink allowances greater than one million metric tons of carbon-equivalent emissions are shown in Table 2. Although the Bonn Agreements were formulated during the second part of COP 6, they were not adopted as official decisions of the Conference. Instead, further discussion and formal adoption were deferred until COP 7.

Table 2: Countries Receiving Sink Allowances Exceeding 1 MMT since 1997

(Million metric tons of carbon)

Country	Allowance
Canada	12.00
Germany	1.24
Japan	13.00
Romania	1.10
Russia	17.63
Ukraine	1.11

COP 7 was held in Marrakech in October - November 2001. It refined and extended the Bonn Agreements in three main areas: (1) defining the 'principles, nature and scope' of the international flexibility mechanisms; (2) finalising the accounting rules for sinks derived from landuse changes and forestry; and (3) designing an enforcement mechanism to discourage noncompliance. The result was a document called the 'Marrakech Accords' that COP participants hoped would remove all remaining obstacles to ratification of the Kyoto Protocol.

Finally, COP 7 further relaxed the Kyoto emissions target by granting a Russian request that its sink allowance be increased from 17.63 million metric tons (MMT) to 33 MMT. Thus sinks have relaxed the Kyoto targets by roughly 70 MMT, which together with the withdrawal of the United States makes the Kyoto Protocol's targets to 2012 very loose. Indeed, if world economic growth remains slow for a few years, the protocol's emissions targets may not be binding.

The United States withdrew from the protocol in March 2001, a move which was angrily denounced by surprised commentators in Europe and around the world. It was described as arrogant, isolationist, and a 'betrayal [by the Bush Administration] of their responsibilities as global citizens'.[20] Yet the announcement was really nothing more than a blunt public acknowledgment of a fact that was well known within the policy community: the Kyoto Protocol was already dead in the United States. The US Senate, which must ratify all international treaties by a two-thirds majority, overwhelmingly opposed the protocol and had voted 95-0 against US participation as early as July 1997, five months *before* the protocol was signed.[21] Opposition was so great that the Clinton Administration, which negotiated and signed the protocol, never bothered to submit it to the Senate for ratification. Even if the Bush Administration had enthusiastically supported the treaty – which it did not – there was little it could have done.

What doomed the protocol in the Senate is a critical flaw in its design: it requires each participating industrialised country to agree to achieve a specified emissions target regardless of the cost of doing so.[22] This was also the main factor that doomed the Protocol in Australia. The focus on rigid targets also makes the treaty impractical as a long-term climate policy for the rest of the world as well. Because the costs of reducing emissions are unknown and could be very large, countries with substantial emissions have insisted on increasingly lax targets as a condition for their continued participation. Japan, Canada and Russia, for example, were able to negotiate large increases in their 'sink' allowances during COP 6, and COP 7.[23] Between the US withdrawal and the increase in sink allowances, the original Kyoto Protocol has been relaxed substantially. The effect on estimated emissions permit prices in the 2008-2012 period is dramatic. Relative to the original Kyoto agreement, permit prices are likely to be reduced by 14 per cent[24] to 85 per cent.[25] [26] As a result of the change in targets the price of carbon fell from $US64 per ton to $16 per ton by 2010 (under a given scenario about the future).[27] The McKibbin (2002) Report to the Australian Government[28] showed that higher Russian economic growth by just 1 per cent raised the likely permit price by 2012 by 50 per cent and raised the cost of Kyoto for Europe from 0.8 per cent of GDP to 1.1 per cent of GDP. There are so many assumptions that might turn out differently in these projections that a range of cost projections is critical and uncertain even about the near future. Surprisingly when the McKibbin (2002) report was released and still today, some commentators continue to pick a single year number from one scenario in that report to argue for Kyoto ratification in Australia, when the reality is that the uncertainty about the costs and the range of possibilities that are the basis of the report are conveniently ignored.

Fatal problems with the Kyoto Protocol approach

The fundamental principle on which the Kyoto Protocol is based – setting 'targets and timetables' for reducing greenhouse gas emissions – is both economically flawed and politically unrealistic. To ratify the protocol, a developed country must be willing to agree to reduce its emissions to a specified level - typically about 5 percent below the country's emissions in 1990 – by 2008 to 2012 regardless of cost. Australia was able to negotiate a rise of 8 per cent from 1990 levels and to have land clearing included which was effectively a major relaxation of the underlying target. Recent predictions are that because of land clearing, the target is achievable yet emissions from energy continue to rise unabated.[29] Because costs could be large[30] (perhaps not in the period from 2008 to 2012 but there is enormous uncertainty about future periods), most developed countries will never ratify a treaty based on targets and timetables, or they will insist, as a precondition for ratification, that their targets be diluted through an accounting adjustment which allows credit for activities that absorb carbon (called sinks). Countries that do ratify are unlikely to comply with the Protocol if the constraints become seriously binding. Already our modeling estimates that Japan is 16 per cent above its Kyoto target and it is unclear how it can possibly hit the target unless emission permits are very cheap in the first commitment period. During 1997, at the time of the Kyoto negotiations, one suggestion that made Japan's target look feasible was to build up to 20 nuclear power plants. By 2004 it is not possible to build any new nuclear power plants in Japan, given recent crises in the Japanese nuclear power industry. Developing nations, who will become the world's largest emitters in coming decades, have even less incentive to sign on, given the enormous uncertainty about their growth paths and therefore the costs of a binding emissions target.

The issue of costs is crucial. The array of uncertainties associated with climate change, make it impossible to tell whether the benefits of the treaty are worth its costs. Nor is there any evidence that the targets set by the protocol are the optimal levels of greenhouse gas emissions, either for an individual country or for the world as a whole. If anything, cost-benefit calculations based on studies to date tend to suggest that the expected costs exceed the expected benefits, at least for developed countries.

The Protocol's greatest weakness, however, is not the lack of clear cost-benefit justification. After all, governments often face uncertainty when evaluating potential policies. Because the damages caused by climate change could be very large, a prudent legislature might want to adopt a climate policy to hedge its bets as long as it could keep its costs within bounds. But Kyoto's 'targets and timetables' design makes that impossible. Governments that adopt the protocol risk taking on a disastrously expensive commitment – and surrender part of their sovereignty in the process.

The Kyoto agreement also fails to give governments any incentive to police it and lacks credible compliance measures. Monitoring polluters is expensive, and punishing violators would impose costs on domestic residents in exchange for benefits that will go largely to foreigners. Governments would be strongly tempted to look the other way when firms exceed their emissions permits. Negotiators have tried to devise a strong international mechanism to monitor compliance and penalise violations, but so far have produced only a paper tiger: the Protocol's compliance mechanism is not a credible deterrent for anything beyond very minor violations.

Nor has the Protocol found a way to include significant participation by developing countries. Because these countries are responsible for a relatively small share of historical greenhouse gas emissions, they are especially reluctant to incur large costs and give up their sovereignty in a climate change agreement. At present the only incentive for a developing country to undertake a specific emissions commitment is the incentive to join a system of international permit trading. If developing countries are given greenhouse gas allowances large enough to exceed their emissions permits, they could earn foreign currency by exporting excess permits. Essentially, developed countries would pay developing countries for abatement. But massive exports of permits risk driving up a developing country's exchange rate and driving down its other exports (similar to the United Kingdom experience when North Sea Oil was discovered – this is called the Dutch Disease or Gregory effect). Accessing a global permit market also risks causing a severe short run structural shock because to be in a Kyoto style permit trading system would almost necessarily require the price of carbon in these countries to be equal to that in industrial countries – a situation which is far from true today.

An international permit trading system which forms an important part of the cost equalisation aspect of Kyoto is also problematic. It will be a market with a few large countries that might restrict trade to change the permit price. It is a market where the value of all permits depends on the behavior and institutional weaknesses of all participating countries. It requires strict monitoring, and an as yet undetermined enforcement mechanism; otherwise the value of all permits is affected by weakness in any part of the system. A global emissions trading system is not analogous to markets in other commodities because the supply of permits is arbitrary and value only exists because of government fiat – many governments.

Thus Kyoto is unlikely to attract any more participants into its binding target approach. It may work if political will can be sustained over long periods and depending on the future evolution of the global economy but it is just as likely to run into an iceberg somewhere in the near future. It is dangerous to risk such an important global issue as climate change on the hope that costs turn out to be low and emissions are easily reduced within an arbitrary time frame. Technological innovations, which will ultimately be the answer do not always arise on time as planned by well meaning government planners.

The Blueprint: a realistic 'hybrid' approach

The issue of managing uncertainty is fundamental to designing systematic response to climate change. However, uncertainty is not the only issue that the design of a practical climate change policy should consider. As economic efficiency is just one aspect that needs to be taken into account, there is also a need to trade this off against a range of other issues related to notions of equity as well as dealing directly with political realities of national self interest and the need to have a sustainable system that will last for many decades. A climate policy's political prospects globally will be substantially better if it does not require large transfers of wealth – either between countries or between households and firms within a country – or the surrender of a significant degree of national sovereignty. Because the system will need to remain in effect for many years, it must be designed to allow new countries to enter with minimum disruption and to survive the exit of some of its participants in extreme circumstances.

Neither of the standard market-based economic policy instruments – a cap and trade permit system or an emissions tax - satisfies all of these criteria. An ordinary cap and trade permit system would require participants to achieve a rigid emissions target regardless of cost (ie, the price of permits or the cost of abatement varies with the demand for permits). An emissions tax, although fixing the cost of abatement, has the disadvantage of involving potentially huge transfers of wealth either within countries for a domestic system or between countries for an international system, and would be politically unrealistic. However, a hybrid policy, combining the best features of the two, would be an efficient and practical approach.[31]

The particular hybrid policy proposed by McKibbin and Wilcoxen[32] (hereafter referred to as the Blueprint) focuses on a long term goal for emissions reductions but minimising short term costs in achieving those targets. They do this by focusing on the price of carbon in the short run but guided by information on the expected future price of a carbon target in the long run. They also focus on having the approach implemented on a country by country basis with coordination across countries but no trading of permits between countries. This coordination of national actions is fundamentally different to the Kyoto approach of centralisation of actions imposed on all participants.

