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Scenarios as tools for international environmental assessments

Experts' corner report
Prospects and Scenarios No 5

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In order to provide possible inputs to the developing work programme of the EEA, and to stimulate debate on issues that may contribute to the identification, framing and evaluation of environmental policy measures, the EEA, from time to time, asks independent experts to summarise their views on topical or upcoming issues, so that the EEA can consider publishing them as Experts' corner reports.

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A great deal of additional information on the European Union is available on the Internet.
It can be accessed through the Europa server (http://europa.eu.int).

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Foreword

In our path to sustainability we need to look beyond tomorrow because to create a better future we must be able to imagine it. Scenarios and prospective analyses are not merely attractive and intellectually challenging exercises; they are efficient tools for synthesising and communicating complex and extensive information to decision makers and the public.

According to its mandate the Agency is requested to produce information for improved decision-making. Such information is not complete unless it goes beyond 'business-as–usual' to generate alternative scenarios. 'Environment in European Union at Turn of the Century', published in 1999, reports the results of the first comprehensive scenario exercise undertaken by the Agency and since then we have been seeking further improvements in the area of scenarios and prospective analysis.

This report one of the four state-of-art studies undertaken by the EEA during the last two years in order to improve an upgrade the use the scenarios, models and participatory methods in its assessments: *Cloudy Crystal Balls*, a comprehensive review of existing scenario studies relevant for Europe in the context of sustainable development, was published in November 2000. *Participatory Integrated Assessment Methods,* an assessment of their potential use in the Agency was published in August 2001. *ShAir,* a study focusing on improved Air pollution and Greenhouses Gases Outlooks, the seed of the current European Topic Centre for Air and Climate Change, will soon be published.

Drawing on major European and International scenario building exercises — such as European Commission 'Scenarios Europe 2010', the recent activities of the Intergovernmental Panel on Climate Change and the World Water Commission — this report proposes a thorough approach to scenario development combining qualitative and quantitative information, which can be useful for the EEA or any other similar organization developing environmental assessments. I would like to thank the author for his contribution to the further development of environmental scenarios.

Our mission is to contribute to a better-informed decision making process by providing better insights on how alternative futures might unfold and on where alternative paths might leads us. But to complete our mission we need politicians and decision makers to support us in this task, with resources, involvement and courage — the courage to look at the long term consequences of their actions and make hard choices when necessary.

Domingo Jiménez-Beltrán
Copenhagen, October 2001

Contents

Summary

Scenarios can serve as useful tools in international environmental assessments for evaluating future environmental problems and assessing policies to resolve them. This report summarises some scenario-building exercises that are particularly relevant for this purpose. It draws especially on recent activities of the Intergovernmental Panel on Climate Change and World Water Commission. Based on the experience of these and other groups, the report lays out a ‘story-and-simulation’ (SAS) approach to developing scenarios which could be especially relevant to international environmental assessments. This approach combines qualitative and quantitative information and consists of two main elements: a storyline and a set of model calculations. The storyline describes in story form how relevant events unfold in the future, while the model calculations complement the storyline by presenting numerical estimates of future environmental indicators and helping to maintain the consistency of the storyline.

The following steps are involved in the story-and-simulation approach:

1. A scenario team and scenario panel are established. The scenario team coordinates the scenario building while the scenario panel provides the creative input and ensures that a wide range of views are represented in the scenarios. The team consists of representatives from the institution sponsoring the scenario building and experts. The panel consists of stakeholders, policymakers and additional experts.

2. The scenario team proposes goals for the scenarios and drafts a first outline of the scenarios.

3. At its first meeting the scenario panel discusses and revises the goals of the scenarios, and drafts a ‘zero order’ storyline of the scenarios.

4. Based on the draft storyline, the scenario team assigns quantitative values to the driving forces of scenarios.

5. Based on the assigned driving forces, the modelling teams quantify the indicators of the scenarios.

6. At the next meeting of the scenario panel, the modelling team reports on the quantification of the scenarios, and the scenario panel and scenario team revise the storylines.

7. Steps 4, 5 and 6 are repeated as necessary.

8. When the scenario team and scenario panel agree on a draft of the scenarios, they are distributed for review by stakeholders and experts via the Internet, open workshops, and other means.

9. Based on review comments, the scenarios are revised by the scenario team and scenario panel.

10. The final scenarios are published and distributed via the Internet, paper reports, meetings, or by other means.

The SAS procedure is offered only as a general guideline to scenario building. It is not necessary to follow the procedure literally step by step in every scenario exercise.

1. Introduction

As society's environmental problems grow along with the growth of population and the economy, new methods have been devised to keep track of these problems. One such method is 'environmental assessment', a technique which provides basic information about the state of the environment for decision-making institutions. But in principle assessments can only assess the current state or condition of the environment, whereas many important environmental problems have to do with the future state of the environment. Examples of such problems are the long-term impact of tropospheric ozone on vegetation, or the impacts of climate change on agriculture and sea level rise. Moreover, assessments often concern themselves with future steps to be taken to solve an environmental problem (e.g. the different phases in an air pollution management programme). Hence environmental assessments typically must cover both the current state of the environment and the future state of the environment. But how can we assess something that does not exist? One way out of this dilemma is to construct scenarios of the future. The first objective of this report is to explain the relevance and value of scenarios and scenario analysis as one of a set of tools for international environmental assessments (in particular those carried out by the European Environment Agency — EEA). For this reason the report provides basic information about the origin and varieties of scenarios.

The report's second objective is to lay out for readers a concrete scenario-building procedure — the SAS (story-and-simulation) approach — that addresses the special requirements of international environmental assessments. As background, the report first reviews a selected number of scenario-building exercises in the environmental field that are particularly relevant to international assessments ([1]).

But first we begin with a review of some of the fundamentals of scenarios and scenario analysis.

