Predicting, deciding, learning:
can one evaluate the 'success' of national climate scenarios?

Short title: '**Evaluating the success of climate scenarios'**

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Abstract

Scenarios may be understood as products and/or processes. Viewing scenario exercises as productive tends to emphasise their tangibility: scenario products may acquire use value unrelated to the processes of their creation. Viewing scenario exercises as procedural tends to emphasise their modes of formation: the process of constructing scenarios may endow value irrespective of the use value of ensuing products. These two framings yield different expectations about how one might evaluate the 'success' or otherwise of scenario exercises. We illustrate three approaches to evaluating the success or otherwise of scenarios using the example of the series of national UK climate scenarios published between 1991 and 2002. These are: predictive success (has the future turned out as envisaged?), decision success (have 'good' decisions subsequently been made?) and learning success (have scenarios proved engaging and enabled learning?). We reflect on the different ways the 'success' of national climate scenarios might be evaluated and on the relationship between the productive and procedural dimensions of scenario exercises.

1 Introduction

The concept of scenarios was originally developed in the 1960s as a way of aiding strategic thinking and decision-making within the Shell oil corporation (van der Heijden, 1997). Rather than seeking to 'predict the future', scenario exercises were originally designed to sensitise an organisation to a wide range of possible futures. Scenarios have subsequently become central in the framing, analysing and negotiating that surrounds the idea of climate change. Introduced into climate change studies by Wigley et al. (1980) with their publication of the first climate change[1] scenario, we now find scenario-construction exercises and scenario analysis existing in many different areas of climate change debate, operating across many different scales and applied to many different sectors. Thus we have greenhouse gas emissions scenarios, climate scenarios, land use scenarios, adaptation scenarios, policy scenarios, and so on. These scenarios may be portrayed and analysed at scales ranging from global and continental to national, regional and local. The ubiquity of scenarios is paralleled by a range of construction methodologies and in institutional ownership arrangements. In the case of climate scenarios, two methodological elements have become dominant in their design: one or more scenarios describing future emissions of greenhouse gases and other climate forcing agents, and one or more climate models used to quantify the climatic consequences of these emissions scenario(s). The procedural and institutional aspects of how climate scenarios are constructed – who authorises the models? who designs the scenarios? who manages the process? - are less often emphasised (see Hulme & Dessai, 2008).

One of the clarifying messages to emerge from a workshop held at Brown University in March 2007 – '*Global environmental futures: interrogating the practice and politics of scenarios'* - was that scenarios can be understood as either social products or as social processes (O'Neill et al., this volume). Valuing scenarios primarily as tangible products is a more likely frame for those operating within the natural sciences or economics; valuing scenarios primarily as learning processes is more likely for those operating within a social science frame. Recognising these twin attributes of scenarios offers a number of different ways in which scenarios may be used, valued and evaluated as they circulate through scientific, social and policy worlds. It is our suggestion in this paper that the production aspects of climate scenarios have received greater attention than have the procedural aspects of their creation, and that the procedural aspects have received much greater attention than has the evaluation of the 'success' of the ensuing scenarios. Despite the ubiquity of climate

[1] There is a formal difference between a 'climate scenario' and a 'climate change scenario' (Mearns & Hulme, 2001); we hereafter encompass both types of scenario in our use of the term 'climate scenario'.

scenarios within climate change debates there remain remarkably few analyses which have reflected on how one might evaluate their success, and even fewer studies that have actually conducted such an evaluation.

In this short contribution, we offer a perspective on how such evaluation might be approached, using the example of four generations of national UK climate scenarios, in the production and use of which the authors have been directly involved (CCIRG, 1991; CCIRG; 1996; Hulme & Jenkins, 1998; Hulme et al. 2002). These scenarios, their construction and context, have been described in an earlier paper (Hulme & Dessai, 2008) and we refer readers to this work for further details rather than repeat them here. In the present paper we offer a three-fold framework for thinking about scenario evaluation in the context of climate change. We ask, and seek to answer, three questions about these specific national climate scenarios: has the future turned out as envisaged? (what we call predictive success); have 'good' decisions subsequently been made? (decision success); have scenarios enabled participation and learning? (learning success). These three questions might broadly be related to the evaluation criteria of credibility, saliency and legitimacy offered by Cash et al. (2003) in their assessment of science-policy interfaces. We conclude the paper with a discussion about whether this is a helpful framework for thinking about climate scenario evaluation and what is thereby implied about the future role of climate scenarios in climate change decision-making.

