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Useful global-change scenarios: current issues and challenges

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Abstract

Scenarios are increasingly used to inform global-change debates, but their connection to decisions has been weak and indirect. This reflects the greater number and variety of potential users and scenario needs, relative to other decision domains where scenario use is more established. Global-change scenario needs include common elements, e.g., model-generated projections of emissions and climate change, needed by many users but in different ways and with different assumptions. For these common elements, the limited ability to engage diverse global-change users in scenario development requires extreme transparency in communicating underlying reasoning and assumptions, including probability judgments. Other scenario needs are specific to users, requiring a decentralized network of scenario and assessment organizations to disseminate and interpret common elements and add elements requiring local context or expertise. Such an approach will make global-change scenarios more useful for decisions, but not less controversial. Despite predictable attacks, scenario-based reasoning is necessary for responsible global-change decisions because decision-relevant uncertainties cannot be specified scientifically. The purpose of scenarios is not to avoid speculation, but to make the required speculation more disciplined, more anchored in relevant scientific knowledge when available, and more transparent.

Keywords: scenarios, assessment, global change, climate change, emissions, decision support

1. Introduction to scenarios

A scenario is a description of potential future conditions, developed to inform decision-making under uncertainty (Parson *et al* 2007). Scenarios aid decisions by representing high-stakes uncertainties that cannot be resolved before choices must be made, but are weakly understood—in that they cannot adequately be represented by probability distributions on known parameters, but rather may include the causal factors shaping environmental or socio-economic outcomes, values at issue, or the identity and motivations of other actors who can influence outcomes (Morgan *et al* 1998, Lempert *et al* 2006).

The antecedents of modern scenarios lie in war games, developed as aids for military planning and decision-making, testing of procedures, and officer training (Brewer and Shubik 1979). In the Cold War era, when nuclear weapons raised the stakes and expanded the uncertainties of international conflict, scenarios and related war-game techniques were first applied outside purely military problems, to study potential international crises with linked political and military dimensions. Over the past few decades, scenario use has broadened further to include strategic planning, analysis, and assessment by many businesses and other organizations (Schwartz 1991, Shell International 2003, Van der Heijden 1996). In all these domains, scenarios are used to inform decisions under uncertainty, especially uncertainties resistant to formal analytic methods; to scope and explore weakly understood issues; and to integrate knowledge from diverse domains.

2. Scenarios in global-change applications

Scenarios are also increasingly used to inform debates and decisions relevant to management of long-term environmental

issues, particularly global climate change[1]. Prominent examples of global-change scenarios include those produced by the Inter-governmental Panel on Climate Change (IPCC) (Nakicenovic and Swart 2000), the US National Assessment of impacts of climate change (NAST 2001), the UK Climate Impacts Program (UKCIP 1998), and the Millennium Ecosystem Assessment (MEA 2006). Global change's high stakes and deep uncertainties make the value of scenarios here clear, but their use is complicated by large structural differences between global change and other decision domains where use of scenarios is more thoroughly established and studied.

The most important difference concerns the relationship between scenario producers and potential users. In other domains such as corporate strategic planning, scenario users are usually identified, few in number, and fairly similar in perspectives, often situated within one organization or a few related ones. Users or their representatives can be engaged in key stages of scenario creation and application, to provide input on such matters as relevant choices, high-priority uncertainties and their plausible realizations, and criteria for desirable outcomes. Even if users cannot fully agree on these, they can at least clarify and bound their disagreement. Such user engagement is generally judged essential to effective use of scenarios (Van der Heijden 1996).

By contrast, potential users of global-change scenarios are vast in number and in the variety of their responsibilities, knowledge, objectives, capabilities, and authority. They include such disparate groups as economists analyzing optimal emissions reductions, climate scientists performing model intercomparisons, assessors of regional and local impacts, and planners and officials whose decisions will be affected by climate change, at scales from the local to the global. These potential users embrace profoundly different views of the nature of the problem (including whether there is one at all), the objectives to be pursued, the criteria for desirable outcomes, the range of appropriate and relevant actions, and the locus of relevant authority. In many cases, relevant decisions and users are unidentified or unknown to those creating scenarios.