1.1. Where does the concept of scenario come from?

The word 'scenario' is borrowed from performance theatre where it refers to the sequential elements of a screenplay such as the actions of its performers or changes in the stage setting. 'Scenario' was taken over by strategic planners after World War II to describe a method for war game analysis, and eventually it entered the civilian vocabulary through the work of Herman Kahn and others (see, e.g., Kahn and Wiener, 1967). In common usage scenarios now refer to 'a sequence of emerging events', or 'an account of a projected course of action or events' (Webster's Ninth Collegiate Dictionary, 1989). In environmental studies, 'scenarios' have been defined somewhat differently. For example, the Intergovernmental Panel on Climate Change (IPCC) describes scenarios as 'images of the future, or alternative futures' that are neither predictions nor forecasts, but an alternative image of how the future might unfold (Nakicenovic et al., 2000). There are also specific types of scenarios such as emission scenarios which are defined by the IPCC as 'projections of the future state of the society and environment based on specific assumptions about key determinants such as population, economic growth, technological change, or environmental policies' (Alcamo et al., 1995). The different types of scenarios are further elaborated below.

1.2. What does a scenario consist of?

The principal elements of a typical scenario used in environmental studies are:

1. **Description of step-wise changes**. The main element of a scenario is the portrayal of step-wise changes in the future state of society and the environment. For example, emission scenarios depict the change in emission levels of one or more substances over time, while climate change scenarios cover the change of temperature and other climate variables over time and

(1) However, this report does not exhaustively review the rich literature on scenarios and scenario development, which is interesting but not of central interest to the objectives of the report.

space. These changes can be expressed, for example, in the form of a diagram, table, or even as a set of written phrases.
2. **Driving forces**. These are the main factors or determinants that influence the step-wise changes described in a scenario. As an example, some of the driving forces of greenhouse gas emission scenarios are assumed population, economic growth, and the rate at which energy use becomes more efficient (Alcamo et al., 1995; Nakicenovic et al., 2000). Values for these driving forces (along with most of the other elements of scenarios) must be assumed by the scenario developers, or taken from other studies.
3. **Base year**. The base year is the beginning year of the scenario. For quantitative scenarios, the base year is usually the most recent year in which adequate data are available to describe the starting point of the scenarios.
4. **Time horizon and time steps**. The time horizon describes the most distant future year covered by a scenario. The selection of an appropriate time horizon for a scenario depends very much on the objectives of the scenarios. If the scenarios aim to describe the steps in Europe to reduce air pollution emissions, then the appropriate time horizon might be 10 to 20 years. If they describe the longer term effects of climate change then it could be 100 years or more. The number of time steps between the base year and time horizon of the scenarios are usually kept to a minimum because of the large analytical effort needed to describe each year. In the world water vision scenarios (described later) only two time steps were used between 1995 and 2025, and in the SRES scenarios (also described below) time steps of 10 years were used.
5. **Storyline**. A storyline is a narrative description of a scenario which highlights its main features and the relationships between the scenario's driving forces and its main features. These storylines can be newly constructed for each new scenario study, or they can be taken from previous scenario exercises. Since the storylines require intensive discussions and compromises between the different people involved in the scenario exercise, a large amount of time and effort can be saved by using storylines from previous exercises. (Moreover, some of the acceptance of these existing storylines might be transferred over to the new scenarios.)

1.3. How can scenarios be useful in environmental assessments?

Since scenarios are helpful for thinking about the future, they can also be useful tools for assessing either the future implications of current environmental problems, or the future emergence of new problems. In particular, scenarios can be used to:

- provide a picture of future alternative states of the environment in the absence of additional environmental policies ('baseline scenarios'). In this way scenarios are a device to illustrate the impacts of society on the natural environment, and to point out the need for environmental policies to avoid these impacts (e.g. to illustrate how continued agricultural practices may lead to more intensive eutrophication of European rivers and the Baltic);
- raise awareness about the future connection between different environmental problems (e.g. between climate change and threats to biological diversity);
- illustrate how alternative policy pathways can achieve an environmental target;
- combine qualitative and quantitative information about the future evolution of an environmental problem;
- identify the robustness of environmental policies under different future conditions; forexample, to examine if 'best available treatment' of wastewater will be a sufficient policy for achieving water quality targets under alternative population scenarios;
- help stakeholders, policymakers and experts to 'think big' about an environmental issue, i.e. to take into account the large time and space scales of a problem;
- help raise awareness about the emergence of new or intensifying environmental problems in Europe over the next few decades. For example, scenarios about acid rain (see, e.g., Hordijk, 1995) and climate change (see, e.g., Alcamo et al., 1996b and van Daalen et al., 1998) have been used to raise the awareness of policymakers about emerging problems.

It can be argued that many of these tasks are already handled by existing assessments and policy analyses. While this may be true, it can also be argued that scenarios can provide added value to these assessments: (a) first of all, these assessments must handle and assimilate an enormous amount of information and insights, and scenarios provide an effective format for bringing this information together; (b) second, assessments must gather and assimilate information in both quantitative and qualitative form, and scenarios are capable of representing both forms of information; (c) lastly, the results of an assessment must be communicated to a large and diverse audience, both technical and non-technical. scenarios can be written in the form of stories, and in this form they can communicate the results of an assessment in a transparent and understandable way.

Perhaps the most important function of both scenarios and environmental assessments is that they act as a crucial bridge between environmental science and policy. They influence policymaking by summarising and synthesising scientific knowledge in a form that can be used by policymakers to develop policies. They help policymakers visualise the different aspects and connections of an environmental problem, as well as its large time and space scales. Conceivably scenarios and environmental assessments can also help decision-makers devise the policy steps needed to solve a problem. Perhaps this potential will become more evident as we describe scenarios and scenario exercises in the following pages.

2. Types of scenarios

2.1. Qualitative vs. quantitative

Scenarios come in two basic forms: qualitative and quantitative. Qualitative scenarios describe possible futures in the form of words or visual symbols rather than numerical estimates. They can take the shape of diagrams, phrases, or outlines, but more commonly they are made up of narrative texts, the so-called 'storylines' mentioned earlier. An example is given by the European Commission's 'Scenarios Europe 2010' presented below. It was already pointed out that qualitative scenarios have the advantage of being able to represent the views of several different stakeholders and experts at the same time. It was also noted that well-written storylines can be an understandable and interesting way of communicating information about the future, at least as compared with dry tables of numbers or confusing graphs. But the drawback is that qualitative scenarios do not, by definition, satisfy a need for numerical information. This is a big disadvantage because environmental assessments usually require some analyses of numerical data. For example, an assessment of air pollution would be expected to contain numerical information about the magnitude of emissions, while an assessment of the state of biodiversity would be expected to include numerical trends of different species.

