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Participatory Scenario Development for Supporting Transitions towards Sustainability

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Abstract

Scenario development and analysis is widely considered a key instrument for addressing the long-term social-ecological challenges society faces. Scenarios provide a rigorous framework for explicitly dealing with complexity and uncertainty and can help integrating the broad spectrum of perspectives in the assessment and decision making processes. While the scenario method has therefore been used in a large variety of sustainability issues and on varying spatial scales, little research has addressed the question of how scenario processes can be designed and conducted to most effectively influence the relevant decision processes.

This paper both analyzes to what extend scenario development can contribute to efforts for supporting transitions towards sustainability and develops a conceptual framework of how scenarios can most effectively influence change in such processes. A literature synthesis reveals five modules that capture the essential elements of approaches for navigating sustainability transitions. Scenario development and analysis can most successfully contribute to three of these modules, namely *Integrated Assessment*, *Policy Development*, and *Transdisciplinary Participation*. By building on insights from previous work on the influence of science on policy in general, the attributes *Credibility*, *Salience*, *Legitimacy*, and *Creativity* are identified as useful criteria of effective scenarios. This conceptual framework is verified and further elaborated by a content analysis of publications on designing scenario processes. Finally, approaches for simultaneously enhancing all four criteria are discussed and further research on innovative methods for stronger and more active transdisciplinary participation in scenario development is suggested. The paper attempts to contribute to the further development of useful tools for putting the emerging sustainability science into practice.

Introduction

The ecosystems of planet Earth are experiencing intense anthropogenic influences (e.g. Turner 2002, Watson et al. 1998, Vitousek et al. 1997) that increasingly diminish their capacity to provide the ecosystem goods and services humanity depends on (Daily 1997, Millennium Ecosystem Assessment 2003, Reid et al. 2005). In recognition of these and other consequences of human interventions in the Earth system, implementing the concept of sustainable development has emerged as one of the central challenges for society (Annan 2000, Clark and Munn 1986, Kates et al. 2001, NRC 1999, UN 1992, UN 2002, Watson et al. 1998, WCED 1987).

Although the actual meaning of the concept remains rather vague and disagreement persists on the clear definition and emphasis on what exactly is to be developed, to be sustained, and for how long (Kates and Parris 2003, NRC 1999), it is a widely shared notion that the challenge of sustainable development is to reconcile society's development goals with the planet's environmental limits over the long term (Clark and Dickson 2003). Slowing harmful trends and accelerating favorable ones (cf. Kates and Parris 2003) require encompassing societal efforts for successfully navigating a transition towards sustainability (NRC 1999).

Many of the most promising efforts for supporting transitions have taken a scenario-based approach for exploring and evaluating possible future risks and opportunities as well as the potential consequences of alternative policy options. At least since the seminal "Limits of Growth" study by Meadows et al. (1972), scenarios have been applied on numerous issues of the environment and of

sustainability, ranging from studies at the global and regional (e.g. Cosgrove and Rijsberman 2000, Raskin et al. 2002, Gallopin et al. 1997, Nakicenovic and Swart 2000) to the local scale (e.g. Peterson et al. 2003a, Peterson, Cumming and Carpenter 2003b).

Although scenarios are frequently considered key instruments for supporting sustainability transitions (Swart, Raskin and Robinson 2004, Wiek, Binder and Scholz 2006, NRC 1999), little research has considered the issue of how scenarios can be designed and developed to most effectively exploit their potential for influencing such processes. Against this background, this paper attempts to address the following two questions:

1. To what extent can scenario development and analysis contribute to efforts for supporting transitions towards sustainability?
2. How can scenarios effectively influence change in the relevant discussion and decision making processes?

Relevant literature is synthesized to identify the essential elements, or modules, prevalent in approaches for navigating sustainability transitions. A review of publications on scenario methods reveals the range of applications and basic steps of scenario development. Juxtaposing the modules of transitions support and the steps of scenario development reveals the possible contributions of scenarios. By drawing on previous work by Swart et al. (2004), a more detailed analysis of the contributions of the different kinds of scenarios to the research challenges of sustainability science is conducted.

A hypothesis and conceptual framework on the effectiveness of scenarios on policy is developed on the basis of insights from previous works on the influence of science on policy, in particular the seminal Global Environmental Assessment Project (Mitchell et al. 2006b). This conceptual framework is verified and further elaborated by a content analysis (e.g. Weber 1990, Neuendorf 2002) of publications on designing scenario processes. Finally, innovative methods for stronger and more active transdisciplinary participation are proposed for simultaneously enhancing the criteria. The paper closes with recommendations for further research.

Modules for Navigating Sustainability Transitions

Navigating transitions towards sustainability in most cases is an unprecedented and extremely challenging task due to, among other factors, the high degree of complexity of coupled social-ecological systems (e.g. Gunderson and Holling 2002, NRC 1999) and the need to integrate various kind of knowledges, disciplinary backgrounds, values, and perspectives of experts, decision makers, stakeholders, and lay citizens in the process of assessing and addressing the issues. In recognition of these challenges, sustainable development is increasingly interpreted not as a clearly determinable and calculable goal but rather a process of Adaptive Management and Social Learning amid uncertainty and surprise (see NRC 1999, Parson and Clark 1995, Milbrath 1989).

Adaptive Management (Berkes and Folke 1998, Holling 1978, Walters 1986) intends to address the high degrees of complexity, uncertainty and unpredictability in ecosystems through systematic efforts to learn from practical experience. At its core is the idea to formulate policies as hypotheses, to consider management actions as experiments to test the hypotheses, to implement monitoring systems for acquiring reliable data about the consequences of the experiments, and to develop effective management institutions for learning from successes and failures (Clark 2002, Gunderson, Holling and

Light 1995). While the initial conceptualization of adaptive management remained a primarily technical approach (Lee 1999), the need for a stronger incorporation of the human dimension in adaptive management through processes of adaptive governance (see Dietz, Ostrom and Stern 2003), transdisciplinary participation, and collective action was stressed (e.g. Parson and Clark 1995, Lee 1993, McLain and Lee 1996) and incorporated in its recent applications.

Social Learning is a an approach that is closely related to this revised interpretation of adaptive management and has gained growing attention in the literature and practice of dealing with issues of the environment and sustainable development (e.g. Mostert et al. 2007, NRC 1999, Pahl-Wostl 2006, Pahl-Wostl and Hare 2004, Social Learning Group 2001a, Social Learning Group 2001b). Social learning can be defined as a process of developing and sustaining the capacity of experts, decision makers, stakeholders, and lay citizens to manage the environment effectively. It includes procedures for incorporating different perspectives, conflict resolution, joint decision making and implementation, and learning from practical experiences (Pahl-Wostl et al. 2007a).

The last decade has seen the emergence of a number of approaches for intentionally influencing sustainability transitions that are rooted in the ideas of adaptive management and social learning. Prominent examples of such concepts are Adaptive Co-Management (Berkes, Colding and Folke 2003, Olsson and Folke 2004), Transition Management (Martens and Rotmans 2002, Martens and Rotmans 2005, Kemp, Parto and Gibson 2005, Kemp, Loorbach and Rotmans 2007, Rotmans, Kemp and van Asselt 2001, Elzen and Wieczorek 2005), Integrated Assessments and Planning (Ravetz 2000), Sustainability Indicators (Bell and Morse 2003), and others.

