4. Issues, Challenges, and Controversies in Climate-Change Scenarios

This section draws out several general issues that have been present in climate change scenario exercises thus far, and that pose challenges for expanding the usefulness of scenarios to climate change analysis, assessment, and decision support.

4.1. Scenarios and Decisions

As discussed in Section 1, the general purpose of scenarios is to inform decisions, but their connection to specific identified decisions can be more or less close and direct. In interpreting and evaluating present experience with scenarios and identifying key challenges in making them more useful, it is important to distinguish scenario exercises by their major characteristics, including their specificity, their proximity to decisions, the degree of normative presumptions embedded in them, and where they lie in the causal chain outlined in Section 2.

To consider how scenarios can help inform climate-change decisions, we must first specify more sharply the types of decisions that comprise a response to climate change, who makes them, and in what environment – i.e., with what responsibilities, authority, resources, and concerns. These issues carry implications for what benefits scenarios can offer, and how they might be designed and what information they might represent to most effectively provide those benefits. In this section we consider the major concrete decisions that comprise the societal response to climate change. Decisions that pertain to assessment, modeling, and research are considered in Section 4.2. Since development of the decision agenda for climate change remains at a relatively early stage, this discussion must be somewhat hypothetical, extending from rather thin current practice to reasonable speculation about future decisions and likely information needs.

A basic fact about climate-change decision-making is that there is no single global climate-change decision-maker. Because the dynamics of climate change operate on multiple spatial scales from the local to the global, it is not subject to unitary or coordinated decision-making. Rather, a large number of decision-makers with diverse responsibilities will affect and be affected by climate change. Because of climate's recent appearance on policy agendas and its dense connections to other issues, many of these decision-makers' primary responsibilities are defined as something other than climate change. Some of them are already considering how climate change might affect their responsibilities, but many are not.

In Section 2 we described climate-change decisions using the conventional dichotomy of mitigation versus adaptation. To consider potential contributions of scenarios in more detail, we propose a three-way division of these decisions based on three types of decision-maker, dividing them into three groups, whom we call *national officials*, *impacts and adaptation managers*, and *energy resource and technology managers*. These can often be identified as particular programs, divisions, agencies, organizations, or individuals, and can be distinguished from each other by the nature of their responsibilities and types of information they might consider in making their decisions. All three groups face decisions under uncertainty with long-term consequences related to climate change, and so might benefit from scenarios providing structured information and assumptions about the values at stake, the available choices, and their consequences under alternative climate-change futures.

National officials' responsibilities are the broadest, and the most likely to be explicitly identified as related to climate change. They develop national policies on greenhouse-gas emissions, including both regulations and incentives that influence emissions directly, and policies to motivate investment in technologies that will influence future emissions trends. They negotiate policies internationally with officials from other nations, and with sub-national officials who may share mitigation responsibilities or undertake mitigation measures at their own initiative. They also have responsibilities to anticipate and respond to climate-change impacts in their nations. Their climate-change responsibilities are open-ended, and not limited to mitigation and adaptation: to the extent that other responses such as geoengineering are considered, or design of systems and institutions for assessment, it will mostly be national officials, acting domestically or negotiating internationally, who make those decisions. They are also responsible for overall national welfare, including not just the environmental effects of their decisions but also other national interests such as economic prosperity and security, so their climate-change decisions may be linked with these other responsibilities.

Impacts and adaptation managers have responsibility for particular assets, resources, or interests that might be sensitive to climate change. They must decide how to anticipate, prepare for, and respond to the threat, minimize its harm, and maximize any associated benefit. These may be private or public actors – e.g., owners or managers of long-lived assets such as ports or water-management facilities; managers of lands, forests, or protected areas; emergency preparedness or public health officials; officials making zoning or coastal development policy; or firms in insurance or financial markets who may bear secondary risks from impacts or seek to develop new instruments to exchange these risks. Unlike national officials, these actors' decisions are purely *responses* to climate change, realized or anticipated: they have little influence over how the climate will change. Their responsibilities will often connect with the impacts-related responsibilities of national officials, but are narrower and more specific in spatial scale or sectoral scope. Impacts and adaptation managers would be concerned not with aggregate climate-change impacts on the United States, but with more specific impacts such as those on seasonal flows and water-management operations on the Upper Mississippi.

Energy resource and technology managers include developers and operators of fossil or non-fossil energy resources, investors in long-lived energy-dependent capital stock such as electrical utilities, and researchers, innovators, and investors in new energy-related technologies. These decision-makers are mostly but not exclusively in the private sector. Their decisions may have consequences that interact with various processes operating over multiple time-scales, from short-term market responses, to decadal-scale processes of investment, resource development and depletion, and penetration of new technologies, to century-scale processes of climate change.[171] These actors' decisions will strongly influence society's ability to control greenhouse-gas emissions and consequently the effectiveness and cost of mitigation policies. This group also includes energy consumers such as firms or public agencies considering mitigation actions in their own operations. While their areas of responsibility may in some cases be vulnerable to

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[171] Shell International 2001; Davis 2003.

climate change and its impacts, the largest climate-related threats or opportunities for this group are likely to come not from climate change itself, but from climate-change policies, particularly national mitigation policies, as well as other market and regulatory decisions that will determine the outcomes of private mitigation activities.

At greatly varying levels of precision and specificity depending on the state of relevant knowledge, scenarios can present two types of information to support decisions by these actors. Scenarios can represent potential future developments that may threaten decision-makers' interests or values, call for decisions, or challenge conventional thinking and practices. And they can provide a structure to assess potential consequences of alternative decisions for things that matter to the decision-maker. Beyond this generality, the three types of decision-makers differ substantially in the types of information they need, the time horizons of their decisions, and the type and extent of causal connections between their decisions and the conditions specified in scenarios.

Scenario Needs: National Officials

As national officials have the broadest responsibilities related to climate change, they are also likely to have the broadest information needs. In their responsibilities to build national adaptation capacity and manage key vulnerabilities, their needs are similar to those of impacts and adaptation managers: scenarios of potential future climate change under specified emissions assumptions, and resultant impacts on particular resources and communities in their nation, with particular focus on areas of greatest vulnerability. They will likely have less need for fine spatial and sectoral detail in potential impacts, but more need for consistent scenarios that allow comparison and aggregation across sub-national regions and sectors. These will help to prioritize, identify key areas of vulnerability, and estimate aggregate costs for planning purposes.

In their responsibilities for national mitigation policy, national decision-makers will also need information about the aggregate impacts of climate change, since the more severe climate impacts are likely to be, the greater the justification and likely political support for mitigation measures. But mitigation decisions also require additional information – including projections of future emissions in the absence of explicit mitigation efforts, and the consequences of alternative mitigation policies, in their effects on emissions, their cost, and their implications for other dimensions of national interest.

These needs introduce a dimension of complexity into mitigation scenarios, sometimes called "reflexivity," that is not present in scenarios for impacts and adaptation. Because mitigation policies seek to reduce future emissions by altering the socio-economic drivers of emissions growth, the analysis of mitigation policies and their consequences must be coupled to the causal logic of emissions scenarios. Whereas climate scenarios can be treated as exogenous when assessing adaptation decisions, emissions scenarios cannot be treated as exogenous in assessing mitigation decisions. Any emissions scenario embeds some assumptions about mitigation policies, which may have to be changed to assess particular mitigation policies. This effect will be strongest when emissions projections and mitigation options are being considered at the same spatial scale, e.g., national mitigation policies are being assessed relative to national emissions projections. The effect of national mitigation strategies on global emissions will be weaker: no nation controls global emissions trends, and the effects of small nations' mitigation strategies on global trends can be very small.

Scenarios to inform mitigation decisions are also likely to require considering alternative assumptions about the policy context in which these decisions are made. The effects of national mitigation strategies – including how much they reduce national emissions, as well as their costs and other consequences – will depend on the economic, technological, and policy context, including related decisions by other major nations, individually and through international coordination. These may be among the most important factors determining the consequences of national mitigation policies. Assumptions about the policy context will be less important in scenarios to inform international mitigation decisions, since when decisions are globally coordinated there is no "elsewhere" – but alternative assumptions about nations' degrees of compliance and form of implementation of international commitments may still be needed.

Scenarios of emissions, climate change, and impacts inform mitigation decisions by helping to characterize the potential severity of climate change and therefore how important it is to control emissions. This support is indirect, serving primarily to elevate or moderate the general level of concern on the issue. More focused work on mitigation has been done using constructed scenarios of limited emissions, often aiming at stabilizing atmospheric concentrations at various levels, and examining the configurations of technology, energy resources, and economic and population growth that are consistent with the specified scenario. Some studies have used quantitative models to estimate costs of such scenarios, relative to an assumed baseline emissions scenario.[172]

Scenario Needs: Impacts and Adaptation Managers

Of the three, impacts and adaptation managers are the group for whom the most effort has been made to provide useful scenarios, and the most has been achieved. To assess the threats and opportunities they face and evaluate responses, these decision-makers need scenarios of potential future climate change, its impacts in their areas of responsibility, and the factors that influence vulnerabilities. With few exceptions, these actors' decisions will have no effect on the climate change to which their decisions must respond, so scenarios of climate-change stresses can be constructed independently of assessment of potential decisions, without concern for feedbacks by which the decisions may require modifying the conditions specified in the scenario.

Particular decision-makers' needs will be highly specific in the variables they require, and their time and space scale and resolution. A planner of water-management infrastructure may need monthly or finer-scale rain and snow projections over their watershed; a designer of coastal infrastructure may need probabilistic projections of specific characteristics related to sea level, storm intensity and frequency, storm surge, or saltwater intrusion. But in their climatic elements, these information needs all rest on a common core of scenarios of global climate change and emissions drivers. This dual structure of information – highly particular climate variables, based on a set of common 'core scenarios' – suggests a cross-scale organizational structure for providing scenario information: commonly produced scenarios of climate change

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[172] Morita et al 2001; CCSP SAP 2.1a.

and other components requiring consistency, specialized expertise, or high-cost resources; development of decentralized capabilities in impact assessments to adopt these core scenario elements and develop assessment-specific extensions; and close communication between these groups to ensure that useful variables are generated and saved, and that information and documentation are transferred accurately.

This is the area of climate-related decisions for which the provision of information from climate-change scenarios is most advanced. Still, further progress is needed in the development and use of scenarios of socio-economic conditions, and in creation of methods and tools to augment centrally provided scenario information with information tailored to specific impact assessments and support for related decisions. In addition, for many if not most areas of impacts, there are likely to be important interactions between climate change and other changes and stresses affecting decision-making over the same time period, requiring scenarios of multiple stresses that represent potential climate change in the context of other important and linked dimensions of change, such as population growth and development.

Scenario Needs: Energy Resource and Technology Managers

The consequences of decisions by energy and technology managers will predominantly be influenced by the mitigation policies in effect, nationally and internationally, over the lifetime of the relevant investments. Consequently, these actors will most benefit from scenarios that explore alternative policy regimes and their consequences for the value of energy and technology assets. For some, the predominant concern may be overall policy stringency, perhaps summarized as alternative emissions-price trajectories over time; for others, specific details of policy design and implementation may need to be considered in scenarios. Scenarios of emissions, climate change, and impacts, are largely background information for these actors – factors that only matter for decisions via their likely influence on policy stringency, and so that do not need to be explicitly represented in scenarios. These actors may be in a position to exercise some influence over policy, but they do not make it and their influence is unlikely to be so strong that climate-policy scenarios would have to incorporate feedbacks from their own advocacy efforts.

Unlike the other two types of decision-makers we have distinguished, these actors are likely to be in competitive relationships with each other. If, for example, they are investors allocating research effort between higher and lower-emitting energy sources, those who better anticipate future policy will benefit relative to those who do worse. If these actors use scenarios to help inform their planning and decision-making, they may consequently choose to produce them privately. Effective scenarios over the relevant time scales can connect, with some intermediate analysis, to practical guidelines for investments.[173] As for the other types of decision-makers, these specialized scenarios could be based on general scenarios of global emissions and climate change. Several prominent emissions scenarios including SRES have explicitly excluded consideration of mitigation policies. When these are included, they have typically been formulated at a high level of abstraction and generality. The most specific exploration of mitigation policies in scenarios have been in exercises such as post-SRES and

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[173] Ged Davis, personal communication. (posted expert review comments).

2.1a that have identified trajectories consistent with various levels of atmospheric stabilization, but these have not posed the questions about what stringency, timing, and form of mitigation policies are plausible or likely.

Representing Decisions in Scenarios

A serious challenge that arises in attempts to develop scenarios to support all types of decision concerns how to represent decisions within scenarios – a challenge that is often referred to as "reflexivity." To avoid scenarios that are either circular or contradictory, the most basic distinction to draw is between decisions by the scenario's targeted users and decisions by other actors. From the users' perspective, decisions by others over which they have no influence are indistinguishable from non-choice events. If the factors influencing these decisions are confidently understood, they might be represented deterministically, just like well understood biophysical or economic processes. In the more likely event that others' choices cannot be confidently predicted, they might be represented as uncertainties – again, just like an uncertain biophysical or economic process. As with all uncertainties, how to treat them depends on judgments of their importance for the users' decisions: if they are of the highest importance, they can be represented in alternative scenarios; if not, they can be fixed at some best-guess value for all scenarios. In either case, these decisions are treated as exogenous uncertainties.

The representation of decisions by scenario users is fundamentally different. Since these are assumed to be under the users' control and the scenarios are intended to inform their choice, these should not be represented as exogenous uncertainties within the scenarios. Rather, alternative choices should be stipulated independently from the scenarios. Users can then explore their implications under challenges and boundary conditions imposed by scenarios that include representation of the most important uncertainties. Various degrees of coupling can be required between the logic of scenarios and the analysis of consequences of the users' decisions: in scenarios for impacts, these can usually be separate; in scenarios for mitigation, they may have to be closely coupled, since emissions scenarios may change under alternative mitigation assumptions.

