In: Frank Biermann, Sabine Campe, Klaus Jacob, eds. 2004. *Proceedings of the 2002 Berlin Conference on the Human Dimensions of Global Environmental Change "Knowledge for the Sustainability Transition. The Challenge for Social Science"*, Global Governance Project: Amsterdam, Berlin and Oldenburg. pp. 67-75.

The Precarious Role of Scenarios in Global Environmental Politics. Political options versus scientific projections

Harald A. Mieg [*1]

SUMMARY

In 1967, Kahn and Wiener introduced the concept of scenario construction as a tool for science-based strategic decision-making. More recently, the IPCC (the Intergovernmental Panel on Climate Change) has been employing such scenarios to translate climate-change research findings into international politics. The history of the IPCC scenarios provides evidence of the potential of scenarios to elicit political resonance but also irritation. The IPCC-1990 scenarios took into account political developments and included a business-as-usual scenario. The IPCC-2000 scenarios were designed as purely non-intervention, gaining in scientific evidence but, as scenarios, loosing out in terms of direct political relevance. The status of these scenarios has effectively changed from an option-in-context into a form of soft prediction. The transformation of IPCC scenarios can be interpreted from two points of view. Firstly, seen from a cognitive point of view, scenarios seem a perfect support for decision-making, however, tending to disregard incremental processes and to underestimate seemingly non-measurable factors (such as social values). Thus, it is difficult to find a validated scientific basis for intervention scenarios. Secondly, when we analyze science and politics as two different functional systems and two different professional spheres, the definition of scientific scenarios for political action runs into conflict with the political business at hand.

The scenario method was introduced by Herman Kahn in the late 1960s as a tool for strategic planning. In his book (with Wiener), "The Year 2000," Kahn explained what scenarios are for:

> Scenarios are hypothetical sequences of events constructed for the purpose of focusing attention on causal processes and decision-points. They answer two kinds of questions: (1) Precisely how might some hypothetical situation come about, step by step? and (2) What alternatives exist, for each actor, at each step, for preventing, diverting, or facilitating the process. (Kahn & Wiener 1967, p. 6)

Scenarios represent different possible futures. They describe *options and their contexts*. The scenario method has been used in strategic corporate planning and, more recently, by the IPCC—the Intergovernmental Panel on Climate Change—to translate findings of climate-change science into international politics (cf. IPCC 1990; 1992; 2000).

IPCC SCENARIOS

1990-1995

The IPCC report of 1990 communicated the results in four scenarios of climate policies for the time until the year 2100. Scenario A depicts business as usual:

> [T]he energy supply is coal intensive and on the demand side only modest efficiency increases are achieved. Carbon monoxide controls are modest, deforestation continues until the tropical forests are depleted and agricultural emissions of methane and nitrous oxide are uncontrolled […] (IPCC 1990, xxxiv).

The other three scenarios depict increases in efficiency in the use of carbon fuels, carbon monoxide controls, halted deforestation, and a shift towards renewables and nuclear energy (cf. Table 1). Thus, the IPCC-1990 scenarios are based on the variation of several "key" parameters that supposedly influence emissions of greenhouse gases, including: population growth, economic growth, deforestation, end-use efficiency of energy uses (cf. den Elzen 1994, chap 5; IPCC 1992). The construction was undertaken by an US-Dutch expert group (cf. den Elzen 1994).

In 1992, IPCC revised the 1990 scenarios assigning them a no-policy status (Leggett, Pepper & Swart 1992). Particularly, Scenario A ("Business as usual") was split into scenario 92a and 92b (see Figure 1). In 1994, IPCC clearly focused the purpose of emissions scenarios to "non-intervention," namely:

> As input to evaluating the environmental/climatic consequences of "non-interventions", i.e. no action to reduce greenhouse gases. For this purpose a non-intervention scenario is devised, and then used as input for a climate or similar model to evaluate the scenario's environmental/climatic consequences. (Alcamo et al. 1995, 251)

[*] Swiss Federal Institute of Technology Zurich, Switzerland. Contact: harald.mieg@env.ethz.ch.

[1] I thank Rajendra K. Pachauri for his comments on the previous version of this paper.

