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Scenarios

Guidance for an Uncertain and Complex World?

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ABSTRACT

Scenarios are novel tools to explore an increasingly uncertain and complex world. Their increasing use reflects the limitations of the control paradigm as well as the rise of democratic pluralism in values and behavior. In conjunction with simulation models, the scenario approach has been applied in several large global change projects. To draw lessons for future scenario projects, this chapter reviews two projects: TARGETS and SRES. To improve the next round of global change scenarios, suggestions are made: First, we must acknowledge the need to deal adequately with scientific knowledge and the insights from a branch like "complexity science." Second, people's values must be taken explicitly into consideration. Simulation games and policy exercise are helpful in this respect.

INTRODUCTION

Having been asked to write about scenarios, I have interpret this within the focal question for the 96th Dahlem Workshop: How can we best use human–environment systems history and models to generate plausible future scenarios that can integrate with various policy, decision making, and stakeholder communities? I will—and only can—do this within the context of my personal experience in global change modeling, in energy and greenhouse gas emission scenario construction, and in investigating past and present aspects of the search for sustainable development (Rotmans and De Vries 1997; Nakicenovic et al. 2000; De Vries and Goudsblom 2002; MNP 2004).

In this contribution I will first briefly describe the scenario method and interpret it in the historical context. Next, I discuss some global change-related

scenarios on long-term (up to 2100) global developments, with an emphasis on model-based scenario construction efforts and the perspective of sustainable development. In particular, I use the TARGETS model-based scenarios and the emission scenarios for the Intergovernmental Panel on Climate Change (IPCC). I then give some suggestions for improvement, focusing on uncertainty, complexity, values, and participation. I end with some statements for discussion. Throughout this chapter I have been parsimonious with references, on request.

THE SCENARIO METHOD

The scenario method has become rather widespread over the last few decades. The many practitioners have given a large array of definitions.[1] Common elements are:

- Scenarios are a tool for [better] [strategic] decision making.
- The scenario method emphasizes the construction of alternative futures in order to prepare for divergent plausible futures.
- To this purpose, existing mental models should be challenged and qualitative ("storytelling," narrative) as well as quantitative ("modeling") approaches are to be used.
- It is important to know for whom scenarios are made and for which purpose. Credibility, legitimacy, and creativity are important aspects, then, of process and product.
- Scenario construction is a training in finding key trends, recognizing prevalent myths, and imagining attitudes of key players (see Box 19.1).

One should not make more than three or four scenarios because people cannot handle more due to cognitive limitations. The identification of the driving forces (i.e., what makes it going), of predetermined elements (in particular slow changing variables), and of critical uncertainties provide the structure or *logic* of a scenario (Schwartz 1991). It is claimed that the scenario method presents people with multiple perspectives on the world, which is an alternative or at least a complement to the conventional languages of business and science in dealing with the often complex and ill-structured questions of today's world.

Of course, long before the advent of scenarios, governing elites were interested in anticipating future events and in strategy development. Influential advisers to the ruling elite have earned their place in history. Often, priests were at the forefront of such endeavors as a conduit to allow the gods participate in judging, legitimizing, and rationalizing. Usually, the objective was sustaining and/or expanding power within a rather well-defined organizational context. There have always been those who challenged the rulers with opposing views of what the future could or should be—rebels, visionaries, prophets. Thomas More

[1] See, e.g., Notten et al. (2003) for a recent overview of the scenario literature and scenarios.

Box 19.1 Some related concepts.

Scenarios are, it seems, halfway myth and plan. A *myth* is "the way things are" as people in a particular society believe them to be (Schwartz 1991), often unconsciously. *Strategy* is the art of deliberately recognizing major trends, establishing one's own course of action, and translating this into practical *plans*. Part of scenario construction is the process of *visioning*. "Visioning means imagining, at first generally and then with increasing specificity, what you really want…not what you have learnt to be willing to settle for. Visioning means taking off all the constraints of assumed 'feasibility'" (Meadows et al. 1992). As such they express the ethos of their times (Heilbroner 1995).

offered his Utopia as a visionary critique, Karl Marx offered a rationale for the demise of capitalism, Jules Verne expanded technical possibilities far beyond the known options, and religious leaders have promised mixtures of catastrophe and salvation. Such views were rooted in deviant valuations and interpretations of the present, which often provoked violent oppression.[2] Nowadays, there are hundreds of individuals and organizations who offer their view of the future, which ranges from alerts and warnings to technological paradise and fundamentalist doom.[3]