For global climate scenarios, the question of how to represent decisions arises most acutely in deciding how to represent mitigation decisions. Following the general reasoning above, treatment of these should depend on what type of decisions is being informed. In climate scenarios to inform impact assessments and related decisions, scenario users are not considering mitigation decisions and likely have little influence over them, so emissions scenarios should include assumptions about the likely or plausible range of mitigation efforts. In estimating this range the possibility must be considered that it may be truncated if sustained rapid emissions growth generates future political pressure for aggressive mitigation – e.g., due to increasing signs of climate change, alarming projections of future change, or other environmental harms from rapid expansion of coal or synthetic fuels.

It is not assured that such a negative-feedback mechanism will be effective, of course. Many factors could intervene: mitigation measures may not gain enough support to be adopted; socio-political capacity to enact stringent policies may be diminished; policies adopted may be ineffective; or early technology or policy decisions may unwittingly create lock-ins to highemitting future paths. But to the extent that such a negative-feedback mechanism does operate, persistence of the highest emissions paths beyond a few decades would become unlikely.

Parallel reasoning may apply to extremely low emission paths, if sustaining such low emissions requires continued costly mitigation efforts that come to be perceived as unnecessary. This negative-feedback mechanism will likely be weaker than that operating at the high end of the emissions distribution, however, because long time-constants mean that increasing signs of climate change are likely to continue through most of the 21st century even if we follow a low-emissions path. If impacts assessors and managers judge these negative feedbacks to make extreme emissions paths sufficiently unlikely, particularly high ones, they may reasonably decide not to consider these extreme emissions futures in their planning for adaptation.

For scenarios developed to inform mitigation decisions, particularly at the international level, the situation is different. Informing these choices requires information about potential emissions paths and their consequences under all levels of mitigation effort that decision-makers might plausibly consider – including no additional measures, or even reversal of previous measures if these are on the agenda. Consequently, while extreme emissions futures should be excluded in scenarios for impacts based on negative mitigation-policy feedbacks, these should not be excluded when assessing mitigation decisions. If scenarios that truncate high-emissions futures based on assumed stringent mitigation efforts are used to support a decision that stringent mitigation is not necessary, the decision is based, contradictorily, on the presumption of the contrary decision. If the scenarios are to inform mitigation decisions, these decisions must be considered explicitly, not presumed in the underlying logic of the scenario.

This argument is complicated by the fact that no single actor controls emissions and mitigation strategy, either over the whole world or over the entire time horizon considered. National officials choose only for their own nations in the near term. Even when they negotiate global mitigation, they only act for the near term. They may view their responsibilities to include long-term planning and institutional design for future mitigation as well, but their successors will decide whether to continue, strengthen, or otherwise change mitigation measures adopted today, or adopt new ones. From the perspective of current national officials, mitigation decisions by other nations and in the future fall between the two cases discussed above: they are not controlled by the scenario user, but can be influenced to some degree. For policy choices by other nations, national officials may need to be advised in two modes, reflecting their dual responsibilities to make national policy and to negotiate international agreements. In the latter capacity, alternative approaches to global mitigation strategy should be represented as choices. But when they consider national decisions separate from or in the absence of a globally coordinated strategy, relevant decisions of other major nations should be represented as uncertainties. This may require use of two distinct types of scenarios to advise development of different aspects of national mitigation policy.

How to represent future mitigation decisions poses a still harder dilemma. On the one hand, it appears risky or even irresponsible to assume that the bulk of mitigation efforts can be left to future decision-makers, perhaps based on the assumption that increased wealth or technological prowess will make it easy for them to do so. On the other hand, assuming that future decision-makers cannot be relied on to act responsibly at all can easily lead to decisions that incur excessive costs, by trying to achieve rapid mitigation immediately or tie future decision-makers' hands.

Two approaches appear promising for integrating future mitigation decisions into scenarios to inform current decisions. Scenarios could presume that today's decision-makers choose the future path of mitigation, allowing them to assess and contribute to a trajectory of effort that considers the welfare of both current and future citizens. Alternatively, scenarios could treat future large-scale mitigation choices as uncertainties represented in alternative scenarios, while also considering how current choices can seek to influence the opportunities and incentives faced by future decision-makers. Whatever assumption about future policy decisions is made for purposes of developing scenarios, however, actual current policy should seek to develop institutions and procedures that allow future adaptations in response to changes in knowledge and capabilities.

To summarize the current state of scenario use for mitigation and adaptation decisions, the importance of connecting the two is widely recognized and their use is growing, but not much is yet realized or fully developed. There is a large gap between, on the one hand, the widely recognized value that scenarios could provide to climate-change decisions and the aspirations of those producing scenarios to provide that value, and current practice on the other hand. There has been little use of scenarios to directly inform climate-change related decisions, although there appears to be a sharp increase in the interest of decision-makers and early attempts. This rapid increase is particularly evident for informing decisions related to climate-change impacts and adaptation. There are fewer indications of similarly direct use of scenarios to inform mitigation decisions, perhaps in part because nearly all current mitigation decisions have been near-term.

Mitigation decisions at the national and international level have taken scenarios into account indirectly. Most scenarios have been constructed to provide inputs to assessments, models, or other analyses. This has included serving as inputs to the production of other types of scenarios, which then describe other potential future conditions that depend on those specified in the scenario, as for example a model-based climate scenario depends on inputs from an emissions scenario. While these uses can be characterized as supporting decisions (i.e., decisions about assessments, modeling, and research), their connection to concrete decisions of mitigation and adaptation is indirect, achieved through contributions such as supporting strategic planning and risk assessment, providing advance analysis for potential future decisions, exploring plausible extreme cases, helping to characterize and prioritize key uncertainties, or educating decision-makers or the public about present knowledge and uncertainty. The major scenario exercises discussed in this report fall into this category, including the IPCC emissions and climate scenarios, the US and UK assessments of climate impacts, and the Millennium Assessment scenarios.

BOX 4.1.1:
Scenarios for Climate-Change Adaptation in the New York Metropolitan Region

Three linked activities – the Metropolitan East Coast (MEC) assessment of the US National Assessment, the New York Climate and Health project (NYCHP), and the New York City Department of Environmental Protection (NYCDEP) Task Force on Climate Change – have used or are using scenarios to assess impacts of climate change on the New York Metropolitan Region, identify areas of vulnerability, and inform regional planning and decision-making.[174]

The MEC assessment laid the foundation for agencies in the region to address climate change and consider both adaptation and mitigation responses. The assessment began with a regional workshop in April, 1998 involving about 150 participants, including representatives of public agencies at the municipal, regional, state, and federal levels as well as climate researchers from the region. The workshop provided direction for the subsequent assessment, conducted by sector teams of researchers and officials from public agencies responsible for the study sectors. Teams developed regional scenarios of climate change and sea level rise based on the downscaled climate-model scenarios provided by the US National Assessment, plus two additional scenarios based on projection of recent regional climate trends and historical extreme events. The MEC scenarios were used to project climate-change impacts on beach nourishment, 100 and 500-year flood heights, wetland aggregation and loss, adequacy of the water supply system under droughts and floods, illnesses from acute air-pollution episodes, and peak energy loads. These impact projections in turn were used for preliminary assessment of adaptation strategies and policies.

Following the MEC Assessment, the New York Climate and Health Project developed updated climate scenarios for the region in consultation with an Advisory Board of public and private stakeholders and scientists. This study further analyzed public health impacts, focusing specifically on the effects of ozone air quality and extreme heat events. The updated climate scenarios used the IPCC A2 and B2 emissions scenarios driving a global climate model and a regional climate model to create down-scaled scenarios for the region. These were augmented with newly developed scenarios of future regional land use and population growth based on the IPCC A2 and B2 storylines, to support modeling and analysis of public-health impacts.

In response to the widespread public attention received by the MEC Assessment Report, the Commissioner of the NYCDEP established the Climate Change Task Force, a collaboration between regional researchers and the agency that manages the water system. The Task Force is using the latest climate-model simulations from the IPCC Fourth Assessment Report, as well as additional global and regional climate models, to develop new regional scenarios. These will include model-based probability distributions of average and extreme temperature and precipitation change, as well as sea-level rise. The Task Force is also developing qualitative scenarios of extreme sea level rise in the region, based on collapse of the West Antarctic and Greenland ice sheets and modification of the thermohaline circulation. DEP is using results of the Task Force study to develop a comprehensive adaptation strategy for the New York City water system, including assessment of many specific adaptation options, that considers both uncertainties in future climate change and managerial factors such as the time horizon of different adaptation responses and capital turnover cycles.

These activities provide a successful example of scenario-based assessment of climate impacts and adaptation options. The scenarios are connected with the concrete responsibilities and concerns of stakeholders, who were involved in their design from the outset. Although officials have found the wide range of uncertainty in climate scenarios difficult to incorporate into infrastructure design specifications,

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[174] Rosenzweig and Solecki, 2001; Kinney et al., 2005; Rosenzweig et al., 2005.

particularly for precipitation, the exercise has effectively conveyed the challenges posed by future climate uncertainty to current decisions of planning and infrastructure design. That stakeholders have been willing to support and participate in three separate phases of these activities, and that NYCDEP has decided to incorporate them into a strategic planning exercise, provides clear evidence of the practical utility of the exercises.

Box 4.1.2.
Scenarios of Sea Level Rise along the Gulf Coast

Sea-level rise is one of several factors that contributed to the decline of coastal ecosystems along the U.S. Gulf of Mexico coast in the 20th century illustrated in Figure 1.[175] In southeastern Louisiana, where the local rate of land surface subsidence is as high as 2.5 cm per year, rise in local "relative sea level" may be the most important factor in the rapid loss of coastal zone wetlands that has occurred over the past several decades.[176]

Despite the importance of sea level rise in historical losses of coastal lands, planning projections of future changes in coastal Louisiana used by both Federal and state agencies prior to the devastating impact of Hurricanes Katrina and Rita in 2005 were based on just one scenario: no change in the rate of sea level rise. No alternative sea level scenario was considered in the plans then being developed to restore and protect the Louisiana coastal zone.[177] This assumption stands in sharp contrast to the projections of the IPCC, which state that the global average rate of sea level rise in the 21st century may increase 2 to 4-fold over that of the 20th. Such increases will exacerbate wetland losses throughout the Gulf Coast region, and obstruct restoration plans that do not take account of likely increases in water levels and salinity.

The ecosystem modeling team working for the State of Louisiana and the U.S. Army Corps of Engineers in the aftermath of the 2005 hurricane season is presently integrating accelerated sea level rise scenarios into planning exercises that will aid federal and state agencies in evaluating restoration alternatives[178]. The State of Louisiana is consulting with the Rand Corporation to obtain probability estimates for various scenarios of sea level change to help guide engineering decisions and the design of projects aimed at restoring levees and coastal landforms that protect coastal communities[179]. Sea level rise scenarios are also being used by transportation experts to assess the impacts of climate change and variability on the Gulf Coast transportation sector (CCSP Product 4.7). For this assessment of transportation impacts, a sea level rise simulation model developed by the U.S. Geological Survey generates scenarios of sea level change using over a dozen different AOGCMs and 6 different SRES emission scenarios. An example of the sea level rise scenarios developed for this assessment is presented in figure 2.

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[175] Gosselink, 1984; Williams *et al*., 1999; Burkett *et al*. 2005.

[176] Shinkle and Dokka 2004; Barras *et al*., 2003.

[177] U.S. Army Corps of Engineers, 2005.

[178] http://www.clear.lsu.edu/clear/web-content/index.html

[179] Presentation by Randy Hanchey, Louisiana Department of Natural Resources, to Governor's Advisory Commission on Coastal Protection, Restoration and Conservation, Baton Rouge, LA, June 22, 2006.

Sea level rise scenarios are not just important in regions like Louisiana that are experiencing rapid local subsidence. The Big Bend region of the Florida panhandle is experiencing very little vertical movement of the land surface, so sea level there has been rising at approximately the global average rate of 1 to 2 mm per year. But even here, coastal wetlands positioned on flat limestone surfaces may be subject to highly nonlinear effects as sea level reaches a threshold at which large areas are subject to increased salinity or inundation.

Regional scenarios of potential sea level rise are needed to support coastal management and protection activities, as well as plans for wetland restoration and post-hurricane reconstruction. Absent consideration of such scenarios, restoration and rebuilding programs are likely to lock in errors that result in wasted resources and avoidable increases in future vulnerability.

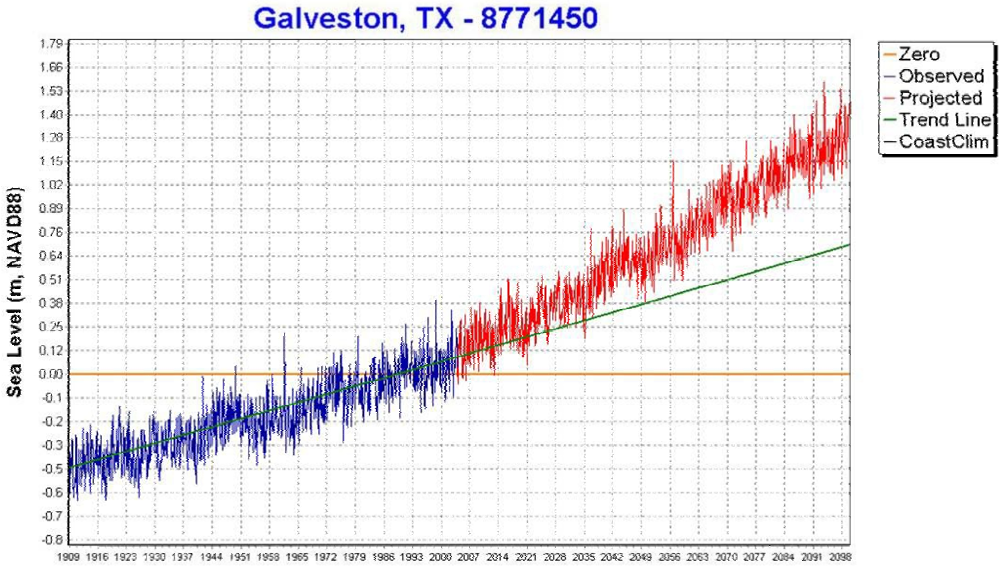

Figure 4.1.1. Output from a Gulf Coast sea level rise scenario tool

Source: Tom Doyle, USGS, Lafayette, Louisiana.