Table 1: IPCC climate change scenarios as communicated in the IPCC-1990 report

	CO_2				methane & nitrous oxide	CFC	
	energy mix	supply: efficiency	carbon monoxide-controls	deforest-ation	agriculture	Montreal Protocol	timing
A "Business as Usual"	coal	-	modest	+	+	partially im-plemented	
B "Low Emissions"	natural gas	+	+	-	?	+	
C "Control Policies"	renewables & nuclear power	+	+	-	-	CFC phase out	> 2050
D "Accele-rated Poli-cies"	renewables & nuclear power	+	+	-	-	CFC phase out	< 2050

Note. Only some of the parameters used for scenario construction are communicated (for details cf. den Elzen 1994). The scenarios are constructed by varying the state of the different parameters for greenhouse-gas emissions. To some extent, the scenarios build on one another: scenario B is "better" than A, as C is "better" than B and so on; scenario C contains the same preferable regulations as scenario B and some more (such as the use of renewables). Scenario D has an additional time limit. The table shows only those specifications that were explicitly made; for instance, we can assume that scenarios C and D have carbon monoxide (CO) controls. Source: Mieg (2001, Table 6.1). Copyright 2001 by Lawrence Erlbaum Associates. Reprinted with permission.

The IPCC-"Climate Change 1995" report slightly redirected attention from global warming to the scientific study of "radiative forcing." The IPCC-summary for policymakers started in 1990, under the heading "We are certain of the following," with a focus on the greenhouse effect and global warming that is increased by human activities (IPCC 1990, xi). The policymakers summary of the 1995 report started with the remark that "considerable" scientific progress has been made since 1990 and then, under the heading "Greenhouse gas concentrations have increased," focused on radiative forcing (IPCC 1996, 3). The attentive reader of the reports may also notice a change in terminology: Whereas the 1990 report speaks of "predicting" climate change, the 1995 report speaks of "projecting" it (cf. IPCC 1996, 31; IPCC 1990, xxv).

2000-2001

In contrast to the 1990 scenarios, those of 2000 (IPCC 2000) do not include any policies or intervention. Particularly, there is no business-as-usual scenario. Instead, these new scenarios follow one of four specific story lines. These being (IPCC 2000, 4-5):

> The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. [...]
>
> The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly [...].
>
> The B1 storyline and scenario family describes a convergent world [...], as in the A1 storyline, but with rapid changes in economic structures towards a service and information economy, with reduction in material intensity, and the introduction of clean and resource-efficient technologies. [...]
>
> The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability.

The driving forces are: population growth, economic development, technology, energy, and agriculture (land-use). All in all, 40 scenarios were constructed, based on an intense study of scientific scenario literature and using six different modeling approaches (IPCC 2000, 335-351). Figure 2 shows the four scenario families. Part of the construction was an open process which lasted from June 1998 to January 1999 (IPCC 2000, 353-377); during that time the storylines and, for each storyline, a so-called marker scenario were presented on the web and open to discussion.

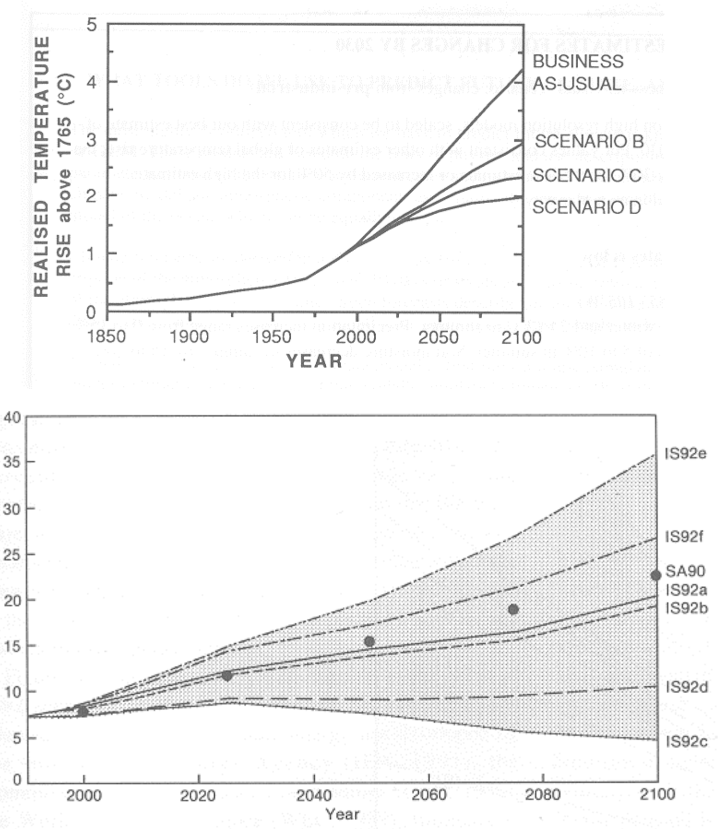
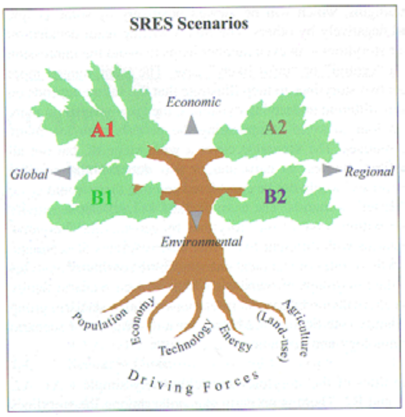