While the specific design of the concepts and the emphases on certain aspects vary, most concepts contain the following six basic elements, or modules (see figure 1, cf. e.g. Loorbach and Rotmans 2006, Magnuszewski, Sendzimir and Kronenberg 2005, Sendzimir et al. 2007): Integrated Assessment, Policy Development, Implementation, Evaluation, and Transdisciplinary Participation.

Integrated Assessments are needed to develop a comprehensive and interdisciplinary understanding of the structure and dynamics of the coupled social-ecological system under consideration and to explore the causations of current problems. The assessments must include considerations of past and current development trends and linear and non-linear interrelations both within the particular system and across its spatial scales. Furthermore, the actors must agree on indicators that can be used for tracking the development of the system.

The *Policy Development* module is comprised of four distinct parts: exploring alternative future developments and their potential consequences, discussing the options and potential threats and opportunities, deciding on the future goals and exploring ways to attain these, and finally choosing policy measures that are to be implemented (and thereby tested).

Evaluation is an essential element of any adaptive management process. Appropriate indicators must be monitored over time to both detect emerging threats and opportunities and to acquire reliable data for the evaluation of the effects of particular policy actions. The feedback from the study of the development of the indicators must be used to iteratively evaluate and, if necessary, alter both the ends and means of the navigation.

The need for *Transdisciplinary Participation* of experts, decision makers, stakeholders, and lay citizens in issues of environmental management and sustainable development is widely acknowledged (Kasemir et al. 2003, Thompson Klein 2004, Tress, Tress and Fry 2005, Wickson, Carew and Russell 2006, Hirsch Hadorn et al. 2006). Participation of diverse groups of actors can help incorporating the

wide range of perspectives, values and know ledges, improve the substantive quality of decisions, resolve conflict between competing interests, build trust in institutions, and educate and inform the actors (Beierle and Cayford 2002).

Taken together, the modules can form a management cycle (see figure 1, p. 6) in which the effects of implemented policies are monitored and iteratively fed back into the assessment and formulation of subsequent policies. However, as conveyed with the term ‘module’, the cycle should not be considered a linear “stages heuristic” (for a critique, see Sabatier and Jenkins-Smith 1999), but rather a holistic approach in which the particular modules will come into play at different times when necessary.

Contributions of Scenarios

Broadly defined, scenarios are descriptions of how the future might unfold, rather than predictions of what the future will be. They reflect different assumptions about the evolution of current trends, the possible effects of critical uncertainties, and emerging influential factors (UNEP 2002). Formal usage of the scenarios began at the end of World War II in the field of war game analysis (van der Heijden 1996, Shoemaker 1993). The civilian use of the scenario technique in a variety of planning purposes was pioneered by the work of Herman Kahn and others (Kahn and Wiener 1967) and further developed by the seminal work of Pierre Wack and colleagues at Royal Dutch/Shell in the 1970s and 1980s (e.g. Wack 1985a, Wack 1985b). Today scenarios are applied in a wide array of contexts, ranging from business planning (e.g. Gausemeier, Fink and Schlake 1995, Georgantzas and Acar 1995, Schwartz 1996, van der Heijden 1996, von Reibnitz 1987, Wack 1985a, Wack 1985b) to public policy (e.g. Ringland 2002, Leney et al. 2004).

Scenarios can be used for different purposes. While recently a number of approaches elaborated typologies were developed for characterizing the different objectives, processes, and contents of scenario development (e.g. Bishop, Hines and Collins 2007, Börjeson et al. 2006, Bradfield et al. 2005, Marien 2002, van Notten et al. 2003), this paper confines itself to consider only the very basic distinction between backcasting and forward-looking scenarios (cf. Jäger et al. 2007). Backcasting scenarios (e.g. Robinson 2003) consider “how could” questions to address the alternative paths of how a desired end state in the future could be reached. Forward-looking scenarios ask “what if” questions to explore how the future will unfold, starting from the present.

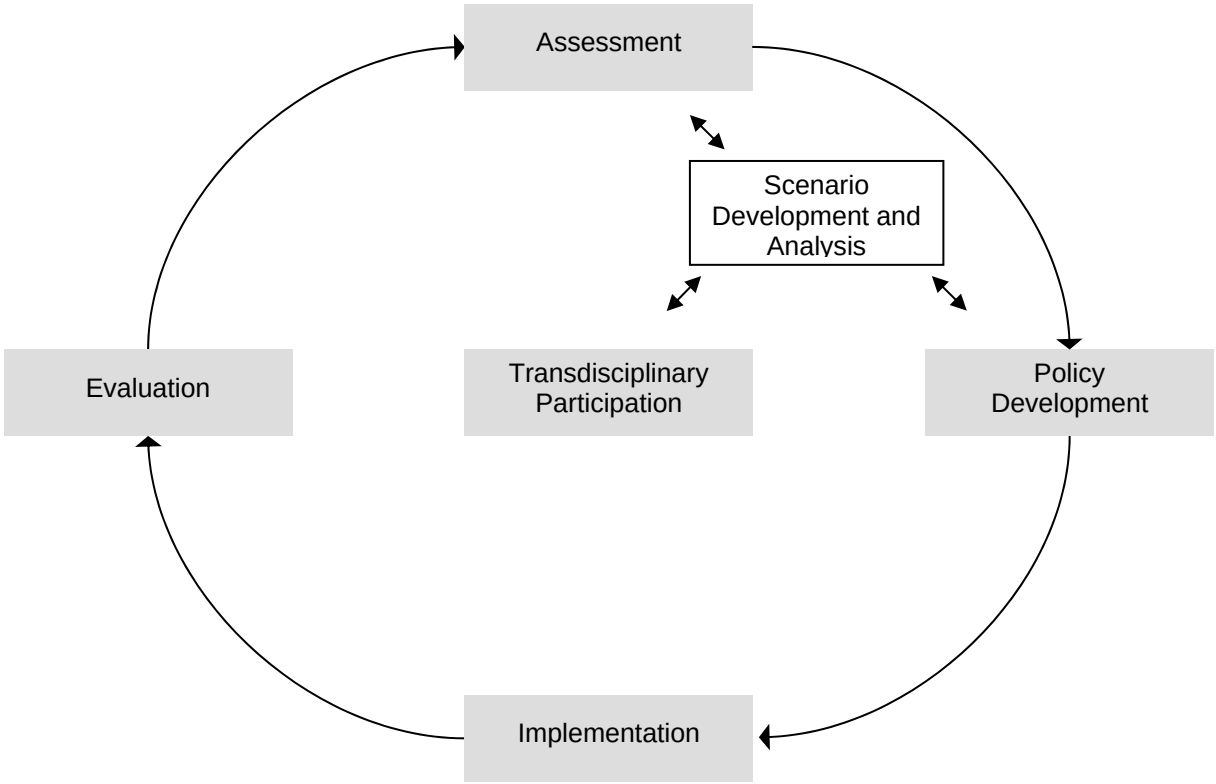
Methods and tools for scenario development are described in a variety of literatures, including the works of Schwartz (1996), von Reibnitz (1987), and Ringland (1998), and Alcamo (2001). This paper follows Jäger et al. (2007) who proposed a simple framework of four main steps for developing scenarios. The first step, ‘Clarifying the Purpose and Structure of the Scenario Exercise’, consists of the definition of the scope and issue of the scenarios, the selection of the stakeholders and participants, and the identification of themes, targets, indicators, and potential polices. The second step is termed ‘Laying the Foundations for the Scenarios’ and is comprised of the identification of the driving forces and critical uncertainties and the creation of a scenario framework. The ‘Development and Testing of the Actual Scenarios’ takes place in step three and involves the elaboration of the scenario narratives, the quantitative analysis, and an exploration of policy options. The last step is ‘Communication and Outreach’. It is stressed that the execution of the steps does not need to be carried out in this order and that some of the aspects may be forgone in particular scenario processes.