BOX 4.1.3.
Scenarios in the California Water Plan

The California Department of Water Resources produces an updated California Water Plan every five years. The plan assesses and projects water supplies and demands, and evaluates current and proposed demand-management programs and supply investments, to "provide a framework for water managers, legislators, and the public to consider options and make decisions regarding California's water future." (Plan home page).

Prior plans through 2000 had only constructed a single future scenario. The 2005 plan represented a major advance, in that it explicitly considered uncertainty in supply and demand projections. Three alternative scenarios of supply and demand conditions were constructed through 2030 – one extending current trends in population and economic growth, agricultural production, environmental restrictions on water use, and water conservation occurring without policy initiatives, e.g., through equipment replacement, technological change, and revised building codes, and one presenting higher and lower increases in the demands on California's water resources. The report of the 2005 plan includes a discussion of global climate change and the potential challenges it poses to water supply and demand in California, but climate change is not represented in the plan's three scenarios.

In addition to adopting these scenarios, the State of California is developing data and analytic capacity to enrich the treatment of uncertainty and climate change in future plan updates. In parallel with development of the three principal scenarios in this plan update, DWR sponsored development of several analytic tools and models to begin developing the capacity for more sophisticated treatment of uncertainty in future plans. In addition, the California Climate Change Research Center with co-sponsorship from DWR is developing fine-scale regional climate-model scenarios to support analysis of climate-change impacts on water resources.[180] It is planned to incorporate these climate-change scenarios explicitly in development of the next plan update, in 2010.

4.2. Scenarios in Assessments and Policy Debates

Within large-scale assessments of climate change or other environmental issues, scenarios can serve several roles. Most straightforwardly, they can provide specific required inputs to other parts of the analysis, as the IPCC emissions scenarios support the controlled comparison of climate-model runs. They can also serve as devices to organize and coordinate the multiple components of a large-scale assessment, particularly when much of the assessment is forward-looking. In the IPCC assessments, for example, emissions scenarios have not just been used to drive coordinated climate-model projections, but have also increasingly been followed through to coordinate characterization of climate impacts and adaptation opportunities, and used in a more preliminary way to organize assessments of the economic and technological implications of alternative mitigation strategies. Similarly, the US National Assessment and UK Climate Impacts Program have both attempted to identify a small set of climate and socio-economic scenarios, to coordinate and gain comparability across multiple studies and allow aggregate assessment of impacts and vulnerabilities at the national level.

In a broad assessment including many teams considering separate questions of climate-change, impacts, mitigation, and adaptation, simple coordinating devices are needed to make teams' work comparable and allow synthesis to produce aggregate conclusions. Emissions scenarios are natural devices to provide such coordination, both because emissions hold the clearest near-term opportunities for intervention, and because they have clear and recognized connections both directions in the causal chain, to every aspect of the climate-change issue. But however essential these efforts at coordination around scenarios may be, their implementation has not been wholly satisfactory in practice. In part, this weakness has reflected management issues rather than the use of the scenarios themselves. To serve as coordinating devices, scenarios must be developed and disseminated early in the process, preferably before the work of assessment teams even begins. Moreover, they must be documented with detailed information

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[180] California DWR 2005, Pg 4-32.

about the process and reasoning used to generate them, including explicit identification of underlying assumptions and supporting data, models, and arguments. In practice, timely, detailed, and transparent dissemination of scenario information has rarely been achieved. These are important tasks that need planning and resources to ensure proper execution.

Scenarios used in large-scale assessments can also make other contributions, by virtue of the prominent dissemination that a major assessment provides. They may, for example, be used as inputs to planning or decision-support processes that did not participate in the original assessment, or were not even considered by the producers of the scenarios or the assessment. In such use, they may gain a more direct connection to decision-making than they had in their original production or use. Such derivative uses appear to be especially likely for scenarios of global emissions and the model-based climate scenarios based on them, because these types of scenarios are one required input, directly or with additional subsequent analysis and assessment, to many different decisions by diverse actors. Examples of such uses are the widespread citation of IPCC scenarios in research announcements of opportunity and climate-relevant decisions being undertaken by many private firms. Because potential users differ widely in their specific needs for scenario-based information, such derivative uses would require that the origin and meaning of the scenarios, in terms of underlying reasoning and assumptions, treatment of uncertainty, and assumptions about baselines and the degree of mitigation effort underlying emissions scenarios, be conveyed clearly, explicitly, and simply.

Scenarios can also contribute to the broad framing of public and policy debate on the issue. This effect may be especially pronounced for scenarios produced as part of a large, prominent, official assessment, because the assessment gains prominence and because scenarios can provide compact, salient results that can be the most widely noted, reported, and recalled pieces of information from an assessment.

In this role, scenarios become prominent in policy debates in which many contending views and interests are present – views and interests related to climate change, potential responses to it, or other linked issues. In such a setting, scenarios inevitably become political objects, in two senses. They are subject to political forces that seek to influence their development, and political reactions to them once developed. These pressures pose challenges and risks that differ quite markedly from those that apply in using scenarios to inform decision-making, where we tend to assume a greater degree of commonality of knowledge, perspective, and interest in the process among participants and some group of relatively well-defined users.

Within scenario exercises, various actors – including the political sponsors of the scenario exercise or assessment – may seek to bias scenarios' content to help advance their policy preferences or their broader political objectives. This does not mean that scenarios should not have normatively determined content. It is not possible to eliminate normative biases in scenarios, and even predominant normative influence in a scenario can be useful if it is explicit. For example, scenarios can be constructed to examine what kinds of futures are both desirable and attainable, or to posit a highly desirable future and work through feasible paths to reach it.

But these uses are distinct from scenarios constructed to characterize uncertainty about future conditions for strategic planning, risk analysis, and assessment. Scenarios better serve these applications if they focus on likely or plausible futures, including those that pose sharp decision-making challenges, rather than desirable ones. When scenarios in such uses present a desired state – as the SRES scenarios all showed various degrees of North-South income convergence – this can weaken subsequent uses, since certain undesirable or unjust futures that might represent significant risks are not considered.

Scenarios can also be biased to show a problem in an extremely unfavorable state, to help promote political action to address it. This strategic biasing of scenarios should also be avoided if scenarios are to provide fair guidance to decision-making but it, like attempts to represent desirable futures, can be subtle. Other than exhorting scenario developers to avoid both these biases, providing transparency on the assumptions and information underlying scenarios and being explicit about likelihood judgments can both provide some protection against these biases.

Other political pressures come onto scenarios in the broader use, debate, and criticism that they are subject to after release. For impartial support of policy decisions, scenarios should fairly present knowledge and uncertainty about potential variation on important dimensions. This typically requires consideration of a wide range of potential futures – often a wider range than relevant decision-makers might initially think plausible, due to well know habits of conventional thinking and excessive confidence.

Because scenarios have implications for decisions, and sometimes – particularly with scenarios that are in one way or another extreme – the broad directions of preferred choices if the scenario should be true are likely to be widely agreed. A scenario may represent developments so severe that most people would judge it to demand intervention, or developments that most people would judge inconsequential or beneficial, so not meriting any intervention. Within a wide-ranging set of scenarios, some may imply calls for urgent action while others raise no such alarms. Consequently, such a wide range of potential futures in a set of scenarios – even if this is faithful representation of present knowledge and uncertainty – provides opportunity for partisan distortion and efforts to make scenarios policy-prescriptive.

In global change scenarios, these conflicts and opportunities for bias arise most acutely over emissions scenarios. Since much of the uncertainty about climate change beyond 2050 comes from uncertainty in future emissions trends, actors with strong policy preferences can highlight emissions scenarios that lend support to their view. Those who advocate aggressive mitigation may highlight the highest-emissions scenarios to emphasize the elevated risk of climate change that would follow. Those who oppose mitigation may highlight the lowest-emission scenarios to suggest that no action to limit emissions is warranted. Both these tactics – highlighting either the top or bottom of a wide range of possibilities to support your preferred policy – are easy to employ. Because scenarios are used when knowledge of causal processes is weak, it is easy to make any scenario you wish to highlight appear salient and likely, even if it is extreme. It is equally easy to probe inside the details of any scenario you wish to denounce to find inconsistent or implausible implications, particularly when a scenario is rich in detail.

But while political actors may have legitimate reasons to highlight one extreme scenario or another, it is not appropriate for any such scenario to dominate assessment or consideration of decisions. Claiming that only a single scenario is plausible – especially one near the top or bottom of the present range – is claiming to predict the future, moreover that the future will be extreme relative to present understanding. Such claims can be readily dismissed. Claims that a particular scenario is *implausible* cannot be so readily dismissed, however, since scenarios represent only the imperfect judgment of the team that produced them. Leaving aside scenarios that violate clear principles of science (e.g., one whose energy assumptions violate the laws of thermodynamics) or economics (e.g., one that presumes a large new capital stock in a few decades without the investments needed to create it), it is possible to construct pictures of the next century so extreme or unprecedented that most observers would agree they do not merit serious consideration. But short of such an extreme – which describes no global-change scenario discussed here or known to us – claims that a broad class of potential futures is implausible should have to pass a high hurdle. Identifying specific extreme or implausible elements within a scenario does not suffice to make this case, since virtually any scenario will be found to contain these if scrutinized closely enough. Nor does identifying ways that a scenario of future change diverges from some established trend or pattern, since established trends can and do change.

Historical studies of forecasting exercises such as energy forecasts have repeatedly found them much too confident the future will extend recent trends.[181] The threshold any single scenario must pass is that it appear plausible or instructive enough to merit consideration in planning and analysis, and this is a judgment to be made by developers and users – with enough transparency about underlying assumptions and reasoning that users can make an informed judgment. In constructing a set of scenarios, the range of conditions they represent should encompass present knowledge and relevant uncertainties that might influence mitigation or adaptation decisions. Since subjective judgments cannot be avoided in constructing scenarios, the range provided should err on the side of being broad rather than narrow, at least initially. Identifying problems with one scenario or another does not necessarily impugn the credibility even of a single scenario, certainly not a whole set, because scenarios cannot be consistent in every underlying detail.

In subsequent revisions as knowledge advances, scenarios can continue to play their role coordinating assessments and framing policy debates with more focus and less arbitrariness. Continuing research and analysis might come to identify some scenarios as severe in their consequences and others as inconsequential, or might revise the initial characterization of the determinants and feasibility of particular scenarios, including suggesting that some are too unlikely to merit serious consideration. These judgments can be incorporated into decisions of which scenarios merit continuing analysis, which ones can be dropped due to appearing increasingly implausible, and what type of new ones raising issues or outcomes not previously considered need to be added. One major basis for updates in scenarios will be policies and targets adopted, which can set a baseline to focus further deliberations. Perfect attainment of targets and success of policies should not be assumed, but scenarios can focus subsequent debate by posing such questions as ‘What if we just meet this target; what if we fall short by this much; and what if we exceed it by this much, or adopt these additional measures?

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[181] Smil 2006; Greenberger et al 1983.

Box 4.2.1.

Scenarios of Ozone Depletion in International Policy-making[182]

Emission scenarios of CFCs and other ozone-depleting chemicals exercised substantial influence on policy debates over control of these chemicals to protect the ozone layer. Until the early 1980s, these policy debates used a convention to project future ozone losses that was originally adopted as a simplifying research assumption: constant emissions forever. Projections were stated in terms of the resultant equilibrium ozone loss. This convention has obvious advantages for research, similar to those of simple standard greenhouse-gas scenarios such as doubled-CO_2 equilibrium in climate models. It was a simple way to standardize model input assumptions, allowing exploration of scientific and modeling uncertainties without the confounding effect of different emissions assumptions. Moreover, because this convention made no claim to realism, it avoided distracting atmospheric-science debates with arguments over whether one emissions projection or another was more realistic. But while the resultant calculations of steady-state ozone loss were not projections of realistic future trends, they were frequently mistaken as such.

The question of what future emissions trends were likely only became a prominent point of policy debates around 1983. World CFC production had dropped nearly a third in the late 1970s due to both regulatory and market-driven reductions in aerosol spray propellants, their largest use, and declined further in the recession of the early 1980s. It was widely argued that further restrictions were unnecessary because CFCs' major markets were saturated and further growth was highly unlikely. The resumption of sharp growth in 1983 undermined this claim, making it clear for the first time that managing the ozone risk required considering scenarios of CFC growth as well as steady-state and decline. How much emissions might grow and what it would mean for the atmosphere remained highly controversial, however.

Emissions of other chemicals complicated the picture. Advances in stratospheric chemistry showed that future ozone loss depended not just on CFCs, but also on several other types of emissions including carbon dioxide, methane, and nitrous oxide. But the knowledge and computing capacity to credibly model interactions among all these pollutants only began to appear in the early 1980s. In 1984, a major scientific assessment conducted the first standardized comparison of multiple stratospheric models using a few simple scenarios of emissions trends for CFCs and other chemicals. This exercise had the striking result that under a wide range of trends in other emissions, constant CFC emissions would lead to only very small ozone losses, while CFC growth above about 1% per year would lead to large losses.

This result, together with resumed growth in CFC production, was highly influential in breaking the deadlock in international negotiations that had persisted since the mid-1970s. Although not the only factor that mattered, this result was crucial in persuading long-standing opponents of CFC controls to accept limits on their future growth. This decisively shifted the agenda for the subsequent negotiations that in 1987 yielded agreement on the Montreal Protocol, which cut CFCs by 50%.

In this debate, scenarios used in model-based projections of ozone loss served to identify divergent trends in future risk that were robust to a wide range of assumptions about trends in other emissions over which there was disagreement. By parsing projected futures into high-risk and low-risk cases, scenarios served to coordinate and simplify a policy debate and so help to focus an agenda for collective decision-making.

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[182] This example drawn from Parson (2003).

Box 4.2.2.
Climate-Change Scenarios for the Insurance Industry

The insurance and reinsurance industries face large financial risks from climate change. These can arise in many business lines, including crops and livestock, business and supply-chain interruptions, and various life and health consequences, but the most clearly recognized risk is in insurance for property damage from weather-related events, especially windstorms and floods.