How should we interpret the scenario method in historical perspective? Let me try a concise answer. With the emergence of science and technology as the "modern world view," old centers of authority were increasingly challenged and new and powerful actors appeared on the scene: scientists, entrepreneurs, corporations, citizen groups (or today's nongovernmental organizations, NGOs). The legitimacy of decision making had to change. Science and technology began to offer tools for deeper and more rational forms of control and management: physical, as in factories and transport and nowadays ecosystems, as well as mental, as in offices and media.[4] Useful and influential as this control paradigm may have become, it has also met its limitations in the past decades—a development sometimes associated with postmodernism. With the spread of education, communication, and democratic forms of governance and with the ever more visible unintended—and for many undesirable—consequences of this "mechanization of the world," what used to be seen as unprecedented success has been increasingly challenged. Simultaneously, science has become aware of the limitations of its "Newtonian paradigm" and is offering novel perspectives

2 Castells (2000) discusses such forces at work in the information age. He distinguishes three sources of identity: legitimizing by the powers-that-be, resistance against it by those suppressed, and solidarity for a common project for societal reform. Examples of the last are ecological and feminist movements.

3 Modern alerts can often be identified from the titles: *Limits to Growth* (Meadows et al. 1972), *Social Limits to Growth* (Hirsch 1976), *Limits of Organization* (Arrow 1974), *Limits to Competition* (Group of Lisbon 1995), and *Limits to Certainty* (Giarini and Stahel 1993).

4 Illustrative examples are the use of optimal control techniques to analyze management options in large societal systems.

in the study of complex systems such as the climate, ecological, and human–environment systems.[5]

I argue that the scenario method, with its explicit consideration of uncertainties, multiple perspectives, and stakeholders, is only a logical next step in this development. Naturally, the modern-day equivalents of the centers of authority—the corporate and government planning institutions—are among the first to apply such novel methods. Resistance comes from (some) engineers and social scientists. The former do not subscribe to the nonscientific approach, preferring to adhere to the control paradigm instead; the latter may have built their careers on mimicking mechanical science methods or fear invasion of their domain by latter-day scientists. Politicians may also show signs of dislike, as they will always be tempted to prefer command and control over participation and pluralism. Let us look at this closer through some examples.

GLOBAL SCENARIOS

Global [Change] Modeling

One of the predecessors in the search for more sustainable forms of human activity is the book *The Limits to Growth* published in 1972 by Meadows et al. At the request of a group of industrialists—the Club of Rome—a number of scientists at MIT in Boston constructed a system dynamics model of the global system and showed that humanity would face a future full of catastrophes unless there were drastic changes in the mechanisms that cause exponential growth in population and economic production.[6] In subsequent years, the *Limits to Growth* analysis was severely criticized for various reasons: no regional dynamics, in particular the rich–poor gap; no or insufficient price response dynamics; too pessimistic resource base estimates; and no or insufficient technological progress. Several attempts were made in the 1970s and 1980s to eliminate these perceived shortcomings, leading to a variety of global change models. Integration became a buzzword and global change modeling became part of *integrated assessment modeling* (IAM). Variation in input assumptions became established practice, and the resulting outcome was no longer called "model run" but "scenario."

Simultaneously, the quest for sustainable development intensified with publications from the UN Environment Program (UNEP) and the World Bank's World Development Reports. Government and business circles became more deeply involved, partly in response to expanding NGO activities. The "good

5 Although the signs of this change are manifold, Funtowicz and Ravetz's (1990) introduction of the concept of postnormal science is widely recognized as a milestone.

6 In 1992 a new edition of the book appeared with the title *Beyond the Limits* (Meadows et al. 1992). The authors concluded that many trends in the period from 1970–1990 confirmed the claims made in *Limits to Growth*. In 2004 the book *Limits to Growth: The 30-year Update* was published (Meadows et al. 2004).

intentions" of all those concerned about environmental degradation and social and economic inequity were confronted with the involvement of practitioners of "the dismal science": economics. Macroeconomic modelers entered the scene and issues such as the cost-efficiency of policy instruments and the trade-offs between development and environmental and social objectives became prominent. For instance, Duchin and coworkers (1994) did an extensive analysis of the macroeconomic feasibility of the objectives suggested in the UN report, *Our Common Future*, of the UN World Commission on Environment and Development (WCED), also called the "Brundtland Report" (WCED 1986). It was concluded that the positive effects of technological adjustments such as recycling and energy efficiency are insufficient to realize the development aspirations sketched in the Brundtland Report on a sustainable basis.