The framework of steps for scenario development can be well integrated into the cycle of modules for navigating sustainability transitions (see figure 1). Steps one and two of scenario development can be

considered parts of the module "Integrated Assessment" in that they help eliciting and comparing the stakeholders' understanding and mental maps of the relevant system, its main impact factors, interconnections, and dynamics. The remaining steps of scenario development that include the actual development, evaluation, and dissemination of the scenarios can clearly provide significant contributions to the "Policy Development" module. Furthermore, scenarios are well-suited to facilitate the inclusion of various actors in collaborative discussion, decision making, and learning processes (e.g. Aligica 2005, Berkhout, Hertin and Jordan 2002).

However, it also becomes obvious that scenarios and scenario development cannot fulfill all the tasks needed for navigating sustainability transitions. Scenario development is not appropriate for "Implementation" or "Evaluation" (cf. Wiek et al. 2006). Nevertheless, scenario development processes can help facilitating the work in these modules through developing the social capacities for dealing with unexpected changes and uncertainty, help realizing the complexities and linkages in coupled social-ecological systems, and identifying appropriate indicators for tracking the consequences of policies and for identifying emerging threats and opportunities.

Figure 1: Modules for Navigating Sustainability Transitions



Source: own conceptualization, based on frameworks from the fields of Adaptive (Co-)Management (e.g. Magnuszewski et al. 2005, Sendzimir et al. 2007) and Transition Management (Loorbach and Rotmans 2006).

To analyze in more detail how scenarios can contribute to the approaches for navigating sustainability transitions, I draw on a seminal article published by Swart et al. (2004) in which they compared an amended list of research challenges of the emerging sustainability science (see also Kates et al. 2001)

with the potential contributions of scenarios and scenario development. The results are summarized in table 1.

Table 1: Contributions of scenarios to sustainability science.

Research Challenges of Sustainability Science	**Potential Contribution of Scenarios and Scenario Development**	**Proposed Types of Scenarios**
Spanning spatial scales	- integrate across spatial scales and link local to global perspectives	Backcasting and Forward-Looking
Accounting for temporal inertia and urgency	- link long-term goals with today's decisions	Primarily Backcasting
Recognizing the wide range of outlooks	- reflect different perspectives on system functioning, goals of sustainability transition and ways to get there	Backcasting and Forward-Looking
Reflecting functional complexity and multiple stresses	- incorporate considerations of complex linkages and multiple stresses through integration of qualitative expert knowledge	Primarily Forward-Looking
Integrating across themes and issues	- help broaden perspectives to incorporate aspects from both human and natural systems and help discovering interconnections	Backcasting and Forward-Looking
Reflecting uncertainties, incorporate surprise, critical thresholds and abrupt change	- creativity in scenario development offers a way to consider the possibilities and potential consequences of discontinuous changes in complex, non-linear systems	Backcasting and Forward-Looking
Accounting for volition	- contribute to explore normatively distinct future visions and ways to attain them	Primarily Backcasting
	- help eliciting and reflecting on mental models of the world	
Combining qualitative and quantitative analysis	- incorporate (and link) qualitative and quantitative features	Backcasting and Forward-Looking
Engaging stakeholders	- promote communication, facilitate iterative feedback, offer a way to test (and influence) human perceptions and goals	Backcasting and Forward-Looking
Source: Swart et al. (2004), summarized		Source: this paper

A Framework for Effective Scenarios

Against the background of the manifold contributions of scenarios and scenario development to approaches for navigating sustainability transitions, the question arises of how scenarios can be designed and conducted most effectively exploit this potential. Before addressing this issue in detail, models for explaining the influence of environmental science on policy in general will be reviewed.

Three insights structure this paper's conceptualization of the influence of science on policy: First, the influence of scientific information on decision making processes seems to be quite limited (cf. Funtowicz and Ravetz 2001). As many scholars have pointed out, decision makers cannot be assumed to always base their decisions on comprehensive and objective scientific assessments on the issue at stake and on the various policy options to address it. Instead, decision makers face substantial constraints on temporal resources and cognitive capacities when trying to make "good" decisions, especially on such uncertainty- and complexity-laden issues like sustainable development. In consequence, decision makers act only 'boundedly rational' and tend to rather use personal experience and other heuristics that decrease the need to collect and process information (Kahnemann, Slovic and Tversky 1982, Simon 1982, Simon 1983). As such, decision making can be described as a process of 'muddling trough' in which scientific information is only one aspect of "a broad, diffuse, open-ended, mistake-making social or interactive process, both cognitive and political" (Lindblom 1990).

Decisions are made only in those situations in which the usually independent streams of problem definitions and solutions of an issue come together (Kingdon 1984). Political decisions develop from the ongoing interactions between actors that are concerned with a particular issue (Sabatier and Jenkins-Smith 1999), and such collaborations can over time create shared opinions on the existence of problems, their causations and consequences, the need for action and appropriate options to choose (Sabatier 1988).

Second, it seems that science indeed influences decisions in some instances, even despite such generally limited influence. Studies have shown that cognitive and normative uncertainties sometimes create contexts of so called “policy windows” or “fluid moments in history”, in which innovative and creative ideas are considered and decision makers are receptive to and interested in new information (e.g. Kingdon 1984, Lee 1993). Baumheier (1993) notes that promoters of new policies need to react quickly since policy windows open up for only short time periods. It has further been argued that due to public debate and emerging political pressures, policy windows can have significant influence on decisions (Heiland 1999, Rucht 1994).

Third, research has shown that the influence of scientific assessments should not only be measured in the direct contributions to decisions and alterations of actor behaviors, but include considerations of how the issues are framed and discussed and what kinds of options are considered (Clark, Mitchell and Cash 2006, Social Learning Group 2001a, Social Learning Group 2001b).