In the past two decades, weather-related insurance losses have increased rapidly. By some estimates losses have doubled, even controlling for population and insured value – a much faster increase than for losses due to non-weather events. Climate change is likely to increase insurance risks in multiple ways, increasing the frequency and severity of loss events and also their correlation. Historically based pricing, which is often required by regulations or market conditions, can compound insurers' vulnerability by preventing them from anticipating and adapting to the new risk environment.

Insurance companies do not use scenarios of future climate change in pricing decisions, because property and casualty contracts are written for short periods, usually one year. Since 1992's Hurricane Andrew, they have mostly been priced using historically based Catastrophic Event Risk Models (Cat models). These estimate losses using a simulated distribution of storm conditions based on historical experience, together with estimates of the durability of the insured property. While future climate change poses no risk for these short-term pricing decisions, insurers are concerned that climate change may already have invalidated the historical distributions on which these models are based, either by increasing the probability of severe events or the correlation among them.

There have been two public exercises using climate-change scenarios to explore longer-term risks to the insurance industry. The first, conducted for the Association of British Insurers in June 2005, examined potential impacts of climate change on the costs of extreme weather events (both insured and total economic costs) under the six SRES marker scenarios, as well as IS92a and a scenario of CO_2 stabilization at 550 ppm. Using highly simplified assumptions about changes in the distribution of storm wind speeds under climate change, the analysis calculated changes in losses due to US hurricanes, Japanese typhoons, and European windstorms associated with each emissions scenario using Cat models. No other impacts of climate change, and no changes in the socio-economic conditions that determine exposures, were considered. Consequences of each scenario were calculated for average insurance losses, extreme insurance losses, reserve requirements, and risk premiums.

The second scenario exercise, conducted by Harvard Medical School researchers with sponsorship by Swiss Re and UNDP, used two scenarios of 21st-century climate change to examine potential impacts on human and ecosystem health, and associated economic costs, not limited to the insurance industry.

The two climate scenarios both assumed CO_2 doubling by approximately mid-century, one with continued incremental climate changes and one with hypothesized nonlinear impacts and abrupt events. They examined potential changes in infectious and water-borne diseases, asthma, agricultural productivity, marine ecosystems, freshwater availability, and natural disasters including heat waves and floods. The analysis was based primarily on qualitative judgments.

The first scenario has increases in property losses and business interruptions following recent trends, emergence of new types of health-related losses, and increasing difficulty in underwriting. The combined effect of increased losses, pressure on reserves, inflation of constructions costs after disasters, and rising costs of risk capital result in a gradual decline in insurance profitability. As commercial insurability declines and cash-short governments (already providing flood and crop insurance) are unable to assume new risks, more climate-related losses are shifted back to individuals and businesses.

The second scenario is qualitatively similar but more severe. There are substantial increases in both average losses and variability, leading to large premium increases and withdrawal of insurers from many markets. As a result, many developments whose financing is contingent on insurance are left stranded, particularly along coastlines. As many insurance firms succumb to mounting losses, those remaining establish strict limits on coverage, shifting more exposure back to individuals and businesses.

Neither of these exercises was connected to any specific, near-term business decision faced by insurance companies. Both could serve longer-term decision-making, however, including planning for reserve accumulation, providing supporting analysis for advocating public policies to reduce greenhouse-gas emissions and prepare for climate change, and providing support for changed regulations allowing more flexible pricing of risks experiencing long-term increases. Such exercises can also serve to inform firms' long- term risk-avoidance strategies, including decisions to exit certain areas of business.

Box 4.2.3.
Scenarios of Climate Impacts in the Columbia River Basin

Researchers at the University of Washington, in conjunction with the US National Assessment, studied climate impacts on the Columbia River system, which is the primary source of energy and irrigation water for the Northwest states and one of the most intensively managed river systems in the world.[183] The project examined the response of annual and seasonal flows both to existing patterns of climate variability, and to projected 21st century climate change.

The study found that flows were strongly influenced by two large-scale patterns of climate variability: the El Nino/Southern Oscillation (ENSO), an irregular oscillation of the tropical atmosphere and ocean with a period of a few years; and the Pacific Decadal Oscillation (PDO), an oscillation over the central and northern Pacific with a period of a few decades. The warm phases of both ENSO and PDO bring warmer, drier winters to the Northwest, causing large decreases in winter snowpack and major changes in Columbia flows. Average annual flow decreases by about 10% and flows shift earlier in the year, bringing larger reductions in peak June flow and substantially increased risk of summer water shortage. The cool phase of each oscillation has the opposite effect, and the effects of the two oscillations are nearly additive.

The team projected effects of future climate change through 2050 using eight different climate models driven by one emissions scenario (1% per year CO_2 concentration increase), which projected average regional warming of 2.3°C by the 2040s, with precipitation increases of roughly 10% in winter and a few percent in summer. In the Columbia, these changes are projected to increase flows in winter (both because there is more precipitation in winter, and because more of it falls as rain) and to decrease flows in summer (because there is less snowpack and it melts earlier in the spring). The impact of summer decreases is likely to be substantially more serious than that of winter increases. Because the Columbia is

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[183] Mote et al 2004; Payne et al 2004.

a snowmelt-dominated system, winter flows could double or even triple and remain below the present spring peak.

Assessing the impacts of these flow changes requires assumptions about trends in demand for various water uses and how the system is managed. The group used a model of reservoir operations that calculated the combined effects of specified flow changes and various alternative system-operation rules on the reliability of different water-management objectives, such as electrical generation, flood control, irrigation supply, and preserving flows for salmon. Under historical climate variability, all these objectives can achieve high reliability in high-flow years (i.e., in the cool phase of ENSO or PDO), but conflict between them occurs in low-flow (warm) years, when only one top-priority objective can be maintained at or near 100% reliability and other uses suffer substantial risks of shortfall. Alternative operating rules distribute this shortfall risk among uses.

When the same model was used with projected climate change in the 2040s, it showed a pattern of competition between uses similar but additional to that which already applies in low-flow years, suggesting the possibility of increases in already sharp conflict between uses over allocation of available flows. One objective could be maintained near full reliability, but other uses suffered reliability losses up to 10% from the climate-change trend, in addition to effects of continued climate variability. (Reliability decreases by less than summer flows because the river's intensive development allows some of the increases in winter flow to be held in reservoirs for summer use.)

In this analysis, scenarios helped to illustrate interactions between management decisions and climate change and variability, and to explore opportunities and limits for adaptation through management changes alone, with no change in infrastructure or larger-scale policies. This analysis has not been incorporated into any operational decisions, but has been integrated into the Fifth Conservation Plan issued by the Northwest Power and Conservation Council.[184] More detailed assessment of climate-change impacts would require extending this analysis to include projected changes in water demands, both through direct climate effects and through scenarios of regional economic and population growth, allowing a more realistic assessment of potential effects of new water-management investments and changes in large-scale policies to alter water demand, balance competing uses, or improve coordination among the multiple organizations involved in managing the river system.

4.3. The process of developing scenarios: Expert-stakeholder interactions

Scenario exercises are collaborative activities that need to be managed. As discussed in Section 1, scenario exercises involve numerous managerial decisions, such as how participants are chosen, which jobs are assigned and how these jobs fit together, how disagreements are resolved, and how much time and money is dedicated to the exercise. These matters can be decisive for the success of a scenario exercise, but in many cases the challenges and tradeoffs they pose are fairly obvious. For example, scenario exercises need sufficient time to build a team, research scenario components, consult repeatedly with users, and disseminate results but the necessary time is often not available, so various compromises are required. Adding participants expands the expertise and the range of perspectives represented, but increases the time needed for team building and internal communication. Delegating parts of the exercise to smaller groups can overcome this tradeoff, but can introduce coordination problems and

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[184] www.nwcouncil.org/energy/powerplan/plan

inconsistencies between groups. Accepting external direction on a scenario exercise increases the likelihood that the scenarios are seriously considered by external decision-makers, but also increases the risk that scenarios are perceived as biased or simply reflecting conventional wisdom. These issues pose significant challenges and call for judgment and skill in their resolution, but they apply to any collaborative analytic activity and are not in any way unique to scenario exercises.

The more central process problems for scenarios concern the relationship between experts and stakeholders in the design, creation, evaluation, and application of scenarios. There has been substantial experience and research in processes for involving stakeholders in environmental decisions, in the United States and other domains.[185] In longer established areas of scenario use – strategic planning for corporations or other organizations, or military and security planning – there are widely understood principles for the relationship between scenario developers and users. Typically in these applications, scenarios are addressed to a clearly identified, relatively small and homogeneous set of users who are likely to have substantial agreement on what values they are trying to advance, what issues are relevant for their decision-making, and what choices are feasible, acceptable, and within their power and authority. In such applications, scholars and practitioners of scenarios agree that there should be close, intensive collaboration between developers and users in the production, revision, and application of scenarios.

High-level decision makers are typically not involved in the detailed work of research, analysis, modeling, and cross-checking, but may be intensively involved in problem definition, identification and elaboration of key uncertainties, large-scale scenario design, evaluation and criticism of scenario outputs, and deliberation over lessons and implications. In many cases the actual decision-makers are not available to participate in scenario exercises, so surrogates are used who have a thorough understanding of their priorities, concerns, and decision situation. Whether actual decision-makers or, more typically, surrogates, the level of involvement of these users must be high given their intimate knowledge of what key challenges and concerns are to be addressed, what factors and processes are relevant, and what actions are feasible and acceptable. If the purpose of a scenario exercise is to encourage broad and creative thinking of decision-makers, their intensive involvement is even more essential. Although this argument is strongest in the context of scenario exercises within a single organization with clear responsibilities, objectives, and values, it also applies to some extent to exercises directed at larger groups that are sufficiently homogeneous in these respects, e.g., scenarios for property and casualty insurers, for organized labor in the United States, or for European environmental groups. In such cases, there are compelling reasons for intensive involvement of users in scenario development. The only associated difficulties would be in selecting representation from multiple organizations to achieve the desired breadth of perspective, while maintaining a manageable group size.

Similar arguments for intensive involvement of users in scenario development are widely advanced for climate change scenarios, but here the issues are more complex. Some climate-change scenario exercises closely match the conditions above, such as scenarios for impacts and

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[185] See, e.g., Chess and Purcell 1999; EPA 2001; Gregory and McDaniels 2005; Holling 1978; NRC 1996; Renn et al 1995.

adaptation in specific industries, resources, or regions; e.g., impact assessments for the New York City metropolitan region, or the insurance and reinsurance industries. In such cases where a scenario exercise connects directly to the decision responsibilities of a specific, relatively homogeneous group, the arguments above for the value of intensive user involvement in scenario production apply precisely.

But climate change scenarios are typically developed for a much more diverse set of users and stakeholders. This is particularly the case for scenarios produced for large-scale, official assessments such as the IPCC or US National Assessment. Climate-change stakeholders – defined by the CCSP as "individuals or groups whose interests (financial, cultural, value-based, or other) are affected by climate variability, climate change, or options for adapting to or mitigating these phenomena[186]" – are an enormous group, diverse in their interests and responsibilities. Potential stakeholders may be difficult to identify, and may have conflicting interests in the construction and use of scenarios. With users so diverse, scenarios may be limited to broad, exploratory purposes, such as signaling how serious the issue is or providing indirect input to many actors' decisions.

Under these conditions, the factors determining the most useful nature and extent of stakeholder participation are much more complex than in homogeneous-user scenario exercises. Certain users and uses may be clearly identified, such as the analysts and modelers who need scenarios as inputs to subsequent analyses, e.g., climate modelers who need input from emissions scenarios or impact assessors who need input from climate scenarios. Here, the case for close collaboration of users in scenario development is strong. These users may have highly specific scenario needs, including such prosaic factors as the format, resolution, and medium of the output, which scenario developers need to understand and meet. This may require one-time consultation, or ongoing interactions if the needs change. More intensive interaction may be required when users' specific needs are hard for scenario producers to meet. For example, climate modelers may need emissions data at fine spatial resolution and for specific gases or aerosols, which are not readily available from the energy-economic models used for emissions scenarios. In this case, detailed consultation is needed to ensure that the two groups understand each others' needs and capabilities in enough detail.

The provision of climate-scenario data to support impact assessments is more difficult. Narrowly targeted impact assessments (e.g., one sector or resource in one region) can benefit from intensive stakeholder involvement in scenario production. This would allow an assessment team to draw on special expertise about local resources and processes and to connect to relevant decision-makers. This is clear, for example, for coastal managers considering the establishment or revision of setback lines for coastal-zone construction as sea level rises,[187] or rangeland managers considering the purchase of conservation lands or easements for the purpose of providing migration corridors. But scenarios are more typically produced to serve not just one specific impact assessment but many, particularly within large-scale assessments like the IPCC. In contrast to climate modelers, these stakeholders are numerous and diverse in their disciplinary foundations, methods, and tools, and operate at scales much smaller than global. Their data

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[186] CCSP 2003, p. 112.

[187] McLean et al., 2001.

needs are likely to have some commonalities, but substantial differences. Involving a representative collection of users in scenario production is likely still productive, but variance in users' needs makes the questions of stakeholder participation complex. A large and reasonably representative group will need to be involved, as well as a range of disciplinary and modeling experts, while keeping the total size of the scenario team manageable. Moreover, choosing representatives to participate is not likely to be straightforward. Users may lack expertise in each others' data needs, or their needs may be distinct or even in conflict.

The larger and more diverse in preferences and values the potential users and stakeholders for a scenario exercise are, the more difficult it is to figure out which of them should be involved in scenario production, and in what capacity. There is some value in having people with practical responsibilities related to climate change involved, rather than just researchers, if only to provide a general sense of the usability of data and analysis in supporting real decisions. As with more focused user groups, the general case for stakeholder involvement is strongest in the initial scoping and design of a scenario exercise, and in the evaluation of scenarios for relevance, practicality, and addressing key concerns. The case for stakeholder involvement is less strong in the actual work of background research, analysis, and modeling to generate and quantify specific scenarios.