Figure 1. On the top: Increases in global mean temperature from 1850 to 2100. This figure shows the increases in global mean temperature from 1850 to 1990 due to observed increases in greenhouse gases, and predictions of the rise between 1990 and 2100 resulting from different scenarios (IPCC 1990, fig. 9, xxiii). At the bottom: Revised no-policy scenarios of 1992, the dots indicating the 1990-"Business as usual" Scenario A (Leggett, Pepper & Swart 1992, 81, fig. A3.1). Copyrights by IPCC. Reprinted with permission.

Contrary to 1990, the IPCC-2000 scenarios are not explicit regarding global temperature changes. They further extend the range for emissions of greenhouse gases derived in the 1990/1992 scenarios to higher emissions (but not towards lower emissions). The IPCC-2000 scenarios are, however, interpreted in the Climate-Change 2001 Synthesis Report (IPCC 2001). In particular, they are used to answer Questions 3 and 9 which explicitly refer to temperature change and its consequences:

> Question 3: "What is known about the regional and global climatic, environmental, and socio-economic consequences in the next 25, 50, and 100 years associated with a range of greenhouse gas emissions arising from scenarios used in the TAR (projections which involve no climate policy intervention)? [...]" (IPCC 2001, 8).
>
> Question 9: "What are the most robust findings and key uncertainties regarding attribution of climate change and regarding model projections of:
>
> • Future emission of greenhouse gases and aerosols?
>
> • Future concentrations of greenhouse gases and aerosols ?
>
> • Future changes in regional and global climate? [...] (IPCC 2001, 30)".



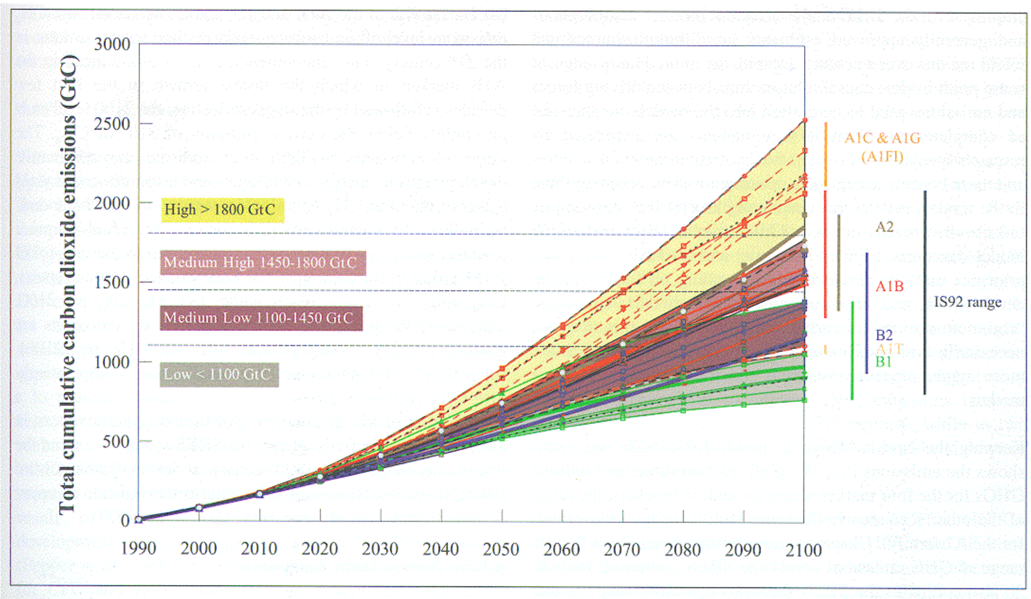


Figure 2. On the top: The four families of IPCC-2000 emission scenarios. Source: IPCC (2000, fig. 4-1); SRES: Special Report on Emissions Scenarios. At the bottom: CO_2 emissions according to the four families of IPCC-2000 emission scenarios Source: IPCC (2000, fig. 6-8). IS92: IPCC 1992. A1B, A1C, A1FI, AT: variants of the storyline A1 scenario family. Copyrights by IPCC. Reprinted with permission.