The idea is relatively simple (detailed policy is outlined in McKibbin and Wilcoxen[33]). An analogy to what is required can be found in government bond markets and monetary policy in most countries. The long term government bond is in relatively fixed supply and the market price of these bonds generates a long term interest rate. The short term interest rate is set by the central bank and the quantity of liquidity is determined by demand, given that the supply of liquidity is whatever is required to fix the price (there is no arbitrary quantity constraint). The short term interest rate is fixed. The long term interest rate is determined by the market but it is presumably the expected future short term interest rates. This is an effective example of using markets with a combination of fixed short term prices and market determined quantities and fixed long term quantities with market determined prices.

A similar issue of mixing long term price determination with short term fixed prices can be applied to carbon emissions. There is a very long term target for emissions which we would like priced so that long term investment decisions can be undertaken both using the information in the long term market as well as using the market to hedge decisions in case circumstances change - but we would like to guarantee the short term cost to the economy.

To do this we argue that each country would issue two kinds of emissions permits: long term permits that entitle the owner of the permit to emit one metric ton of carbon every year for a long period (even with a declining allowance over time), and annual permits that allow one ton of carbon to be emitted in a single, specified year. Both types of permit would be valid only within the country of issue – unlike the Kyoto Protocol, there would be no international permit trading. Each year, governments would require firms within a country to have a total number of emissions permits, in any mixture of long term and annual permits, equal to the amount of emissions they produced that year.

The number of long term permits each country could issue would be decided by international agreement and could be based on the limits in the Kyoto Protocol – on average about 95 per cent of most countries' 1990 emissions. It would be up to each government to decide how to allocate its long term permits: some countries might want to give them to existing fuel users as a form of grandfathering, while others might prefer to sell or auction the permits to raise revenue. Once distributed, the long term permits could be traded among firms, or bought and retired by environmental groups.[34] In addition, the government itself could buy back permits in future years if new evidence on climate change indicates that emissions should be cut more sharply or in extreme circumstances they could change the units of these permits in a uniform way.

Annual permits would be sold at a stipulated price determined by international negotiations, such as US$10 per ton of carbon. To put the fee in perspective, in the United States, this is equivalent to a tax of US$1.40 per barrel of crude oil, raising the price of a US$20 barrel of oil by about 7 per cent. There would be no limit on the number of annual permits that could be sold in a given year. Every ten years, countries would meet to evaluate the information on emissions, climate change, and climate science and then decide whether or not to change the agreed annual permit price to be in place for the following decade.

It is important that the annual price be denominated in a common unit (for example $US) because the Blueprint is designed to equate the short term marginal cost of carbon in all countries. The long term permit market would likely trade in local currency units in each economy where the long term price reflects the expected future short term prices and expected changes in exchange rates.

Because it has two kinds of permits, the Blueprint is a bit more complicated than a simple cap and trade permit system. However, it has all of the strengths of a traditional permit system and has additional advantages as well. It performs especially well in comparison to the Kyoto Protocol in terms of the economic costs, the certainty of costs, the incentives facing government, households and firms and the ability for individuals to manage the risk of climate change especially as these risks impact on long term investment decisions.

Like the Kyoto Protocol, the Blueprint encourages energy producers to keep emissions steady or, even better, to cut them. Firms that can cut emissions cheaply will do so and then sell unneeded long term permits to those whose emissions are increasing. As a result, emissions in each country will be reduced, and in a cost-effective manner. Unlike the Kyoto approach, the Blueprint also encourages adaptation since it gives clear signals of expected costs of mitigation which can be used by individual firms and households to decide on individual actions for adaptation.

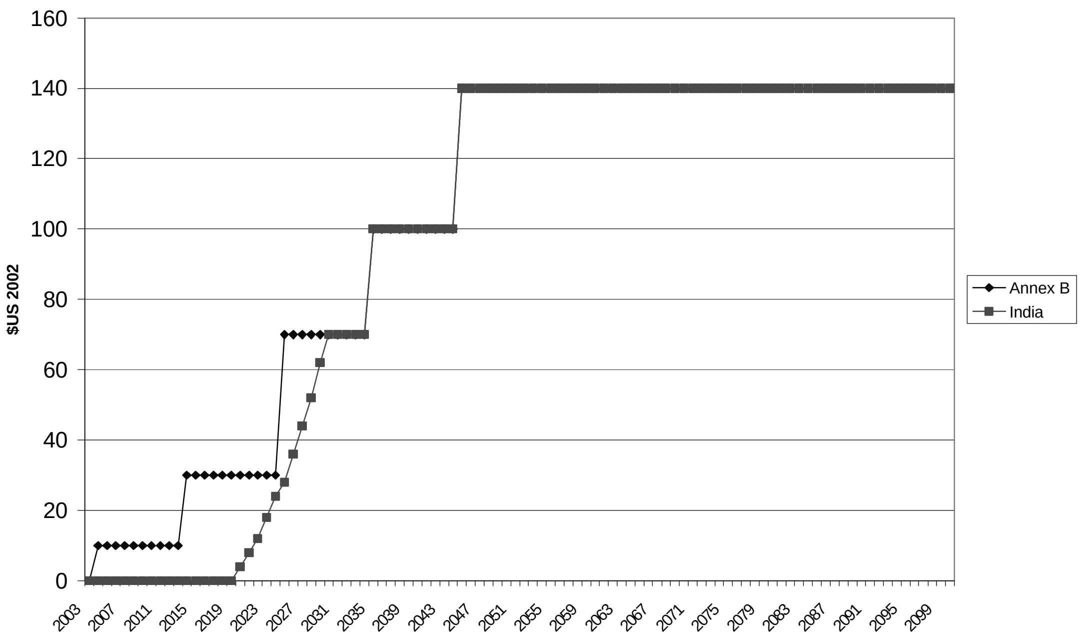
Unlike the Protocol, however, the Blueprint provides an upper limit on the cost of compliance. No firm would have to pay more than US$10 per ton to reduce its emissions in the short run because it could always buy an annual emissions permit from the government instead. There is no need for international permit trade because prices are equal in the short run by design (as long as the long term permit target is binding). Adopting the hybrid, in other words, does *not* require a country to make an open-ended commitment to reduce its emissions regardless of cost. As a result, it has a far better chance of ratification in the US or other countries having large carbon emissions. Moreover, that absence of a rigid upper limit on carbon emissions would also increase the possibility of significant participation by developing countries. The hybrid policy would have many other desirable attributes as well. These are summarised briefly below and discussed in more detail elsewhere.[35]

A key strength of the Blueprint is that it would be very stable with respect to changes in the mix of participating countries. Because permit markets are separate between countries – linked only by the common price of an annual emissions permit – the entry or exit of one country from the system would have no effect on the price of permits circulating in other countries. In contrast, a change in the list of countries participating in the Kyoto Protocol would cause windfall gains or losses to ripple through permit markets around the world. The defection of a large country would destroy a global permit market – the market only has value because the promises of participating governments.

Another advantage of the Blueprint is that countries would manage their own domestic permit trading system independently, using their own legal systems and financial institutions. International cooperation, although helpful, would not be essential beyond the initial design of the system. Monitoring firms to make sure they comply with the policy would be an internal matter for each country. Unlike the Kyoto Protocol, the Blueprint provides incentives for governments to monitor and enforce the agreement within their borders. One incentive is the revenue that could be raised from the sale of annual permits: low compliance would cause a government to sell fewer annual permits that it could have, lowering permit revenue. In addition, and perhaps more importantly, holders of long term permits will pressure their governments to be vigilant in order to maintain the market value of long term permits: low compliance would reduce prices in the permit market. The Kyoto Protocol, in contrast, requires international monitoring and a new international institution to ensure compliance. Moreover, poor monitoring and compliance in one country could debase the entire global permit trading system because it would affect emissions permit prices throughout the developed world.

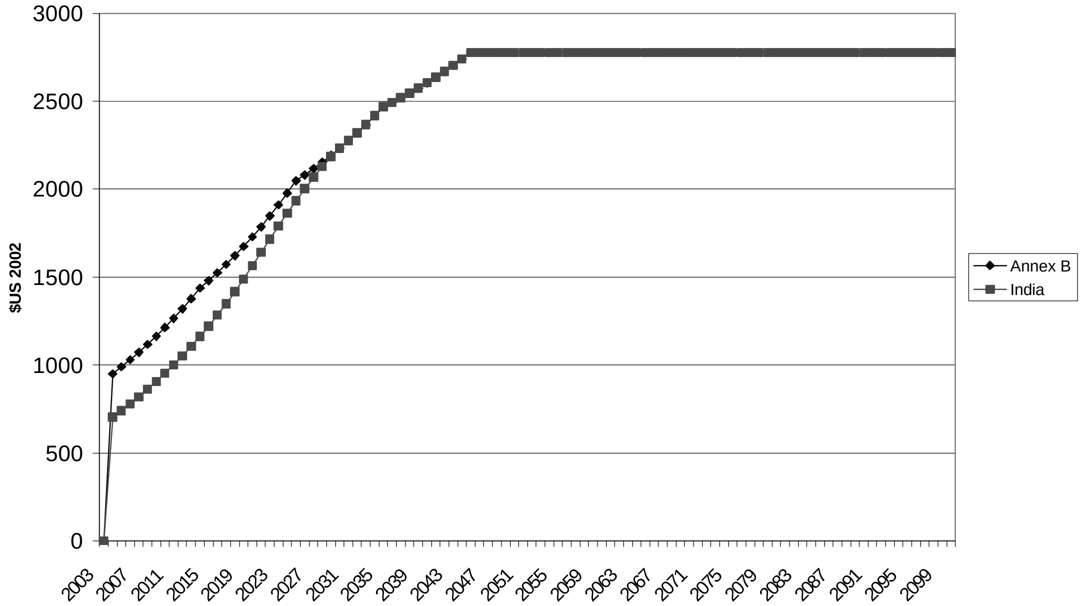
In contrast to Kyoto, developing countries are included explicitly in the Blueprint with long term commitments but no short term costs.[36] In the case of developing countries, the long term permit allocation would need to be negotiated although we could use the Kyoto targets for developed countries. For developing countries a larger target, perhaps a doubling of emissions, would be negotiated. These would then be allocated within the country. Within a developing country like India or China, the annual permit price would be zero while the quantity of long term permits exceeded the amount of carbon emissions in the short run. Over time, as the emissions rose above the number of long term permits the price of annual permits would begin to rise to the world price. This would occur if we allow an allocation of long term permits well in excess of current emissions. However, the price of long term permits would reflect the expectation that the developing country would eventually reach the emission levels that caused the carbon emission constraint to be binding. Thus the long term permit market with positive prices would provide a financial incentive to begin to change the developing country carbon emissions over time even though the annual cost to industry of a carbon permit would initially be zero.[37]