The Global Environmental Assessment project (Farrell and Jäger 2006, Jasanoff and Martello 2004, Mitchell et al. 2006b) went further in asking how environmental assessments must be designed and conducted to be most likely to make use of opening “windows of opportunity” and, in effect, influence decision making in public policy. On the basis of a number of case empirical case studies from national and international environmental assessments (see Mitchell et al. 2006b), the authors concluded that environmental science is more likely to be influential on policy if the assessment process is perceived as not only scientifically credible but also salient to political concerns and legitimate by the assessment’s audiences (Cash et al. 2003, Mitchell et al. 2006b). While other concepts for explaining the effectiveness of scientific assessments in policy making exists, this set of criteria has been identified as one of the most comprehensive (McKnie 2007).

Credibility was described as the degree to which the users of environmental assessments consider the science as correct and its evidence and argumentation as adequate (Cash and Buizer 2005, Cash et al. 2003). At least, the information contained in the assessment should be regarded as more correct than competing claims (Mitchell, Clark and Cash 2006a). While credibility might seem as a property that is relatively easy to achieve, it was stressed that many issues of the environment and sustainable development face high degrees of complexity and uncertainty which makes arguments difficult to comprehend for non-experts (Mitchell et al. 2006a).

Salience asks if an assessment is relevant to its audience and if the objectives are adequately addressed. The information must be provided in a way that is responsive to local conditions and issues of concern, must connect to aspects that the decision makers find relevant and that they can influence and must be provided at an appropriate time period before relevant decisions are made (Mitchell et al. 2006a). As McKnie (2007) summarized, salient assessments consider the ecological, temporal, spatial, and administrative scales and timeliness.

Legitimacy considers the degree to which the assessments have been “respectful of the stakeholders’ divergent values and beliefs, unbiased in its conduct, and fair in its treatment of opposing views and interests” (Cash et al. 2003: 8086). This is based on the notion that if science shall be adopted as a

basis for decisions, the process of producing the science must be perceived as "fair and legitimate by those whose future they might affect" (NRC 1999). Legitimacy includes considerations of the composition of the actors involved in the development of the scenarios, the evaluation of their consequences, and the decision making and dissemination process (Mitchell et al. 2006a), and the process of information production, discussion, and dissemination shall be open, transparent and observable (Cash and Buizer 2005).

As described above, this set of criteria was developed for describing the influence of environmental assessments on policy. Scenarios however can be considered a special kind of assessments that primarily do not address the current, but the future state of the environment (Alcamo 2001), leading to even higher degrees of uncertainty and complexity. In recognition of the special characteristics of scenarios, Alcamo et al. (2006) were the first to propose the additional criterion of "creativity" to reflect the need for new and innovative thinking about possibilities and surprises in the process of scenario development.

Based on these findings from the literature, the conceptual framework of effective scenarios thus contains the criteria *credibility*, *salience*, *legitimacy*, and *creativity* (see figure 2). The following hypothesis is proposed to describe their interconnection:

> *Scenarios tend to be influential in policy to the degree that they are perceived as simultaneously credible, salient, legitimate, and creative by the scenario users.*

Figure 2: Framework for Influential Scenarios

Credibilty	**Legitimacy**
- Plausibility	
- Internal Consistency	
- Comprehensiveness	
Salience	**Creativity**
- Goal-directedness	- Innovative Thinking
- Relevance	- Challenge Assumptions

Source: own conceptualization, based on earlier works by Cash et al. (2003), Mitchell et al. (2006b), and Alcamo et al. (2006).

Verification and Further Development of the Framework

The content analysis of publications on scenarios and scenario development revealed that the literature is very rich in describing methods and approaches for scenario development, but most often gives only little hints concerning the criteria for designing influential scenarios. This seems odd, since the advantages and disadvantages of varying approaches for scenario development can arguably only be

discussed on the basis of certain scenario attributes that they different methods can be compared against. Many of the criteria that could be found in the literature indeed fit to the credibility, salience, legitimacy, and creativity criteria, however, some of these have to be interpreted differently. The resulting framework is illustrated in figure 2 and explained in detail in the following paragraphs.

Credibility

The review of scenario literature showed that credibility indeed seems to be an important criterion of effective scenarios. Four distinct but related sub-criteria for credible scenarios were identified.

Most importantly, the credibility of a scenario is determined by the degree to which the audiences perceive the scenarios as *plausible* (Alcamo et al. 2006, Götze 1991, Leney et al. 2004, van der Heijden 1996, von Reibnitz 1987, Schwartz 1996), or at least "not-implausible" (Alcamo 2001). Plausible scenarios are considered feasible and attainable within a given timeframe (Leney et al. 2004) and are based on a sound and empirically verified analysis of the existing conditions (Götze 1991, Wack 1985a). Only plausible scenarios are considered capable of serving as a basis from which the users can further develop knowledge and understanding (van der Heijden 1996) and failure in attaining plausibility thus risks easy dismissal by scenario users (Alcamo 2001).

A second and closely related aspect is *internal consistency* both within each scenario (Alcamo 2001, Götze 1991, Leney et al. 2004, von Reibnitz 1987) and among the set of scenarios (Shoemaker 1995). Internal consistency involves that the assumptions and causal relationships are consistent with existing information (Alcamo et al. 2006, Shoemaker 1995) and that the scenarios "grow logically (in a cause/effect way) from the past and the present" (van der Heijden 1996).

Another aspect of credibility is *comprehensiveness*, the degree to which the set of scenarios produced covers the range of available alternatives or possibilities (Götze 1991, van der Heijden 1996). Although there seems to be consensus that scenarios need to be comprehensive, it is not clear if the range of considered scenarios need to include all options (Wack 1985b), a wide range of possible or plausible options (Leney et al. 2004, Götze 1991, Shoemaker 1995), or at least the extremes of the assumed future alternatives (von Reibnitz 1987). Scenarios should highlight competing perspectives and describe generically different alternatives rather than variations on one theme (Shoemaker 1995). However, most authors propose sets of two to four scenarios as most effective to reflect the uncertainties and at the same time keep the number of scenarios at a practical size (e.g. van der Heijden 1996).

Enhancing credibility involves employing high degrees of transparency and scientific rigor in the process of scenario development and its documentation (Alcamo et al. 2006, Ringland 2002). Since scenarios usually deal with complex issues that allow for multiple perspectives and mental models, the rationale for choosing a particular set of impact factors and the assumptions about causal relationships inherent in both qualitative and quantitative scenarios must be made transparent (Alcamo et al. 2006, Götze 1991, Leney et al. 2004). Sufficient documentation is needed to make the scenario development process retraceable by experts, decision makers, stakeholders, and lay citizens (Alcamo 2001, Schwartz 1996).

Salience

Salience asks if a scenario is relevant to its audience and it the objectives of the scenario exercise are adequately addressed. It thus has two qualities:

Quite obviously, scenarios must be *goal-directed* to be influential. They must be designed to fulfill their objectives (Alcamo 2001), adequately address the issues at stake (Ringland 1998) and prove useful for acquiring the information necessary to make the decisions among alternative options (Leney et al. 2004, Götze 1991).

Another aspect is *relevance* for the users. Scenarios must be tailored to the existing knowledge, cognitive abilities, current concerns and mental maps of the potential scenario users (Shoemaker 1995, van der Heijden 1996). They should explicitly draw upon the audience's own language, history, and context (Ringland 1998) and specifically address the "deepest concerns" of the users (Wack 1985a). Scenarios should "grow from the platform of an ongoing strategic conversation" (van der Heijden 1996) so that users can more easily assume ownership of the scenarios and put them to work (Schwartz 1996).