The Art of Scenario Building - The Definition of Types of Variables

The scenario method is well established in economic and political planning (cf. Cooke 1991; Godet 1987; Götze 1993; Ringland 1998; Schnaars 1987; Scholz & Tietje 2001; Wilkinson 2002). Most scenario building methods are based on the analysis of impact variables such as population growth (in global scenarios) or the development of a specific market (in a business scenario). Sometimes these variables are called "factors," "parameters" or "forces." In the following, I will discuss distinctions between scenario variables.

First, we can simply distinguish between *relevant* and irrelevant variables. A variable is relevant in regard to a specific purpose and a specific system. In the case of business scenarios, we have to take into account other kinds of systems than in the case of global scenarios. In the first case the system might be an enterprise and its market, in the second case it is the Earth. Furthermore, if we want to construct scenarios for global freight transportation, different variables become relevant to those needed in global warming scenarios. Finally, the purpose of constructing non-intervention scenarios as defined in the 1994 evaluation of 1992-IPCC scenarios (Alcamo et al. 1995, 259, BOX 2) sets aside political parameters. Such parameters—for instance global alliances— would have been relevant for alternative purposes like "to evaluate the environmental/climatic consequences of intervention to reduce greenhouse gas" (loc. cit.).

Second, we can distinguish between *active* and *passive* variables. Active variables have a strong impact on the other variables. Passive variables are strongly influenced by other variables. To be clear, the distinction of active and passive variables is relative to a set of variables. A particular variable might be active in one set of variables and passive in another. Very active variables are sometimes called "driving forces." There are established measures for activity and passivity of variables (starting with Duperrin & Godet 1973).

Third, we can distinguish between *steering* variables and *context* variables. Steering variables are active variables that can be changed by political or managerial decision-making. Steering variables can be policies and specific interventions such as taxes, prohibition or investments. Context variables are variables that cannot be used to exert an impact on other variables. World population growth and global economic development are—at this point in time—context variables in almost every scenario. Context variables are sometimes called "external variables" or "trends." In the IPCC-1990 scenarios, policies defined steering variables. The 2000-scenarios lack any steering variables. Therefore, they cannot answer the second kind of questions that scenarios as defined by Kahn should answer, namely: What alternatives exist, for each actor, at each step, for preventing, diverting, or facilitating the process?

Fourth, we can distinguish between *independent* variables and *dependent* variables. Independent variables are active variables for which we have varying input data. Dependant variables are the target output variables in our analyses using scenarios. In the IPCC-1990/1992 scenarios, global warming was the main dependent variable. After 1992, IPCC scenario building clearly focused on emissions. In general, when defining dependant variables, we seem to put too much weight on measurable variables such as GDP or emissions; seemingly non-measurable variables such as social values or political movements occur—if at all—only as independent variables (Mieg 1998). This phenomenon influences modeling in that we are less aware of effects on seemingly non-measurable variables (e.g. influences on social values) than on measurable variables.

COGNITIVE SCENARIO CONSTRUCTION - "JOINTS"

Scenarios have a *hypothetical* form "if X then Y" and describe steps between "hypothetical situations" X, Y, and Z. From the point of view of cognitive psychology, constructing scenarios is an instance of *mental simulation*. This is true for someone who constructs the scenarios as well as particularly for someone who has to understand—to reconstruct—them. We can divide the process of scenario construction into four steps (cf, Jungermann & Thüring 1987, 1988; Mieg 2001; see Figure 3).

The first step consists of the activation of knowledge about the problem. However, the *problem* knowledge has to be arranged. This leads to the second step: the construction of a *mental model* (Johnson-Laird 1983). A mental model is a partial representation of the world. Among facts and other data, it contains causal knowledge of the type: "If parameter p changes then parameter q will change, too." A mental model for assessing climate change would include a model of the climate system, physical laws and knowledge about relevant parameters, for instance the current amount of CO_2-emissions.

The third step consists of *mental simulation*, that is using—"running"—the mental model to cognitively simulate specific problem constellations, for instance, to consider future economic development and climate change. This leads to specific inferences, for instance, about what are the driving forces and the key parameters. In the last step we have to select relevant inferences in order to arrive at useful scenarios. The selection of inferences might shed new light on the mental model and lead to the insight that more knowledge is needed.