In the early 1990s, the first attempts at scenario analysis became more widely publicized as a somewhat belated and modified continuation of the famous *The Year 2000: A Framework for Speculation on the Next Thirty-Three Years* by Kahn and Wiener (1967). Schwartz (1991) discussed the scenario approach, giving practical advice on how to do it and illustrating it with real-world examples in multinational companies. Hammond (1998) published a scenario study that reflected several years of discussion within the Global Scenario Group and explicitly considered regional diversity (www.gsg.org).[7]

I tend to have most affinity with and expectations about scenarios that combine storytelling and modeling.[8] The storytelling part consists of carefully constructed narratives, built around interpretations of past and current observations and trends. The modeling part implies an attempt to introduce consistency and sharpness by quantifying certain parts of the narrative on the basis of available (statistical) data and formalized (mathematical) relationships. I will briefly discuss two projects in which simulation models were used to construct storyline-based scenarios: the TARGETS project (Rotmans and De Vries 1997; De Vries 2001) and the Special Report on Emission Scenarios (SRES; Nakicenovic et al. 2000; IPCC 2001) for the IPCC. I leave out other interesting scenario developments which have taken place in the last decade, such as:

- The Millennium Institute's Threshold 21 (T21) model, an offshoot of the Global 2000 Report to U.S. President Carter. This is a system dynamics one-country model which had the objective of providing a generic tool for the exploration of sustainable development strategies (see www.threshold21.com).
- The International Futures (IFs) model, a tool designed to help understand the state of the world and develop strategies for desirable futures. Rooted

7 This largely qualitative research was supported with the PoleStar model, a country-based accounting framework aiming to provide transparency and consistency.

8 Labeled "computer-aided storytelling," this has somewhat reluctantly been taken up in economic science, too.

in earlier global models (e.g., WIM and GLOBUS), it emphasizes the analysis of the potential for conflict between nations (see http://www.du.edu/~bhughes/ifs.html).

- The IMAGE model, developed since the early 1990s for climate change-related research and broader global change scenarios (Alcamo et al. 1998) (arch.rivm.nl/image, www.usf.uni-kassel.de). It is a typical IAM of intermediate complexity and has been used extensively in the Global Environmental Outlook 3 in the construction of scenarios within the SRES framework (www.unep.org).
- Two other interesting, recent scenario studies are the VISIONS project (www.icis.unimaas.nl), which used novel software tools and participatory methods to develop three regional scenarios for Europe, and the Millennium Ecosystem Assessment (www.millenniumassessment.org), which contains four scenarios to explore the causes and consequences of global ecosystem degradation.

The Targets Project

The TARGETS model is an IAM on global change at a high level of aggregation. It was the result of a 5-year project (Rotmans and De Vries 1997; De Vries 2001) on global change at the Dutch National Institute for Public Health and the Environment (RIVM). The project's main objective was to operationalize the concept of sustainable development, using a systems dynamics approach. Pressure–State–Impact–Response (PSIR) chains and transitions were used as guiding concepts.[9] The system was conceived of as a collection of well-defined subsystems interacting with each other—population and health, water, land and food, energy, and biochemical cycles. Subsystems were described on the basis of meta-models, that is, simplified "expert models" of the long-term dynamics, integrated horizontally (between subsystems) and vertically (modeling human behavior on top of the environmental dynamics "substrate").

The resulting world model, TARGETS1.0, was a meta-model, not an expert model, representing in a coherent and systematic way the various insights from scientific disciplines on the functioning of the Earth system in order to frame sustainability issues and provide a context for debate. A series of global scenarios for the 21st century have been constructed with the model, using the cultural theory of Thompson et al. (1990) to make coherent interpretations and assumptions of how the world fits together and how it should be run. Cultural theory combines insights from cultural anthropology and ecology in distinguishing cultural perspectives, based on the degree to which individuals behave and feel themselves part of a larger group of individuals with whom they share values

[9] A more recent, similar integrated Earth system model is the Global Unified Metamodel of the BiOsphere (GUMBO), with a focus on the dynamics and values of ecosystem services (Boumans et al. 2002).

and beliefs (the "group" axis) and the extent to which individuals are subjected to role prescriptions within a larger structural entity (the "grid" axis). The resulting four perspectives are related to their position along these two axes: the *hierarchic* (high on both), the *individualist* (low on both), the *egalitarian* (high in "group," low in "grid"), and the *fatalist* (low in "group," high in "grid"). It was then assumed that utopian futures unfold if both the world view ("how the world functions") and the management style ("how the world I managed") are in agreement.[10] If not, dystopian futures will unfold.

From a scenario point of view, the findings from the TARGETS model experiments can be summarized in these utopia–dystopia terms:

- Continuing large growth in population and material welfare will cause ever more pressure on the natural environment, but this can be managed for the next 100 years if new and powerful technologies—geared to more efficient resource use—are put into practice and if natural ecosystems—flora and fauna—are not [too] vulnerable. This would lead to an *individualist utopia*—a highly managed, high-tech world with a materialist outlook.
- If these conditions cannot be met, the future will develop in less attractive and dystopian ways. The burden of environmental degradation may be shifted onto the weakest members of society and an impoverished world of islands of extreme wealth in the middle of mass suffering and crime may evolve.
- It is also possible that the egalitarian ideal of frugality will gain ground so that economic growth will be less or less energy and material intensive. This could be triggered through ecological disasters or "grass-roots" environmental initiatives, violence resulting from large and visible income gaps, changes in consumer preferences and lifestyles, rebirth of spiritual/moral movements, or a combination of all these. The pressure on the environment in such an *egalitarian world* will then be much less, meaning that catastrophes are avoided or at least anticipated and hence better handled.
- It is very well possible that the future contains a mix of elements of these utopias and dystopias but that the mainstream unfolds along the lines of the hierarchic perspective. Many of the present trends will continue. If this happens on the basis of correct knowledge, a *hierarchic utopia* will unfold with incremental policy measures on the basis of institutional expertise, conventions, and control. If these conditions are not met, "overshoot and collapse" will occur in more-or-less serious forms because of waiting too long for more knowledge/expertise or because governments get bogged down with bureaucratic and regulating ineffectiveness and corruption.

[10] See Vries et al. (2002) for such an approach with respect to past human–environment interactions in Himalayan and Alpine villages.

The only consolation in the face of such an oncoming disaster is perhaps that the emergency actions are well organized.

What did we learn from the TARGETS project? In retrospect, it can be summarized:

- A "one-world" IAM like TARGETS can be made to reproduce most of the available statistics on the system Earth since 1900. This is largely a form of calibration—validation in a more rigorous sense is difficult because many of the model variables are nonobservable aggregates and many of the presumed relationships are generalized forms of dynamic processes observed at the local/regional scale. Hence, such models are useful for framing issues about long-term population–resource–environment developments, which lends a more of synthesizing and conceptual rather than hypothesis-testing value. A next step has to be to disaggregate in representative regions and develop generic dynamic models on the basis of past records. Such an approach has, for instance, been attempted by Wirtz in his simulation of the Neolithic transition (De Vries et al. 2002).
- The TARGETS model experiments showed that the most widely published result of the 1972 *Limits to Growth* report—overshoot and collapse—is one of the many possible outcomes, namely the one in which egalitarian environmentalists are right about the finiteness and fragility of the natural system and the power is in the hands of those who act upon the opposite assumption.
- The project made clear that transcending disciplinary boundaries in knowledge is difficult. Scientists from different disciplines use different methods and concepts—and they are attached to them. There is a surprising lack of generalized "stylized facts" knowledge in the areas in-between the disciplines (e.g., about water–energy and food–health links). Integration remains a challenge but it would help if more research were done on issues in-between specialized disciplines and if novel methods, such as looking at the system in terms of networks, were applied.
- Constructing "perspective-based scenarios" invites people to take part in the discussion and makes people's values visible in the debates about where the world might and/or should be headed. Although much effort was put into communicating the insights with good visualization techniques and interactive use,[11] participatory use of the model was not very successful due to lack of a rigorous method and serious time and budget constraints. Moreover, there was a marketing problem (which has only grown since then). In communicating with the media, I got the impression that announcing doomsday for April 30, 2019 would have made a more

[11] For this purpose, a new simulation environment, M, for model development and interactive communication was developed at RIVM (http://www.m.rivm.no/info/ftp.htm).

lasting impression than the rather sophisticated risk-oriented results of the TARGETS approach (see also Meadows, this volume).

I will come back to possible solutions to these shortcomings.

The Special Report on Emission Scenarios (SRES)

The threat of human-induced climate change has rapidly become one of the most prominent environmental issues on the global agenda. In 1988, to assess the causes and consequences of human-induced climate change, the IPCC established three working groups. They published reports in 1990, 1996, and 2001 (www.ipcc.ch; see also Nakicenovic et al. 2000; IPCC 2001 and Hosoda et al. 2000). The 1990 report contained one of the first emission trajectories published, the so-called IS92 scenarios. With almost no endogenous relationships and lack of qualitative, descriptive detail, one could hardly speak of scenarios. In 1997 the IPCC established a team to develop a series of Standardized Reference Emissions Scenarios **(SRES)** [**Bert**: We have a conflict in acronyms here: **S**pecial **R**eport on **E**mission **S**cenarios vs. **S**tandardised **R**eference **E**missions **S**cenarios. Could I using SRES to refer to **S**pecial **R**eport on **E**mission **S**cenarios and spelling out the other where necessary?]. The objective of this team was to review existing emission scenarios and to revise the earlier IPCC IS92 emission scenarios. The new scenarios should project future greenhouse gas emissions from all sectors, without considering specific climate policies and their impact on emission reductions. They should provide a baseline or benchmark against which climate policy scenarios (mitigation, stabilization, adaptation) could be evaluated.