The salience of scenarios can be enhanced by designing the scenario development process explicitly according to the needs of the users and specifically adapted to the temporal and financial resources available (Berkhout, Hertin and Jordan 2001a). Linking scenario exercises into current ongoing visioning and implementation planning processes and facilitating constant exchanges and collaboration between scenario developers and scenario users can further heighten salience through harmonization of the scenario agenda, its goals and expected results (Alcamo 2001, Wack 1985b, von Reibnitz 1987, van der Heijden 1996). However, such iterative reconciliations between scenario users and developers most often proved particularly difficult which lead Wack (1985a) to identify the missing interface between developers and decision makers as one of the key problems of scenario planning.

In contrast to the obvious need for salience, many scenarios are not conducted with a constant focus on the decisions to be made and therefore lose relevance. Salience has thus been interpreted as of uttermost importance for ensuring the effectiveness of scenarios and it should be sustained under all circumstances (van der Heijden 1996).

Legitimacy

Legitimacy asks to what degree the scenarios are perceived as legitimate and procedurally fair to the various stakeholders affected by the conclusions and subsequent decisions. Scenarios that promote particular beliefs, values, or political agendas and that neglect certain perspectives and concerns will most probably not be perceived as legitimate (Alcamo et al. 2006) and therefore tend to be less effective.

Interestingly, the legitimacy criterion did not receive much attention in the scenario literature. This may be due to the fact that most literature on scenarios deals with the application of scenario methods in business planning, a context in which the legitimacy of strategies, plans and decisions is of much less importance than in public policy settings. However, literature on scenarios use in public policy have implicitly and explicitly noted its importance (e.g. Ringland 2002).

Much similar to the credibility criterion, the legitimacy of scenarios can be enhanced my making the process of information production, evaluation and dissemination open and observable. Fostering interactions between users and producers of scenarios in a transdisciplinary setting and being explicit in the values and assumptions underlying the scenarios can be assumed to further improve the scenarios' scores on the legitimacy criterion (cf. NRC 1999). Participation should begin at an early stage of the process (Berkhout et al. 2001a), include representatives with disparate sets of interests (Ringland 1998) and employ a simple framework for facilitating communication and collaboration

across a wide range of divergent user groups (Ringland 2002). However, it is assumed that efforts for countering distrust in scenarios require as much efforts and time as in countering distrust in environmental assessments in general (Mitchell et al. 2006a).

Creativity

Creativity is an important criterion of scenario development since it addresses the certain need in scenarios to think creatively about the future developments that would not have been considered by following only "conventional" thinking and analyses of current trends. This notion is based on the finding that knowledge relevant for planning for the future can broadly be categorized into three classes: Things we know we know, things we know we do not know, and things we do know we do not know (Shoemaker 1995). If we only follow conservative lines of thought, at least the latter category of future developments is omitted and thus leaves many potential risks and opportunities not conceived. Two qualities of creativity can be identified:

First, creativity asks to what degree scenarios initiate and facilitate *innovative thinking*. Scenarios are only worth pursuing if the shed light on a new perspective to the issues. Scenarios must be surprising (Leney et al. 2004) and add a new perspective to the issues at stake (van der Heijden 1996). Since only creative thinking allows for imaging the uncertainties and possibilities of the future, scenarios must explicitly consider nonlinear, interrupted, and unprecedented trends (Alcamo 2001).

Second, scenarios need to *challenge* the scenario users' current *assumptions* on future developments and lead them to recognizing, questioning, and altering their mental models, in case such modification is justified and necessary (Alcamo 2001, van der Heijden 1996, Wack 1985a). The scenarios must have the capacity to break old stereotypes (Schwartz 1996), broaden the understanding of the users (Alcamo 2001), and engage their audiences to think outside of the conventional realm (Leney et al. 2004). Alcamo (2001) described such challenging scenarios as "low in probability but high in consequence".

Balancing the criteria

Scholars of criteria of effective environmental assessments in general found that significant trade-offs exists among them. The criteria are perceived as tightly coupled and efforts to enhance one of them often undermine the others (Cash et al. 2003, Eckley et al. 2002, Mitchell et al. 2006a).

The content analysis strongly suggests that the interdependencies between the criteria also hold true for environmental scenarios. As one example, Leney et al. (2004) elaborate on the tension between the perception of scenarios as credible and salient, and their potential to challenge current assumptions. While scenarios should be salient in resonating with current mental models of the users in areas that they are concerned and anxious, they must also provide a new, creative perspective for being meaningful and actually changing the users' thinking (van der Heijden 1996). Along these lines, Vygotsky (1986) coined the term "zone of proximal development" in referring to the interface at which the newly acquired knowledge of the scenario users come together with the logic of experienced reasoning. The learning capacity of the scenario users would ultimately be limited to this zone of proximal development.

Approaches for Enhancing Scenario Influence

In addressing the question of how the *credibility*, *salience*, and *legitimacy* criteria could be most effectively enhanced in environmental assessments, Cash et al. (2003) and Mitchell et al. (2006b) suggest the three basic functions: *communication*, *translation*, and *mediation*. '*Active, iterative and inclusive communication*' was identified as crucial for any attempt to enhancing the criteria. *Translation* was needed to facilitate mutual understating that is often hindered if representatives from different disciplines and professional backgrounds come together. *Mediation* finally was proposed to effectively balance the simultaneous enhancement of the three criteria in situations in which strong conflicts persist between the actors that cannot be resolved with mere communication and translation (Cash et al. 2003).

Enhancing the *creativity* of scenarios can be achieved through the involvement of diverse groups of decision-makers, experts, stakeholders, and lay citizens in the process of scenario development. In addition to *communication*, *translation*, and *mediation*, this paper proposes the function of *inspiration* to reflect the need to create an open and receptive climate in which new and unconventional ideas are embraced (cf. Ringland 1998). Integrating various stakeholder groups can result in a wide spectrum of perspectives on an issue that allows for innovative ideas and new considerations. Participation of "remarkable people" (Schwartz 1996) and "free thinkers" (cf. Kok et al. 2006a) like poets and journalists that are used to think imaginatively can further enhance the degree of creativity.

The recent years have seen the emergence of a number of projects that included processes of participatory scenario development (e.g. Kok, Biggs and Zurek 2007, Kok et al. 2006a, Kok, Rothman and Patel 2006b) and the potentials of the approach are currently further explored in a Working Package of the European Research Project "SCENES – Water Scenarios for Europe and Neighboring States" (van Vliet et al. 2007). Innovative approaches are applied primarily in semi-quantitative methods that combine the elicitation of cognitive, mental maps of how a social-ecological system might function with formal models for more detailed explorations and evaluations of future environmental changes. Examples of such methods are Fuzzy Cognitive Maps (e.g. Kosko 1986, Özesmi and Özesmi 2003) and Causal Loop Diagramming (e.g. Sterman 2000, Magnuszewski et al. 2005, Sendzimir et al. 2007).