Figure 5: Stylized Annual Permit Price



Source: Figure 6 in McKibbin (2005).

Figure 6: Stylized Value of Perpetual Permits
(Assuming r=5%)



Source: Figure 7 in McKibbin (2005)

Figures 5 and 6 show one scenario in which the permit prices rise in each ten year step of negotiations over the common carbon price. Initially annual permits start at $US10 per ton in industrialised economies and eventually rise to $US140 per ton by 2044 as a result of new information that climate change is more serious than expected. While the industrialised economies are facing a tightening carbon constraint, the annual price in India does not rise above zero until 20 years after the commitment and then only gradually rises towards the world price as carbon emissions exceed the long term permit allocation. Thus in this scenario, India's capacity to pay and rate of emissions growth determine when they begin to incur costs towards abatement. However, the firm commitment to eventually take action is priced in the long term permit market from the beginning of the period. In Figure 6, long term permits are valuable from the commencement of the policy, as seen from the $705 per long term permit. This price is calculated assuming perfect foresight about the future annual price and a discount rate of 5per cent. The actual value of long term permits, if this approach were implemented, would of course depend on the range of expectations about future carbon prices and future emissions profiles in India, but this example shows how a market for a long term asset, such as the long term permit, can be used to price expected future carbon prices and give incentives for abatement and adaptation even while the current cost of carbon to industry is zero.

The attractiveness of the Blueprint for creating institutions to aid in economic development in developing countries should not be underestimated. The ability of investors in energy systems to effectively hedge their investment over a long period of time should be very attractive for the development of energy systems in developing countries. Rather than cash transfers the Blueprint relies on creating institutions and assets to encourage foreign direct investment. The time frame of the assets we propose to be created (by committing to a global climate regime) is currently unparalleled. Developing countries could use this new asset as a way of attracting foreign investment and enhance the development process by creating what is effectively a futures market in energy. This is far more likely to induce foreign investment than the CDM or other similar mechanisms that face very high administrative costs. Critics might argue that the problem with developing countries is the inability to create the sorts of institutions the above scheme would require. This may be a problem in the near term but it likely to be easier for developing countries to create property rights and institutions *domestically*, than to impose according to the characteristics of that developing country., than it would be to impose within a developing country, the types of institutions and property rights required under the Kyoto Protocol for a developing country to be able to sell carbon rights into a *global* market.The required synchronisation of property rights globally in a form reflecting developed countries' practices is exactly why it is difficult to see how the Kyoto Protocol could be implemented outside the small group of industrialised countries with similar institutional structures that are already involved.

Overall, the Blueprint is a practical and politically realistic approach to both reducing greenhouse gas emissions (ie, mitigation) as well as giving clear incentives to consider adaptation strategies. The main criticism leveled against the Blueprint is that it does not guarantee precisely how much abatement will take place each year or by a certain time in the future. This is actually one of its main *advantages*. If firms discover that it is very expensive to keep their emissions below their holdings of long term permits, the option to buy annual permits allows them to emit more, although at a cost of US$10 per ton. The long term permit prices give a powerful long term signal to industry and consumers in addition to the short term price signals. As a practical matter, however, the Blueprint would do far more to reduce emissions than a stronger treaty that could never be ratified or enforced. The Blueprint gives a better outcome for carbon concentrations at a lower cost than the Kyoto Protocol.[38] More importantly as assumptions about the future are changed, the expected costs of the Protocol change dramatically whereas with the Blueprint the costs are stable and capped by the annual fixed permit price. This ability of the Blueprint to deal with manifest uncertainty about the future is a significant improvement over Kyoto.

Where the world and Australia can go from here

Both mitigation and adaptation should be part of a sensible climate policy approach.[39] It is clear that responses will have to be at both the government level as well as at the industry and household levels. Indeed the role for government in our view is to create the environment for individuals to take action on both mitigation and adaptation strategies through clear allocation and protection of property rights and clear restrictions on certain activities. Private markets with both short-term economic signals constrained by cost considerations, and long term economic signals driven by environmental outcomes, should be created. The creation of these markets, which don't currently exist, will enable companies and individuals to take actions to achieve the long run environmental goals at low economic cost in both the short run and the long run. These markets can also be used to provide firms and households with a way to manage risk, which is of fundamental importance given the inherent uncertainty around all aspects of climate change.

One example of how to achieve this in a practical way is through a mix of sensible policies such as the abolition of distortions in the world coal market.[40] Indeed this could easily be extended to world energy markets as well. Another is the McKibbin Wilcoxen Blueprint proposal in which the role of government in designing the market mechanism, imposing regulation and minimising the short term cost of climate policy is combined with long term signals to encourage individual action for both mitigation and adaptation strategies to emerge as part of individual self interest. If actions by individuals and firms are not encouraged then it is unlikely that there will be an effective and low cost response to the potential of global climate change.

There is a need for the Australian government to act now so that incentives are created for both mitigation and adaptation strategies. In particular the issue of property rights needs to be addressed. This is not just over greenhouse gas emissions but over a range of areas that are likely to be affected by climate change, such as water and land use. Many of these areas will better be able to adapt to climate change if the economic principles outlined above are implemented. The success of strategies for mitigation and adaptation will ultimately depend on a combination of government intervention and mechanisms that encourage individuals to undertake their own actions. The issues of risk sharing, abatement, adaptation and transitional assistance will all have to be addressed in the formulation of a sensible policy.

We have argued that an approach such as the McKibbin Wilcoxen Blueprint will be particularly effective for developing countries both to reduce future trends in carbon emissions and also as a development mechanism for encouraging foreign direct investment in energy sectors. Because this approach is implemented at the country level and coordinated globally it is feasible for countries to implement the Blueprint individually. If Australia were to formalise the current approach of acting in consultation with the rest of the world, then by implementing the Blueprint it would take an important step forward; demonstrating that a sensible and more attractive approach than the Kyoto Protocol exists and that the Blueprint approach will extend the horizon of targets and create institutions to sustain the policy.[41] Once property rights are distributed there will be powerful coalitions in support of effective climate action if needed. Politically the creation of property rights in carbon emissions would be an attractive and possibly valuable asset that the government can distribute to both existing fossil fuel producers and users as well as Australian citizens to compensate for any energy price increase that might emerge if technological solutions do not rapidly emerge. It would be like the privatisation of Australia's major telecommunications carrier (Telstra) except that the shares (or long term emission permits) are given to stakeholders rather than sold. If energy prices were to rise as a result of the Blueprint, which in fact they should if conservation on the demand side is to be achieved while technological breakthroughs are awaited, the compensation for higher energy prices is built in automatically.

The idea that subsidies to industries to reduce emissions are the way forward is a risky strategy. It focuses all attention on one aspect of carbon emissions which in turn is focused on a small group of industries who received the subsidies. It does nothing to address the demand for energy by households, for transportation or other uses. It does nothing to reduce carbon emission if the subsidy is targeted to the wrong technology. Should it be clean coal? Should it be renewables? Who will pay for the subsidies? What will prevent investment in lobbying rather than R&D from being the largest investment in this system? The Blueprint internalises all of these issues and is a self funding approach in which there is enough compensation to support structural adjustment. It also creates markets for industry and individuals to manage long term climate risk. Subsidies don't and can't do that. Individual responsibility to manage decisions within a clearly defined system of regulation and transparent property rights is what is needed to address climate change; not piecemeal subsidies to some sectors of the economy, or arbitrary targets that may or may not be reached because of changing political winds.

Politicians should embrace a system like the Blueprint. It directly addresses the ongoing problem of climate change. By establishing property rights over carbon and removing direct subsidies it minimises the extent of lobbying by industry. It gives the government who creates the property rights the opportunity to allocate this new form of wealth however it wishes. It is unlikely that future governments will change that allocation, in the same way that real estate is not frequently redistributed after an election. It compensates fossil fuel intensive industries (and their shareholders) for past carbon investments and creates a market for hedging future investments which creates value in reducing uncertainty. This is particularly important when the future demand for energy in Australia is likely to be rising and key medium term supply decisions need to be made in coming years. And if the Blueprint is shown to be an attractive system that works as well as expected, it would encourage other countries to adopt a similar price based system. In contrast to a country by country carbon target, a global system based on costs and efficiency would benefit an efficient, low cost energy exporter like Australia, even in a world of tightening carbon constraint.