Can a scenario process be completely open? In political settings, some insulation from users may be needed to insure consistency across participating models and analyses. Whatever approach to stakeholder participation is adopted, numbers must be kept manageable. Despite recent progress in scenario methods allowing a substantial increase in the number of participants, there are still practical limits. Although requirements for expertise external to the core scenario team increase with scenario complexity, a scenario process is unlikely to work with a hundred people in the room. A few scenario processes have engaged much larger numbers of participants, but these have greatly reduced the complexity of the scenario-creation process by limiting it to specifying inputs to a single interactive model, or have involved large numbers of participants in independent, parallel sessions interacting with a computer-based model or scenario construction system.[188] These tensions between representational realism, participation, and managerial feasibility pose challenges for design of processes of representation and consultation in scenario development, on which further progress is needed.

Box 4.3.1.
Scenarios in Acid-Rain Assessments: Two Approaches

Two programs, one in the United States and one in Europe, developed scenarios in integrated-assessment models of acid rain to inform policy decisions on controlling sulfur emissions. Among many differences between the programs they took sharply different approaches to involving stakeholders, and differed strongly in how effectively they informed decision-making.

The US National Acid Precipitation Assessment Program (NAPAP) was created in 1980 as a 10-year, $570-million research program to study all aspects of acid deposition: emissions, atmospheric transport

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[188] See, e.g., Envision Sustainability Tools 1999; Rothman et al 2003; Stockholm Environment Institute 1999.

and deposition, impacts, and economic analysis of alternative control strategies.[189] Managed by a committee of six lead government agencies and supported by a full-time staff office, the program involved roughly 2,000 researchers.[190] Although charged to conduct both scientific research and assessment, NAPAP strongly emphasized scientific discovery over policy relevance in its allocation of resources, selection of questions, and scheduling of activities.[191] Its assessment report was extremely opaque on the origin and interpretation of its scenarios, and did not use them to integrate across the multiple disciplinary domains of the issue or characterize the implications of alternative policies. Moreover, NAPAP released its assessment report several months after passage of the 1990 Clean Air Act Amendments adopted new acid-rain controls, although some commentators have noted that scientific participants and assessment staff contributed to the policy debate through prior informal exchanges with policy-makers.[192] Overall, NAPAP is regarded as having succeeded as a research program, but fallen critically short of providing useful information for decision making.

An alternative approach to acid-rain assessment was taken in Europe as part of the policy debates under the Convention on Long-Range Transboundary Air Pollution (LRTAP). The core of this assessment was a cooperative program for monitoring and modeling acid emissions, transport, deposition, and impacts (EMEP). In contrast to NAPAP, EMEP focused more on assessment than research. It was specifically established to inform the policy process, and closely linked to it.[193] Scientific models of components of the acid-rain issue were chosen for their ability to contribute to a simplified integration of the problem, while scenarios of emissions and controls were chosen in consultation with officials, in an attempt to replicate the policy alternatives under consideration.

The culmination of this pursuit of simple, accessible, and policy-relevant models was the RAINS model, developed by a research team at the International Institute for Applied Systems Analysis (IIASA) in Austria. As a result of its flexibility, ease of use, and relevance to policies under consideration, the RAINS model was used extensively by policymakers in the negotiation of sulfur-control agreements under the Convention, and had substantial influence over the distribution of controls adopted.[194]

The contrast in approach and outcome between these two programs suggests the potential value of close interaction between experts and stakeholders in producing scenarios, at least when the stakeholders are relatively expert officials responsible for a specific set of decisions. In the EMEP case, such close interaction helped to ensure the credibility of baseline emissions scenarios and the relevance of proposed control scenarios, despite the diverse and sometimes contending interests of the participating officials. The contrast between the two programs also suggests that there can be significant tradeoffs between scientific and assessment objectives in programs that seek to integrate the two activities.

4.4. Communication of Scenarios

Since scenarios are made to be used by someone other than their developers, they must be communicated. The involvement of users in the production of scenarios can aid in

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[189] NAPAP, 1982; Herrick, 2004.

[190] Herrick, 2004.

[191] Roberts, 1991; Cowling, 1992; Russell, 1992.

[192] Perhac, 1991; Roberts, 1991; Patrinos, 2000.

[193] Gough et al 1998.

[194] Levy 1995.

communication of scenarios in two ways: first, by helping to ensure the scenarios are understandable and useful to their intended users and second, by involving stakeholders in the dissemination and validation of scenarios to their constituencies. When the intended users are a single organization or a small, homogeneous group, the engagement of users in scenario development may achieve the desired level of communication with little additional effort. But when potential users and stakeholders are more numerous and diverse, the communication of scenarios becomes more important and complex.

The global change scenarios discussed in this report must be communicated to multiple audiences with diverse interests and information needs. Although the specifics of what must be communicated will vary from case to case, any communication of scenario-based information to a large diverse public audience is likely to require certain common elements. Just as uncertainty is central to scenario exercises, it is central to the problem of effectively and responsibly communicating scenarios. Whatever decisions are made in resolving these issues must be reflected in the communication of scenarios to those outside the scenario development group. For example, scenario outputs should acknowledge the unavoidable elements of subjective judgment in developing scenarios, and scenario developers should be prepared to explain and defend the judgments they made. Where particular scenarios were constructed to have specific meanings – e.g., a reference case, a plausible worst-case, or the exploration of a particular causal process taken to its extreme – these should be clearly conveyed, including whatever degree of specificity in conveying judgments of likelihood that has been decided. A particularly important distinction to communicate clearly is between scientific uncertainty and scenario uncertainty, e.g., requiring explicit statements of when and how scenarios change (such as the reduced projections of future SO_2 emissions in the 2001 IPCC scenarios), and clear explanations of the effects of such changes. Scenarios' communication strategy should attempt to steer users away from certain common pitfalls, such as choosing one scenario and treating it as a highly confident prediction, or taking the range spanned by a set of scenarios as encompassing all that can possibly happen.

In addition to the scenarios' content, sufficient information should be provided about the process and reasoning by which the scenarios were developed. This allows users and stakeholders to scrutinize the data, models, and reasoning behind key decisions that shaped the scenarios. It also provides stakeholders with the information needed to determine their level of confidence in the scenarios, and the opportunity to critique assumptions and suggest alternative approaches. Ideally, conveying this information can engage the broader user community in the process of updating and improving scenarios. If scenario developers have explicitly articulated any measure of the confidence they place on scenarios or distributions of associated variables, this information and any supporting reasoning and analysis should also be made available. Providing transparency rather than claiming authoritative status for scenarios is likely to increase users' confidence that the scenarios have reasonably represented current knowledge and key uncertainties. It also provides users with the tools to develop alternative representations if they are unconvinced.

In large and complex assessments such as the IPCC and US National Assessment, communication of scenarios and underlying information both to various groups within the assessment and to potential outside users can pose serious representational and managerial challenges. Scenario exercises have experimented with various visual techniques for conveying complex information in vivid and understandable form, including landscape representations, maps, and pictures, as well as various graphical and tabular formats.[195] Exercises have In USNA, climate scenarios and other related information were provided to participating assessment teams in several formats (e,g., tabular summaries, models, graphic representations), through websites backed up with workshop presentations. In the IPCC, the Task Group on Data and Scenario Support for Impact and Climate Analysis (TGICA) was established in 1997 to facilitate distribution of climate scenario data, model results, and baseline and scenario information on other environmental and socio-economic conditions, for use in climate impact and adaptation assessments. Data, scenarios, and supporting information are distributed over the internet by the IPCC Data Distribution Center (DDC).[196]

To compactly communicate uncertainty in climate scenarios, the TGICA and several national scenario efforts have developed various graphical methods, including scattergrams showing the range of projected temperature and precipitation changes generated by several climate models using four SRES marker scenarios, and comparing these projected changes to estimates of natural variability.[197] In Figure 4.4.1, each data point represents one climate-model projection associated with a given SRES emissions scenario. Efforts to develop similarly compact representations of the distribution of scenarios for extremes as well as annual and seasonal averages are underway.

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[195] See, e.g., Svedin and Aniansson 1987.

[196] Information on the TGICA is at ipcc-wg1.ucar.edu/wg1/wg1_tgica.html. The DDC is jointly operated by the UK Climatic Research Unit and the Deutsches Klimarechenzentrum, with several mirror sites around the world. Data are provided via the web or CD-ROM. All data distributed are in the public domain.

[197] Ruosteenoja *et al*., 2003; Mearns and Tibaldi ___

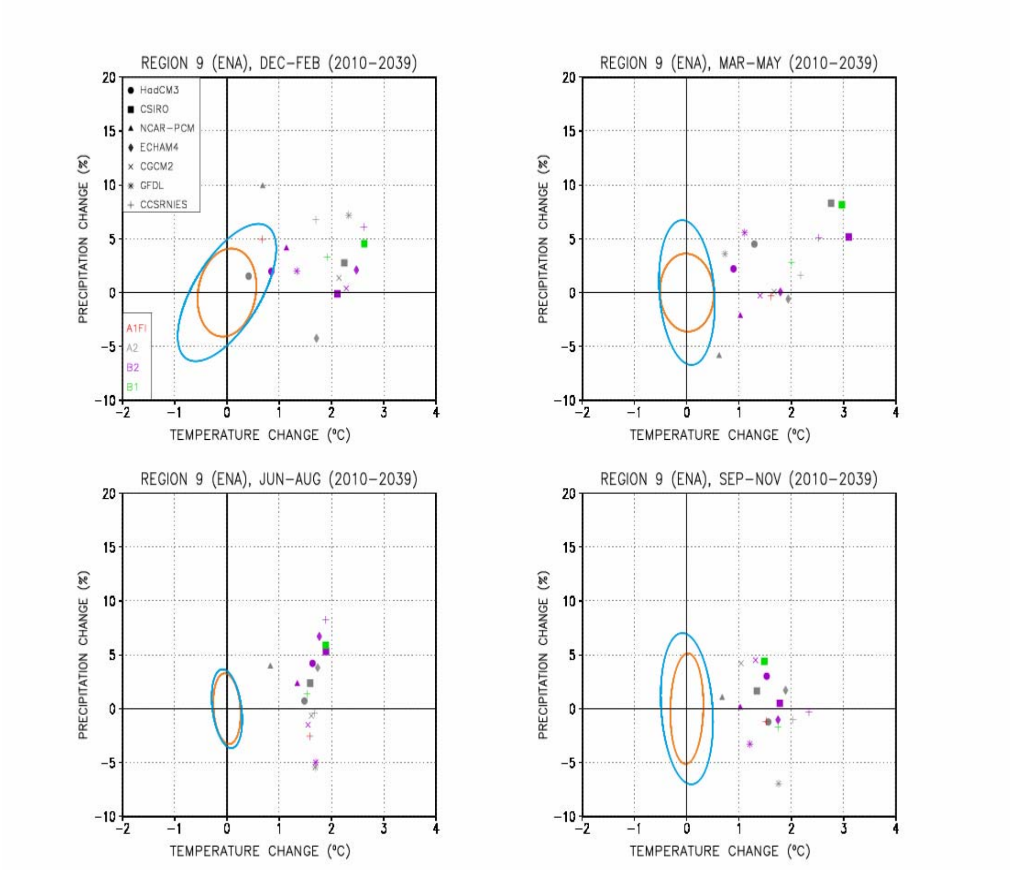

Figure 4.4.1. Regional scattergram for eastern North America, 2040-2069. The x-axis shows temperature changes in °C, the y-axis precipitation changes in percent. Each point shows one model's projection under one emissions scenario. A point's color denotes the corresponding emissions scenario, its shape the corresponding model (per legend, lower left of figure). Ovals show 95% confidence bounds for natural 30-year climate variability, calculated from unforced 1000-year runs of the models CGCM2 (orange) and HadCM3 (blue). Points outside the ellipses indicated projected climate change significantly outside the range of natural variability, most frequently due to changes in temperature rather than precipitation.[198]

To help users select climate scenarios for impact assessments, an alternative to summarizing climate-model scenarios in such scatter plots is to combine various climate-model results using statistical methods to construct explicit probability distributions for important climate variables. Figure 4.4.2 shows one such method, which assigns weights to model results based on their bias in simulating the current climate (smaller biases are assigned higher weight) and their correspondence with other model results (outliers are assigned lower weights). This method compactly communicates multiple model results, clearly conveying which ones fall at the top and bottom of the distribution ("unlikely to be higher than this" or "lower than this"), and which fall in the middle of the range.

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[198] IPCC DDC, ipcc-ddc.cru.uea.ac.uk/sres/scatter_plots/regional_galleries/region_plots9/index.html, Figures downloaded February 16, 2006.

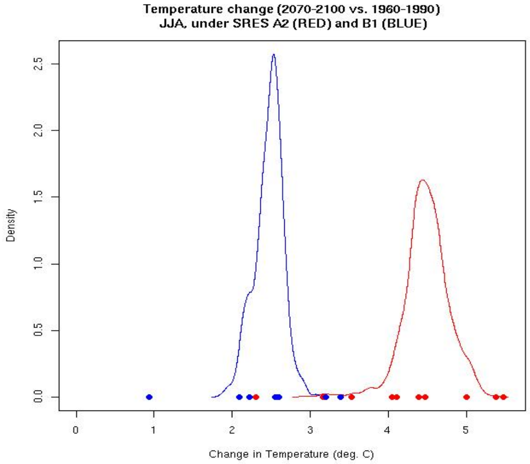

Figure 4.4.2. Constructed probability distributions of model-simulated temperature change in 2070-2100 compared to historical temperature (1960-1990) in the Gulf Coast region, using 19 climate models with the SRES A2 (red) and B1 (blue) scenarios. Each point along the x axis represents a different model run.

This current focus on collections and intercomparisons of model-based projections with various emission scenarios represents a new approach for communicating scenario-driven model output to those engaged in assessment and adaptation activities. It has enabled users to consider a broader range of emission scenarios and climate models than was feasible at the initiation of the USNA and previous IPCC assessments. It allows users to consider all available model/scenario combinations to span the literature, or alternatively to consider only scenarios that exceed thresholds of interest or are projected to occur within some specified probability range. Future assessments should benefit from this type of multi-model, multi-scenario approach, which gives the choice of scenarios to those who are better equipped to determine the appropriate level of risk to be considered in the assessment process.