The four steps serve two fundamental cognitive tasks; problem representation and delimiting relevance (cf. Mieg 1993; 2001). The *problem representation* has to be complete or—at least—representative in order to be valid. The overall task is to bring a complex world into the limited space of a mind. Using scenarios, we would often like to know about their validity. However, we lack evidence for future phenomena. Therefore, the validity of a family of scenarios can only be tested in regard to its present problem representation (Ulbrich & Mieg 2002). *Delimiting relevance* means to view the problem representation from the perspective of a specific purpose or problem to be resolved. The purpose might be, for instance, to find scenarios that can easily be communicated to the public, or to arrive at scenarios that direct future research. Different purposes result in different relevance decisions.

A huge difference in purpose lies between exploratory and anticipatory scenarios (cf. Ducot & Lubben 1980). *Anticipatory* scenarios define relevant effects and situations that might arise. Scenario building with anticipatory scenarios starts with the scenarios and then tries to track them back to the present situation. Scenario building with *exploratory* scenarios works the other way round. It starts with an analysis of the present situation and tries to derive different scenarios for future development. From the point of view of cognitive psychology, scenario building with exploratory scenarios is a forward-problem solving process (cf. Johnson-Laird, 1999), focusing on the correct *representation* of the problem and its present context. In contrast, scenario building with anticipatory scenarios is a backward-problem solving process focusing on defining the *relevant* options.

Cognitive problem representation and delimiting relevance are both subject to central cognitive constraints. Mental simulation involves conscious analytical thinking and therefore short-term memory processes. Due to the very limited capacity of the short-term memory (storing 7± 2 items, cf. Miller 1956), cognitive simulation can use only a limited number of contents and variables. This is the simple reason why neither in 1990/1992 nor in 2000 more than 7 IPCC-scenarios or scenario families were constructed. To overcome the limitation of short-term memory, we can either select relevant variables or use items with condensed contents (so-called cognitive "chunks"). Such condensed items are abstract terms or formulas, for instance for physical laws. Science is built on such abstractions as "radiative forcing" and "climate." These abstractions, however, are generally not in use outside science.

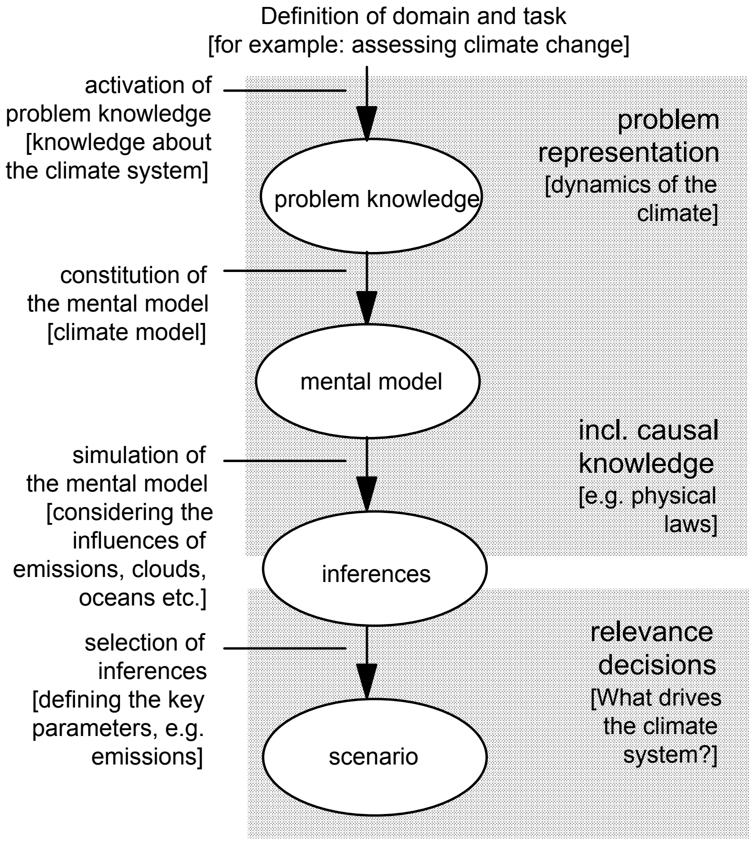


Figure 3. Mental scenario construction from a psychological point of view (after Jungermann & Thüring 1987, 1988, fig. 1; the examples and the shaded spaces are added). Source: Fig. 6.3 from Mieg (2001). Copyright 2001 by Lawrence Erlbaum Associates. Reprinted with permission.