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Professor Warwick McKibbin is Executive Director of the ANU Centre for Applied Macroeconomic Analysis (CAMA) in the Research School of Pacific and Asian Studies at the Australian National University, A Professorial Fellow at the Lowy Institute for International Policy and a Senior Fellow at the Brookings Institution in Washington D.C.. He is also a member of the Board of the Reserve Bank of Australia. He specialises in the development of global economic models with a focus on climate change policy, global demographic change, infectious diseases, macroeconomic policy design, international trade and finance issues and economic issues in Asia.

[1] McKibbin WJ (2002). 'Modelling Results for the Kyoto Protocol', report prepared for the Australian Greenhouse Office, Canberra.

[2] International Climate Taskforce (2005). *Meeting the Climate Challenge*, Recommendations of the International Climate Taskforce. Institute for Public Policy Research, London.

[3] McKibbin W and A Stegman (2005). 'Convergence of Per Capita Carbon Emissions' Lowy Institute Working Paper in International Economics (forthcoming).

[4] For an exhaustive survey of the scientific literature on climate change, see Intergovernmental Panel on Climate Change (2001), *Climate Change 2001*, 3 vols, Cambridge: Cambridge University Press; and McKibbin, WJ and PJ Wilcoxen (2002a), *Climate Change Policy After Kyoto: A Blueprint for a Realistic Approach*, Washington: The Brookings Institution: chapter 2, for a summary; and Nordhaus, WD (1991). 'The Cost of Slowing Climate Change: A Survey,' *The Energy Journal*, 12, 1; and Nordhaus, WD (1993). 'Reflections on the Economics of Climate Change,' *Journal of Economic Perspectives*, 7, 4..

[5] See Bagnoli, P, W McKibbin and P Wilcoxen (1996). 'Future Projections and Structural Change' in N Nakicenovic, W Nordhaus, R Richels and F Toth (ed). *Climate Change: Integrating Economics and Policy*, CP 96-1 , International Institute for Applied Systems Analysis (Austria):, 181-206. McKibbin WJ, D Pearce and A Stegman (2004). 'Long Run Projections for Climate Change Scenarios' Lowy Institute for International Policy Working paper 1.04, for some examples involving changes in productivity projections.

[6] Castles I and D Henderson (2003). 'The IPCC Emissions Scenarios: An Economic-Statistical Critique' *Energy and Environment*, 14, 2: 159-185 Multi-Science, United Kingdom.

[7] McKibbin, Pearce and Stegman (2004) *op cit.*

[8] Based on the results presented in Weyant, J (ed) (1999). 'The Costs of the Kyoto Protocol: A Multi-model Evaluation,' *The Energy Journal*, Special Issue.

[9] See Buchner B, C Carraro and I Cersosimo (2001). 'On the consequences of the U.S. withdrawal from the Kyoto/Bonn Protocol', FEEM (Fondazione Eni Enrico Mattei) Working Paper 102.2001; Bohringer, C (2001). 'Climate Policies from Kyoto to Bonn: from Little to Nothing?' ZEW Discussion Paper 01-49, Mannheim; Löschel, A and ZX Zhang (2002). 'The Economic and Environmental Implications of the US Repudiation of the Kyoto Protocol and the Subsequent Deals in Bonn and Marrakech,' *Weltwirtschaftliches Archiv – Review of World Economics*, 138, 4; and McKibbin WJ and PJ Wilcoxen (2003). 'Climate Policy and Uncertainty: The Role of Adaptation versus Mitigation', in *Living With Climate Change: Proceedings of a National Conference on Climate Change Impacts and Adaptation.* National Academies Forum, Canberra; for evaluations of the extent of changes since the original Kyoto Protocol of 1997.

[10] This point was stressed by an anonymous referee and is addressed at length in Nordhaus, WD (1994). *Managing the Global Commons*, Cambridge: MIT Press

[11] 'Appropriate' can be defined more broadly to take into account a range of issues such as economic efficiency (ie, minimum cost), fairness, and other social and environmental considerations as well as political realities.

[12] For more information about the UNFCCC and the various related meetings that followed it, see the UNFCCC web site: http://www.unfccc.org/.

[13] The Annex B list is a subset of the countries listed in Annex I of the UNFCCC. It excludes Belarus, which had not ratified the UNFCCC by the time COP 3 was held, and Turkey, which requested that it be removed from Annex I at COP 3.

[14] Decision 9 of COP 2 established the base periods for Annex I countries.

[15] Gases other than carbon dioxide are converted to a carbon-equivalent basis using global warming potentials' established by the Intergovernmental Panel on Climate Change. A country's carbon-equivalent emissions over the five year period 2008-2012 was required to be less than or equal to the specified fraction of base period emissions.

[16] The exact reduction depends on the treatment of land use changes, which had not been finalised by the end of COP 6.

[17] The European Union, in particular, was in favour of limiting the degree to which compliance could be achieved by trading and JI. The United States was opposed to any restrictions.

[18] Details can be found in McKibbin and Wilcoxen (2002a) *op cit.*

[19] Sink allowances enable countries to offset a portion of their carbon emissions by enhancing activities, such as forestry, that remove carbon dioxide from the atmosphere.

[20] 'World Leaders Criticize Bush on Global Warming', Associated Press, 30 March 2001.

[21] Senate Resolution 98 of the 105th Congress, generally known as the 'Byrd-Hagel Resolution' after two of its authors.

[22] This is known as the 'targets and timetables' approach and it will be discussed in more detail below.

[23] Sink allowances enable countries to offset a portion of their carbon emissions by enhancing activities, such as forestry, that remove carbon dioxide from the atmosphere.

[24] Bohringer (2001) *op cit*.

[25] Kemfert, C (2001). 'Economic Effects of Alternative Climate Policy Strategies', FEEM Working Paper 85.01

[26] See Buchner *et al* (2001) *op cit* for a survey of estimates.

[27] McKibbin, WJ and PJ Wilcoxen (2002b). 'The Role of Economics in Climate Change Policy', *Journal of Economic Perspectives*, 16, 2: 107-130.

[28] McKibbin W (2002) 'Modelling Results for the Kyoto Protocol: Sensitivity Analysis' report prepared for the Australian Greenhouse Office, Canberra.

[29] This is not obvious when overall emissions are discussed such as in the recent report by the Australian Government (2004). *Securing Australia's Energy Future, Australian* Government, Canberra, Recent projections on the composition of emissions can be found in Australian Greenhouse Office (2004). 'Tracking to the Kyoto Target 2004, Australia's Greenhouse Emissions Trends 1990 to 2008-2012 and 2020' Australian Government, Canberra.

[30] Costs are estimated to be less than expected in 1997 before the relaxation of targets and the withdrawal of the US but they are still highly uncertain as argued earlier.

[31] The economic theory behind regulation under uncertainty is due to Weitzman, Martin L (1974). 'Prices vs. Quantities,' *Review of Economic Studies*, 41: 477-91, and the theory underlying hybrid regulatory policies is due to Roberts, Marc J, and A Michael Spence (1976). 'Effluent Charges and Licenses under Uncertainty,' *Journal of Public Economics*, 5: 193-208. Other usual references on the debate between prices versus quantities in environmental policy include Hoel, Michael and Larry Karp (2002). 'Taxes vs. Quotas for a Stock Pollutant,' *Resource and Energy Economics*, 24:. 367-384; Newell, RG and W.Pizer (1999). 'Regulating Stock Externalities Under Uncertainty,' Resources for the Future Discussion Paper 99-10, Washington: Resources for the Future; Pezzey, J (2003). 'Emission taxes and tradable permits: a comparison of views on long run efficiency'. *Environmental and Resource Economics,* 26, 2: 329-342. A hybrid approach to climate change was first proposed by McKibbin, WJ and PJ Wilcoxen (1997). 'A Better Way to Slow Global Climate Change,' *Brookings Policy Brief*, 17, June, Washington: The Brookings Institution, and has subsequently been endorsed or promoted by a range of authors and institutions such as Pizer, WA (1997). 'Prices vs Quantities Revisited: The Case of Climate Change,' Resources for the Future Discussion Paper 98-02, Washington: Resources for the Future. For further details, see McKibbin and Wilcoxen (2002) *op cit*.

[32] McKibbin and Wilcoxen in various papers (1997) *ibid*, (2002a) *op cit*, and (2002b) *op cit*.

[33] McKibbin and Wilcoxen (2002a) *ibid.*

[34] Countries could participate in the Blueprint even if they lacked appropriate markets where permits could be traded. In that case, a firm's allocation of long term permits would essentially be an emissions quota. Without tradability, the country would no longer be guaranteed of reducing its emissions at minimum cost. However, the existence of annual permits would reduce the excess cost caused by an inefficient allocation permits.

[35] In McKibbin and Wilcoxen (2002a), (2000b), *op cit*.

[36] As outlined in McKibbin and Wilcoxen (2002a) *ibid*.

[37] McKibbin WJ (2005). 'Climate Change Policy For India' in R Jha (ed) *Economic Performance and Welfare in South Asia* Palgrave Macmillan. Pp 121-150, gives a more detailed overview of how this would work in India.

[38] McKibbin WJ and PJ Wilcoxen (2004). 'Estimates of the Costs of Kyoto-Marrakech Versus The McKibbin-Wilcoxen Blueprint' *Energy Policy* 32, 4, Elsevier: 467-479.

[39] See McKibbin and Wilcoxen (2003) *op cit*.

[40] As advocated by Anderson K and W McKibbin (2000). 'Reducing Coal Subsidies and Trade Barriers: Their Contribution to Greenhouse Gas Abatement' *Environment and Development Economics,* 5, 4: 457-481.