On the other hand, quantitative scenarios (as represented, for example, by the IMAGE scenarios presented later) provide needed numerical information in the form of tables and graphs. Their disadvantage is that the exactness of their numbers is sometimes taken as a sign that we know more about the future than we actually do. For example, a scenario estimate that emissions of carbon dioxide are 22 gigatons in 2100 is interpreted by some to mean that we know that emissions will be this figure 100 years from now.

Another disadvantage is that quantitative scenarios are usually based on results of computer models, and these contain many implicit assumptions about the future. It has been argued that these models tend to represent only one point of view about how the future will unfold, and in this way produce scenarios that are unnecessarily narrow in view. An additional drawback is that the basics of modelling are difficult for the non-specialist to understand.

But there are also advantages of producing quantitative scenarios based on models. Model developers point out that their assumptions about the world are written down in the form of model equations, and model inputs and coefficients. Although these are not easily understood by non-experts, these assumptions are at least written down and are often more transparent than the undocumented and unspoken assumptions behind qualitative scenarios. After all, most of the assumptions behind qualitative scenarios usually remain locked in the heads of the stakeholders and experts that specify these scenarios. Another advantage of quantitative scenarios based on models is that these models are often already published in the scientific literature and have therefore received some degree of scientific scrutiny. Later we will also see that models can be useful for checking the consistency of qualitative scenarios.

So there are convincing arguments on both sides of the question of qualitative versus quantitative scenarios. Which approach should we choose? One answer is that it depends on the goal of the scenario exercise. If the goal is to inform European policymakers about general social and cultural trends in Europe over the next 10 years, then a qualitative approach (as used in the 'Scenarios Europe 2010' of the European Commission) may be suitable. If the goal is to estimate the level of emission reductions needed to avoid the impacts of climate change, then a quantitative approach (as used, for example, in the IMAGE global change scenarios) may be appropriate. If, on the other hand, the goal is assessment of the future European environment, then perhaps a combined qualitative and quantitative approach is called for. Later in the report we describe how such an approach was used by the Intergovernmental Panel on Climate Change and the World Water Commission.

2.2. Exploratory vs. anticipatory

Another way to classify scenarios is to distinguish between 'exploratory' and 'anticipatory' scenarios. Exploratory scenarios (also known as 'descriptive' scenarios) are those that begin in the present and explore trends into the future. This comes close to the original meaning of the word 'scenario' in the sense that it is a sequence of emerging events. Examples of these are the SRES emission scenarios to be presented later. By contrast, anticipatory scenarios (also known as 'prescriptive' or 'normative' scenarios) start with a prescribed vision of the future (either optimistic, pessimistic, or neutral) and then work backwards in time to visualise how this future could emerge. Examples of this type of scenario are the utopian visions published in the 19th century, including Fournier's socialist utopia and Proudhin's anarchistic utopia. A more recent example are the IIASA scenarios of the future environment of Europe, to be described shortly.

Exploratory scenarios are much more common in environmental studies, perhaps because they require less speculation about the future than anticipatory scenarios. Or perhaps it is because researchers are more comfortable with the forward progression of time in exploratory scenarios than with the backward direction of anticipatory scenarios. Another common justification of the exploratory approach is that it purports to be more 'value free' than the anticipatory approach. For example, the IPCC specifically states that the SRES scenarios are of the exploratory type and 'should not be construed as desirable or undesirable in their own right. (...) They [the scenarios] represent pertinent, plausible, alternative futures' (Nakicenovic et al., 2000).

On the other hand, the difference between exploratory and anticipatory scenarios sometimes blurs in practice. For example, the world water vision scenarios are both exploratory scenarios in that they explore the evolution of the world water situation from the present time, but also anticipatory in that they prescribe three different end states in the world's freshwater situation.

2.3. Baseline vs. policy scenarios

2.3.1. Purpose of baseline scenarios

Another useful way to classify scenarios is to distinguish between 'baseline' and 'policy' scenarios. Baseline scenarios (in the context of environmental studies) are also known as 'reference' or 'benchmark' or 'non-intervention' scenarios. They present the future state of society and the environment in which environmental policies either do not exist or do not have a discernable influence on society or the environment They can be used for the following purposes:

1. To evaluate the consequences of current policies or 'no new policy intervention'; similarly, to provide a reference case for new policy interventions. For example, what would be the expected trends in NO_x emissions in Europe up to 2025 under current trends in traffic and energy use, and assuming that no new control policies were implemented?

2. To take into account the uncertainty of driving forces. For example, what would be the expected trends in NO_x emissions in Europe up to 2025 if (a) current trends in traffic and energy use continued? or (b) if public transportation expanded faster than private vehicle use? or (c) if larger, American-style vehicles became the main type of private vehicle?

3. To take into account the uncertainty of environmental conditions. For example, what are the expected levels of O_3 in different parts of Europe in the 2020s (a) under average climate conditions? (b) if a drought occurs over much of central Europe?

But it is more difficult than one might think to conceive of a world completely without environmental policies because these policies already permeate society and act directly and indirectly on society and nature. The developers of the SRES scenarios encountered this issue while developing baseline scenarios of the emissions of greenhouse gases and other atmospheric substances that may be regulated by climate policies. The problem is that one of these substances is sulfur dioxide (SO_2), which is important to both climate policy and air pollution policy. It turns out that emissions of SO_2 are already regulated in most OECD countries because of air pollution policy rather than climate policy. In this case, what is a valid baseline scenario of SO_2 emissions? Should these scenarios include or exclude regulations that were intended to control air pollution rather than climate change?