The SRES team decided to use different *storylines* or narratives, each describing in qualitative terms how the future could evolve. These narratives were the basis for the input assumptions to be used by the six modeling groups involved. Each group (two from the U.S.A., two from Japan, and two from Europe) used its own energy model, which of course caused large problems of harmonization.[12] Most models were significantly better than the models used for the earlier emission scenarios: more regions/countries; inclusion of energy efficiency, renewable options and fuel trade; learning-by-doing dynamics; linkage with land-use land cover and material flow models to evaluate the role of carbon sequestration and traditional and modern biofuels; and linkage with macroeconomic models to analyze leakage and rebound effects. The time horizon was set at the year 2100, countries were clustered into four regions, and 13 emission sources were taken into account.

[12] Fourteen modeling groups have interpreted some or most of the narratives into their models. This resulted in over 40 different emission paths but for communication purposes only one model was selected to represent one of the narratives. The SRES scenarios were used in the third assessment of IPCC (2001).

Early in the process it was decided to organize the storylines in four *scenario families* based on divergence along two axes: (a) whether the world will continue on the path of globalization or reverse in a more protectionist regionalization of economic, cultural, and political blocks, and (b) whether the prevailing attitude of people will be toward material welfare and high-tech consumerism or tend toward social and environmental quality-of-life aspects. This led to the four scenarios which have become known as A1, B1, A2, and B2 after the SRES team had decided to choose neutral names. In daily practice, A stands for economic and B for environmental, 1 for global and 2 for regional. Evidently, the storylines leave ample room for divergent interpretation and emphasis even within a scenario family.[13] Figure 19.1 shows the two axes and the names of scenarios constructed by various individuals and organizations over the last decade as arranged by me.

The SRES project has accomplished a lot, thanks to the tremendous efforts of all participating groups and project leaders. It can be argued that SRES was trendsetting in its attempt to merge the quantitative and qualitative (story-scenario model), to use multiple logics and perspectives, and to simulate at regional/local scale. A major achievement has been that modelers from various backgrounds as well as policy analysts and decision makers have been and still are confronted with each other's expertise, ignorance, and values. The scenario approach has contributed significantly to this outcome. Another advantage of the narrative approach, widely used, is that scientists working on other aspects of the climate change issue, such as mitigation or adaptation potential, can begin to build on these storylines (e.g., Hosoda et al. 2000). For instance, in a B1 future, the world is quite able and willing to introduce effective and efficient emission reduction and help potential victims in adapting; the A2 future, however, would offer a very different prospect.

Obviously, such an effort will not—and cannot—be without omissions and errors. An entire volume can be devoted to a discussion about the merits and shortcomings of the SRES approach and the resulting scenarios. I will thus confine myself to a couple of critical comments.

1. The four proposed leading storylines—indicated as *marker scenarios* in the modeling context—give too much room for divergent interpretations. For instance, globalization (1 vs. 2) was (and is) not a well-defined process, measured by economists as an increase in the flows of goods and capital, discussed by demographers in terms of migration, described by Di Castri as *"une diversité globalement uniforme: plus de diversité locale…mais la meme partout"* (Theys 1998) but hardly considered at all

[13] The storylines are described in the SRES report but they have grown significantly in quantity and diversity of interpretation (e.g., Nakicenovic 2000). There are clear links with the previously discussed TARGETS scenarios: whereas the A1 world reflects the market- and high-tech-orientation of the individualist, the B1 and possibly even more the B2 worlds would be driven by egalitarian values.

Figure 19.1 Depiction of two axes and the names of scenarios constructed by various individuals and organizations over the last decade.

from a cultural point of view.[14] Similarly, the distinction between economic versus environmental (A vs. B) is not at all clear. I have come across a variety of dichotomies: market versus government, deregulation versus overregulation, competition versus coordination, efficiency versus equity, consumer tech versus green tech. It will be helpful to bring in aspects of governance and technology more explicitly.

2. In my experience, confusion about how to interpret the storylines occurred because key assumptions from high-level aggregate empirical relationships ("stylized facts" or meta models) were not well understood. To mention a few of the ones used: net population growth declines with income and, directly and indirectly, with globalization; economic growth and energy intensity are bell-shaped functions of income; and

[14] In fact, the "cultural clash" aspect of a storyline, notably the A2 scenario, was taboo just like the prospects of terrorism or collapse due to famine, disease, and mismanagement. Such avoidance may be symptomatic for UN processes.

globalization in the form of less trade barriers—operationalized by lower transport costs—increases economic growth via higher rates of capital and technology transfer **(De Vries et al. 2000) [Please add to reference list]**. Many more such assumptions are hidden and/or implicit and lifted from country to region level; I will come back to this.