[41] For a recent survey of a range of alternatives to Kyoto including the Blueprint, see Bodansky, D (2004). *International Climate Efforts Beyond 2012: A survey of Responses,* Pew Centre for Climate Change.

THE GREENHOUSE AND THE GARBAGE CAN: UNCERTAINTY AND PROBLEM CONSTRUCTION IN CLIMATE POLICY

Aynsley Kellow

In November 2004, NSW Premier Bob Carr launched a report his government had commissioned from the CSIRO's Division of Atmospheric Research on the regional climate of the future for his state. Mr Carr's press release stated that 'NSW can expect fewer frosts but more frequent droughts, heatwaves, rainstorms and strong winds.' Mr Carr's statement was quite unequivocal. It was full of statements of what climate change 'will mean' and concluded that 'There's only one way to avoid this worrying bundle of problems – cut greenhouse gas emissions.'[1] These statements came in a considered, written statement. They were not the result of some extemporising in a press conference. And yet they represented a serious overstatement of the certainty which attaches to knowledge about climate change. They point to some problems in the manner in which uncertainty is dealt with politically in this important issue.

Ironically, just a few months previously, a piece in the leading journal *Nature* had announced in its title, 'Reliable regional climate model not yet on horizon.'[2] Was this forecast astray? Had CSIRO made a breakthrough only over-the-horizon radar could have seen coming? In fact, neither of these was the case, for the CSIRO report contained an important, explicit, up-front caveat, which stated:

This report relates to climate change scenarios based on computer modelling. Models involve simplifications of the real physical processes that are not fully understood. Accordingly, no responsibility will be accepted by CSIRO or the New South Wales government for the accuracy of projections in this report or actions on reliance of this report.[3]

Not only are regional climate models subject to such uncertainties, but global climate models are also largely incapable of providing information with a degree of certainty we would prefer. They contain many simplifications and 'fudge factors' (such as 'flux adjustments') and - even with the best available supercomputers – can handle cells only as small as about 300km. While climate modellers admit to the limitations of their efforts and call (inevitably) for more funds for more research, no amount of research is likely to provide policy makers with the degree of certainty they would like. Even if we could produce computers which could encompass all the necessary detail, from the planetary scale to the molecular, the data available to feed into them is highly limited.

If that were not enough, the earth's climate is a complex non-linear system. With climate change, we are dealing with a problem involving not just 'virtual risks' (in that they are generated by computer models), but risks which may well be unknowable.[4] Economists have techniques for dealing with decision-making under uncertainty, and I do not wish to discuss those here at any length (with one brief exception[5]). Rather, my concern is with the way in which this uncertainty has been, and is being, handled politically. Premier Carr's statement is but one example of the way in which political actors misrepresent the nature of the policy problem. They frequently do so because they consider that only by raising a sense of alarm will sufficient support be generated for policy responses they 'know' are necessary; authority is prone to coping with ignorance by denying its existence,[6] so the understatement of uncertainty is nothing unusual.

There seems to be at work a phenomenon which is known in law enforcement circles as 'noble cause corruption' which arises when police officers know a suspect is guilty and make sure they are convicted by either fabricating evidence or suppressing evidence which might create uncertainty in the minds of a jury.[7] The nobility of the cause is why Premier Carr's gross understatement of the uncertainties of climate change went unchallenged. As with noble cause corruption in law enforcement, such practices in policy-making are dangerous, not least because they can have consequences unintended by (and at odds with the preferences of) those committing them. We need to be careful of what we wish for.

This paper examines the extent to which uncertainty has been downplayed in the climate change policy process, and the consequences of this problem construction. It then draws on the literature from political science and other disciplines to suggest how the public policy problem has been defined and the agenda set on climate change, before suggesting that the flawed nature of the Kyoto Protocol requires that the problem be redefined in the light of an awareness of the interests at play if climate change policy is to be improved.

Uncertainty in climate change policy

It is often thought that political systems are incapable of managing risks and uncertainties. In fact, they do it all the time. While it is popular to claim that any government looks forward only as far as the next election, governments are constantly exercising judgment on the basis of knowledge that is far from certain about events that are in the distant future. Indeed, governments care *more* about the future than private actors, and their time preference results in discount rates lower than those applied by private actors.

Typically, 20 years is a long time for private investors, and very few private firms concern themselves with events even 50 years into the future, let alone the century time span which features commonly in discussions of climate change. Many private firms are unlikely to *exist* in 50 years time, and, to the extent that they are concerned with the threats and opportunities surrounding climate change, they are often either concerned (as with the insurance sector) with changes in (insured) risks over a much shorter time frame, or with threats and opportunities which arise from government policies with current effect but which address goals more remote in time.

It is customary to distinguish between 'risk' and 'uncertainty'.[8] Risk usually refers to some hazard and the probability of its occurrence (having long since lost the positive meaning it carried in the early days of capitalism). With risks, the probabilities are generally known with some degree of certainty. Future probabilities can be extrapolated from past probabilities with a sufficient exactitude that insurers and reinsurers can profitably cover future losses.

Climate change differs from many conventional risks. Not only does it constitute a very large risk, but it has several characteristics which make it particularly troublesome. First, it concerns risks over a very long period, even for governments. Second, it involves large amounts of uncertainty. And, perhaps most disconcertingly, it is unlikely that the degree of uncertainty involved can ever be reduced to levels with which politicians feel comfortable. Leading climatologist Stephen H Schneider recently admitted that global warming, which he *believed* was a real phenomenon, could not be proved in the conventional sense, but only through (inevitably subjective) prior estimates constantly updated in the light of evidence.[9]

The Bayesian analysis upon which Schneider relies contrasts with what he terms 'the strict old fashioned frequentist statistical belief system' which he sees as involving the collection of data (direct observations) of the hypothesised phenomena (temperature increases) and then 'when you get enough of it to produce frequency distributions you can assign objective probabilities to cause and effect hypotheses.' This confuses Classical frequentist approaches to probability (which are derived *a priori*) with an essentially inductive approach to knowledge, which they are not.[10] For this reason, neither Classical probability theory nor Bayesian analysis is 'scientific' in the Popperian sense of falsifiability, and neither represents a path to scientific verification. The validity of the climate models will ultimately be verified by observational data as it emerges. Whether the six-year trend of decline from the peak year of mean global temperature in 1998 continues or whether it is but a short interruption before a resumed pronounced warming trend will provide us with such data in the near future. The calibration of most climate models to *other* climate models makes agreement among models (and researchers) of limited value for verfication compared with tests against observational data.

Bayesian techniques do allow, as Schneider claims, statements of probability to be revised in the light of both prior information and new information, and are suitable for assessing future risks with incomplete knowledge, but not only are they the only statistical procedure consistent with true induction (learning by experience, or revising probability estimates in the light of new information), but they are inherently subjective. The problem with climate science is not that it should *not* be judged by the quality of falsifiable propositions, but that falsification or otherwise occurs only in the future and might involve future outcomes we find undesirable. It is not the science which depends on Bayesian techniques (since climate science can make falsifiable statements), but our assessment of the risks posed by the incomplete information provided by this science.

This blurring of science and risk assessment is important, because Bayesian analysis does not arbitrarily exclude human intuitive perceptions and is (as Schneider notes) subjective in nature. But Bayesians acknowledge that all scientific evidence is filtered through human perceptual faculties.[11] They also understand that (rather than objective probabilities inhering in the things analysed), risk reflects interactions between those things and subjectively held beliefs. Climate scientists fail to see both that such an approach necessarily involves their own values, and that it invalidates the whole *Intergovernmental Panel on Climate Change* (IPCC) 'projections' approach, where we are asked to take risk management decisions on the basis of climate model results driven by scenarios which assume that humans will *not* respond to the emerging perceived risks of climate change.

As noted above, the uncertainties in climate science have many sources. First, there are those in the physical science of climate science. These stem from both the data and the nature of the phenomena under study. On the first point, we have nothing resembling a reliable global temperature record that extends back beyond about the middle of last century, and (as the geologists are wont to remind the meteorologists) we are dealing with phenomena which have varied over geological timescales. On the second point, we must rely for knowledge about the future on complex mathematical models which necessarily simplify enormous complexity in attempting to account for coupled, non-linear systems. With the best supercomputers currently available, much has to be simplified, but even with significant advances in computing and modelling it is inherent in the nature of such systems that they will remain in large part not known with the kind of certainty we would prefer.

It is for this reason that most documents pondering future climate change carry a caveat similar to that in the report by CSIRO for the NSW government released in November 2004. There is, however, another source of uncertainty, and one which both allows scope for subjective reactions to future uncertainties and occurs in a self-reactive context. That is to say, our subjective perceptions will affect our interpretations of uncertainty and the way in which we respond to those perceptions.

Sources of uncertainty

One aspect of climate science over which there is widespread agreement is that a doubling of atmospheric carbon dioxide will raise global temperatures by around 0.7°C. Most of the disagreements in the natural sciences relate to various feedback mechanisms (positive and negative) which might produce a range of future global mean temperatures anywhere between double that number and 5.8°C, which was the upper end of the range that appeared in the IPCC's Third Assessment Report.

Some notable climate scientists consider that warming towards the lower end of this range is the most likely. Hansen, for example, considers that warming of only a degree or so is likely by the middle of this century.[12] Others point to the possibility of increases of 5.8°C (often rounded up to 6°, as it was in some media treatment of the NSW regional impacts study[13]) and invoke the precautionary principle to argue that the dire consequences associated with such rapid warming should be avoided by all means possible, usually beginning with rapid decarbonisation of the global economy. The range of uncertainty would thus appear to encompass everything from somewhat benign warming to catastrophic warming, but the problem for policy-makers is worse than this would suggest, because the chaos theory which underlies these modelling results suggests the earth's climate could also quickly cool. Climate change is the ultimate 'wicked' problem - one which is not amenable to easy resolution. The range of temperatures presented to the policy community by the IPCC actually widened between the Second and Third Assessment Reports; the higher upper range might have added a sense of alarm, but it also added greater uncertainty.