Eventually the scenario developers decided that a baseline scenario of SO_2 emissions should take into account air pollution regulations because these controls were put into place independent of climate policy. A general guideline in this situation is that a baseline scenario should exclude the impacts of all policies directly related to the main theme of the scenario. (In the case of the SRES scenarios the main theme was climate policy, and therefore the impacts of climate policies (for example, the reductions of carbon dioxide emissions due to a tax on the carbon-content of fuel) were excluded from the baseline scenarios. However, these scenarios are allowed to include the impacts of policies indirectly related to the main theme.) Therefore, the SRES scenarios did include the effects of air pollution policy.

2.3.2. How many baseline scenarios?

An important point to keep in mind about baseline scenarios is that the driving forces of environmental problems can take many different directions. For example, international organisations normally provide a wide range of projections for population or gross national product, especially over long projection periods. Accordingly, rather than develop a single baseline, it is better to develop multiple baselines that reflect different trends, some of which have a lower probability, and some higher. For instance, the SRES scenarios mentioned above are made up of multiple baselines describing the trends of greenhouse gas emissions. On the other hand, because developing scenarios requires extensive effort and expense, scenario studies often limit themselves to only one baseline scenario. This was the case in the world water vision exercise in which only a single business-as-usual baseline scenario was developed (although it contained many regionally-differentiated sub-scenarios).

The recommended number of baseline scenarios depends, among other things, on their time horizon and the degree to which they diverge within this time horizon. An example of this divergence is given in the IPCC report on emission scenarios which showed that different scenario estimates from the literature clustered closely together in 2020 and 2050, but diverged widely by 2100 (Alcamo, et al. 1995). Hence, it can be argued that more baseline scenarios are needed to cover the range of possibilities in 2100 than in 2025. As a general guideline, the longer the time horizon, the greater the divergence of scenario estimates because of the increasing uncertainty of social and environmental systems with time ([2]). Hence, the longer the time horizon, the greater the need for multiple baselines.

Another important consideration is the number of subject areas that the baseline scenarios must cover. In general, the larger the number of subjects, the larger the number of interactions between subjects, and the more complex the scenarios. This means, practically speaking, the larger the number of subject areas, the smaller the number of baseline scenarios that can be developed. Two examples are presented later of scenarios that cover several different subject areas: the IMAGE scenarios cover many different aspects of global environmental change and the IIASA scenarios cover many different environmental problems in Europe. In this case the IMAGE scenarios had three baseline scenarios and the IIASA scenarios four.

How can we sum up the question of the number of baseline scenarios? We can divide this question into different parts. First, should there be an odd or an even number of scenarios? This question was discussed by the developers of both the IPCC–SRES scenarios and the world water scenarios. Both groups came to the conclusion that when confronted with an odd number of scenarios, both researchers and policymakers tend to focus on only the middle scenario. This was one factor that led to development of an even number of SRES scenario 'families'.

The next question is: should it be two, four, or more baseline scenarios? The disadvantage of having only two baselines is that users of this information may assume (unless they are otherwise informed) that these two scenarios represent the two extremes of baseline conditions. This argues for four or more scenarios in which two can represent the extremes of baseline conditions and two intermediate conditions. (This was another motivation for the IPCC to develop four families of SRES scenarios.) But, based on experience, having two or more baseline scenarios is usually too unwieldy. It takes too long a time to explain

(2) However, the estimates of different scenarios do not always diverge with time. For example, Alcamo and Swart (1998) showed that different scenarios of CO_2 emissions from deforestation actually converged over their 100-year time horizon because of their converging assumptions about the rate of deforestation.

results to policymakers and their advisors, and there are too many reference points for the development of policy scenarios. For example, the IPCC is now using four marker SRES scenarios as reference scenarios for developing 'mitigation' scenarios. These new scenarios describe different ways to mitigate baseline emissions, for example by shifting to low-carbon fuels, reducing fertiliser use, or expanding forest area (Morita et al., 2000). The problem is that each of the four baseline scenarios can serve as the starting point for several different mitigation scenarios, each depicting a different trend of emissions into the future. It is easy to imagine the confusing proliferation of different emission scenarios that could result, which would be very difficult to evaluate or to communicate to policymakers.

To sum up the question of number of baseline scenarios: first, since the driving forces of environmental problems can take so many different directions, it is better (in principle) to develop multiple baselines that reflect different trends. Next, the recommended number is either two or four, depending on their content and the circumstances of their usage. For scenarios with a longer time horizon (several decades) and which do not lead to proliferating numbers of policy scenarios, four might be the right number of scenarios. For scenarios which cover several different subject areas, two might be the preferred number.

2.3.3. Policy scenarios

Whereas baseline scenarios portray a 'default' view of the future, policy scenarios (in the jargon of environmental studies) depict the future effects of environmental protection policies. Policy scenarios are also sometimes known as 'pollution control', 'mitigation' or 'intervention' scenarios.

Some of the purposes of policy scenarios are to:

1. identify policies that attain specific environmental goals or norms. For example, what reductions in NO_x and SO_2 emissions in different European countries will slow and eventually reverse the acidification of lakes in Europe?

2. examine the economic and environmental impacts of specific environmental policies. For example, what would be the expected trends in NO_x emissions in Europe up to 2025, if EU standards for NO_x emissions from power plants were adopted throughout Europe after 2010? What would be the consequences on O_3 in the lower atmosphere? What would be the direct costs of complying with these standards? What would be their indirect costs on the economy?

3. take into account the uncertainty of future environmental conditions and societal driving forces. For example, if all wastewater in the Oder river basin was treated to remove 90 % of its nutrient content, what would be the maximum nutrient content in the river under average flow conditions versus drought flow conditions occurring every 10 years? For the same level of nutrient treatment, what would be the maximum nutrient content in the Oder river if the population in the river basin either remained at its current level or decreased 2 % per year because of emigration?

The recommended number and type of policy scenarios depends very much on the circumstances of the environmental study. Again, too many scenarios may lead to 'scenario fatigue', i.e. providing more information to policymakers and their advisors than they can absorb.