3. The world will not unfold according to the logic of one single storyline over a 100-year period. Whenever one of the scenarios tends to become dominant, opposing forces will start to compromise and erode important features of such a world view and lead to new directions.[15] For instance, the tensions in the A1 narrative will (and did) show up as rising income disparity with large groups of people being marginalized; tax evasion and the associated "race-to-the-bottom" dynamic; partly in response, increasing transaction costs due to litigation, regulatory complexity, and security measures; burden shifting, for instance when deteriorating public service forces people to spend more and more private time on waiting, communicating, etc. The B1 future will be confronted with the negative aspects of large bureaucracies (e.g., inertia, inefficiency, and corruption), which may drive it into more market and/or protectionist directions. The A2 future may well be confronted with such serious environmental deterioration that globally and socially/environmentally oriented forces will emerge. In that sense, a serious shortcoming of the SRES scenarios is that (a) no attempt was made to include the possibly false underlying assumptions and the associated risks in terms of environmental and economic damage, and (b) the response in terms of social and political feedbacks toward one of the other three logics has not been considered. This, of course, reflects the absence of an explicit sociocultural dynamic over and above some rather simple economic and demographic "stylized facts."
4. A fourth and serious shortcoming in SRES was, in my view, the fact that the computer models became leading in what had been envisaged. Translating storylines into model assumptions is expectedly a procrustean process. All of the models used had (and still have) a bias in terms of process relationships and data reliability which may make them somewhat realistic to project the future economy–energy–emission path for the U.S. or Europe; this causes, however, serious distortions and pseudo-insights if applied, for instance, to 800 million Chinese or Indian farmers in 2030 in a setting of traditional culture and economic protectionism. This has been shown to be especially devastating for the B2 scenario: the models cannot realistically cope with, for instance, energy demand-price or renewable energy penetration rate dynamics in a diverse, equity- and envi-

15 This has been illustrated with the TARGETS model in "the battle of perspectives" (Janssen and De Vries 1998).

ronment-oriented world.[16] To some extent the models became a legitimization not for how world regions are but how they should be, thus representing (inadvertently?) the ideology of the Washington consensus (World Bank, IMF) that dominated the 1990s.

These comments do hopefully indicate that it makes no sense to assign probabilities to the scenarios. SRES rightly states that *there is no single most likely, "central" or "best-guess" scenario*. In a way, all four scenarios are highly implausible. Once the system boundaries are enlarged to include the human system and not just industrial and power plants or pollutant flows, the only way forward is to refine and adjust continuously the storyline logic and improve the model structure, data, and applications accordingly.[17]

HOW CAN GLOBAL CHANGE SCENARIOS BE IMPROVED?

In essence, my critique and suggestions for improvement boil down to four keywords: *uncertainty*, *complexity*, *values*, and *participation*. We must address explicitly and scientifically uncertainty and complexity. A new epistemology is needed. We should incorporate people and their values in the process of scenario construction and use. Participatory methods, such as simulation games and policy exercises, are necessary complements.

Uncertainty and Complexity

Most of the scenario analyses discussed thus far are about (parts of) an extremely complex socionatural system: Earth. The merits and limitations of the classical science and engineering methods—in the vein of the control paradigm—have become ever more evident in the course of the 20th century. Still, many issues relevant for global change are clouded by uncertainties and controversies, giving rise to divergent or even antagonistic interpretations of what happened and expectations of what might and should happen.

Philosophers of science (epistemology) have proposed that uncertainty and ignorance be acknowledged and identified and have suggested ways to so (Funtowicz and Ravetz 1990). Science itself, notably mathematics and systems theory, has contributed to new ways of addressing complex systems, introducing notions such as self-similarity and self-organization, chaos and catastrophe,

16 This was one of the reasons that the B2 scenario quickly became a middle-of-the-road dynamics-as-usual scenario, without fulfilling its promise of offering think-space to alternative visions, values, and rules. In turn, the resulting middle-of-the-road emissions path led those who were not interested in the storyline to interpret it as "the" medium scenario.

17 This, of course, in no way dismisses the modelers of the task to do careful sensitivity analyses and evaluate the importance of uncertainty in assumptions for the objectives and policies at hand.

bifurcations and resilience. Economic science is picking up these advances in branches such as behavioral economics and ecological and evolutionary economics, and are introducing ideas about transaction costs and technology transitions, for instance. As a result and in combination with the advent of strong computers and satellite data, our insights into the evolution of socionatural systems are expanding enormously.[18] How can these developments be incorporated in the generation of useful, plausible scenarios for humankind? Let me briefly mention four avenues.

The first concerns *uncertainty analysis*. The models used for (global) scenarios are usually not scientific in terms of practical validation (comparison of simulated results with observational data) and conceptual validation (scrutinizing the concepts and theoretical laws of the system under consideration).[19] Various plausible but sometimes contradictory explanations of phenomena can be constructed. In the discussion on climate change impacts and mitigation options, there are, for instance, important uncertainties regarding size and cost of energy resources and regarding temperature response to rising greenhouse gas concentrations. The quest is for a balanced use of sensitivity and uncertainty analytical tools, ranging from multi-regression Monte Carlo techniques to Delphi expert panels (see www.nusap.org). The outcomes can—and should—guide the construction of scenarios.