This breadth of potential uses strongly shapes the characteristics of global-change scenarios and the obstacles to their effectiveness. Understanding its implications can provide guidance for making scenarios more useful, which may diverge from practice in other domains. The rest of this paper reviews major characteristics of current global-change scenarios, assesses how well they serve decisions, and proposes changes to improve their usefulness.

3. Global-change scenarios—major elements of current practice

There are four significant differences between scenarios for global change and in other domains. Global-change scenarios are mostly produced and used within large-scale, official assessments. They are mostly simple, quantitative, model-based, and highlight emissions trends and resultant model-calculated climate change. Their connections to decisions are usually weak and indirect. And they have been subject to sharp public controversy[2].

The most common and prominent instances of production and use of global-change scenarios have been in large-scale official assessments, such as those of the IPCC and other national and international bodies. Assessments are processes that summarize and synthesize scientific knowledge to support decisions (Mitchell *et al* 2006). Although assessments can support decisions in many ways, some of which do not require scenarios, they often include descriptions of how environmental conditions might evolve under alternative assumptions of future human drivers, which do require scenarios. For example, assessments frequently include comparisons of multiple models' projections of future climate change under specified scenarios of future emissions. These model outputs may then serve as climate scenarios to provide input to analyses of sea-level rise, changes in agriculture or ecosystems, or other impacts. Used in this way, scenarios serve as organizing devices to structure and integrate multiple areas of an assessment, linking both to downstream discussions of climate impacts and to upstream discussion of socio-economic and technological conditions consistent with specified emissions trajectories.

Scenario-based results are often the most vivid, concrete, and prominently reported messages from an assessment. They can attract widespread public attention, framing the issue and encoding its basic character and severity in public debates. They thereby escape their creators' control, e.g., in being put to uses their creators did not foresee and cannot influence, even to assure that all linked elements, assumptions, and qualifying explanations are conveyed and understood.

The characteristics of global-change scenarios are strongly shaped by their production and use in assessments. Although scenarios could serve diverse decisions by focusing on many environmental or socio-economic conditions, they usually highlight emissions and modeled climate change, the elements that assessments specifically need. Although the models used to produce emissions scenarios often involve sophisticated representations of economic structures and energy technologies, this complexity is not evident in the trajectories of emissions and a few aggregate socio-economic indicators that are the main disseminated outputs of scenarios. Scenarios are usually global in scale, with detail limited to major world regions[3], the scale of responsibility and assembled expertise of the assessments that produce them. This scale influences what characteristics scenarios include, favoring variables that aggregate easily over those whose specification and interpretation depend on local knowledge or context.

Relative to scenarios in other domains, global-change scenarios highlight quantitative elements, usually produced by formal models or drawn from authoritative external sources.

[1] Any scenarios constructed with this purpose will be referred to here as 'global-change scenarios', no matter what mix of socio-economic and bio-physical conditions they describe.

[2] This analysis reflects the collective judgment of the author team of the CSSP study of global-change scenarios, led by the author (Parson *et al* 2007).

[3] Scenarios whose spatial scale and resolution are fixed by models generating them, such as global climate models, are an exception.

Qualitative and narrative elements, if present at all, are less developed, less prominently reported, and only weakly linked to quantitative elements. Even when scenario exercises have begun with narrative scenarios, these have faded in significance as the exercise proceeded. This tendency may be explained by two aspects of the assessments that produce and use scenarios. First, assessments undergo intensive review processes closely modeled on scientific peer review. Scenarios that appear more scientific in character and are more familiar to participants and reviewers pose fewer risks in such a review process. On the other hand, assessments are not usually linked to any specific decision or decision-maker, despite their mandate to inform decision-making in general. While experience in other domains suggests users want scenarios to include uncertainties that can only be represented in qualitative or narrative terms, the weak relationship to particular users means that such preferences find little voice in global-change scenario exercises. Rather, the capabilities, needs, and familiar methods of scenario producers, usually quantitatively oriented analysts and modelers, are likely to dominate. There have even been challenges in scenarios meeting the needs of other modelers within the assessment process who need scenario inputs—the one type of user specifically identified to scenario developers (Parson *et al* 2007, Hulme 2008).