Since the involvement of various actors is of high relevance for enhancing the criteria of effective scenarios and, ultimately, their influence on policy, it is suggested to concentrate further research on such innovative methods for stronger and more active transdisciplinary participation in the process of scenario development. Two questions for further research stand out:

1. Can the above described criteria of effective scenarios be validated in empirical case studies?
2. Do innovative methods of stronger and more active transdisciplinary participation indeed yield higher values on the criteria of effective scenarios?

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References

Alcamo, J. 2001. *Scenarios as tools for international environmental assessments*. Luxembourg: Office for Official Publications of the European Communities.

Alcamo, J., K. Kok, G. Busch, J. A. Priess, B. Eickhout, M. Rounsevell, D. S. Rothman & M. Heistermann. 2006. Searching for the Future of Land: Scenarios from the Local to Global Scale. In *Land-Use and Land-Cover Change, Local Processes and Global Impacts*, eds. E. F. Lambin & H. Geist, 137-155. Berlin, Heidelberg: Springer-Verlag.

Aligica, P. D. (2005) Scenarios and the growth of knowledge: Notes on the epistemic element in scenario building. *Technological Forecasting & Social Change,* 72**,** 815-824.

Annan, K. A. 2000. *We the Peoples: The Role of the United Nations in the 21st Century*. United Nations Publications.

Baumheier, R. 1993. *Kommunale Umweltvorsorge: Chancen und Probleme präventiver Umweltpolitik auf der kommunalen Ebene am Beispiel der Energie-und der Verkehrspolitik*. Birkhäuser.

Beierle, T. C. & J. Cayford. 2002. *Democracy in Practice: Public Participation in Environmental Decisions*. Washington, D.C.: Resources for the Future.

Bell, S. & S. Morse. 2003. *Measuring Sustainablility: Learning from Doing*. London, UK: Earthscan.

Berkes, F., J. Colding & C. Folke. 2003. Navigating Social-Ecological Systems: Building Resilience for Complexity and Change. Cambridge, UK: Cambridge University Press.

Berkes, F. & C. Folke. 1998. Linking Social and Ecological Sytems: management Practices and Social Mechanisms for Building Resilience. Cambridge, UK: Cambridge University Press.

Berkhout, F., J. Hertin & A. Jordan. 2001a. Socio-economic futures in climate change impact assessment: using scenarios as 'learning machines'. In *Working Paper*. Tyndall Centre for Climate Change Research.

--- (2002) Socio-economic futures in climate change impact assessment: using scenarios as ‘learning machines’. *Global Environmental Change,* 12**,** 83-95.

Bishop, P., A. Hines & T. Collins (2007) The current state of scenario development: an overview of techniques. *Foresight,* 9**,** 5-25.

Börjeson, L., M. Höjer, K. H. Dreborg, T. Ekvall & G. Finnveden (2006) Scenario types and techniques: Towards a user's guide. *Futures,* 38**,** 723-739.

Bradfield, R., G. Wright, G. Burt, G. Cairns & K. Van der Heijden (2005) The origins and evolution of scenario techniques in long range business planning. *Futures,* 37**,** 795-812.

Cash, D. W. & J. Buizer. 2005. *Knowledge-Action Systems for Seasonal to Interannual Climate Forecasing: Summary of a Workshop*. Washington, D.C.: The National Academies Press.

Cash, D. W., W. C. Clark, F. Alcock, N. M. Dickson, N. Eckley, D. H. Guston, J. Jäger & R. B. Mitchell (2003) Knowledge systems for sustainable development. *Proceedings of the National Academies of Sciences,* 100**,** 8086-7091.

Clark, W. C. (2002) Adaptive management, heal thyself. *Environment,* 44.

Clark, W. C. & N. M. Dickson (2003) Sustainability Science: The emerging research program. *Proceedings of the National Academies of Sciences,* 100**,** 8059-8061.

Clark, W. C., R. B. Mitchell & D. W. Cash. 2006. Evaluating the Influence of Global Environmental Assessments. In *Global environmental assessments: information and influence,* eds. R. B. Mitchell, W. C. Clark, D. W. Cash & N. M. Dickson, 1-28. MA: MIT Press.

Clark, W. C. & R. E. Munn. 1986. *Sustainable development of the biosphere*. Cambridge [Cambridgeshire]; New York: Cambridge University Press.

Cosgrove, W. J. & F. R. Rijsberman. 2000. *World Water Vision: Making Water Everybody's Business*. London, UK: Earthscan.

Daily, G. C. 1997. *Nature's Services*. Washington, D.C.: Island Press/Shearwater Books.

Dietz, T., E. Ostrom & P. C. Stern (2003) The Struggle to Govern the Commons. *Science,* 302**,** 1907.

Eckley, N., W. C. Clark, A. Farrell, J. Jäger & D. Stanners. 2002. *Designing Effective Assessments*. Copenhagen, DK: Harvard Global Environmental Assessment Project and European Environmental Agency.

Elzen, B. & A. Wieczorek (2005) Transitions towards sustainability through system innovation. *Technological Forecasting & Social Change,* 72**,** 651-551.

Farrell, A. E. & J. Jäger. 2006. *Assessments of Regional and Global Environmental Risks: Designing Processes for the Effective Use of Science in Decisionmaking*. Resources for the Future.

Funtowicz, S. O. & J. R. Ravetz. 2001. Global risk, uncertainty, and ignorance. In *Global Environmental Risk,* eds. J. X. Kasperson & R. E. Kasperson. London: Earthscan.

Gallopin, G. C., A. Hammond, P. Raskin & R. J. Swart. 1997. *Branch Points: Global Scenarios and Human Choice - A resource papaer of the Global Scenarios Group*. Stockholm: Stockholm Environmental Institute.

Gausemeier, J., A. Fink & O. Schlake. 1995. *Szenario-Management: Planen und Führen mit Szenarien*. München: Carl Hanser Verlag.

Georgantzas, N. C. & W. Acar. 1995. *Scenario-driven planning: learning to manage strategic uncertainty*. Westport, CT: Quorum Books.

Götze, U. 1991. *Szenario-Technik in der strategischen Unternehmensplanung*. Wiesbaden: Deutscher Universitätsverlag.

Gunderson, L. H. & C. S. Holling. 2002. Panarchy: Understanding Transformations in Human and Natural Systems. Washington, D.C.: Island.

Gunderson, L. H., C. S. Holling & S. S. Light. 1995. Barriers and Bridges to the Renewal of Ecosystems and Institutions. New York: Columbia University Press.

Heiland, S. 1999. *Voraussetzungen erfolgreichen Naturschutzes*. ecomed-Verl.-Ges.

Hirsch Hadorn, G., D. Bradley, C. Pohl, S. Rist & U. Wiesmann (2006) Implications of transdisciplinarity for sustainability research. *Ecological Economics,* 60**,** 119-128.

Holling, C. S. 1978. *Adaptive Environmental Assessment and Management*. London: Wiley.