3. Examples of scenarios and scenario development

This section describes five examples of scenario exercises (Table 1) with the aim to inform the reader about some alternative approaches to developing scenarios. The first example deals with qualitative scenarios of Europe's future and addresses many social, political and economic issues concerning Europe. The second, third, fourth and fifth examples have the state of the environment as a central theme. The second set of scenarios are also largely qualitative (with some quantitative aspects) and deal with the future of Europe's environment, while the third example illustrates a quantitative scenario exercise using a global model to quantify scenarios of global change. The fourth and fifth examples address scenarios of global greenhouse gas emissions and the world water situation, respectively. They are recent and prominent international examples of scenario construction, and they blend both qualitative and quantitative approaches. These last two examples are thought to be most relevant to international environmental assessments of the type carried out by the European Environment Agency and other institutions.

Table 1. **Examples of scenarios**

Scenario name — Theme	Type of scenario (qualitative or quantitative)	Type of scenario (anticipatory or exploratory)	Number of scenarios	References
European Commission scenarios — 'Scenarios Europe 2010'	Qualitative	Anticipatory	5 Combined baseline & policy [1]	Bertrand et al., 1999
IIASA scenarios — 'Future environments of Europe'	Combined	Anticipatory	Approx. 4 [2] Combined baseline & Policy [1]	Stigliani et al., 1989
IMAGE scenarios — 'Global change'	Quantitative	Exploratory	3 baseline 14 policy [3]	Alcamo et al., 1996a Alcamo and Kreileman,1996 Leemans et al., 1996
SRES scenarios of the IPCC — 'Global greenhouse gas emissions'	Combined	Exploratory	4 baseline scenario 'families'	Nakicenovic et al., 2000
World water vision scenarios — 'The world water situation'	Combined	Combined	1 baseline 2 policy	Cosgrove and Rijsberman, 2000 Alcamo et al., 2000

(1) No distinction was made between baseline and policy scenarios.

(2) A different number of scenarios were developed for different topics within the study. The average number of scenarios was around four.

(3) The references cited in the right column describe 14 policy scenarios, although many additional policy scenarios are described in other publications of the IMAGE team.

3.1. Example 1: The European Commission scenarios — 'Scenarios Europe 2010'

3.1.1. Background

The imminent approach of the year 2000 was used as an occasion by many institutions to reflect upon future developments which could affect their activities. One example was the scenario study carried out by the European Commission to examine developments in Europe up to 2010. The stated objectives of these scenarios were 'to stimulate debate inside and outside the Commission on the future of European integration, and to develop a tool to put the (European) Union's policies and strategies into perspective and contribute to their improvement' (Bertrand et al., 1999, p. 12). The scenario developers were very direct about their purpose when they wrote that 'illustrating the future by means of scenarios is a way to overcome human beings' innate resistance to change'. The scenarios were developed by civil servants of the Commission, and the community of these civil servants was apparently one of the main target groups of the scenario exercise.

3.1.2. Elements of the scenarios

The 'Scenarios Europe 2010' are qualitative in that they communicate their message by means of a narrative, also called a 'script' or 'storyline'. There are a total of five individual scenarios (Box 1), with each one taking a sharp view of Europe' future.

- The 'Triumphant markets' scenario presents the implications of fully accepting the American model of unbridled competition, technological innovation and corporate organisation with one result being rapid growth in the new economy.
- The 'Hundred flowers' scenario describes a Europe that strongly emphasises local and regional communities versus central government and institutions. Without centralised structures, growth slows somewhat.
- A central focus of the 'Shared responsibilities' scenario is the reform of public administration from hierarchical governance to more horizontal structures. Here economic growth is also rapid, but there is a greater emphasis on social responsibility than in the 'Triumphant markets' scenario.
- In the 'Creative societies' scenario the values of social equality and ecological consciousness play prominent roles in European development. Economic growth slows, citizen governance increases.
- The 'Turbulent neighbourhoods' scenario is described as a 'sort of regression', with main themes being fear of the future, preoccupation with security, and new power of the State to ensure this security. The lack of cooperation within Europe slows economic growth.

Box 1: The different scenarios in 'Scenarios Europe 2010'

1. Triumphant markets
2. Hundred flowers
3. Shared responsibilities
4. Creative societies
5. Turbulent neighbourhoods

Source: Bertrand (1999).

3.1.3. Procedure for developing the scenarios

Since these scenarios are a good example of qualitative scenarios, we devote a considerable amount of space here to describing the procedure used for their development. The scenario building was organised and coordinated by the Forward Studies Group of the Commission. They named their procedure the 'Shaping actors — Shaping factors' approach because it involves selecting the main 'actors' and 'factors' shaping future events. The procedure consists of two main stages. The first involves developing theme-specific 'partial' scenarios, and the second in synthesising these into 'global' cross-cutting scenarios.

Developing the partial scenarios

Five themes of particular importance to the future of Europe were selected for the partial scenarios: institutions and governance; social cohesion; economic adaptability; enlargement of the European Union; and the European environment. Five individual working groups, each made up of 12 to 15 Commission civil servants, then developed the partial scenarios for each theme. To do so they followed these steps.

- **Presenting a background paper**. The Forward Studies Group composed and presented a background paper on each of the five themes to the appropriate working group.
- **Selecting variables**. By means of a brainstorming exercise, the group compiled a comprehensive list of variables that related to the theme under consideration. These variables were then classified as 'factors' or 'actors'. Next, the initial list, usually numbering around 50, was reduced to a manageable number (10 to 15). For example, the working group on 'Economic adaptability' selected a total of 13 variables which included 'factors' such as technology/organisation and industrial policies, and 'actors' such as trade unions and transnational corporations.
- **Constructing mini-scenarios**. The groups then outlined 'mini-scenarios' (storylines of a few sentences each) about future changes of each variable.
- **Selecting pivot variables.** The list of variables was then further reduced to five or six so-called 'pivot variables' which were most likely to make a difference between scenarios.

- **Selecting the partial scenarios**. Up to this point the groups had selected a small number of pivot variables consisting of both factors and actors. As noted, each of these variables had a mini-scenario associated with it. Now each group combined a small group of consistent mini-scenarios into a total of five different 'skeleton' scenarios. Each of the skeleton scenarios was made up of around six to eight of the mini-scenarios.
- **Writing storylines**. The coordinators of the scenarios now wrote a storyline (about 3 000 words) for each of the skeleton scenarios. This amounted to five partial scenarios for each of five themes (institutions and governance; social cohesion, etc. as listed above) for a total of 25 partial scenarios.