The possibility of a sign reversal aside, it is important to note where the source of this uncertainty lies. While some (about half) originates in the uncertainties inherent in the climate models, much originates in the emission scenarios which are fed into the models, and these scenarios present particular challenges and dangers.[14] It is important to understand to what uses scenarios can legitimately be put. Scenarios are 'what if' exercises that can illuminate possible futures. They cannot be taken as forecasts, and those who represent IPCC ranges for future temperatures as forecasts of the future seriously misrepresent the science. But even the approved wording of 'projections' is, strictly speaking, inappropriate.

The scenarios developed and presented in the *Special Report on Emissions Scenarios* (SRES) represent a range of possible futures assuming no action is taken to mitigate greenhouse gas (GHG) emissions. Already, we can see a problem with the use of 'projection', because we know that substantial policy action has been taken to mitigate GHG emissions in a large number of countries, and other factors (principally economic collapse in former communist states and the 'dash to gas' in the United Kingdom) have also produced reductions in the rate of increase in GHG emissions that a projection of past trends in evidence at the common base year of 1990 would have produced. In fact, the (non-binding) collective target in the Framework Convention on Climate Change of stabilisation at 1990 levels by 2000 on the part of industrialised nations was essentially met, largely by luck and only in part by good management.

Projections ordinarily take as their starting point the status quo, yet the IPCC scenarios do not, instead having embedded in them rates of increase in GHG concentrations which exceed those of the 1970s (0.39 per cent) and 1980s (0.45 per cent). The rate of increase in global concentrations of GHGs actually declined in the 1990s (to 0.42 per cent), and methane concentrations appear to have stabilised, yet all IPCC scenarios assume accelerating rates of increase - until 2020 for the B1 scenario, 2030 for the A1 scenario and 2040 for the A2 scenario and thus rates of increase up to around double the *actual* rate for the past three decades. The scenarios are strictly speaking therefore *not* projections, but possible (and perhaps not even likely) future states of affairs. They assume certain rates of economic growth for the developing world which get them where we would *wish* them to be by the end of the century, rather than where we think they might be, and (as Ian Castles and David Henderson have pointed out[15]) make incorrect use of statistics to get them there. Using Market Exchange Rates (MER) rather than Purchasing Power Parity (PPP) measures overstates the magnitude of the journey to be undertaken, and inflates the GHG emissions necessary along the way.

A key question for policy-makers is therefore: what are the probabilities of the various scenarios occurring? This is a question the IPCC has essentially avoided, yet it is fundamental to the policy problem. As McKibbin *et al*[16] have pointed out, the lack of the use of Bayesian techniques to attempt to attach probabilities to the subjective storylines which underlie the SRES scenarios means that 'policy makers inevitably overlay their own implicit distributions, which may well be based on political rather than scientific considerations.' Thus, scenarios which suggest that (*if* the climate models hold, and *if* we take no explicit actions to mitigate GHGs) global mean temperatures *might* rise by 5.8°C by 2100 are being used politically to define the climate change problem as being one requiring a response to the likelihood that global mean temperatures *will* rise by up to 5.8°C, which is not the same thing.

One study which has attempted to attach probabilities to the various model outcomes (including emissions) suggests that a figure of 5.8°C is highly *unlikely*, with a probability of less than 1 percent, and produces a 'most likely' figure of 2.5°C.[17] This makes it highly misleading to talk about 'up to 5.8°C' and suggests climate change is a problem less worrying and requiring less urgent decarbonisation than political actors such as Premier Carr have portrayed.

This focus by political actors on scenarios which are highly unlikely suggests that the climate change problem has been politically constructed. This does not mean that it is not a serious problem, but that the way in which it has been defined and placed on the policy agenda reflects the exercise of political power. As Hansen *et al*[18] have pointed out, decarbonisation is not necessarily even the best option, because other GHGs to those covered by Kyoto can be mitigated with less technical difficulty and at less cost. Political scientists would quickly add that this is the case with all policy problems. But the particular way in which the problem has been constructed has important consequences for how we respond to it.

To demonstrate this, we can look at how the problem looks when probabilities are attached to outcomes. Climate change becomes less frightening, more manageable, and provides more options. If the 5.8°C figure is highly unlikely, and the most likely figure is 2.5°C, we can act with less haste and more caution. Interestingly, this is in the ballpark of more moderate projections of scientists who are both 'global warmers' (such as James Hansen) and critics (such as Garth Paltridge[19]). Hansen has suggested about 1°C by 2050 and Paltridge a range of 1-3°C by 2100 (with something less than that attributable to anthropogenic causes). Paltridge also noted that it is not the global mean temperature which is important, but the distribution of climate, especially changes in the 'tails' of the statistical distribution of extreme events around the mean.

This sentence is not comprehensible This construction was performed not only by politicians and environment, but was undertaken by key IPCC figures, such as Chair Bob Watson. The IPCC belatedly used new emissions scenarios to *produce* the 5.8ºC figure after the main review process, and Watson then used this as the headline to bolster support for the negotiation of the details needed to make Kyoto operational.

The first draft of the Working Group 1 Third Assessment Report (WG1 TAR), which was produced on 6 November 1999, showed a figure with a range of 1.5-4.0°C. In the second draft of 16 April 2000 the range had increased to 1.3°C-5.0°C, and by the third and final draft of the report of 22 October 2000 - after the main scientific review process had been completed, and in time to be leaked to the media and revealed by Watson at the Sixth Conference of the Parties to the Framework Convention on Climate Change (COP 6) in The Hague - it had risen to 1.4°C-5.8°C. The later, higher results reflected subsequent 'tuning' of models using more scenarios.

Watson reportedly told COP 6 that the Earth's surface temperature was now higher than for 1,000 years and new forecasts [*sic*] put the expected [*sic*] temperature rises until 2100 at between 1.5 and 6.0°C - double the previous estimates.[20] Similarly, *The Times* reported[21] the upper limit as a *prediction*, and a likely one at that: a headline in 'Global warming "will be twice as bad".'

The use of the words 'forecasts', 'expected' and 'will be' substantially misrepresented the IPCC science by suggesting much greater certainty than is warranted on the basis of modelling with highly inadequate physical and economic data. If Watson was misquoted in any of these misrepresentations, he made no effort to correct them - which is the whole point about noble cause corruption. Inaccuracy has been allowed as long as it supports the dominant problem construction. In contrast, the IPCC has been vigilant in correcting those whom they think have represented the IPCC consensus in the other direction - the clearest example of which has been the issuing of a press statement in Milan in December 2003 attacking Castles and Henderson over their critique of the SRES scenarios.

There is no doubt that many who have helped construct the prevailing climate change policy problem have done so (at least in part) because they think it will make us do things that are worth doing anyway - things like engaging in energy conservation and developing alternative energy technologies. In addition to protecting the earth from dangerous climate change, here is the 'noble cause' which 'justifies' the political construction of the problem as one which requires urgent decarbonisation of the global economy, as well as 'noble lies' such as the incorrect use of statistics (MER rather than PPP) in developing emission scenarios, neglecting any probability analysis, adhering to scenarios even when actual emission trends depart from them, and so on.

Consequences of problem definition

In doing so, advocates have struck a Faustian bargain, because a climate change policy scenario which emphasises mitigation over adaptation, urgency over more considered policy-making and decarbonisation by shifting away from fossil fuels has its own problems, and has consequences they almost certainly do not want. It is true that decarbonisation policies will favour renewable technologies such as photovoltaics, wind energy and bio-fuels, but such energy sources are subject to environmental constraints, in addition to cost considerations. While we are likely to see technologies such as hydrogen fuel cells replace much of the present and future stock of internal combustion engines, we must first produce the electricity to produce the hydrogen, and renewable technologies currently in use are unlikely to be able to supply this demand *and* replace current and future fossil fuel use in the electricity sector. Rapid, immediate decarbonisation means shifting from coal to gas and nuclear electricity generation. James Lovelock has not only recognised the need for nuclear expansion but (much to the chagrin of his environmentalist supporters) actively advocated this option. Market recognition of this reality underpins a doubling in the spot price of uranium over the past year.

Even if we were able to reduce the cost of various alternative (and renewable) energy sources, they all tap into the energy of the sun in one way or another, and incoming solar radiation is effectively fixed for a given area of land. This means that there is a substantial impact (and opportunity cost) of alternative energy in terms of land use: land devoted to solar energy is land not available for agricultural production or for natural ecosystems. In a Canadian study cited by van Kooten,[22] the area required to generate 1000Mwe of electricity (a little less than the output of the Loy Yang A Power station in Victoria) is $100km^2$ for photovoltaics, $100\text{-}180km^2$ for wind, $24{,}000km^2$ for canola bio-oil, and $272{,}000\ km^2$ for wheat-based bio-alcohol. To put this in context, in 2001 in Canada $11{,}413\ km^2$ were sown to wheat and $4{,}369\ km^2$ to canola.

For these reasons, opportunities for solar-based renewable strategies will be limited by the availability of low cost land, and this technology is likely to produce substantial siting conflicts, especially as what was once regarded as 'wasteland' is now wilderness. An early photovoltaic station in the Mojave Desert in the US was far from popular with environmentalists, and siting disputes over wind energy are becoming more frequent as it scales up. While there is still strong opposition to siting nuclear energy facilities in advanced industrial countries, this is absent in many of the industrialising economies and reductions in reactor construction costs have brought about a nuclear resurgence. Pushing hard for decarbonisation is therefore *simultaneously* encouraging investment in renewables (which is expanding rapidly from a low base) and nuclear energy. Nuclear energy is likely to win this contest, as it can deliver on a far more attractive scale than the renewable alternatives, so after the relatively painless shift of much capacity from coal to gas, nuclear is increasingly the decarbonised electricity technology of choice.