4.5. Consistency and Integration in Scenarios

One of the most often stated requirements for scenarios is that they be “coherent” or “internally consistent.” This is clearly an important goal. Since scenarios usually specify multiple characteristics of an assumed future, whether as multiple elements of a narrative or multiple quantitative variables, it is necessary to consider carefully how well these elements fit together. There are complexities and difficulties that arise in the pursuit of such consistency, however, and in some scenario exercises the pursuit of consistency, together with the goal that scenarios integrate many components of a broad issue such as climate change, poses risks to the validity and usefulness of the scenarios.

Certain simple elements of internal consistency in scenarios are unproblematic. Elements of a scenario, for example, should avoid gross contradictions in view of well established knowledge about the behavior of biophysical or socio-economic systems. Similarly, elements of scenarios should not inadvertently move far outside the bounds of historical experience or presently recognized causal processes. Such inadvertently implausible assumptions can arise, for example, when multiple elements of a scenario are specified independently without cross-checking; e.g., independent end-year specifications of a region's population and GDP without checking the implied growth rate in GDP per capita, or specifying energy-related emissions trajectories without checking what they imply for resource availability. Avoiding these pitfalls requires thorough cross-comparisons of related values with each other, of terminal values with implied time-trends in the intervening period, and of values within and between regions. Only when extreme or unprecedented outcomes are inadvertent should they necessarily be avoided, however. Intentionally presenting future conditions that initially seem implausible, with an explanation of how they could in fact arise, can be a valuable contribution to risk assessment, by broadening decision-makers' expectations of what ranges of future developments are plausible.

Statements about internal consistency in scenarios usually claim much more than the mere absence of gross contradictions and inadvertently implausible values, however. Rather, they tend to claim that the multiple elements of a scenario are related to each other in a way that reflects reasonable, well-informed judgments about causal relations, suggesting that some types of events or trends are more likely to occur together, some less. When the goal is expressed as "coherence" rather than "internal consistency," an even higher level of perceived affinity among scenario elements is suggested, evoking normative or even aesthetic aspects.

Expressed in probabilistic terms, statements about internal consistency may be interpreted as claims that a scenario is more likely to occur than some set of hypothetical alternatives; that is, a claim that the particular alignment of factors in the chosen scenario, or ones similar to it, is more likely than other alignments that were not chosen. One might, for example, claim that a scenario with rapid economic growth and growth in energy use was more internally consistent than one in which the economy grew rapidly but energy use did not. But where do these perceptions of greater or lesser likelihood come from, and how valid are they? In some cases there might be a well-founded theory or model that says certain outcomes tend to be related. Alternatively, some explicit analyses might connect the claim to some underlying assumptions that are open to scrutiny and criticism. But in the absence of such transparent foundations for judgments of what scenario conditions are consistent and what are not, these claims can only rest on more diffuse judgments by scenario developers, refined and tested through various deliberative processes – e.g., arguing about the claims, working through their implications relative to those of alternative specifications, identifying additional bodies of research and scholarship that can be brought to bear, etc. While the use of subjective judgments and deliberative processes cannot be avoided in scenario development, they pose significant risks of error and bias that are well established in empirical research on judgment and decision-making; e.g., excessive influence of articulate or charismatic individuals, re-affirmation of unfounded conventional wisdom, insufficient adjustment away from arbitrary initial characterizations (anchoring), etc.[199] While there are many devices and methods available to help identify and limit the influence of such processes, continual vigilance is required – just because a scenario looks consistent does not mean that it is – and success at avoiding these can never be guaranteed.

These difficulties can be compounded when, in addition to consistency, a goal of scenario "integration" is also pursued (although the precise meaning of "integrated" can be difficult to

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[199] Slovic et al 1976.

ascertain). The integration of a scenario is a function of its complexity or breadth, which is related to the number of characteristics jointly specified in a scenario. In global-change applications of scenarios, integration typically refers to a more specific type of breadth. In the case of integrated-assessment models, an integrated scenario would specify all major components of the causal chain of global-change issues, typically multiple dimensions of emissions and their socio-economic drivers, climate, impacts of climate change, and possibly certain forms of responses.

Asking a scenario to be integrated in this way imposes on the scenario the burden of capturing all relevant elements of the future. Such an expansive scenario may occasionally be needed – e.g., for preliminary assessment of a threat for which no relevant data or current research exists. However, the risks of error, bias, and arbitrariness in such a scenario are greatly increased, because so much of reality (with whatever unknown causal processes by which it actually operates) is being stuffed into the scenario.

More likely, an integrated scenario would be constructed by combining exogenous assumptions about some elements with model-calculated values for others. This approach does not avoid increasing the risks of inconsistency and contradiction as the breadth and integration of a scenario is expanded, particularly when multiple models are used. Since models embody specific, quantitative causal relations among variables, they do not require – or indeed allow – all variables to be specified. Scenarios provide only those external (exogenous) inputs that the model does not produce. These scenario-based inputs should be consistent with each other, but to a lesser extent than the precise standard that defines consistency in a scenario. These exogenous inputs, together with model results, can jointly comprise a scenario that is generated for some alternative use.

Consistency problems grow when scenario exercises involve multiple models and attempts are made to achieve model harmonization. When scenarios are constructed partly out of exogenous inputs provided by a scenario (made consistent as much as possible through qualitative or intuitive causal reasoning) and partly out of models, it is frequently the case that multiple models are used. Using multiple models in parallel can allow for more extensive exploration of causal relations, and helps to characterize uncertainty in scenarios since different models embody different representations of causal processes. It may also enhance the credibility of the process.

But models of the same broad set of phenomena – e.g., models of the economy and energy sector – frequently differ in which variables they require as exogenous inputs and which ones they calculate endogenously. In this case, some variables must be specified exogenously for some models, but are calculated endogenously by others.

This creates various problems for consistency. In general, when scenario exercises are conducted in this way, there will be some elements for which distinct, inconsistent specifications are provided – some of which are assumed and others which are model-calculated. Attempting to avoid this poses even more serious problems, however. It is not usually possible to arbitrarily perturb the exogenous input variables so all inputs and outputs match across all models, since such perturbations will influence other variables in the model. Consequently, avoiding these inconsistencies will require manipulating internal relationships within models to make their outputs match the specified values, given the common inputs. But such reverse-engineering of internal model relationships to match specified outputs, in addition to being exceedingly cumbersome and arbitrary, can corrupt the internal logic of models, obscure the interpretation and significance of results, and make it impossible to use model variation to illuminate uncertainty.

For example, in an exercise to generate non-intervention scenarios of potential future emissions, little insight is likely to be gained from defining scenarios in terms of the resulting emissions and forcing the different models to generate these emissions targets.[200] Less obvious is that it may be equally fruitless to define scenarios in terms of GDP and energy consumption trajectories and to force multiple models to reproduce these. Some models may include these variables as exogenous inputs, but other models may produce these variables as the endogenous result of a variety of parameters and structural assumptions, including productivity factors, elasticities of substitution in production, and assumptions about the rate and mechanisms of technological progress. For this reason, multi-model exercises such as the Energy Modeling Forum usually avoid strong coordination of inputs, instead seeking to harmonize a few of the most essential and commonly used inputs.[201] If a multi-model exercise is to be pursued, the most useful approach would be to make common assumptions about the variables that are furthest back in the causal chain. However, given the wide variation in model structures, achieving model harmonization will remain a challenge.

In addition to consistency within a scenario, consistency across scenarios within an exercise also requires attention. Ideally, factors not explicitly recognized as the basis for inter-scenario differences should be consistent across scenarios. Or alternatively, all bases for differences between scenarios should be explicitly recognized and stated.

When models are used in a scenario exercise, significant variation in model structures suggests less mature underlying knowledge, or at least greater recognition of knowledge gaps, than when model structures converge and all remaining uncertainty is over exogenous input parameters. For scenarios to provide faithful representation of present knowledge and uncertainty, this variation should not be suppressed or concealed. Consequently, when scenarios are defined over variables that include outputs of some participating models as well as inputs, it is crucial not to pursue false consistency by forcing models to match the target outputs through manipulation of their internal causal processes. This is suppressing model uncertainty.

One preferable alternative would be for the results of scenario exercises involving both exogenous inputs and multiple models to explicitly distinguish between three classes of variables: 1) a minimal set, exogenous to all; 2) those specified exogenously for some models, but generated by others; 3) model outputs, whose variation reflects partly model and partly

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[200] Note that this is not the case if the purpose of scenarios is to explore the implications of specified limits on future emissions. If an emission constraint is assumed to be imposed by policy, then different models can be used to explore the implications of that constraint for costs, technologies, and other impacts. In this case, caution is needed in deciding what other model variables, if any, should be constrained.

[201] Weyant and Hill 1999.

parameter uncertainty. An alternative way to use multiple models is to let each model produce one scenario, as was done in the selection of the SRES marker scenarios. With this approach, each scenario represents a particular realization of uncertainty over both exogenous inputs and model structure. This approach does not suppress uncertainty, but confounds model uncertainty with parameter uncertainty. It may be preferable to cross exogenous inputs with models to produce a larger number of scenarios from which subsets can be extracted as needed, perhaps organizing these as a nested hierarchy of scenarios similar to the SRES 6 marker scenarios, 40 SRES scenarios, and hundreds of scenarios in the literature review.

There are good reasons to combine narrative with quantitative approaches, as scenario exercises have increasingly sought to do. But the connection between qualitative and quantitative aspects of global-change scenarios has been inadequate, diminishing the usefulness of the exercises due to inconsistencies within each type of scenario and between the two types. This problem has partly been due to limited time and resources, but has also reflected substantive difficulties in linking the two types of scenario that have been understood or managed well. Narrative scenarios typically specify deep structural characteristics like social values and the nature of institutions, which are associated with structural characteristics of models such as the determinants of fertility trends, labor-force participation, savings and investment decisions, and substitutability in the economy. Consequently, the distinctions between alternative narrative scenarios correspond more closely to variation of model structure than to variation of parameters, because they reflect different basic assumptions about how the world works. Better integrating the two approaches will require developing ways to connect narrative scenarios to model structures, rather than merely to target values for a few variables that models are then asked to reproduce. This has not happened because scenario exercises have not had the capability or resources to direct new model development, or to induce modelers to undertake substantial structural changes to their models. This would require substantial efforts, including getting modelers to interact with scenario exercises in a new way, but might hold more promise for allowing scenarios to usefully inform discussions about large-scale policy choices for mitigation and adaptation.

4.6. Treatment of Uncertainty in Scenarios

Representing and communicating uncertainty is perhaps the most fundamental purpose of scenarios. This section discusses how scenarios represent uncertainties, how these methods connect scenario exercises to simpler formal exercises in analysis of decisions under uncertainty, and what challenges are posed in how uncertainty is represented. It also addresses several important debates about how to treat uncertainties.

In most scenario exercises, uncertainty is represented not in a single scenario, but in variation among multiple scenarios considered together.[202] The choices to be made in deciding how to represent uncertainty include the following:

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[202] When a scenario exercise uses just one scenario, this usually presents some specific threat or challenge posed to existing procedures or decision-makers. In these cases, uncertainty is still represented by differences among scenarios, but the single scenario is implicitly contrasted to the status quo.

- What characteristics are varied;
- By how much these characteristics are varied, separately and together (e.g., should extreme values of multiple characteristics be combined, or extremes of some combined with the middle cases of others);
- How many scenarios to create and consider together;
- What description, documentation, or other information is attached – including whether, how, and how specifically measures of likelihood are assigned.

4.6.1. Uncertainty in simple quantitative projections: basic approaches

How these choices are made, and their implications for scenario use and effectiveness, are closely related to the large-scale decisions in designing a scenario exercise outlined in Section 2.1. In particular, the role of uncertainty in a scenario exercise is strongly linked to scenario complexity, richness and use. In the simplest case, a scenario exercise may be dominated by a single quantitative variable, so all uncertainty could be represented by alternative future levels or time-paths of that variable. This cas is so simple that many scholars and practitioners argue it should not be considered a scenario at all.[203] Still, even this simple and extreme case raises significant issues. We begin here and then move to more complex cases.

If we also assume the probability distribution is known, the situation reduces to a formal exercise in analysis of decision-making under uncertainty. Given a known set of choices and outcomes of each choice under each uncertain outcome, alternative choices can be evaluated by formal methods such as seeking the best outcome on average or under some risk-averse valuation scheme, or looking for robust strategies. This decision-analytic approach can be extended to situations of a few uncertain variables with a known joint distribution, multiple decision-makers who evaluate outcomes differently, or (with somewhat more difficulty) decision makers with different probability distributions.

Further relaxation of these simplifying assumptions moves us toward activities more widely recognized as scenario exercises. First, if a scenario exercise is addressed to more than just a few decision-makers with known choice sets and outcome valuations, scenarios are no longer simply inputs to an analytic exercise but become descriptions of potential future states that must be communicated directly or indirectly to decision-makers for their reflection and deliberation. Second, if distributions of important uncertain quantities are unknown, it is necessary to exercise judgment of how to draw on relevant knowledge to construct and describe alternative future values of the quantities, and how to represent these values to users with a manageable number of scenarios.

Of course, since scenarios describe future conditions, the distributions of quantities in scenarios cannot be known in the same sense that the distribution of current characteristics – e.g., the November daily high temperature at O'Hare Airport – can be known through repeated observations. Probabilistic statements about future conditions always incorporate subjective

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[203] E.g., Wack 1986, in this case, the scenario is just a "quantification of a clearly recognized uncertainty".

elements. Despite this unavoidable element of subjectivity, many forms of current knowledge – including data, models, and expert judgments – are relevant to forming these judgments about future conditions. In constructing scenarios of population growth, for example, the distribution of observed past growth rates can be used to construct a range or distribution of plausible future values.

Projections can also be based on model representations of knowledge of causal processes. For example, instead of simply extrapolating past population growth rates, one could use a demographic model that represents trends in fertility rates, lifespan, and migration to calculate a resultant population trend. Formal modeling can represent the structural relationships transparently, reducing the risk of generating inconsistent projections. Structural models can possibly also perform better in extrapolating to conditions beyond the observed range of behavior. Because models represent causal relationships among multiple variables, these models can extend the range of current and historical data that are relevant to projections, although this may result in an expansion of data needs. Models can also help characterize uncertainty in future quantities of interest, by allowing the uncertainty to be attributed to input parameters – explored through sensitivity analysis or simulation techniques such as Monte Carlo – or to model structure.