Developing the global scenarios

- **Selecting combinations of partial scenarios**. The next step was for the scenario coordinators (assisted by a steering group of 10 Commission civil servants) to construct provisional 'global scenarios' made up of one partial scenario from each of five themes, for a total of five partial scenarios per global scenario. The main challenge was to find the right combinations of partial scenarios. To do this each of the many possible combinations of partial scenarios were ranked for consistency. After some merging and elimination, five of the most consistent and distinctive global scenarios were selected.
- **Clarification of key scenario drivers**. The key drivers of the selected provisional global scenarios were selected after reviewing the partial scenarios. The role of the drivers were precisely described for each scenario.
- **Review of scenarios**. The provisional scenarios were evaluated and critiqued at 10 presentations within the Commission and 20 outside the Commission.
- **Writing storylines**. The coordinators wrote a script of approximately 4 000 words for each of the provisional global scenarios.
- **Finalisation of scenarios**. The storylines were reviewed by the authors and the steering group and then revised and published.

The whole procedure took about two years, and involved a total of 60 Commission officials. The involvement of so many people over a protracted period was in itself an accomplishment since it engaged all of these officials in thinking about the future. Indeed, the scenario builders had hoped that the exercise would create an atmosphere for more pro-active planning within the Commission, or as they put it, would contribute to the building of a 'futures culture' within their organisation.

One positive aspect of the 'Shaping actors — Shaping factors' approach is that it seems to be flexible enough to accommodate a wide range of topics in an understandable way. In any event, the Norwegian Government found it attractive enough to employ it in their scenario exercise 'Norway 2030' (as reported by Bertrand et al., 1999).

3.2. Example 2: The IIASA scenarios — 'Future environments of Europe'

3.2.1. Background

In the 1980s the International Institute for Applied Systems Analysis (IIASA) launched the biosphere project to study the large-scale impacts of society on the Earth's biosphere. As part of this project IIASA organised a scenario study of the future state of the European environment. The goals of the study were to:

1. characterise the large-scale environmental transformations that could be associated with Europe's socioeconomic development;
2. describe and assess alternative steps to manage interactions of Europe's future development with its natural environment;
3. identify research and monitoring priorities.

Source: Stigliani et al., 1989).

3.2.2. Elements of the scenarios

The scenarios were organised into two clusters of topics: 'Socioeconomic futures' and 'Environmental futures'. 'Socioeconomic futures' included population, energy, industry, agriculture and forestry, while 'Environmental futures' covered climate, hydrology, atmospheric pollution, soil quality, water quality, biota and land use. A small set of scenarios were developed for each of these individually, but there were no common or shared scenarios, nor were the topics related to a common baseline scenario. A default or 'conventional wisdom' scenario was identified for some of the topics but this did not necessarily correspond to the default scenario of other topics. The authors did not distinguish between 'baseline' or 'policy' scenarios, although in retrospect they came closer to the 'baseline' category.

The scenarios were mostly qualitative, but some of the narratives were supplemented by quantitative illustrations and calculations from particular European case studies. For example, under the subtopic 'Soil quality', a map showed the soils in the Netherlands that might become salinised as a consequence of sea level rise. In other cases the narrative was supplemented by European-scale calculations as in the 'Agriculture' subtopic which included calculations of the arable area in Europe in 2030.

A unique aspect of this scenario study was the attempt to identify 'not-impossible turning points' where slow-changing trends in society and nature take a sharp turn towards the better or worse. The aim here was to alert policymakers about the cumulative impacts of society on nature, and to enable them to devise policies to avert these impacts. An example of turning points for agriculture is given in Box 2.

Box 2: Excerpt from the 'Agriculture' scenario narrative in the IIASA scenarios — 'Future environments of Europe'

Arable land, used for growing annual or permanent crops, currently covers about a third of Europe. An annual increase in productivity of 1 % is assumed for growing cereal crops until the year 2000 and 0.5 % for the period 2000–30, being an extrapolation of present trends. (...) In total some 40 million ha of agricultural land are expected to be taken out of production, corresponding to about 30 % of the current land used for growing cereal crops. (...) Not-impossible turning points for European agriculture are:

1. a further increase in productivity could be as much as 2 % per year. Such an increase may result in a further reduction of agricultural land when compared to the conventional scenario;
2. adaptation to poor local conditions such as soil, water, or climate. This could maintain the socioeconomic structure of rural areas, although it would further aggravate the current problems of agricultural surpluses.

Source: Stigliani et al., 1989.

3.2.3. Procedure for developing the scenarios

One of the main techniques used to develop these scenarios was called 'policy exercises', described as a 'flexibly structured process designed as an interface between academics and policymakers' (Brewer, 1986; Toth, 1988). The policy exercise is carried out in one or more periods of collaboration between scientists, policymakers and support staff, where a period consists of preparations, workshops and evaluation. The product of this interaction is the narrative of the scenarios.

A major component of the policy exercises was the development of 'future histories' in which scenario developers first specify the end state of the future environment and society, and then work backwards to imagine the steps that would lead to this state. This is a typical approach for generating anticipatory-type scenarios.

The time span between the conception and completion of the scenarios was approximately three years. Final results of the scenario exercise were presented at international meetings and to four committees of the Dutch Parliament (because of the special support and interest of the Dutch in the study). The scenarios were also documented in a special issue of a scientific journal (Stigliani et al., 1989).

3.3. Example 3: The IMAGE scenarios — 'Global environmental change in the 21st century'

3.3.1. Background

As a contribution to scientific and policy studies of climate change, a set of scenarios were developed by a team at the Dutch National Institute for Public Health and the Environment (RIVM). The scenarios were meant to provide a global view of the direction of key environmental changes over the next 100 years, and to examine some ideas about how unwanted changes could be avoided. Many of the scenarios were developed as a result of discussions with decision-makers from different countries through the so-called 'Delft process'. This process consisted of a series of workshops featuring a dialogue between computer modellers and policymakers involved in the negotiations leading up to (and following) the adoption of the Kyoto Protocol of the Framework Convention on Climate Change (Alcamo et al., 1996; van Daalen et al., 1998).