4. Global-change decision-makers and their scenario needs

Thus far, the connections of scenarios to practical decisions managing global-change issues have been weak and indirect. This reflects no particular failure of scenario efforts, as it follows from the primary use of scenarios in assessments—themselves usually unconnected to specific decisions—and the early state of decision agendas. But decision agendas are advancing rapidly. Proposals to limit emissions are being proposed in many jurisdictions, and managers in many climate-sensitive sectors such as water, forests, and coastal zones now see the need to consider climate in long-range planning and management. It is thus necessary to ask how well scenarios serve decisions now or soon on multiple actors' agendas, and how their utility can be improved.

To do this, in view of the variety of global-change decisions, it is first necessary to disaggregate. A preliminary taxonomy would distinguish three types of decision-makers, with distinct responsibilities, uncertainties of concern, and scenario needs: impacts and adaptation managers, national officials, and energy resource and technology managers.

Impacts and adaptation managers have responsibility for particular assets, resources, or interests sensitive to climate. They need scenarios of future climate change, its impacts in their areas of concern, and factors shaping their vulnerabilities. Particular actors' needs will be highly specific in the characteristics and scale specified. A water-system planner may need monthly or finer-scale rain and snow projections over a watershed, while a coastal planner may need probabilistic projections of sea level, storm intensity and surge, or saltwater intrusion. These all depend, of course, on a common core of emissions and climate scenarios, modified by whatever mitigation efforts are judged likely. It is for this group that the most effort has been made to provide useful scenarios. Substantial progress has been made in providing climate information, through datasets and tools to downscale model results to impact-relevant scales (e.g., Scheraga 2008), but other needs—e.g., scenarios of socio-economic conditions relevant to vulnerability, and methods to integrate climate with other variables, including local ones—are not well met.

National policy-makers have both adaptation and mitigation responsibilities. For adaptation decisions, their scenario needs are similar to those discussed above, aggregated to national scale. For mitigation decisions, however, in addition to climate change and national impacts under specified emissions, they need scenarios of the economic and political environment of their mitigation choices. This includes fine-scale description of emissions trends in their jurisdictions; socio-economic factors that influence emissions and the cost and effectiveness of mitigation measures; and the external political and economic setting for their choices, including actions of other nations. While some jurisdictions adopting mitigation targets have produced baseline emissions projections from which effects of policies are measured, there are as yet no published scenarios that present such broader context for mitigation choices, including such factors as disaggregated emissions trends, determinants of mitigation effectiveness, external policy context, or examination of major uncertainties.

Energy and technology managers, mostly in the private sector, include resource producers, investors in energy-dependent capital such as electrical utilities, and innovators and investors in energy technologies. For these actors, the key uncertainties are climate-change policies in force over the life of proposed investments and research programs, rather than climate change itself. They need scenarios of alternative market conditions, technological uncertainties, and policy regimes, to assess effects on the value of energy and technology assets. As is the case for national mitigation decisions, there are presently no published scenarios providing such information—although in this case, decision-makers may not wish to publicize scenarios being used to guide their strategies.