Estimating output distributions based on assumed distributions of uncertain input parameters does not capture all uncertainty of importance for assessment and decision-making. The input probability distributions are not known with certainty, nor are the structural assumptions that determine the mapping of inputs onto outputs within any particular model. Uncertainty analysis can embrace this additional level of uncertainty, sometimes called "meta-uncertainty," by stepping up one more level of abstraction – considering not just uncertain quantities, but uncertainty about their uncertainty, or alternatively, probability distributions over probability distributions of unknown quantities. Methods to represent and process such meta-uncertainty mirror those used for first-order uncertainty. This is an active area of research, but its importance for assessment methods and their application is unclear. This level of abstraction increases the difficulty of communicating scenarios and their underlying reasoning transparently and comprehensibly to non-specialists. Moreover, since any step of analysis represents an act of potentially fallible judgment, taking the step to meta-uncertainty still does not capture all possible uncertainty. It is not clear whether, for purposes of constructing and using scenarios, the explicit separation of uncertainty in outcomes from uncertainty in probability distributions brings more benefit than could be gained from simple heuristic guidance to assume distributions are wider than initially seems necessary.

Subjective bias is a major risk in all scenarios, which can be reduced but not eliminated through use of existing data and formal modeling. Judgment is an essential element in constructing scenarios, both to apply relevant data and models when these are available, and to build future descriptions using less formal methods when they are not. The expert judgments supporting such less formal projections may be better founded than mere uninformed speculation, since there is typically much relevant knowledge available beyond what is explicitly captured in present datasets and models. Approaches to developing expert-judgment based projections vary widely in their structure and formality, from simply asking one or more experts to state their best estimate of some unknown quantity, to highly structured elicitation exercises that provide multiple cross-checked estimates of the same quantity.[204] Such methods must attend to risks of overconfidence and bias, which are well documented in experts as well as laypeople Carefully designed elicitation protocols can reduce the effects of such biases, e.g., by prompting experts to broaden their estimates of uncertain quantities, but cannot eliminate them.[205] An additional challenge to these methods is that there is no generally accepted method for selecting or aggregating estimates from multiple experts.

4.6.2. How many scenarios, over what range?

In communicating scenarios to users – even in the extreme case that the scenario only specifies values of one quantitative variable – limited time, resources, and attention usually require that only a few discrete values or time-paths are specified, not a complete distribution. Scenario developers must consequently decide how many scenarios to provide and how to space them.

How many scenarios to provide will rest on a judgment of the value provided by each additional point from the underlying distribution relative to the burden of producing and using each new scenario, while still keeping the process manageable. If the use made of each scenario is expensive – e.g., running a large model or spending the time of busy senior people – then the number of scenarios that can be adequately treated may be very few. The 1992 IPCC scenario exercise provided six separate scenarios, of which nearly all subsequent analyses used just one or two. Of the forty scenarios produced by the SRES process, only six (initially four) were highlighted as "marker" scenarios, while most subsequent analyses used just two or three.[206]

Deciding how many scenarios to provide also involves some element of attempting to forestall predictable errors in their use. While the most obvious and frequent choice in providing scenarios of a quantitative variable has been to provide three – one high, one low, and one in the middle – it has been widely noted that this practice runs the risk that users will ignore the top and bottom, pick the middle, and treat it as a highly confident projection –suppressing the uncertainty that scenario developers tried to communicate by the spacing of the high, middle, and low scenarios. The same risk applies to any odd number of scenarios, leading many developers of quantitative scenarios to the informal guideline that the number of scenarios provided should always be even, so that there is no "middle" scenario for users to inappropriately fix on.

More specific guidance on the appropriate number and range of scenarios must reflect both scenario developers' sense of the underlying distribution from which scenarios are drawn, and their intended use. One must consider whether departures in both directions from the middle are of similar importance, or whether only departures in one direction need be represented. For example, one might judge that in an assessment of impacts of climate change a scenario drawn from the lower tail of potential climate change is likely to provide little substantive insight, since in most cases the impacts of a small-change scenario is predictably small.

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[204] Morgan and Keith 1995.

[205] Kahnemann and Tversky 1974; Wallsten and Whitfield 1986.

[206] Scenarios A2 and B1, sometimes augmented with A1B.

One must also consider how far out in one or both tails of the distribution a set of scenarios should go. Empirical research practice typically draws ranges for unknown quantities to capture 90 to 95 % probability, but there may be good reasons to go further in constructing scenarios. Possibilities further out might be important enough, in their consequences or their effect on preferred decisions, that they must be considered despite their low probability. Assessments and policy in both regulation of health and safety risks and national security, for example, routinely focus on highly consequential risks of a much smaller probability than 1%.

It is often suggested that an important condition of a set of scenarios is that they "span the literature" of prior scenarios or projections of the same quantities. While one should be cautious about a set of scenarios spanning a much narrower range than published estimates of the same quantities, there may be good reasons for a wider or different range, or even in some cases for a narrower range. Scenarios are not scientific research: a published scenario may have been constructed to serve various purposes other than providing an independent new estimate of a quantity of interest. Previous scenarios developed to serve some particular purpose may or may not be relevant to a new scenario development process, depending on the relationship between their intended purposes. Moreover, previously published scenarios can be highly self-referential, since many published analyses use prominent prior scenarios as inputs to a new study, or examine a new model by forcing it to reproduce some prior scenario. For all these reasons, previously published scenarios are better regarded as one input to the judgment of developers of new scenarios than an authoritative picture of present knowledge that new scenarios must follow.

4.6.3. Bifurcations and major state changes

While many uncertainties may be treated as a continuous range of possible values, some uncertainties may capture large-scale bifurcations or abrupt changes. For climate change, potential abrupt changes include melting of major continental ice sheets or shifts to some new mode of ocean circulation.[207] Large-scale bifurcations may also arise from breakthroughs in energy technology. Such possibilities are typically not captured either in historical data or models, as they represent changes in the structure of causal relations that render both invalid.

Abrupt changes can pose particular challenges for deciding the number and range of scenarios to include in an assessment or decision-support exercise, either because their consequences are so extreme or because they would fundamentally change our understanding of how the system operates. The decision whether and how to consider these uncertainties consequently turns on the balance between their probability – which is believed to be low but not well characterized – and their high consequences, which must be evaluated relative to the scenarios' intended use. This will be a particularly difficult choice when only a few scenarios are being generated. For example, in a coastal impacts assessment the enormous consequences of the difference between a half-meter and five-meter sea level rise over this century – and the well-identified mechanism by which such a rise could occur – may suggest the importance of explicitly considering a scenario involving loss of one of the major continental ice masses. But including such a scenario runs the risk that users will assign a much higher probability to it than is appropriate either because of its vividness and extremity, or because they presume that

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[207] NRC 2002.

developers' decision to include the scenario meant they assigned high probability to it. When such a scenario is included, scenario developers have a serious responsibility to communicate, loudly and consistently, that its status is different from the others.

A further challenge in representing large-scale or discrete changes in scenarios is that there might be many such possibilities, all of them high-consequence but believed low-probability. Including any one may mislead both by exaggerating its probability and by suppressing the possibility of others (the "unknown unknowns"). The more there are, the more the right approach might be to shift all scenarios further out to reflect the various mechanisms by which conventional understanding may under-represent the tail of the distribution, rather than highlight a particular abrupt-change mechanism by giving it a scenario of its own.

4.6.4. Uncertainty in Multivariate or Qualitative Scenarios

As the characterization of future conditions within scenarios grows more complex, so does the process of representing uncertainty within them. While many of the issues discussed above in the simplified context of scenarios on a single variable also apply to multi-dimensional scenarios, several additional issues arise.

The most basic of these is that with multiple dimensions of variation in scenarios, representing alternative resolutions of multiple uncertainties – but still with the constraint that only a few scenarios can be produced and used – it is necessary to decide which uncertainties are represented. Even when scenarios include only multiple quantitative variables, it is no longer possible for a few scenarios to span all corners of the joint distribution of these variables. Rather, they must combine variations in ways that are most illuminating and important for the purpose at hand, massively reducing the dimensionality of the problem to make it intelligible for users. In addition, increasingly detailed and realistic scenarios often specify characteristics that are qualitative, or described less precisely than cardinal variables. For example, alternative scenarios might specify that current trends of globalization increase, stagnate, or reverse, or that decision-making capacity on climate change increases or decreases. Such characteristics may be judged crucial to include because they may be among the most important drivers of preferred choices or consequences of concern.

Scenarios of this kind pose substantial further challenges in representing uncertainty and interpreting its meaning. Relative to the simple quantitative scenarios we have considered up to this point, these lie in a much higher dimensionality space of future possibilities; they may not lie in any ordinal relationship to each other; and they may include characteristics whose definitional boundaries are not precisely specified. Defining a small set of scenarios to reasonably span the most important uncertainties is consequently even more difficult than for simple quantitative scenarios.

The approach most widely proposed to represent key uncertainties in such scenarios is to seek underlying structural uncertainties that satisfy two conditions: they appear to be most important in influencing outcomes of concern or relevant decisions; and they are linked with variation in many other factors. These underlying uncertainties can be simple discrete states such as peace or war, prosperity or stagnation; or, as in several major global environmental scenarios, they can be deeper societal trends, such as more or less globalization or shifts in societal values toward greater environmental concern, from which variation in many factors is assumed to follow.

This approach, formalized in the Shell scenarios method,[208] involves two steps: first identifying a small number of fundamental uncertainties and a small set of alternative realizations of each; and then, elaborating additional future characteristics associated with each realization through both qualitative reasoning to fill in a narrative, and assembly of data and model results to build a parallel quantitative description to the extent this is judged useful. Repeated, critical iteration between the qualitative and quantitative elements is conducted, to bring additional relevant knowledge and expertise to bear and to check for consistency.

Even more than for simple quantitatively described scenarios, it is normally only possible to produce a few such rich scenarios in any activity. Typical configurations include two or three outcomes on one fundamental uncertainty; four scenarios, produced by jointly varying two realizations of two uncertainties that are presumed independent; or one scenario that continues familiar trends and dynamics, combined with one or two that pose fundamental changes.

Formal uncertainty reasoning states that as the number of characteristics specified in a scenario increases, the likelihood of the scenario decreases, because it represents the joint occurrence of a larger collection of events. Yet this approach, like any responsible use of scenarios, must imply certain claims of likelihood. Every scenario included must be deemed likely enough to merit the resources and attention spent on developing and analyzing it. This applies even to extreme-event scenarios that are intentionally constructed to capture the low-probability tail of the distribution, since even they must be perceived likely enough to merit time and attention given their severity. Since users would reject any scenario that they persistently judged too implausible to consider, when decision-makers find a scenario exercise useful, it validates developers' judgment that each scenario was likely enough to consider.

These two points – that probability must decline as scenario complexity increases, and that any successful use of scenarios must imply the judgment of developers and users that they are likely enough to merit consideration – might appear to pose a contradiction. The contradiction can be avoided – as can the conclusion that rich multivariate scenarios must be arbitrary and of vanishingly small likelihood – in either of two ways. First, if scenario designers in fact succeed at identifying a few deep structural uncertainties that strongly condition outcomes on many other characteristics in a scenario, then the richness of a scenario description need not imply that it is vanishingly unlikely. Whether this is true or not is a judgment to be made by scenario developers and users in each application. If they are sufficiently careful in their development and critical examination of scenarios, their judgment may well be correct. On the other hand, there will often be no way to further test these judgments, and it is in principle possible that the proliferation of additional detail in scenarios – even detail that developers and users recognize is crucial for determining valued outcomes and preferred choices – is arbitrary or erroneous.

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[208] Shell International 2003.

A second route to resolving the contradiction and building up sufficient basis for confidence in the likelihood of detailed scenarios lies in the precision with which scenario characteristics are specified. In rich multivariate scenarios, many characteristics are often specified diffusely: economic growth may be merely "high" or "low", rather than stating a particular value. Even when a characteristic is stated quantitatively, its specific value may be regarded as merely illustrative of a range of similar values; e.g., GDP growth might be set at 4% because a user needs a numerical model input, but it is understood to represent a broad swath of similar values that all count as "high" growth. Interpreted in this way, a multivariate description may remain likely enough to merit examination – and indeed, a modest number of scenarios may exhaust the set of potential futures that matter for the issue at hand. Here one is not assigning likelihood to the precise numerical assumptions used to flesh out the details of a scenario, but rather to cover a broad range of possible future conditions that resemble that scenario more than the other scenarios in the set.

4.6.5 The Debate over Quantifying Probabilities

A major debate in the use of global-change scenarios has concerned whether or not to specify quantitative probabilities associated with scenarios. This debate is central to the meaning and use of scenarios, and has been sharpest over the IPCC's SRES scenarios. Developers of the SRES scenarios decided at the outset of their process that they would make no attempt to assign probabilities to scenarios, in part because they were adopting the Shell approach of developing scenarios from storylines, in which quantitative probabilities are normally avoided. After the scenarios were published, several critics argued that since the most prominent and important outputs of the scenarios were the projections of greenhouse-gas emissions under the six marker scenarios, it was natural – and essential for development of rational climate-change policy – to describe the distribution of emissions in probabilistic terms. For example, how likely are 2100 emissions to lie above the 30 GtC of scenario A2? Below the 5.2 GtC of B1? Should the range spanned by the SRES scenarios be understood to comprise 90% of all probability? 99%? All of it?

Developers of the SRES scenarios stood by their initial decision not to quantify probabilities. Since the controversy only became prominent long after the decision had been made by a writing team no longer in operation, it would have been virtually impossible for the group to retrospectively assign such probabilities. But rather than rely on this argument of managerial infeasibility alone, SRES organizers offered a vigorous substantive defense of their initial decision. This defense relied in part on the statement that the six marker scenarios were all "equally sound," without providing any guidance regarding what this meant other than explicitly denying that it meant "equally likely." Describing each of the six marker scenarios as "equally sound" represents the entirely reasonable case that in developers' judgment these all needed to be considered seriously –without making any further judgment as to their likelihood. While clearly frustrating to those wanting to use the scenarios as a basis for policy, the result is entirely consistent with the IPCC mandate to do assessment, but not to reach policy conclusions.