2 Predictive Success

This criterion of success – 'has the future turned out as envisaged?' - emerges from a view of scenarios as products and, more narrowly, from regarding scenarios as quantitative or semi-quantitative predictions of the future. In this sense then, a scenario is only 'successful' if it can retrospectively be shown to have described reality, with some adequate level of verisimilitude. Such predictive success of a scenario might, for example, be a common expectation within scientific and many policy circles and this criterion also likely has intuitive resonance with the general public.

The justification for such a criterion flows from a view of climate adaptation summarised by Füssel (2007: 265), 'The effectiveness of pro-active adaptation to climate change often depends on the accuracy of regional climate and impact [scenarios].' In this view, good climate adaptation decisions can only be made if climate scenarios are 'accurate', a position consistent with traditional optimum expected-utility approaches to decision-making. A contrasting view of climate scenarios, however, emphasising their innately weak predictive power is implied by the disclaimer which has accompanied successive versions of national climate scenarios for Australia. Thus their most recent report states on the front cover that, '... no responsibility will be accepted by CSIRO or the Bureau of Meteorology for the accuracy of the projections in or inferred from this report, or for any person's reliance on, or interpretations, deductions, conclusions or actions in reliance on, this report or any information contained in it' (CSIRO, 2007). This cautionary warning about the limits of predictive accuracy has not accompanied any of the UK climate scenarios reviewed here.

There have recently been attempts to evaluate IPCC scenarios using this criterion of predictive success – for example van Vuuren and O'Neill (2006) and Pielke et al. (2008) evaluated IPCC's global emissions scenarios against observed emissions trends, and Rahmstorf et al. (2007) and Pielke (2008) evaluated IPCC's global temperature and sea-level rise scenarios against recent observations. A recent study has similarly examined the original *Limits to Growth* scenarios commissioned by the Club of Rome in the early 1970s (Turner, accepted).

Evaluating predictive success of a climate scenario is different to the evaluations that are made of numerical weather forecasts. Daily weather or seasonal climate forecasts are amenable to verification; once a forecast has been produced it is possible the following day or season to assess how well the model has performed. In the case of daily weather forecasts this can be repeated many hundreds of times and robust indices of forecast accuracy can be constructed. Such verification is not feasible for climate scenarios because of the long time scales involved - in the order of decades up to a century and sometimes beyond.

Evaluating the predictive success of a climate scenario (against recent observations) is also a very different exercise to evaluating the performance of a specific climate model (against historical observations). A 'good' climate model with a defined level of predictive skill does not necessarily translate into 'good' climate scenarios; the assumptions and manipulations that take place in the process of climate scenario construction (Hulme & Dessai 2008) mean that the performance of a climate model cannot necessarily be equated with the predictive success of scenarios that derive from it.

We have demonstrated elsewhere (Dessai & Hulme, 2008) how one might evaluate the predictive success of successive generations of UK climate scenarios. We compared various scenario projections – dating from 1991, 1996, 1998 and 2002 - against observations for the period 1990 to 2007 for national-scale indicators of temperature and precipitation. Our analysis showed that recent trends in observed UK climate have indeed fallen broadly within the range of published climate scenario projections (for an example see Figure 1), the greatest ambiguity occurring with summer precipitation.