Jäger, J., D. Rothman, C. Anastasi, S. Kartha & P. W. F. Van Notten. 2007. Training Module 6, Scenario development and analysis. In *GEO Resource Book: A training manual on integrated environmental assessment and reporting,* eds. L. Pintér, D. Swanson & J. Chenje.

Jasanoff, S. & M. L. Martello. 2004. *Earthly Politics: Local and Global in Environmental Governance*. MIT Press.

Kahn, H. & A. J. Wiener. 1967. *The Year 2000*. New York: MacMillan.

Kahnemann, D., P. Slovic & A. Tversky. 1982. *Judgement under Uncertainty: Heuristics and Biases*. New York, NY: Cambridge University Press.

Kasemir, B., J. Jäger, C. C. Jaeger & M. T. Gardner. 2003. Public participation in sustainability science: a handbook. Cambridge, UK: Cambridge University Press.

Kates, R. W., W. C. Clark, R. Corell, J. M. Hall, C. C. Jaeger, I. Lowe, J. J. McCarthy, H. J. Schellnhuber, B. Bolin, N. M. Dickson, S. Faucheux, G. C. Gallopin, A. Grübler, B. Huntley, J. Jäger, N. S. Jodha, R. E. Kasperson, A. Mabogunje, P. Matson, H. Mooney, B. Moore III, T. O'Riordan & U. Svedin (2001) Sustainability Science. *Science,* 292**,** 641-642.

Kates, R. W. & T. M. Parris (2003) Long-term trends and a sustainability transition. *Proceedings of the National Academies of Sciences,* 100**,** 8062-8067.

Kemp, R., D. Loorbach & J. Rotmans (2007) Transition management as a model for managing processes of co-evolution towards sustainable development. *The International Journal of Sustainable Development and World Ecology,* 14**,** 78-91.

Kemp, R., S. Parto & R. B. Gibson (2005) Governance for sustainable development: moving from theory to practice. *International Journal of Sustainable Development,* 8**,** 12-30.

Kingdon, J. W. 1984. *Agendas, Alternatives, and Public Policies*. Boston, MA: Little, Brown.

Kok, K., R. O. Biggs & M. Zurek (2007) Methods for Developing Multiscale Participatory Scenarios: Insights from Southern Africa and Europe. *Ecology and Society,* 12**,** 8.

Kok, K., M. Patel, D. S. Rothman & G. Quaranta (2006a) Multi-scale narratives from an IA perspective: Part II. Participatory local scenario development. *Futures,* 38**,** 285-311.

Kok, K., D. S. Rothman & M. Patel (2006b) Multi-scale narratives from an IA perspective: Part I. European and Mediterranean scenario development. *Futures,* 38**,** 261-284.

Kosko, B. (1986) Fuzzy cognitive maps. *International Journal of Man-Machine Studies,* 24**,** 65-75.

Lee, K. N. 1993. *Compass and Gyroscope: integrating science into democracy*. Washington, D.C.: Island Press.

--- (1999) Appraising adaptive management. *Conservation Ecology,* 3**,** 3.

Leney, T., M. Coles, P. Grollman & R. Vilu. 2004. *Scenarios toolkit*. Office for Official Publications of the European Communities.

Lindblom, C. E. 1990. *Inquiry and Change: The Troubled Attempt to Understand and Shape Society*. New Haven, CT: Yale University Press.

Loorbach, D. & J. Rotmans. 2006. Managing Transitions for Sustainable Development. In *Understanding Industrial Transformation: Views from Different Disciplines,* eds. X. Olsthoorn & A. J. Wieczorek.

Magnuszewski, P., J. Sendzimir & J. Kronenberg (2005) Conceptual modeling for adaptive environmental assessment and management in the Barycz Valley, Lower Silesia, Poland. *Int. J. Environ. Res. Public Health,* 2**,** 194-203.

Marien, M. (2002) Futures studies in the 21st Century: a reality-based view. *Futures,* 34**,** 261-281.

Martens, P. & J. Rotmans. 2002. Transitions in a Globalising World. Lisse: Swets & Zeitlinger Publishers.

--- (2005) Transitions in a globalizing world. *Futures,* 37**,** 1133-1144.

McKnie, E. C. (2007) Reconciling the supply of scientific information with user demands: an analysis of the problem and review of the literature. *Environmental Science & Policy,* 10**,** 17-38.

McLain, R. J. & R. G. Lee (1996) Adaptive management: Promises and pitfalls. *Environmental Management,* 20**,** 437-448.

Meadows, D. H., D. L. Meadows, J. Randers & W. W. Behrens (1972) The Limits to Growth. *New York*.

Milbrath, L. W. 1989. *Envisioning a sustainable society: learning our way out*. Albany, NY: State University of New York Press.

Millennium Ecosystem Assessment. 2003. *Ecosystems and Human Well-Being: A Frameork for Assessment*. Washington, D.C.: Island Press.

Mitchell, R. B., W. C. Clark & D. W. Cash. 2006a. Information and Influence. In *Global Environmental Assessments: Information and Influence,* eds. R. B. Mitchell, W. C. Clark, D. W. Cash & N. M. Dickson, 307-338. Cambridge, MA: MIT Press.

Mitchell, R. B., W. C. Clark, D. W. Cash & N. M. Dickson. 2006b. *Global environmental assessments: information and influence*. Cambridge, MA: The MIT Press.

Mostert, E., C. Pahl-Wostl, Y. Rees, B. Searle, D. Tabara & J. Tippet (2007) Social Learning in European River-Basin Management: Barries and Fostering Mechanisms from 10 River Basins. *Ecology and Society,* 12.

Nakicenovic, N. & R. J. Swart. 2000. Emissions Scenarios. Special Report of the Intergovernmental Panel on Climate Change. 570. Cambridge, UK: Cambridge University Press.

Neuendorf, K. A. 2002. *The content analysis guidebook*. Sage Publications.

NRC. 1999. *Our Common Yourney: a Transition toward Sustainability. A report of the Board on Sustainable Development of the National Research Council.* Washington, D.C.: National Academy Press.

Olsson, P. & C. Folke (2004) Adaptive Comanagement for Building Resilience in Social-Ecological Systems. *Environmental Management,* 34**,** 75-90.

Özesmi, U. & S. Özesmi (2003) A Participatory Approach to Ecosystem Conservation: Fuzzy Cognitive Maps and Stakeholder Group Analysis in Uluabat Lake, Turkey. *Environmental Management,* 31**,** 518-531.

Pahl-Wostl, C. (2006) The importance of social learning in restoring the multifunctionality of rivers and floodplains. *Ecology and Society,* 11.

Pahl-Wostl, C., M. Craps, A. Dewulf, E. Mostert, D. Tabara & T. Taillieu (2007a) Social Learning and Water Resources Management. *Ecology and Society,* 12.

Pahl-Wostl, C. & M. Hare (2004) Processes of social learning in integrated resources management. *Journal of Community and Applied Social Psychology,* 14**,** 193-206.

Parson, E. A. & W. C. Clark. 1995. Sustainable development as social learning: theoretical perspectives and practical challenges for the design of a research program. In *Barriers and bridges to the renewal of ecosystems and institutions,* eds. L. H. Gunderson, C. S. Holling & S. S. Light. New York, NY: Columbia University Press.