The second is *model improvement*. The usual way to achieve this is to add detail (e.g., higher spatial resolution, more countries, etc.). However, it may be more important to improve the meta-models that link the processes in the various subsystems. To mention a few in a question form:

- *Population*: How do aging and income disparities interact with the prospects for economic growth (health costs, savings rate, proneness for radicalism and revolt, female employment)? Which value changes are possible in a world where more than half of human activity takes place in China and India?
- *Economic*: What is the link between physical and monetary fluxes and should *mer* (market exchange rates) or *ppp* (purchasing power parity) be used for intercountry comparison in a distant future? Are the transitions to a service economy and dematerialization universal phenomena? Which role is played by the shadow economy, including organized crime, and how is it related to trade and tax regimes? In which ways might climate change feed back on social and economic conditions?

[18] See, e.g., Steffen et al. (2004) for a recent overview of "Earth science" insights; www.pages.sunibe.ch for research on past human–environment interactions.

[19] I have suggested the concept of "strong knowledge" to indicate the knowledge which is or can be gained from repeated experiments in controlled subsystems. Most knowledge about human systems is, in this sense, relatively weak. Of course, the law of large numbers can be applied to lead to rather certain probabilistic statements.

- *Technology and resources*: Is there such a thing as a "long wave" in economics, with nano- and biotechnology and robotics spurring the next one? How effective are government R&D programs and what are the determinants of technology transfer? Which land-use/cover constraints are to be expected and by which mechanisms are land-change processes mediated? Are large oil deposits associated with dictatorship because both weapons and legitimacy can be bought (the "resource curse")? A rigorous testing of social science hypotheses is welcome here, although it will never eliminate the uncertainties.[20]

The next involves *issue (re)framing*. One of the permanent challenges in global change modeling is to handle adequately different scales in a nested dynamical hierarchy. Ecological research has explored this issue deeply (see, e.g., Berkes et al. 2003). An interesting framework is the syndrome approach (Petschel-Held et al. 1999). *Syndromes* are archetypical nonsustainable patterns of civilization–nature interactions. It has been suggested to distinguish between utilization, development, and sink syndromes. The persistent structural properties of a region, such as its biogeography, determine the disposition for certain syndromes. With high disposition, exposition factors such as natural catastrophes or social revolt can activate a syndrome and cause a downward spiral of degradation collapse. Human history provides illustrative examples (De Vries and Goudsblom 2002). Constructing generic dynamic models for such well-defined syndrome areas and using novel techniques such as network theory and multi-agent simulation is, in my view, a crucial next step.

The fourth avenue is *logic structuring.* From an even broader perspective, one of the more difficult parts of scenario analysis is to create relevant logics for the complex parts of a system. A helpful framework is the cultural theory which introduces three "active" solidarities according to which people manage their social and natural environment (cf. TARGETS approach and VISIONS project). These three cultural biases, it is claimed, provide the requisite plurality if one is to incorporate items (e.g., fairness, risk, and innovation) into scenarios in a structured way. As Michael Thompson (pers. comm.) puts it: "*Uncertainty, far from being an unproductive desert that will only bloom when we have managed to irrigate it with knowledge, is a resource: something that is all the time being colonized and fought over by contradictory certitudes…. Visions of the future function at the individual and collective level as 'final' causes: attractors and repellers ... that variously define in the here-and-now what is technically possible, socially desirable, and morally acceptable*." The dynamic interactions between adherents of different world views can be a way of addressing surprise and discontinuity because much "catastrophic change" may be the result of a rising discrepancy between what (a majority of) people believe

[20] See Ross (2001) for an example of empirical testing of hypotheses on the role between oil richness and democracy.

and what they experience. After all, the unexpected is often the consequence of limited or false information and of restricted or perverted exchange of views and values—as, for instance, recent analyses of the Iraq war show.

Evidently, in each of these items novel ways to model human–environment systems are to play an important role—without any further consideration I mention the importance of spatial dynamics with cellular automata and the complex adaptive systems and multi-agent simulation modeling approaches. Local and regional land-use/cover scenarios are the avant-garde in this endeavor.

Involving People: Values and Participation

In the recent Sustainability Outlook of the Dutch Netherlands Environmental Assessment Agency (MNP), the decision was made to operationalize sustainable development as the continuation and expansion of qualities of (human) life. Which qualities, for whom and how long? It is a continuous balancing act between the prevailing values of (a group of) people on the one hand and available knowledge and skills to satisfy these on the other. It plays itself out between the ends and means, each having its own kind of rationality and methods. To do this, we used the results of value surveys in the Netherlands, which indicated that people's value orientations can meaningfully be grouped in 8 clusters, and a framework for questioning people about their expectations and desires about the future—almost identical to the SRES framework. We found that people are concerned about large-scale environmental disruption, social inequity, and loss of social cohesion and that only a small minority perceives a globalizing, high-tech high-growth world (say, A1) as possible and desirable.[21] This suggests that the dominant view in (neoclassical) economics of humans as maximizers of discounted individual utility with perfect foresight represents only one form of rationality; it has to be complemented with others (cf. Jager et al. 2000).