The 1990 scenarios were communicated as policy scenarios that focus on politically relevant decision points such as carbon monoxide controls and the implementation of the Montreal Protocol that regulates CFC emissions (as in Tab. 1). Kahneman and Tversky called these decision points "joints" and claimed that mental simulation in general is based on joints (1982, 207). *Joints* are dramatic events "that are low in redundancy but high in causal significance" (loc. cit.), a *causally significant* event being one "whose occurrence alters the values that are considered normal for other events in the chain that eventually leads to the target of the scenario" (loc. cit.). Kahneman and Tversky explained *redundancy* only for the negative case (as in joints): "A non-redundant event represents a local minimum in the predictability of the sequence, a point at which significant alternatives might arise" (loc. cit.). In scenario construction, variables containing joints represent very "active" singular *events* like political interventions, industrial alliances or wars.

According to Kahneman and Tversky, the use of joints results in a "tendency to underestimate the likelihood of events that are produced by slow and incremental change" (loc. cit.). The problems the IPCC-1990 scenarios were facing were complementary: they had to plausibly explain the incremental change of climate by linking it to dramatic joints, especially in the field of national and international politics. As said, the IPCC-2000 scenarios refrained from using steering variables; they were free of joints. Instead, they show how different futures evolve on the basis of varying assumptions regarding population growth, economic development, technological change, etc.

POLITICS & SCENARIOS: INCREASING OR REDUCING POLICY OPTIONS

Scenarios containing joints perfectly match the needs of decision making, cognitively and politically. Generally, decision-making means rendering uncertainty into risk (cf. Schön 1967; Mieg 1994). We do not know the future, and we are often even uncertain about our present: when deciding what to do, we change this uncertainty into the risk that our decision might turn out to be wrong resulting in heavy losses.

Decision-making is the content of politics. According to Luhmann (1988), politics is a functional system within society which regulates power; policies are decisions about future decision-making (Luhmann 1971). The power of political decision-making is based on the fact that modern societies try to communicate a wide spectrum of events—from taxation to traffic accidents—as consequences of decisions (Luhmann 1993). Political decision-making means rendering social uncertainty into the risk of what the future society might be. It follows: as scenarios depict alternative futures and joints in scenarios indicate when and how to decide for which future, scenarios containing joints are suitable means of communicating science to politics.

Science is a functional social system different to that of politics (Luhmann 1988). The logic of science is to render uncertainties of knowledge into relative certainties or truth. From a scientific point of view, it is difficult to integrate the uncertainties involved in political decision-making into modeling reality. Even if we know the effects of accelerated control policies on the climate, as in the case of the Montreal protocol and the prohibition of ozone-depleting substances, we do not really know the social and political circumstances that can bring about these policies. The IPCC-2000 scenarios resolved this problem scientifically, by studying aggregated effects of social and economic development such as population growth and technological changes.

There is a constant but not always consonant interaction between the system of science and the system of politics. Communications from one side can have or lack *resonance* on the other side (Luhmann 1988). Resonance does not only depend on a common language but also on the options open to management on both sides. Resonance involves acceptance of the logic of success of the other system. Thus, the standard successful collaboration between science and politics tries to *increase* options for both parties. Science provides justifications for policies that help communicate and justify political decisions to the public—often leading to requests from the political side for scientific evaluation of feasible options (cf. Alcamo, Kreileman & Leemans 1998). Vice versa, politics provide budgets and public awareness for particular research programs. However, irritations arise when interaction results in *reducing* the particular options, for instance, when politics tries to restrict research or define research programs by laws or budgeting. Or, when scientists try to prescribe political options and intervene in political decision-making. A person or a functional social system faced with losing options will show reactance (Brehm, 1966), trying to defend its freedom to decide by refusing all advice that restricts options. From this point of view, scientifically based scenarios for political action ("joints") have a potential for threatening politicians.

Moreover, as Kahneman and Tversky had already noted (1982, 207), using scenarios with joints disregards slow, incremental processes. A variable representing an incremental process would be a context variable that is rather low in activity *and* passivity. These variables might even not be regarded as relevant, unless we know about this particular incremental process. Examples for social incremental processes would be the radicalization of parts of the society because of unemployment or lack of active integration policies; or the changes in global freight transportation chains due to technological and economic development. Climate change as such is an incremental process that was brought to public awareness by science.

Politics does not necessarily react to uncertainty but rather to insecurity. We can say that insecurity is perceived uncertainty (Mieg 2001), for instance, insecurity in job relations or insecurity caused by crime in the streets. If there is scientific evidence for a potential catastrophe, this can strongly support policies to avert the particular catastrophe. The IPCC-1990 scenarios still had a clear message contained in the business-as-usual scenario: if we do not act now, global warming will exceed more than 4 degree Celsius by 2100. The IPCC-2000 report skipped the business-as-usual scenario and reduced the message to estimates of CO_2 emissions that were interpreted for politics in the 2001 synthesis report (cf. IPCC 2001).