But these are the options *now* - if we accept the construction of the climate change problem as one which means (with little uncertainty) that we should decarbonise rapidly and immediately. If we accept that the problem is one on which a high degree of uncertainty is inescapable, then the appropriate response is one that takes this uncertainty explicitly into account, and which retains flexibility and involves continual up-dating with the passage of time. Excess enthusiasm for costly mitigation *now* not only means that fewer economic resources will be available *in future* to adapt to any change, but the environmental effects of these efforts (land use, nuclear waste disposal, and so on) could conceivably rival those of climate change.

Important in this conception of the problem is technological innovation. Twenty years is a long time in terms of technological innovation, and we can already begin to see how additional options might open up during this time (and I discuss two below), but none of this precludes either taking no-regrets measures now or adopting widespread nuclear energy later. The climate change problem should be seen as one involving a constantly-reviewed mix of least-cost mitigation and adaptation options. There is no reason to believe that either mitigation or adaptation is to be preferred on *a priori* grounds, but some amount of adaptation is likely to be needed because the science suggests some change is inevitable, thanks to the inertia of the global climate system. Possible impacts such as enlargement of disease vector range depend crucially for their consequences upon socio-economic factors which can reflect either adaptation policies or consumer decisions under conditions of affluence. Devoting effort exclusively to mitigation regardless of cost when some warming is inevitable is clearly imprudent.

Technology will also expand mitigation options. Consider just two possible alternative technologies which might make substantial contributions to energy supplies in a decarbonised world, if we accept that we have more time for them to develop to the point of commercial application. The first is carbon dioxide removal and sequestration, into which Australia has made a strategic research investment - not surprising given its resource endowment. Carbon dioxide extraction has been undertaken commercially in the past, and we forget that it is a commercial product with uses ranging from ('dry ice') refrigeration and soft drink carbonation to injection into oil wells to increase productivity. The problem is less with technology of extraction than with technology for and costs of disposal once decarbonisation on a large scale swamps existing markets.

The second technology is tidal power. Research is taking place in Scotland into techniques for extracting the energy from tidal currents which daily move millions of tonnes of water at speeds of up to eight knots. There is a potential which dwarfs solar or wind sources of energy. Like all energy utilisation technologies, these will leave an environmental footprint which will need to be considered, but they indicate that a decarbonised future does not depend solely upon nuclear fission, or even the hope of commercial development of fusion energy.

The climate change policy problem conceived as one of continuous adaptation in the face of uncertainty is a problem definition which is more complex, but requires no single response. It is a problem definition which allows multiple responses and the time to choose among them. From our understanding of decision making, it is a problem definition which is less likely to lead to poor decisions, because the absence of hope of finding a better option and time pressures are well-known sources of pathologies in decision-making.[23] Definitions of the climate change problem which overstate certainty and urgency, while they might be seen as forcing the consensus necessary for international action, can also act as a source of decisional pathology.

Problem definition and agenda creation

This raises the question as to why a problem definition which overestimates certainty and the degree of urgency has thus far prevailed in climate change debate. The politics of problem definition is an important, but often overlooked, part of the policy process. As Schattschneider once put it, the definition of alternatives is the supreme instrument of power.[24] Not surprisingly, there are close parallels apparent with deterministic approaches to energy forecasting and planning, where forecasting effectively determined planning and was part of what Langdon Winner[25] called 'reverse adaptation', or the selection of ends to suit an available means. Many electric utilities in the era of deterministic approaches to electricity forecasting and planning were able to produce forecasts of future demand which 'necessitated' their preferred development programs, not just in terms of the amount of capacity needed, but often (because of factors such as lead times for different technologies) the generation mix which would be required to meet the forecast.[26] As Herman Daly[27] noted, forecasting *was* planning.

It would be an overstatement to suggest that this has been the case with climate change. While the IPCC was established to provide an authoritative source of scientific advice, and while its leaders have frequently exhibited preferences for policies which would be privileged by a particular problem construction, the IPCC does not enjoy anything approaching the near-monopoly on knowledge of future demand that was possessed by electric utilities, who were challenged by environment groups and others only with great difficulty (and at the eleventh hour). The construction of the climate change problem as both more urgent and more about decarbonisation than it might need to be is better (and less conspiratorially!) explained by reference to conventional theories of problem definition and agenda formation.

The most simple and obvious of these is Cohen *et al's* 'garbage can' model of organisational choice,[28] which stresses that organisations (as 'garbage cans' where problems and solutions are dumped as they are generated) are collections of choices which seek problems and issues and seek decisional situations in which they can be advanced, so that 'solutions look for problems.'[29] Kingdon developed this idea further, arguing that government agendas are comprised of three distinct streams: problems, policies and politics.[30]

The problem stream involves three mechanisms which bring problems to the attention of policy makers: indicators (the data or 'science' used to indicate the presence of a problem); events; and feedback (which gives information indicating unanticipated consequences or a failure to meet goals). With climate change, it is possible that some of the science might have been subject to various kinds of construction, especially as it has been 'provided' by the IPCC. We certainly know of one significant example in the preparation of the Second Assessment Report where the US government intervened to have the text altered in the key attribution chapter, which enhanced a conclusion about the certainty which attached to the anthropogenic origins of observed claimed change.[31] The first two IPCC assessment reports also neglected discussion of adaptation in response to political pressure from environmental NGOs, fearful that talking about adaptation might be construed as acceptance.[32] The IPCC is, after all, an *intergovernmental* body created to produce consensus - an inherently political process.

The way in which the 'problem stream' has been constructed has also involved the use of events to highlight the problem and feedback, to attribute numerous problems to climate change or suggest that other problems will be made worse by climate change. This has involved the media and overtly political actors such as environment NGOs, rather than most scientists, but there has often been at least tacit involvement by IPCC officials. These have been active in criticising those who have questioned the IPCC consensus position, but have been rarely found correcting those who have misused or misconstrued the consensus position to support the dominant problem construction. Indeed, the recent resignation of hurricane expert Chris Landsea was stimulated by an IPCC lead author with no particular expertise on hurricanes issuing statements to the media. He claimed that severity of the hurricanes of the 2004 season was the result of climate change, when all IPCC assessment reports indicated an absence of any increase in the frequency or intensity of hurricanes, and prospective studies indicated only a modest five per cent increase in hurricane intensity by 2080. Landsea felt this press statement prejudged his contribution to the Fourth Assessment Report and he resigned when the IPCC ignored his complaint.[33]

Environment NGOs have been the most prominent in providing feedback alerting policy makers to the seriousness of the problem and in attempting to exploit any 'indicative' event (usually some extreme weather event) as evidence of climate change (ignoring the IPCC consensus view that there has thus far been no evidence of an increased occurrence of extreme events). In terms of scientific method, this commits the error of bringing evidence to the theory, but politics is not overly concerned with the niceties of scientific method. It has been more than just any construction of the science which has framed and established the climate change policy problem as one of lower uncertainty than might be warranted and as requiring rapid decarbonisation. It is because this problem definition ‘found’ several solutions and resonated with numerous political agendas (Kingdon’s ‘policy’ and ‘political’ streams, which are exploited by policy entrepreneurs).

Interests and problem construction

Much popular writing about climate change politics casts it as a struggle between those who wish to save the world from climate change and fossil fuel interests which seek to prevent action. The dominant problem definition also suits numerous other interests, however, and even failing to differentiate between fossil fuel interests causes considerable misunderstanding of the way in which solutions that favour some interests have favoured a particular problem construction. The interests in conservation and renewables constitute much smaller industrial sectors than the oil sector, so these components of the policy stream cannot be regarded as especially significant in terms of structural power (though they enjoy substantial political support, and therefore are significant components of the political stream). But the interests in other components of the policy stream cannot be dismissed so lightly.

While the fossil fuel industry is often regarded as undifferentiated and opposed to climate change mitigation, the interests of different sectors and companies vary markedly. The need to decarbonise rapidly disadvantages the coal sector most of all and in fact offers short term advantage to gas producers, since a shift from coal-fired electricity generation to combined-cycle gas turbine generation produces GHG reductions per unit of electricity of around 60 per cent. Many oil companies have substantial associated gas reserves and (because decarbonisation is unlikely to create much immediate disadvantage for liquid fuels, so valuable for transport) they are likely to be advantaged substantially when compared with coal producers. Similarly, the nuclear industry (from uranium mining through to reactor design and construction and operation) has been advantaged substantially. Its recent resurgence has much to do with the Kyoto Protocol, as does the soaring spot price of uranium, though the decline in availability from decommissioned weapons is also a factor there.

The composition of national interests varies with the particular fuel resource endowments countries possess. So Australia’s coal endowment makes its national interest different from that of Canada, which has (like Australia) coal and uranium, but also has CANDU nuclear technology and hydro-electric potential for export into the North American market. European nations have no cheap coal, little oil and declining gas reserves, but substantial interests in nuclear energy, taxation and other policies designed to build energy security. Coal for electricity generation in Europe is more expensive than that from Australia, the US, Canada, South Africa and Indonesia by about a factor of four, and mines have either been closed or must be heavily subsidised.[34] Despite the use of world parity pricing for petroleum in Australia, taxation doubles the cost of petroleum to the consumer in Europe. Such measures are unpopular, and lead to occasional protests, but climate change provides a noble cause that helps justify politically unpalatable policies.