The Sustainability Outlook process was initiated to involve people explicitly as stakeholders in the discussion on their local, regional, and global future. Telling a story and supporting it with the best available scientific expertise and models while acknowledging the uncertainties and controversies is, in my view, the way forward. In this way, people become involved with their values and interpretations, and policy for change can become legitimate. This is also part of the previously mentioned issue (re)framing and logic structuring. A framework proposed during the Dutch COOL process is shown in Figure 19.2, which shows how the degree of consensus about values and consensus in knowledge largely determine the problem context. A similar framework, but with different jargon (added in italics), is used in business schools, I discovered later. This brings me to the last point.

[21] An interesting finding in this context is that Europeans are on average positive about their quality of life but see it only vaguely related to economic performance and see no conflict between environment and competitiveness (Special Eurobarometer February 2005 215/Wave 62.1).

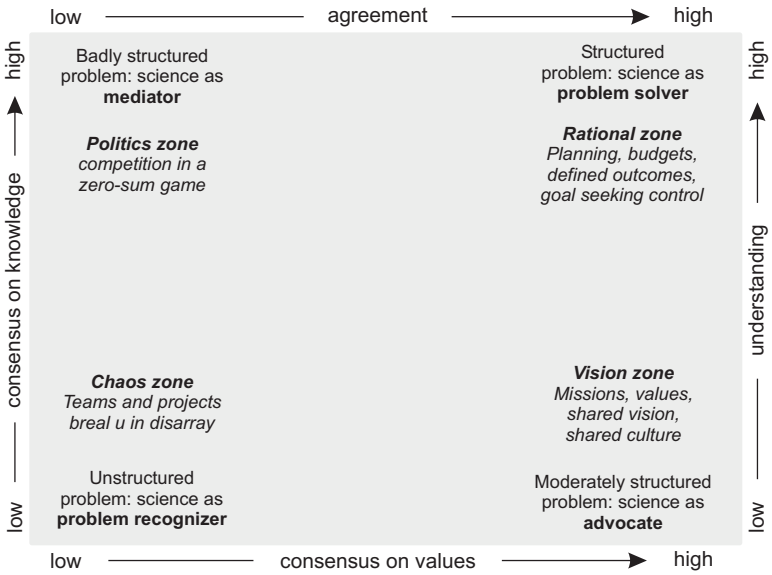

Figure 19.2 A framework proposed during the Dutch COOL process, depicting the degree of consensus about values and consensus in knowledge largely determine the problem context.

Another approach to address ill-structured problems is gaming simulation (Duke and Geurts 2004). Opening people to multiple perspectives is a lofty goal but may easily result in an exchange of views and opinions of bewildering complexity and unclear and quickly forgotten outcomes. One reason is, of course, time and money constraints; another is the lack of a structured setting. When a clear organizational setting is absent, as is often the case with global change issues before the stage of concrete strategies and plans, there is an urgent need for an organizing framework to be able to structure, focus, and prioritize. Gaming simulation can be very helpful. Equally important is the use of simulation games and policy exercises in an educational setting, as this is an effective way to teach the art of scenario construction in a participatory learning mode.[22] Interactive scenario construction is one of the methods which may gain ground as the infrastructure (e.g., internet, simulation tools) further improves.

CONCLUDING STATEMENTS

The art of scenario construction and use is spreading. This is good news because it is one of the more promising avenues to combine qualitative insights on human–environment interactions from the social sciences, in the form of

[22] For example, the simulation games Stratagem and Fish Banks Ltd. (**Bert**: please confirm this url) http://www.sustainabilityinstitute.org/tools_resources/games.html).

narratives, anecdotes, and analogs, with the more formal and quantitative models of the natural sciences. However, experience with long-term global change scenario construction indicates that there are still significant barriers to overcome. Integration across disciplines in concepts, data, and methods as well as transparent and interactive communication of scientific insights are two important areas for improvement. To improve the effective construction and use of scenarios, a more systematic approach in linking narratives to models, via system dynamics causal loop diagrams, network representations, and spatially explicit social interactions is needed. This also requires a more rigorous epistemological foundation of knowledge and the incorporation of recent insights in complex systems. To broaden the realism, creativity, and legitimacy of scenarios, explicit consideration of people's values and a structured involvement of people as stakeholders via gaming simulation is another step forward.

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