The comparison of the first IPCC scenarios in 1990 with the last ones in 2000 shows the dilemma between the need for scenarios that would provide options for decision making, on the one hand, and the need for an exact and comprehensive understanding of the social and natural factors that lead to climate change, on the other. The IPCC-2000 scenarios may seem a retreat of science back to its home business, coming back to validated and more or less exact figures. The status of the scenarios changed from *options-in-contexts* into some kind of *soft predictions*. The 1990-"Business as usual" scenario has developed into the variety of the IPCC-2000 non-intervention emissions scenarios, gaining in scientific evidence but loosing, as scenarios, in political relevance. The 2000-emissions scenarios have reduced the general hypothetical form of scenarios ("if X then Y") to projections on the basis of different underlying assumptions about the driving factors. They have become pure context scenarios.

The transformation of the IPCC scenarios from 1990 to 2000 can also be seen as a re-arrangement of the two professional spheres of science and international politics. Usually, in their interaction with politics, scientists take on the role of experts who provide politics with information and, sometimes, advice. Political decision-making is not part of this role; it would intrude on the professional sphere of politicians (cf. Mieg 2001). Vice versa, a politician defining the methodology for scientific research would intrude on the professional sphere of scientists. Climate change research has had an enormous impact on the agendas of international politics. Now, politics has to translate the scientific concerns about climate change into policies—thereby re-establishing the conventional borderlines between science and politics.

It may well be that the Kyoto-process left many scientists disappointed that it failed to influence or inform politics to a great extent. However, even if the Kyoto Protocol's direct effect on climate change might be next to nothing, the process create,d a whole range of new political instruments such as joint implementation and the "clean development mechanism" (Grubb, Vrolijk & Brack 1999). The creation of these new instruments of international environmental politics was unforeseen and itself opens new scenarios for climate change policies.

References

Alcamo, Joseph, A. Bouwman, J. Edmonds, A. Grübler, T. Morita, and A. Sugandhy. 1995. An evaluation of the IPCC IS92 emission scenarios. In *IPCC 1995* (chapter 6).

Alcamo, Joseph, Eric Kreileman, and Rik Leemans. 1998. Global models meet gobal policy. In *Global Change Scenarios of the 21st Century, Results from the IMAGE 2.1 Model*, edited by Joseph Alcamo, Rik Leemans, and Eric Kreileman. Oxford: Pergamon.

Brehm, Jack W. 1966. *A Theory of Psychological Reactance*. New York: Academic Press.

Cooke, Roger M. 1991. *Experts in Uncertainty*. New York: Oxford University Press.

den Elzen, Michel. 1994. *Global Environmental Change*. Utrecht: International Books.

Ducot, C., and G. J. Lubben. 1980. A typology for scenarios . *Futures* 12(Feb.): 49-57.

Duperrin, J. C., Michel Godet. 1973. *Méthode de Hiérarchisation des Eléments d'un Système*. Rapport Economique du CEA, R-45-41. [Reference taken from: Godet, Michel. 1986. Introduction to ‚La Prospective': Seven Key Ideas and One Scenario Method. *Futures*, (April 1986): 134-157]

Godet, Michel. 1987. *Scenarios and Strategic Management*. London: Butterworths.

Götze, Uwe 1993. Szenario-Technik in der strategischen Unternehmensplanung, 2. Aufl., [The Scenario Method in Strategic Business Planning]. Wiesbaden: Deutscher Universitäts-Verlag.

Grubb, Michael, Christiaan Vrolijk, and Duncan Brack. 1999. *The Kyoto Protocol*. London: The Royal Institute of International Affairs.

IPCC 1990: Houghton, John T., G. J. Jenkins, and J. J. Ephraums, editors. 1990. *Climate Change: The IPCC Scientific Assessment*. Cambridge, UK: Cambridge University Press.

IPCC 1992: Houghton, John T., B. A. Callander, and S. K. Varney, editors. 1992. *Climate Change 1992: The Supplementary Report to the IPCC Scientific Assessment*. Cambridge, UK: Cambridge University Press.

IPCC 1995: Houghton, John T., L. G. Meira Filho, J. Bruce, H. Lee, B. A. Callander, E. Haites, N. Harris, and K. Maskell, editors. 1995. *Climate Change 1994: Radiative Forcing of Climate Change and an Evaluation of the IPCC IS92 Emission Scenarios*. Cambridge, UK: Cambridge University Press.