Scenario evaluations such as these may be important to undertake, but they also raise as many questions as they answer. For example, the relatively poor fit of observed UK summer precipitation to the scenario trends might be for three different reasons: deficiencies in the underlying climate model(s) used – in this case mostly from the Hadley Centre; inadequacies in the way the scenarios were derived from the model(s); or simply due to high levels of natural multi-year variability in UK summer precipitation which cannot be easily represented in climate scenarios purporting to reveal long-term trends in anthropogenic climate change. As noted by Oreskes et al. (1994), falsification of such model 'predictions' may have greater learning value than any number of confirmations of model veracity, a point we return to in the discussion section below. Even though we have between 5 and 15 years of observations against which we can evaluate the scenarios, such periods may not be sufficiently long to provide robust answers to the question: 'were these scenarios a good description of the way future UK climate evolved?'

A second question raised by this type of retrospective evaluation of scenarios' predictive success concerns the multiplicity and nature of climate scenarios that may be involved. Is one evaluating the predictive accuracy of an individual scenario, a family of scenarios or a set of probabilistic scenarios? For example, in the case of the UKCIP98 scenarios (published in 1998) four different national climate scenarios were portrayed, each of them based on a different combination of emissions scenarios and climate model parameters. One might conclude one decade later, as shown in the Dessai and Hulme (2008) study, that realised UK climate has indeed fallen within the projected scenario range, but this implies the scenario family was 'accurate', not necessarily any single scenario. Thinking of scenario success in terms of predictive skill, forces us to conclusions in which we have to judge one scenario in a family of scenarios as 'better' than the others. And yet all four UKCIP98 scenarios were created through the same construction process and were claimed to be 'equally plausible'.

This problem of retrospectively evaluating the predictive success of multiple scenarios emerging from a single scenario exercise becomes even more acute when the family of scenarios are presented in probabilistic form. This is the approach taken in the forthcoming UKCIP08 national climate scenarios (UKCIP, 2008) and increasingly with other new climate scenario products (e.g. CSIRO, 2007). As long as observed climate reality subsequently falls within the stated scenario probability density function, the probabilistic scenarios can be claimed to have predictive success. This again suggests that falsification is the aim rather than confirmation: scientists learn more if reality falls outside a probability density function than if it falls within it.

3 Decision Success

This criterion of scenario success asks a different question – 'have decisions made on the basis of the scenario(s) subsequently turned out to be 'good' ones?' This is an important question to ask because climate scenarios are increasingly being used to climate-proof multi-million pound infrastructural investments and to develop new risk and resource management strategies. At one level, and as with predictive success, this criterion can only be addressed with the benefit of retrospection. For example, since 1990 the environment ministry in the UK has adopted a recommendation, derived from climate and sea-level scenarios, that a future rate of sea-level rise of 6mm/yr should be incorporated into decisions and designs about coastal defence infrastructure in the UK (MAFF, 1999). Whether such a recommendation has contributed to effective decision-making in the coastal zone can only be assessed with the benefit of hindsight. For example after one, two or more decades one could attempt to evaluate whether new coastal infrastructure thus designed has reduced the economic or social damage caused by coastal flooding. The difficulty is that this question can only be answered on the basis of some counterfactual scenario – what damage would have occurred if the original infrastructure design or decision had *not* incorporated the scenario? This counterfactual question can only be answered quantitatively using models to simulate alternative realities – simulations of unfolding realities with and without the scenario-informed infrastructure.

These methodological difficulties in applying this success criterion as initially stated, leads us to modify our framing of decision success. We instead evaluate climate scenarios by asking the question – 'do the scenarios contain a sufficient representation of knowable climatic uncertainties to offer the prospect that decisions taken in the light of the scenarios will prove to be robust?' The justification for framing the criterion this way emerges from a view of decision-making summarised by Groves and Lempert (2007: 76), 'Robust decision-making proceeds from the observation that decision-makers often manage deep uncertainty by choosing strategies whose good performance is relatively insensitive to poorly characterised uncertainties.' The focus of success here is less on the (retrospective) accuracy of the climate scenario(s) or the (retrospective) efficiency of the decision, but more on establishing an enabling condition for 'good' (robust) decisions to be made; i.e., in which a wide range of relevant uncertainties have been considered.