Peterson, G. D., D. Beard, B. Beisner, E. Bennett, S. Carpenter, G. Cumming, L. Dent & T. Havlicek (2003a) Assessing future ecosystem services: a case study of the northern highland lake district, Wisconsin. *Conservation Ecology,* 7.

Peterson, G. D., G. S. Cumming & S. R. Carpenter (2003b) Scenario planning: a tool for conservation in an uncertain world. *Cons. Biol.,* 17**,** 358-366.

Raskin, P., T. Banuri, G. C. Gallopin, P. Gutman, A. Hammond, R. W. Kates & R. J. Swart. 2002. *Great Transition: The Promise and Lure of the Times Ahead*. Boston, MA: Stockholm Environmental Institute.

Ravetz, J. 2000. *City-Region 2020: Integrated Planning for a Sustainable Environment*. Earthscan.

Reid, W. V., H. A. Mooney, A. Cropper, D. Capistrano, S. R. Carpenter, K. Chopra, P. Dasgupta, T. Dietz, A. K. Duraiappah, R. Hassan, R. E. Kasperson, R. Leemans, R. M. May, J. A. McMichael, P. Pingali, C. Samper, R. Scholes, R. T. Watson, A. H. Zakri, Z. Shidong, N. J. Ash, E. Bennett, P. Kulmar, M. J. Lee, C. Raudsepp-Hearne, H. Simons, J. Thonell & N. B. Zurek. 2005. *Millennium Ecosystem Assessment Synthesis report*. Washington, D.C.: Island Press.

Ringland, G. 1998. *Scenario planning: managing for the future*. Chichester: Wiley.

---. 2002. *Scenarios in Public Policy*. Chichester: Wiley.

Robinson, J. (2003) Future subjunctive - backcasting as social learning. *Futures,* 35**,** 839-856.

Rotmans, J., R. Kemp & M. van Asselt (2001) More Evolution than Revolution. *Transition Management in Public Policy, Foresight,* 3**,** 15-31.

Rucht, D. 1994. *Modernisierung und neue soziale Bewegungen: Deutschland, Frankreich und USA im Vergleich*. Campus.

Sabatier, P. A. (1988) An advocacy coalition framework of policy change and the role of policy-oriented learning therin. *Policy Sciences,* 21**,** 129-168.

Sabatier, P. A. & H. C. Jenkins-Smith. 1999. The advocacy coalition framework: An assessment. In *Theories of the Policy Process,* ed. P. A. Sabatier, 117-166. Boulder, CO: Westview Press.

Schwartz, P. 1996. *The Art of the Long View*. New York: Doubleday.

Sendzimir, J., P. Magnuszewski, P. Balogh & A. Vári (2007) Anticipatory modeling of biocomplexity in the Tisza River Basin: First steps to establish a participatory adaptive framework. *Environmental Modelling and Software,* 22**,** 599-609.

Shoemaker, P. J. H. (1993) Multiple scenario development: Its conceptual and behavioral foundation. *Strategic Management,* 14**,** 193-213.

--- (1995) Scenario planning: a tool for strategic thinking. *Sloan Management Review***,** 25-40.

Simon, H. A. 1982. *Models of Bounded Rationality*. Cambridge, MA: MIT Press.

---. 1983. *Reason in Human Affairs.* Stanford University Press.

Social Learning Group. 2001a. Learning to Manage Global Environmental Risks, Volume 1: A Comparative History of Social Responses to Climate Change, Ozon Depletion, and Acid Rain. Cambridge, MA: MIT Press.

---. 2001b. Learning to Manage Global Environmental Risks, Volume 2: A Functional Analysis of Social Responses to Climate Change, Ozone Depletion, and Acid Rain. Cambridge, MA: MIT Press.

Sterman, J. D. 2000. *Business dynamics: systems thinking and modeling for a complex world*. Irwin/McGraw-Hill.

Swart, R. J., P. Raskin & J. Robinson (2004) The problem of the future: sustainability science and scenario analysis. *Global Environmental Change,* 14**,** 137-146.

Thompson Klein, J. (2004) Prospects for transdisciplinarity. *Futures,* 36**,** 515-526.

Tress, G., B. Tress & G. Fry (2005) Clarifying integrative research concepts in landscape ecology. *Landscape Ecol.,* 20**,** 479-493.

Turner, B. L. I. 2002. Toward Integrated Land-Change Science: Advances in 1.5 decades of sustained international research on Land-Use and Land-Cover Change. In *Challenges of a Changing Earth, Proceedings of the Global Change Open Science Conference, 10-13 July 2001,* eds. W. Steffen, J. Jäger, D. J. Carson & C. Bradshaw, 21-26. Amsterdam, The Netherlands.

UN. 1992. *Report of the United Nations Conference on Environment and Development, Rio de Janeiro*. New York: United Nations.

---. 2002. *Report of the World Summit on Sustainable Development: Johannesburg, South Africa, 26 August-4 September 2002*. New York: United Nations.

UNEP. 2002. *Global Environmental Outlook-3: Past, present and future perspectives*. London: Earthscan.

van der Heijden, K. 1996. *Scenarios: the art of strategic conversation*. Chichester: John Wiley & Sons Ltd.

van Notten, P. W. F., J. Rotmans, M. B. A. Van Asselt & D. S. Rothman (2003) An updated scenario typology. *Futures,* 35**,** 423-443.

van Vliet, M., K. Kok, A. Lasut & J. Sendzimir. 2007. *Report describing methodology for scenario development at pan-European and pilot Area scales. SCENES Deliverbale 2.1*. Wageningen, The Netherlands: Wageningen University.

Vitousek, P. M., H. A. Mooney, J. Lubchenco & J. M. Melillo (1997) Human Domination of Earth's Ecosystems. *Science,* 277**,** 494-499.

von Reibnitz, U. 1987. *Szenarien - Optionen für die Zukunft*. Hamburg: McGraw-Hill.

Vygotsky, L. S. 1986. *Thought and Language*. MA: MIT Press.
Wack, P. (1985a) Scenarios: uncharted waters ahead. *Harvard Business Review,* 63**,** 73-89.
--- (1985b) Scenarios: shooting the rapids. *Harvard Business Review,* 63**,** 139-150.
Walters, C. 1986. *Adaptive Management of Renewable Resources*. New York: Macmillan.
Watson, R., J. A. Dixon, S. P. Hamburg, A. C. Janetos & R. H. Moss. 1998. *Protecting Our Planet, Securing Our Future*. Nairobi, Kenia: United Nations Environmental Programme.
WCED. 1987. Our Common Future. New York: Oxford University Press.
Weber, R. P. 1990. *Basic Content Analysis*. Thousand Oaks, CA: Sage.
Wickson, F., A. L. Carew & A. W. Russell (2006) Transdisciplinary research: characteristics, quandaries and quality. *Futures,* 38**,** 1046-1059.
Wiek, A., C. Binder & R. W. Scholz (2006) Functions of scenarios in transition processes. *Futures,* 38**,** 740-766.