Table 2. **Overview of selected results from the IMAGE 2 global change scenarios**

	Emissions				Atmosphere/ocean			Terrestrial		
Indicator	CO_2	CO_2 equivalent	Cumulative CO_2	Cumulative CO_2 equivalent	CO_2 concentration	Temperature change	Sea level rise	Threat to natural vegetation	Area of current maize growing area with increasing yield	Area of current maize growing area with decreasing yield
Year	2100	2100	1990–2100	1990–2100	2100	1990–2100	1990–2100	2100	2100	2100
Unit	Gt C/yr	Gt C/yr	Gt C	Gt C	ppmv	°C	cm	%	%	%
Scenario										
Baseline-A	22.0	31.5	1 691	2 589	737	2.8	43	41	16	32
IS92E	37.5	47.6	2 284	3 181	943	3.2	44	45	23	31
Stab 350	-1.1	5.0	373	1 083	367	0.7	24	15	1	16
Stab 450	3.1	9.8	717	1 475	450	1.3	29	23	5	21
Stab 550	7.6	15.0	961	1 752	517	1.7	33	28	6	25
Stab 650	10.2	17.9	1 130	1 945	564	2.0	36	31	8	26
Stab yr1990	0.9	7.2	233	920	354	0.5	18	11	1	13
ST2000-A	17.2	26.6	1 334	2 228	633	2.4	38	36	11	30
ST2000-B	4.7	14.0	846	1 736	482	1.7	34	28	6	26
ST2000-C	4.7	9.7	845	1 517	481	1.1	29	20	5	18
ST2000-D	11.1	18.3	1162	1 937	574	2.0	36	32	8	26
ST2000-E	2.0	6.1	661	1 271	433	0.6	24	13	1	13

3.3.2. Elements of the scenarios

The scenarios consist of quantitative global estimates of various indicators of environmental change from 1995 to 2100 (e.g. Table 2). They are called 'integrated' scenarios because they give an integrated picture of global developments spanning a wide range of explicitly coupled indicators. These indicators include spatial and temporal changes in emissions of major global air pollutants, surface air temperature, precipitation, agricultural land coverage and natural land coverage. The time step of most driving forces and global change indicators is 10 years.

The primary driving forces of the scenario are population and economic growth rates, and various indicators of the rate of technological change. Using these prescribed primary driving forces, the IMAGE 2 model (see below) was used to compute secondary driving forces of global change, such as energy and food consumption.

The scenarios include three baseline scenarios (Alcamo et al., 1998a), each of which describes the consequences on global environmental change of a different set of 'not implausible' developments of population, economy, and other driving forces.

- Baseline A is an intermediate scenario with medium assumptions about population growth, economic growth and economic activity.
- Baseline B has lower estimates of all driving forces compared to A.
- Baseline C has the same estimate for population growth as A, but higher estimates of economic growth and economic activity.

Several sets of policy scenarios were also developed to examine strategies for mitigating the impacts of climate change (Alcamo and Kreileman, 1996; Leemans et al., 1996;) (Table 2).

3.3.3. Procedure for developing the scenarios

One of the main results of the international climate summit of 1995 was the adoption of the 'Berlin mandate' which called for negotiations leading to a protocol to the Framework Convention on Climate Change in 1997. The IMAGE scenarios were developed by a modelling team at RIVM to provide scientific input to these negotiations. But from the outset the needs of the negotiators were not clear to the modelling team, and the usefulness of scenario analysis was unclear to most negotiators. To try and improve this situation, a dialogue was established between the modelling team and climate negotiators in the form of a series of workshops called the 'Delft process' (because of where they were held). The workshops were organised by Delft Technical University, and negotiators from about 10 to 15 countries attended the three workshops.

A notable feature of the scenario development was that a global model, 'IMAGE 2', was used to develop the scenarios. The IMAGE 2 model is an integrated climate change model developed at RIVM (Alcamo, 1994; Alcamo et al., 1998) which explicitly couples emissions, climate change, and its impacts, and provides global information with geographical and regional detail.

At the first Delft meeting, the IMAGE team presented a selection of scenario results to the negotiators. A set of baseline scenarios showed the consequences of not acting to mitigate climate change, and served as benchmarks for comparing policy scenarios. A set of policy scenarios were also presented that showed the consequences of stabilising greenhouse gases in the atmosphere and other climate policies. One of the main outcomes of the meeting was the request from the climate negotiators for more specific analyses. The IMAGE team responded to these requests and presented several scenarios at the next workshop that showed the implications of different climate policies.

In total the scenarios took about two and a half years to develop. They showed, among other things, that controlling only emissions from industrialised countries would not significantly slow down the build-up of greenhouse gases in the atmosphere. The scenarios also illustrated the significant costs of regional CO_2 emission reductions, although they also showed that international cooperation could substantially reduce these costs.

It can be argued that the aim of the scenarios — that is, to provide input to the climate negotiations — was at least partly achieved through the Delft process (van Daalen et al., 1998). But it is also likely that the scenarios did not provide as much input as they could have because of 'scenario fatigue'. Simply put, there was too much information in the scenarios for the policy advisors to absorb during the Delft workshops. On the one hand, one could argue that this information glut could not have been prevented because global change issues are truly very complex. On the other hand, the modelling team did not experiment very much with the way in which they presented the scenarios. What can be done to avoid scenario fatigue? Obviously the number of scenarios can be limited, and the unimportant messages filtered out before presentations. But another alternative is to exploit information technology, for example video or audio techniques, in order to present information in a more interesting and convincing way.