This appears a more tractable approach to evaluating decision success than dwelling solely on decision outcome. For example, the CCIRG1996 climate scenarios sampled the known uncertainties affecting future UK climate much more narrowly than did the UKCIP02 climate scenarios (see Hulme & Dessai, 2008). This offers an a priori reason for arguing that subsequent decisions made on the basis of the CCIRG1996 scenarios would be less robust than later decisions made on the basis of the UKCIP02 scenarios. Yet we have also shown that in some circumstances the UKCIP02 scenarios may not score very highly on this success criterion (Dessai & Hulme, 2007). Proposed investment decisions for managing drought made by a water company in eastern England solely on the basis of the UKCIP02 scenarios only proved robust to the stated climate uncertainties because of fortuitous circumstances. The climate model underpinning the UKCIP02 scenarios predicted much drier conditions than all the other models that could have been used; investment decisions that had similarly relied on the UKCIP02 scenarios but that related to managing flood risks would not have proved so robust.

4 Learning Success

Both of the above two criteria take an instrumental view of evaluating the success of climate scenarios: did they turn out to be accurate and did they enable robust decisions. Our third suggested success criterion asks a rather different question – 'did the scenarios prove engaging and did they enable learning?' This criterion sits more sympathetically with the view of scenario exercises as, primarily, processes of shared enquiry and mutual learning rather than an emphasis on the practical utility of any tangible scenario products. The justification for this criterion emerges from a view of scenarios summarised by Pulver and VanDeever (2007: 4), '[Scenarios] ... can serve to build networks of individuals linked by common concerns, generate shared understanding, or stabilise interaction between different social worlds.' Rather than using to scenarios to optimise decisions, or even to facilitate robust decisions, this criterion of success emphasises the heuristic, pedagogic and social roles that national climate scenarios can play.

Developing formal metrics of scenario success in this case becomes harder still, but again from the case of the UK climate scenarios we can illustrate some elements that might constitute such a metric. The UKCIP98 scenarios were published shortly after the UK Government established the Climate Impacts Programme to enable a stakeholder-led assessment of nation-wide climate change impacts and adaptation options. As reported by Mackenzie-Hedger et al. (2006: 210), these national climate scenarios helped to engage and consolidate a community of public and private sector organisations wanting to consider climate change in their decision-making ... 'the climate change scenarios have been powerful tools for engagement purposes on their own'. By acting as a shared product, promoted and disseminated through UKCIP acting as a 'boundary organisation' (e.g. Guston, 1999), these scenarios raised awareness, stimulated participation amongst diverse stakeholders and forged a community of learning. In contrast, the previous generation of national climate scenarios - CCIRG96 - pre-dated the formation of UKCIP and were not nearly so successful in establishing wide user engagement. The existence of a boundary organisation to exploit climate scenarios for facilitating social learning at a national scale across very diverse organisations may therefore be a necessary condition for this criterion of scenario success. This reasoning is part of the case made by Miles et al. (2006) for a National Climate Service in the USA.

One metric for evaluating learning success of national climate scenario(s) may therefore be exposure, uptake or usage. The more widely communicated or used a particular set of climate scenarios becomes, the greater the potential for those scenarios to promote social learning amongst strategists or decision-makers. Although a wide range of organisations have used the UKCIP02 climate scenarios for communication purposes or to contribute to strategic or design planning (Gawith et al., submitted). A recent survey of UKCIP stakeholders recently undertaken by Defra showed that over 90 per cent of respondents had made use of the UKCIP02 climate scenarios, the highest uptake of any of the eight surveyed tools and products developed by UKCIP (Defra, 2008). Furthermore, in the judgement of users these climate scenarios exhibited the highest degree of coherence and the most appropriate level of detail of all eight tools and products.