This debate, however, will continue and rests in part on different conceptions of the meaning, and typical contents of a scenario. The simpler the contents of scenarios, the more readily they lend themselves to explicit quantification of probabilities. When scenarios consist only of alternative time-paths of a single quantitative variable, or one such variable is of predominant importance, it is straightforward and sensible to understand the intervals between those time-paths to have probabilities associated with them – subjective ones, of course, as for all descriptions of future conditions.

In this simpler case, there are several strong arguments for being explicit about these probabilities. Stating probabilities explicitly organizes current knowledge about possible outcomes, and allows comparative risk assessment between scenarios and explicit exploration of risk-reducing strategies.[209] Sophisticated decision-makers whose choices depend on uncertainty in these variables need probability information about possible values, not just a set of alternative values, to evaluate choices – whether their approach to decision-making is expected-value, risk-averse, or robust. Moreover, when such scenarios are presented without probability judgments, users will attach their own, often via simple heuristic devices that may misrepresent the developers' understanding. Many subsequent users of the SRES emissions scenarios, for example, have simply assumed the probabilities they needed to conduct further assessments, using such simple devices as counting scenarios or assuming a uniform distribution over the entire range. It is clear that the next major emissions scenario exercise, whether done under IPCC auspices or within the larger community, will have to explicitly confront the need to make more definitive probability statements. Since scenario developers are better informed to do this than others, this is likely to become their responsibility.

Opponents of explicit quantification of probabilities do not dispute that such probabilities can coherently be assigned to simple scenarios in one or two quantitative variables. Rather, they raise practical objections to the use of probabilities even in such simple cases, and principled objections to the suitability of attempting to quantify probabilities for more complex scenarios. Practical objections include the difficulty of developing probability estimates from multiple information sources that can achieve sufficient agreement from diverse experts, and the non-intuitive nature of probability distributions in using scenarios to communicate with non-expert users.

For richer and more complex scenarios, three principled arguments are advanced against seeking to assign probabilities. First, some argue that for the type of events represented in rich, complex scenarios, probabilities cannot be sensibly estimated. At its root, this represents a healthy recognition of the severe methodological problems in aggregating expert judgments – although there are elicitation techniques that go some distance to addressing these. For high-stakes public policy issues, declining to state probabilities and instead letting users assign their own might be viewed as deference to democratic legitimacy or as a recognition that it is more appropriate for the decision makers to make the determination as to the weights of the various futures foreseen by the experts. The contrary argument is that the group developing scenarios presumably has the best access to the expert knowledge needed to make these probability judgments. The real issue here may well be the divide between the creators and users of scenarios, since the large number of relevant creators and users prevents the close face to face interplay that would allow a joint process to determine the likelihoods.

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[209] Webster 2003.

The second argument against assigning probability is that the massively large multivariate space of possibilities from which scenarios are drawn, and the vague and qualitative way that some scenario characteristics are specified, make it impossible to coherently define the boundaries of the outcome space to which probabilities are being assigned. In other words, there is no way to clearly define the interval "between" one scenario and another; and if probability is attributed to a lump of possibilities around a scenario rather than to the interval between them, is it not possible to define clearly the boundaries of the lump to which the probability is assigned. To the extent that scenarios describe different types of worlds, which are distinguished from each other by alternative resolution of a few key uncertainties – e.g., high or low growth, high or low globalization, where the location of the boundary is not precisely specified, it may be difficult to create common ground between users and creators. Here, even if assigning a precise numerical probability is judged too difficult, less precise likelihood measures such as "higher versus lower", or "roughly equal" could be assigned. In some applications where scenarios are intended to capture all the uncertainty of concern to the decision-maker – i.e., scenarios are intended to be mutually exclusive and collectively exhaustive – there may even be a reasonable basis for numerical probability.

A third objection to assigning probabilities to socio-economic characteristics such as emissions scenarios is that of "reflexivity" – the concern that since the purpose of scenarios is to inform decision-making, any probability judgment will be rendered invalid because of changes in behavior influenced by the statement of the scenario and its probability assignment. We have addressed this concern in some detail in Section 4.1 in discussing the representation of decisions within scenarios, in particular in the distinction we have drawn between how mitigation decisions should be treated in scenarios to inform mitigation decisions, and to inform impacts or adaptation-related decisions. We might only add here that as applied to global emissions, this concern would require extreme influence by scenarios on their users' behavior and extreme influence by these scenario users on global emissions. The concern might apply more seriously for scenarios are prepared in close consultation with national mitigation policy-makers, but this is an example of the type of scenario use for which we judge explicit attempts to assign probabilities to be less valuable. In any case, it is not clear that concerns about reflexivity should specially afflict the attempt to assign probability to scenarios describing future behavior, rather than rendering any scenario of human behavior invalid.

A final argument against quantifying probabilities is that attempting to do so may represent a distraction that uses time, generates conflicts, and is of little value to scenario users. Whether this is indeed the case, however, is in part a judgment to be made by scenario users, not developers. Opponents of quantified probability argue that users typically only need scenarios to pass some probability threshold. Beyond this threshold, they will seek robust choices that yield acceptable outcomes under all possibilities, so further refinement of probability serves no purpose. This argument has some merit, but only to the extent that it accurately describes how these scenarios will be used. Quantitative assignment of probabilities to scenarios when high-stakes decisions are implicated is clearly difficult and contentious, as the SRES controversy illustrates. Even if this argument correctly characterizes how scenarios are used, users might still be able to profitably exploit more detailed probability information if it were available – although one must also consider the risk that non-technical users might somehow be more likely to misunderstand scenarios with explicit probability judgments attached (perhaps by taking a stated probability distribution as the "true" distribution) than to misunderstand a simple collection of scenarios presented with no such probability information (perhaps by taking the range presented to embrace the totality of all possibilities). It is also possible that engaging scenario users in an attempt to assign probabilities, even only illustratively, could both draw on relevant knowledge of uncertainties that they possess more than scenario developers, and provide a valuable device to probe and sharpen their understanding of the situation. Any argument that refers to the information needs of specific users becomes less persuasive as the set of potential uses and users, and the likely diversity of their information needs, grow larger.

Overall, we find the arguments in favor of quantifying probabilities to be strongest for scenarios whose major outputs are projections of one quantitative variable (or very few), weakest for complex multivariate scenarios with substantial qualitative or narrative elements. The controversy over probabilities in SRES reflected in part different perceptions of what type of scenarios these were. SRES initially followed a storyline-based process and rejected quantification of probabilities on that basis. Subsequent efforts, however, consisted predominantly of developing quantitative emissions projections and neglected further development of the storylines. Moreover, many users perceived the scenarios as consisting principally of their emissions projections, and were not much interested in the under-developed storylines that lay behind them. The controversy over quantitative probability in this case may suggest that, to the extent that quantitative projections are a major output of a scenario exercise, developers may have responsibility to go further in characterizing the likelihood of the resultant emissions intervals than would be appropriate for the more complex underlying storylines.

Moreover, even for rich narrative scenarios, the arguments against rendering probability judgments are strongest when the exercise is produced for a small number of users with similar responsibilities and concerns. In such a setting, intensive interaction between scenario developers and users can provide whatever additional detail about, or confidence in, the scenarios that users may require to benefit from the scenarios. When scenarios serve potential users who are more numerous and diverse, perhaps not even specifically identified, such intensive interaction is not possible. As a result, the value of explicit likelihood language to elaborate scenarios and to capture the confidence in them that developers intended, increases. To the extent that future global-change exercises continue to strengthen their qualitative aspects and the integration between qualitative and quantitative –which we judge to be valuable directions for future efforts – they should still seek to move further toward explicit characterization of likelihood than has been done thus far, even if these efforts stop short of complete, precise quantification.

BOX 4.6.1
The Global Business Network Abrupt Climate Change Exercise

In 2002, the Office of Net Assessments (ONA), a small strategic planning office in the Office of the US Secretary of Defense, asked the Global Business Network (GBN), a strategic-planning consulting firm expert in scenario methods, to develop a scenario of potential national-security implications of abrupt climate change. ONA conducts assessments on diverse issues of potential national security significance. This request was stimulated by widespread scientific interest at the time in potential abrupt climate change, particularly from shifts in North Atlantic circulation, and more specifically by a 2002 report on the topic by the National Academy of Sciences.[210] Several scientific papers had reported new evidence of rapid climate shifts in the past, and recent observed changes in Atlantic circulation and salinity that some scientists thought might indicate impending larger disruption.[211]

GBN staff developed the scenario by reviewing scientific literature and informally consulting with climate and ocean scientists.[212] They reviewed three past climate events – the cool period in the North Atlantic region of 1300 – 1850 called the "little ice age"; a Century-long period of stronger cooling about 8,200 years ago; and the "Younger Dryas", a rapid re-cooling of nearly 9 °F in the North Atlantic region that occurred 12,700 years ago and lasted 1,300 years[213] -- and decided to base their scenario on the one of intermediate severity, the 8,200-year event. Coming after an extended warm period, this event brought cooling of about 5 °F over Greenland, with cold and dry conditions extending around the North Atlantic basin and substantial drying in mid-continental regions of North America, Eurasia, and Africa.[214]

For their future abrupt-change scenario, the authors constructed a path of climate change to reach conditions like those during the 8,200-year event by 2020. The path to reach these conditions involved rapid warming through 2010, as high as 4 – 5 °F per decade in some regions,[215] followed by a rapid turn to cooling around 2010, as melting in Greenland freshens the North Atlantic and substantially shuts down the thermohaline circulation. By 2020, hypothesized conditions have approached those of the 8,200-year event – cooling of 5 °F in Asia and North America and 6 °F in Europe, with widespread drying in major agricultural regions and intensification of winter storm winds. The authors acknowledge that the scenario pushes the boundaries of what is plausible, both in the rapidity of changes and in the simultaneous occurrence of extreme changes in multiple world regions, but contend that this is defensible and useful for an exercise focused on sketching the nature of challenges posed by a plausible worst case.[216]

The socio-economic and security implications of the climate scenario were developed judgmentally, in consultation with ONA. For the first 10 years, the authors project incremental changes, with general increase in environmental stresses and approximate maintenance of present disparities between rich and poor countries. After 2010, catastrophic cooling in Europe and drying of major agricultural regions worldwide brings widespread shortages of food, due to decreased agricultural production; of water, due to shifted precipitation patterns; and of energy, due to shipping disruptions from increased sea ice and storminess. These shortages produce 400 million migrants over the period 2010-2020, as desperate scarcity generates violent conflict in Europe, Asia, and the Americas. Extending their speculation on security implications into the 2020s, the authors hypothesize widespread southward migration of Europeans and near-collapse of the EU, sustained conflict in East and Southeast Asia including struggles between China and Japan over access to Russian energy supplies, and increasing political integration of a fortress North America to manage security risks and refugee flows.

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[210] NRC, 2002.

[211] See, e.g., Dickson et al, 2002, Hansen et al, 2001, Gagosian, 2003.

[212] Global Business Network, 2004.

[213] Woods Hole Oceanographic Institute, 20?? ("abrupt change" brochure), Alley 2000.

[214] Alley et al, 1997.

[215] Note that these regional projections are 5 - 10 times faster than the IPCC projected global-average rate of warming over the 21st century.

[216] GBN, pg 7; Schwartz interview; GBN Press Release, "Abrupt Climate Change", February 2004, at www.gbn.com/ArticleDisplayServlet.srv?aid=26231

Controversy and Criticism

The project was completed in October 2003 and its reports published in February 2004 and reported in Fortune Magazine the same month.[217] Several weeks later, the London Observer claimed to have obtained the report secretly, and used its extreme scenario to criticize US refusal to join the Kyoto Protocol.[218] Subsequent news coverage took up the theme that the report was secret or suppressed, suggesting the reason was that its extreme scenario called for more urgent action on climate change.[219] In the resultant controversy, DOD stated – accurately – that the report did not represent US policy, but was merely a speculative study by a consultant. The controversy subsided after a few weeks, and interest and concern about the possibility of abrupt change – although not of this precise character – have continued to grow.[220]

This scenario is a sketch of an abrupt climate-change event. There is little fine-scale detail about the hypothesized changes or the underlying reasoning, and no attempt to suggest how likely or unlikely the described event it. It seeks to provide a preliminary answer to the question, what might the worst case look like? Such questions are more often posed to scenarios in security studies than other fields, because of the unique nature of responsibilities of military organizations – responding to diverse, novel, unknown threats with extremely high cost of failure. It would seem likely that many climate-change decision-makers could benefit from such upper-bound scenarios too, but this exercise is the only example of an extreme or worst-case scenario produced for climate change. Major official assessments have focused overwhelmingly on average or best-guess projections.

But the response to this report vividly illustrates the risks of worst-case or extreme scenarios. Produced in consultation with a sophisticated user – and in this case, one closely connected to senior decision-makers – who thoroughly understands the outer-bound nature of the underlying assumptions, they can be valuable devices for preliminary risk assessment and threat identification. But in a wider and polarized policy debate they are hard to explain and at risk of misunderstanding or misrepresentation. Attempting to manage these risks through secrecy appears risky and counterproductive, foregoing the potential value such analyses could provide to multiple decision-makers. More promising might be to integrate extreme-case scenarios explicitly into analyses that also present multiple mid-range scenarios.

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[217] Stipp 2004. (released, January 26, 2004)

[218] London Observer, "Now the Pentagon Tells Bush: Climate Change Will Destroy Us", February 22, 2004, observer.guardian.co.uk/international/story/0,6903,1153513,00.html,

[219] San Francisco Chronicle, "Pentagon-Sponsored Climate Report Sparks Hullabaloo in Europe", February 25, 2004; The Providence Journal, "Pentagon report plans for climate catastrophe", March 3, 2004.

[220] E.g., Alley 2004 cites it as a useful worst-case assessment.