IPCC 1996: Houghton, John T., L. G. Meira Filho, B. A. Callander, N. Harris, A. Kattenberg, and K. Maskell, editors. 1996. *Climate Change 1995: The Science of Climate Change*. Cambridge, UK: Cambridge University Press.

IPCC 2000: Nakicenovic, Nebojsa and Rob Swart, editors. 2000. *Special Report on Emission Scenarios*. Cambridge, UK: Cambridge University Press.

IPCC 2001: Watson, Robert T. et al. 2001. *Climate Change 2001: Synthesis Report*. Cambridge: Cambridge University Press.

Johnson-Laird, Philip Nicholas. 1983. *Mental Models*. Cambridge: Cambridge University Press.

Johnson-Laird, Philip Nicholas. 1998. Formal rules versus mental models in reasoning. In *The Nature of Cognition*, edited by Robert J. Sternberg. Cambridge, MA: MIT Press.

Jungermann, H., and M. Thüring. 1987. The use of causal knowledge for inferential reasoning. In *Expert Judgment and Expert Systems* edited by Jeryl L. Mumpower, L. D. Phillips, O. Renn, and V. R. R. Uppuluri. Berlin: Springer, 131-146.

Jungermann, H., and M. Thüring. 1988. The labyrinth of experts' minds: some reasoning strategies and their pitfalls. *Annals of Operations Research* 16: 117-130.

Kahn, Herman, and Anthony J. Wiener. 1967. *The Year 2000*. New York: Macmillan.

Kahneman, Daniel, and Amos Tversky. 1982b. The simulation heuristic. In *Judgment under Uncertainty: Heuristics and Biases*, edited by Daniel Kahneman, Paul Slovic, and Amos Tversky. Cambridge, MA: Cambridge University Press, 201-208.

Leggett, J., W. J. Pepper, and Robert J. Swart. 1992. Emissions scenarios for the IPCC: an update. In *IPCC 1992* (chapter A3).

Luhmann, Niklas. 1971. *Politische Planung* [Political Planning]. Opladen: Westdeutscher Verlag.

Luhmann, Niklas. 1988. *Ökologische Kommunikation* [Ecological Communication]. Opladen: Westdeutscher Verlag.

Luhmann, Niklas. 1993. *Risk: A Sociological Theory* (2nd ed.). New York: Aldine de Gruyter.

Mieg, Harald A. 1993. *Computers as Experts? On the Nonexistence of Expert Systems*. Frankfurt/New York: Lang.

Mieg, Harald A. 1994. *Verantwortung* [Responsibility]. Opladen: Westdeutscher Verlag.

Mieg, Harald A. 1998. Integrating experts and expert knowledge with organizational and managerial decision making: expert roles and scenario-based planning. Paper presented at the *Conference on Managerial and Organizational Cognition*, New York University, Stern School (May 8-9).

Mieg, Harald A. 2001. *The Social Psychology of Expertise: Case Studies in Research, Professional Domains, and Expert Roles*. Mahwah, NJ: Lawrence Erlbaum Associates.

Miller, George A. 1956. The magical number seven, plus or minus two. *Psychological Review* 63: 81-97.

Morgan, M. Granger, and Max Henrion. 1990. *Uncertainty: A Guide to Dealing with Uncertainty in Qualitative Risk and Policy Analysis.*

Cambridge, UK: Cambridge University Press.

Ringland, Gill. 1998. *Scenario Planning: Managing for the Future*. Chichester: Wiley.

Schnaars, Steven P. 1987. How to develop and use scenarios. *Long Range Planning*, Vol. 20: 105-114.

Scholz, Roland W., and Olaf Tietje. 2000. *Embedded Case Study Methods: Integrating Quantitative and Qualitative Knowledge*. Thousand Oaks: Sage.

Schön, Donald A. 1967. *Technology and Change*. Oxford: Pergamon.

Ulbrich, Susanne, and Harald A. Mieg. 2001. *Möglichkeiten und Grenzen der Gütebewertung von Szenarien am Beispiel der Schweizer Energieplanung* [Chances of and Limits to the Evaluation of Scenarios: Swiss National Energy Planning] (MUB Working Paper 5). Professur für Mensch-Umwelt-Beziehungen, ETH Zürich.

Ulbrich, Susanne, and Harald A. Mieg. 2002. Gütebewertung von Szenarien [Evaluating Scenarios]. *Umweltfocus,* (1), 44-47.

Wilkinson, Lawrence. 2002. *How to Build Scenarios.* www.wired.com/wired/scenarios/build.html