Although usage statistics do perhaps reveal something about the saliency of scenarios amongst stakeholders, on their own they are admittedly a crude measure of learning success. There may remain many organisations that have not used national climate scenarios in any process of learning and mere familiarity with scenarios does not guarantee that organisations assimilate climate change information into their strategic planning of decision-frameworks. Even less does it guarantee that 'good' or more robust decisions result (see section above). The same Defra survey asked respondents to self-evaluate the benefits of the tools and products to their organisation. Over 90 per cent of respondents claimed there were organisational 'benefits' of using the UKCIP02 climate scenarios, and over 50 per cent claimed ‘significant benefits’. These responses were again the highest of all the UKCIP tools and products surveyed. Exactly what these self-evaluated benefits were would need more detailed investigation, but they seem unlikely to be related to our previous two evaluative criteria of predictive or decision success. There is some sense then that in the perception of these stakeholders these climate scenarios have acted to promote awareness-raising, networking and organisational learning.

5 Discussion

Whether one sees the primary value of climate scenarios as products to be used or as processes to be learned from there is no easy way of evaluating their ‘success.’ In this paper we have suggested three different criteria by which scenarios could be evaluated and illustrated their application through the specific example of the four generations of national UK climate scenarios published between 1991 and 2002. We offer three final observations on the value of these different approaches to evaluation.

If national climate scenarios are treated primarily as quantitative products seeking to predict the future we must recognise the limitations to how we evaluate their success. Climate scenarios result from a process of design and construction which always occurs at a particular time and in a specific context. Scenarios as products are ephemeral and are always likely to be displaced by later scenarios. The original CCIRG91 national UK climate scenarios (published in 1991), although projecting climate futures out to 2010, 2030 and 2050, have little use value today. Similarly, the UKCIP02 scenarios (published 2002) are soon to be displaced by the UKCIP08 scenarios (published autumn 2008), and already a new set of scenarios (UKCIPnext) is being contemplated. Even if the CCIRG91 scenarios could somehow be shown to have contained greater predictive skill than UKCIP02, it seems implausible that organisations would want to continue using them given more recent scenario products.

We should also recognise that when applying a criterion of predictive success to scenarios, more is likely to be gained by falsification than by confirmation. If the climatic future turns out differently to that envisaged by a set of scenarios, this offers the prospect of learning what factors in reality were either ignored or not well represented in the scenarios. In the case of national climate scenarios these factors may have two origins. There may be poorly represented physical climate processes in the underlying climate model(s) - for example poor representation of summer convective processes may help explain why UK climate scenarios seem not to have projected the change in summer precipitation that has been observed. There may also be social, economic or technological drivers of greenhouse gas emissions that were poorly understood in the underlying emissions scenarios (this has been shown to be the case in the case of the IPCC Special Report on Emissions Scenarios; Pielke et al., 2008). Evaluating the predictive skill of climate scenarios therefore offers the prospect of learning, although we should beware that the intuitive expectation that learning will progress uniformly over time towards the ‘true’ answer is not always realised (O’Neill et al., 2007). If we consider climate scenarios as products, we suggest that while there can never be a ‘correct’ scenario, ‘incorrect’ climate scenarios can help us better understand physical and social reality.

Our second point emerges from treating climate scenarios as social processes. Here, the retrospectively evaluated predictive success of the scenarios is largely irrelevant, even if their prospectively claimed predictive skill does has value (see below). Instead, we must recognise that social processes of learning are continuous and adaptive. As the relationship between climate change science, society and policy changes, so will the demands, expectations and roles of different social actors in scenario-generating processes. Just as there is no ‘correct’ climate scenario, there is no ‘right’ scenario process. Designing and managing the social processes of climate scenario negotiation and usage is as important and difficult as managing the technical aspects of climate scenario construction.