Less obvious are the interests of the financial sector, especially those of the insurance and reinsurance sectors. The financial sector wants to minimise financial risk, and the insurance sector wants to make money by covering insurable risks. Financiers of projects likely to be affected by climate policy have for some time been subjecting such projects to close scrutiny, with future climate policy settings forming one part of the sovereign risk component of any project. The financial sector is thus largely indifferent to what the settings of climate policy might be, but it would very much like to know, as far as is possible, *what* those policy settings are likely to be. Nevertheless, interests in the City of London are believed to have taken the initiative in the deals struck in the UK which formed a crucial part of securing Russian ratification (and thus entry into force) of the Kyoto Protocol. This negotiation involved not just EU support for Russia's WTO accession, but support for the gas monopoly Gazprom remaining in state hands, and promises of investment in the Russian gas sector underwritten by the carbon credits arising from Russia's endowment of 'hot air'. The benefit for the financiers of the City, who persuaded the Blair government to act, was a degree of stability in the carbon futures market which was to commence full operation in 2005.

Insurers and reinsurers have a much clearer set of interests. Not only does climate change action raise the possibility of a liability protocol being developed at some stage in the future, but the widespread belief that weather-related natural disasters have become more commonplace helps build, if not support, an acceptance of higher insurance premiums. In fact, the IPCC has found no clear evidence of such a change and, while there have been regional variations, most of the effects on insured liabilities appear to have come from human factors which have increased insured losses.

The political stream includes those nations whose national interest compositions are dominated by the above industrial sectors, nations (such as small island states) which are especially vulnerable to the possible effects of climate change, and those handed windfall credits by the selection of a helpful base-year for determining commitments (Russia, and - particularly - the United Kingdom and Germany, which enjoyed post-1990 collapses in GHG emission, yet had made the greatest historical contributions to elevated atmospheric carbon dioxide levels).[35] Margaret Thatcher's rapid embrace of the climate change issue had much to do with her desire to close uneconomic coal mines, and Helmut Kohl quite explicitly used climate change in an attempt to bolster support for the German nuclear program.[36] To these we can add those nations in the South promised wealth transfers under Kyoto (including some which are far from impoverished, but exempted from reduction targets) and those which will gain (particularly in Europe) as Kyoto makes more expensive energy in economic rivals with access to cheap coal (the US, Canada, Australia).

Arrayed on the side of the dominant construction of the climate change problem is, therefore, a set of powerful interests - arguably more powerful than those which have opposed this construction (coal interests, energy-intensive industries such as aluminium, and those oil companies with few interests in gas or - unlike BP-Amoco - photovoltaics). What is important is not whether these sets of interests are unequal or roughly comparable, but that, politically, those supporting the dominant problem construction are practically invisible. The 'fossil fuel lobby' is frequently cast as thwarting climate policy, though that 'lobby' (as we have seen) must be differentiated. The nuclear and reinsurance industries are not seen as active on the other side. Why have such interests received a free pass?

The answer to this question lies in a phenomenon familiar to students of regulatory politics, and most colourfully described by Bruce Yandle[37] with his 'Baptist and Bootlegger' theory of regulation, which accounts for why some economic interests prevail over others in securing advantageous regulation. The answer lies in their coalition (often only tacit rather than explicit) with altruistic agents (in this case, the environment NGOs) which argue a principled, usually morals-based or non-self-interested case for action which cannot be matched by those with only self-interest to call upon. Not only can 'naked' self interest not compete with such a coalition - the advantaged interests hardly need to. The cloak of morality simultaneously disempowers opponents and makes explicit lobbying redundant, so (for example) the nuclear industry was virtually invisible politically from Chancellor Kohl's use of the issue in nuclear politics in Germany in 1987 to at least the Fourth Conference of the Parties in Buenos Aires in 1998, yet it was advantaged all the way.

Conclusions

The argument here is that these factors have helped define climate change as a more certain and more urgent problem (and one more appropriately addressed by rapid decarbonisation) than is necessary. Much of this has been the result of some smart problem construction undertaken in a noble cause - the noble cause which has simultaneously disempowered opponents. But it has also marginalised alternative policy approaches which might have been not only possible, but more appropriate as approaches to policy-making under uncertainty, such as the McKibbin-Wilcoxen[38] proposal, and it marginalised adaptation as a response for a decade. The dominant problem construction has helped form a consensus at the international level, but the focus on international environmental policy-making is now more on the quality of policy adopted rather than just the need to force a consensus, and there have been costs in forcing a consensus.

We know that the absence of hope of finding a better alternative and the absence of time to find a better alternative can lead to documented decision-making pathologies of 'defensive-avoidance' (or 'groupthink') or 'hypervigilance' ('panic') respectively.[39] The attempts to force negotiations with science, and blame and shame tactics, have not worked. There is a growing awareness of the many limitations of the Kyoto Protocol: it will do little to prevent global warming; it omits developing countries where many emissions occur and much growth will occur; it has not been ratified by the largest emitter; it lacks adequate enforcement mechanisms; it allows paper reductions in emissions to be offset against future real increases; and it is overly sanguine about the ability to create the institutions (especially measurement and verification measures) which will permit the establishment of effective emissions trading regimes.[40] Even in normative terms, it is questionable since it is lightest in its impact on those who have contributed most to the problem (as noted above).

The Kyoto Protocol is usually justified as a necessary 'first step', but it might well be a step in the wrong direction, and one which could hinder rather than help future international cooperation. Successful international regimes are typically those which begin modestly and then allow shared understandings of both problems and solutions to emerge.[41] Attempts to force the pace with climate change have sharpened differences of interests rather than yielding a consensus which will carry along the slowest ship in the convoy, to use Peter Sand's analogy.[42] Strong attempts at moral suasion and attempts at problem definition do not thus far appear to have produced a step in a direction which is promising for an adaptive approach to this problem, which is fraught with uncertainty, and which requires that we follow well-established approaches to making policy under uncertainty, rather than proceeding with excess haste and an unwarranted sense of certitude.

The Kyoto Protocol is now being seen as poor international policy. Amid the celebrations over the fact that it has entered into force there is a need to recognise not just what is wrong with this measure, but how it came about. If it is to be improved upon, it must be recognised that various interests have helped shape the policy problem inappropriately. It involves more uncertainty, and is less about decarbonisation than the current problem construction allows. Recognising this is not an obstacle to the development of better policy, but a necessary first step towards this end.

Climate policy has followed the wrong course. Mustafa Tolba, Executive Director of UNEP when the Montreal Protocol was being negotiated, stated that the mechanisms designed for the protocol would be used as the blueprint for the development of a response to the problem of climate change[43] - interestingly, for our theme here, *before* the First Assessment Report of the IPCC had provided the scientific consensus which provided the basis for an international agreement. Montreal, in which the existence of a scientific consensus was seen as a necessary condition for agreement,[44] created advantage for dominant economic interests surrounding a few chemicals of marginal economic importance. Climate change involves significant economic interests, which divide nations; appropriate policy-making requires that these be recognised and the nature of the problem understood as one involving uncertainty and multiple policy options.

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Professor Aynsley Kellow is Professor of Government at the University of Tasmania and a participant in the Law and Policy Programme at the Antarctic Climate and Ecosystems CRC. He represents the Academy of Social Sciences on the Joint Academies Committee on Sustainability, and has published widely on environment and energy policy at both domestic and international levels. His current research interests include Australian Research Council funded projects on interest groups in the mining sector, risk management in the trade system, and Australia's interaction with the OECD.

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[9] Schneider was answering the annual question put by the website *Edge*, which for 2005 was: 'What Do You Believe is True Even Though You Cannot Prove It?' (www.edge.org Accessed 11/1/05).

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[11] Ironically, such scientists see the presence of subjective factors in their opponents, who are frequently dismissed on grounds of association with various interests, but proceed as if they can escape such an influence. A good example of this was the Union of Concerned Scientists' response to the Bush Administration's 'Sound Science' initiative, which they saw as politicising science by attempting to impose a set of somewhat unsurprising standards on science used in regulatory decision-making.

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[30] Kingdon, Jonathon (1984). *Agendas, Alternatives and Public Policies.* Boston, Mass: Little Brown.
[31] Masood, Ehsan (1996). 'Sparks fly over climate report' *Nature* 381: 639.
[32] See van Kooten (2004) *op cit*: 73n; Heal, Geoffrey and Bengt Kriström (2002). 'Uncertainty and climate change', *Environmental and Resource Economics* 22: 3-39; and Kane, Sally and Jason Shogren (2000). 'Linking adaptation and mitigation in climate change policy', *Climatic Change* 45, 1: 75-101.
[33] *The Electricity Daily* (2005). Wednesday 19 January, 24, 12 'Boffin Bashes IPCC, Quits Review'.
[34] See Anderson, Kym (1995). 'The political economy of coal subsidies in Europe.' *Energy Policy* 23: 485-'96; and Anderson, Kym, and Warwick J McKibbin (1997). 'Reducing Coal Subsidies and Trade Barriers: Their Contribution to Greenhouse Gas Emissions' Adelaide, Centre for International Economic Studies, University of Adelaide (Seminar Paper 97-07).
[35] One of the flaws of the Kyoto agreement is surely that it treats GHG emissions as if they were what the economists term a 'flow' resource, whereas the problem is one of 'stocks' as the climate change problem results from an accumulation of GHGs. This makes the allocation of burdens unfair and explains the lack of acceptance. A fair allocation of burdens for mitigation measures would take into account historical contributions since the industrial revolution, not emissions in the single base year of 1990. Brazil (1997). Proposed Elements of a Protocol, FCCC/AGBM/1997/Misc.1 /Add.3.actually suggested this approach during the negotiation of Kyoto, but the winning consensus was comprised of the G-77 and the EU, which captured British and German windfalls under the 'European Bubble' or Burden Sharing Agreement.
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