How well do present global-change scenarios meet these needs? Their primary contents—global and major-region emissions, plus resultant model-generated climate change—are widely needed by decision-makers, including most or all impact managers and national officials, and likely to remain so. But while many users need these core elements, they need them in different ways for different purposes. Some need alternative emissions baselines with no incremental mitigation effort, judged to be low, middle, high, or some extreme 'worst-case'. Others need similar scenarios modified by alternative levels of mitigation effort. For example, impact managers may wish to embed some assumed distribution of likely mitigation in their climate scenarios, giving a narrower range of emissions futures than would be considered by those responsible for choosing levels of mitigation. Still other users may need simple standard emissions scenarios as inputs to climate-model intercomparisons, or specified reduction targets as starting points for back-casting or feasibility analysis. Some users

may need scenarios reflecting a wider range than presently considered of socio-economic conditions relevant to emissions and mitigation capacity, including unfavorable futures such as development failures, extended global recessions, or breakdowns of international cooperation.

Moreover, for no users do these core variables meet all scenario needs. Describing key uncertainties will require additional characteristics, which may be described qualitatively, unavailable as model outputs, and drawn from multiple knowledge domains including local sources and users. Some users, such as energy managers assessing investment strategies, may wish to develop these additional scenario elements confidentially.

5. More useful scenarios: transparency can substitute for representation

The variety of decision-makers' scenario needs calls for a re-examination of standard practice in what goes into scenarios and how they are produced, including the canon that users should be intensively engaged in key stages of scenario development. When feasible, such engagement ensures that scenarios are useful, and that assumptions and values embedded in them are understood and accepted by users. Even in global-change settings, such engagement is valuable when scenarios serve an identified, sufficiently homogeneous group of decision-makers, such as those responsible for managing some specific area of impact or managers of a particular set of energy investments.

But for widely used emissions and climate scenarios, such engagement is usually infeasible. Users are too diverse to engage an adequately representative group, while involving a few who are available or known risks biasing scenarios toward their perspectives and interests. But without such engagement, how are users to understand what each scenario means, how closely its assumptions match their needs, and how they might use it? The only alternative is for developers to provide fully detailed and explicit accounts of scenarios' underlying reasoning and assumptions, so users can understand them, revise them if they wish, and make an informed choice whether and how to use them. While such transparency in scenarios is widely advocated, it is rarely achieved, perhaps because communicating such extreme detail is difficult, laborious, and sometimes contentious and embarrassing. But allowing users to make informed choices, and empowering them to augment centrally provided scenario elements with additional information they judge necessary, requires such a 'traceable account' of how each scenario was produced, including areas of weakness, low confidence, and disagreement.

A particularly controversial area for such transparency is the uncertainty judgments that underlie the presentation of a set of scenarios. Developers commonly present a few scenarios with no information about their judgments of associated probabilities. This practice, developed in domains where scenarios include major qualitative elements and users are involved in scenario development, has been transferred to global change, where these conditions usually do not hold—in particular, where most the most prominent scenario output is often a set of emissions trajectories. Scenario teams have declined to answer even such seemingly simple questions as whether they judge emissions more likely to lie in the middle than at the ends of the envelope of all scenarios, and how likely they are to lie outside the envelope entirely. Instead, they have characterized the meaning of scenarios in opaque terms, e.g., that scenarios in a set are 'all plausible' or 'equally sound'. This approach has been criticized for concealing probabilistic reasoning that must underlie the decision to identify a scenario with a particular emissions trajectory or to identify a particular scenario as 'sound' or 'plausible', and for failing to provide information that some users need.

In other domains, the arguments for avoiding explicit probability judgments are strong: such judgments are technically intractable for complex or qualitative scenarios, and users involved in scenario creation are unlikely to need them. But these arguments have less force for global change, where it is feasible to provide such judgments for relevant emissions ranges spanned by scenarios, and the vast pool of potential users needs such explicit, structured communication devices. In addition to advancing the general goal of transparency in scenario reasoning and assumptions, the attempt to articulate explicit probability judgments may help focus and deepen deliberations even when users are engaged. But the strongest reason for explicit probability judgments is that they can aid inclusion of extremes or worst-cases in publicly conveyed scenarios. A striking weakness of current practice is that scenarios rarely consider extremes, although these are often of greatest importance to decision-makers. For example, no public scenarios have examined world development failure and growing inequity to support analysis of how such dismal trends would effect emissions and the ability to reduce them. Similarly, sea-level rise scenarios in the most recent IPCC assessment explicitly excluded the possibility of loss of a major ice sheet. Such extremes are normally avoided because without explicit probability information to convey their special status as unlikely extremes, their mere inclusion risks making them appear likely. Explicit probability judgments can allow consideration of such tails of the distribution with less risk that they dominate decision-making.