Finally, we note that there exists a constructive tension between the roles of climate scenarios as products and as processes. By emphasising the status of national climate scenarios as products with scientific credibility, predictive authority and national consistency, it becomes possible to mobilise and entrain social actors and organisations into what subsequently becomes a learning process. This was clearly the case with the UKCIP98 and UKCIP02 scenarios; without the credibility and predictive authority carried by these scenario products, stakeholders would not have been so willing to commit time and resources to engaging with them (Gawith et al., submitted). Yet there is a double irony here. The first irony is that once engaged in a learning process about how climate scenarios are constructed and the uncertainties that they carry, stakeholders appreciate the limited predictive skill that scenarios in fact contain, and also their transience. The second irony that comes out of the learning process is the appreciation that this limited predictive skill is nevertheless not a hindrance to their use. Rather than enabling optimised decisions about the future on the basis of predictive accuracy, scenarios can be used to facilitate robust decision-making on the basis of (represented) predictive uncertainties.

We therefore suggest that using climate scenarios in a social learning process may actually require a degree of illusion about their predictive skill (see Dessai et al., in press) before expectations about what the scenarios offer decision-makers can be more appropriately calibrated. The creative tension is between models that may claim they can predict the climatic future, climate scenarios which reveal that in fact they can't, and robust decisions which are relatively insensitive to this discrepancy. This tension may also exist in other areas of science-policy interactions where model-based scenarios play a salient role in policy deliberations (see Evans, 2008).

The ultimate purpose of scenarios – as originally recognised by Shell in the 1960s - is to bring conceptions of multiple possible futures into deliberations, strategies and decisions that are made today. They are to do so in a structured and coherent way in which one learns as much about how we think we can 'know' the future, as one learns about what that future might be. Climate scenarios are not 'predictions' which describe what will happen, but are to be understood as 'predictive judgements' which describe what could happen (Shearer, 2006: 68). They are best understood as 'boundary objects' (Star & Griesemer, 1989; Shackley & Wynne, 1996) whose ultimate evaluation should be made against multiple criteria – for example the three suggested here - reflecting the different social worlds that national climate scenarios are seeking to stabilise.

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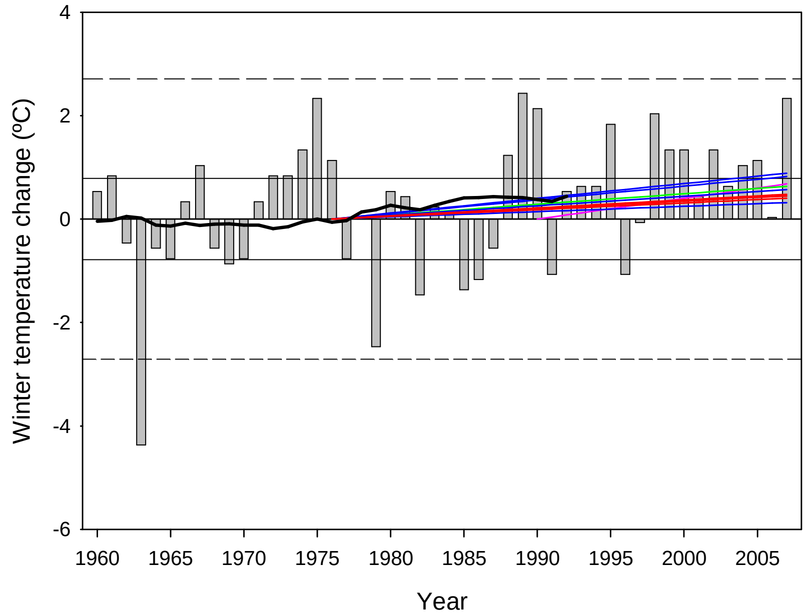

Figure 1: Observed inter-annual changes in winter Central England Temperature from 1960-2007 relative to the 1961-90 mean (grey bars). The observed 30-year overlapping means from 1946-1975 to 1978-2007 are shown in black. UK climate scenario projections are shown in colour: CCIRG91 (pink), CCIRG96 (green), UKCIP98 (blue) and UKCIP02 (red). The thin black horizontal lines represent the bounds of multi-decadal (30-year) natural variability and the dashed horizontal lines represent the bounds of inter-annual natural variability (both defined as ± two standard deviations of the observed record). [From: Dessai & Hulme, submitted]