6. More useful scenarios: a cross-scale scenario and assessment network

The diversity of users' needs from scenarios, with some widely shared and some highly diverse elements, also calls for a new approach to the processes of generating and using global-change scenarios. The core emissions and climate-change elements needed by many users are best provided through centralized national or international processes, which can provide required technical and modeling expertise, high-cost resources, and consistency of reasoning and assumptions across scenarios and regions. The process can rely on specially convened groups as in past exercises, or solicitation of independently produced scenarios meeting standards of transparency and documentation, as now proposed—with

either process providing the broader range of socio-economic assumptions and the greater transparency discussed above.

Beyond these common elements, scenario needs are so unique to their specific responsibilities and contexts that no central process can meet them all. These centralized processes must be augmented by a network of decentralized assessment and scenario capabilities, which can draw on and interpret centrally provided scenario elements, models, and methods, and link them to local expertise, context, and needs to support assessments and decision-making in diverse setting and at diverse scales. The US agricultural extension system has been proposed as a potential model for the mix of centralized and distributed expertise, resources, and responsibilities in such a cross-scale network (Cash 2000).

7. Conclusion: the need for scenarios, their challenge to public debate

Responsible decision-making on global-change issues requires scenario-based reasoning. The alternative to scenarios, which stipulate assumptions about key uncertainties explicitly, is to make implicit, unexamined assumptions about future conditions—often that they will resemble the present. This is not likely to produce better decisions. The main alternative approaches proposed for global-change decisions—e.g., seeking decision strategies that are robust to major uncertainties, and constructing pictures of desired future conditions and examining how to get there—do not avoid the need to specify relevant future trends.

Changes to global-change scenario practice such as are proposed here are likely to make scenarios more useful for decision-making. They are not likely, however, to make scenarios less controversial or less subject to attacks like those leveled against scenarios in the IPCC and the US National Assessment. Global-change scenarios are controversial because they are powerful public framers of the issue, and because they act as proxies for the need to take action. Political actors with strong views on desired action have an interest in attacking scenarios that challenge their preferred course. Consequently, opponents of emission limits attack high-growth scenarios as biased or unrealistic and highlight low-growth ones, while proponents of limits do the opposite. It is easy to attack a scenario, by selecting one scenario in isolation, exaggerating its predictive intent, describing it as 'speculative' or 'unscientific', and digging into its details to find elements that appear implausible or erroneous—which can usually be found.

Defending scenarios against such attacks is more difficult. In doing so, it is important to avoid the temptation to deny or suppress scenarios' inevitably speculative character. Doing so by highlighting scenarios' quantitative and seemingly scientific elements in their creation makes them less useful, and risks disguising the assumptions and judgments that must be made in scenarios as technical matters subject to scientific resolution. Doing so is also futile, because those attacking a scenario can easily demonstrate how its plausibility ultimately rests on its creators' judgments.

Rather, a more effective and honest response requires refocusing on sets of scenarios to represent key uncertainties, explaining that such assumptions are required for responsible decision-making under uncertainty, and—hardest of all—conveying that calling scenarios 'speculative' or 'unscientific' is correct, but beside the point. Scenarios stipulate future conditions that science cannot specify, so they always blend knowledge with judgment and speculation. Such a program of political and public education is not easy, but is necessary. Its basic message is that scenario-based reasoning is not an alternative to speculation. It is an approach that seeks to make speculation more disciplined, more anchored to scientific knowledge where it is available, and more transparent, which is essential to informing global-change decision-making.

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