3.4. Example 4: The world water vision scenarios — 'The world water situation in 2025'

3.4.1. Background

In 1997 the World Water Council organised the First World Water Forum in Mararakech, Morocco, which brought together many private, governmental, academic and advocacy groups concerned with world water issues. One of the important outcomes of the forum was the call for the development of a 'world water vision' to raise global awareness about global water problems and their solution. The primary objective of the vision process was to 'convince the world of the urgency of the water crisis and the need to involve many more people in development of water policy'. Another important recommendation was that the core of the vision should contain a set of scenarios that describe the world freshwater situation in 2025. These scenarios are described in Cosgrove and Rijsberman (2001) and other publications. Here we focus on their development and main features.

3.4.2. Elements of the scenarios

Each world water scenario consists of two main elements: a storyline and a set of model calculations. The storyline describes how future events affecting the world water situation could unfold. It also identifies the important factors that directly affect the future world water situation (e.g. the future extent of irrigated land or the level of water supply infrastructure), or that indirectly affect it (e.g. the rates of population and economic growth) (see Box 3).

Box 3: Excerpt of the business-as-usual storyline of the world water vision scenarios

The business-as-usual scenario assumes that, following some setbacks caused by the Asian and other regional financial crises, global economic growth resumes. Workers in industrial countries who are displaced from traditional sectors use their entrepreneurial skills to develop service businesses. A heightened appreciation for the need to rehabilitate and protect the environment increases demand for environmental services. (...)

The global population continues to increase, reaching 7.8 billion people by 2025. More than 80 % of the world's population — 6.4 billion people — live in developing countries. Throughout the world, the population is older and more urban. About 84 % of the population in industrial countries and 56 % in developing countries live in urban areas. (...)

Per capita material and energy consumption increase as lifestyles throughout the world become more like those in the north. (...) Income inequality between and within rich and poor countries increases tensions, but conflicts over social issues that do occur remain largely within national boundaries. (...)

In some areas with limited water and rapid population growth, the development of water infrastructure lags behind population growth, and the number of people without access to safe water increases. In most parts of the world, however, economic growth, combined with technological improvements, result in better living conditions, including increased access to safe drinking water. (...)

Estimates of increases in area of irrigated agriculture from 1995–2025 range from 5 to 10 % globally. This slow-down in expansion rate for irrigation is due to both a lack of investment funds and vigorous protests (...) that make most large dam projects controversial. (...) Water is used more efficiently, however, particularly in the water-stressed areas of the south. The change reflects the use of more efficient irrigation systems, such as drip irrigation. (...)

Increased technological efficiency and improved management prevent widespread dramatic water crises, but a number of regional crisis arise in some of the most arid regions.

Source: Gallopin and Rijsberman (2000).

Meanwhile, the model calculations 'reinforce' the storyline in two ways. First, they were used to assess the validity and consistency of the storylines. (For example, are the storyline's assumptions about population and economic trends consistent with what it says about future levels of water use in different parts of the world?). Second, they provided 'hard numbers' to supplement the qualitative descriptions in the storyline. In this scenario exercise, models were used mostly to compute indicators relevant to the world water situation, principally water availability and water use in different parts of the world and at different time steps.

Modelling results were taken into account by members of the scenario panel (see below) to refine the storyline. The new storyline led to new model inputs and the models were re-run until a rough consistency was achieved between the storyline and model results. The procedure for developing the scenarios is further elaborated below.

The calculations were carried out by a variety of models of different temporal and spatial coverage and resolution. These included the WEAP model for assessing water availability on the regional level, the Polestar model for identifying driving forces of water use on the regional level, the Podium model for assessing global water resources with national resolution, and the WaterGAP model for assessing global water resources with watershed resolution (see Rijsberman, 2000, for an overview of the assumptions and calculations of these models.)

Three scenarios were developed:

1. 'Business-as-usual' (BAU) is a baseline scenario that examines the consequences of continuing current trends in population, economy, technology and human behaviour up to 2025.
2. 'Technology, economics and private sector' (TEC) is a policy scenario and has a 'world view that is optimistic about the free market system [and] the potential of new technologies. (...) Water pricing, or cost recovery for services, leads to (...) increased capital investment, and reduced demands' (Rijsberman, 2000)
3. The 'Values and lifestyles' (VAL) scenario is also a policy scenario and assumes 'that a strong commitment to avert a water crisis will emerge (...) with efforts focused on reaching a set of global and regional targets. The emphasis is on (...) the importance of human values' (Rijsberman, 2000).

The scenarios have a time horizon up to 2025, with a base year of 1995, and intermediate time steps of 2005 and 2015.

3.4.3. Procedure for developing the scenarios

The World Water Council set up two bodies to oversee the activities of the world water vision and these groups also had a major influence on the development of the world water scenarios. The first was a Vision Management Unit (shortened here to Vision Unit) which managed the day-to-day activities of the world water vision exercise. The second body was the World Commission on Water for the 21st Century (shortened here to World Water Commission) consisting mostly of water experts and retired decision-makers. These two bodies set up a scenario panel of 17 technical experts and stakeholders to provide the creative input to the scenario construction. (The author of this report was a member of the panel.) Four members of the panel were also involved in quantifying the scenarios. The procedure for developing the scenarios was as follows:

1. At their first meeting the scenario panel outlined the storylines of four scenarios: a 'Conventional water world' in which current trends are extrapolated, a 'Water crisis' scenario in which the world water situation deteriorates, and two 'Sustainability' scenarios.
2. A first draft of the storylines was developed by the Vision Unit together with the Stockholm Environment Institute based on the results of the scenario panel meeting.
3. At their second meeting the scenario panel refined the first draft storylines. Since the 'Conventional water world' scenario was believed to lead to future crises, the idea of having separate 'Conventional water world' and 'Water crisis' scenarios was dropped. These two scenarios were combined in a single 'Business-as-usual' scenario. The focus of the two sustainability scenarios was also refined.
4. The driving forces of the scenarios were quantified by the Stockholm Environment Institute based on the storylines.
5. The modelling groups quantified the scenarios as described above.
6. Information was exchanged informally between the modelling groups, the Vision Unit and individual members of the scenario panel. As one example, the WaterGAP modelling team presented estimates that the assumed expansion of irrigated land in the 'Sustainability' scenarios could lead to an intensification of water scarcity in many regions. These estimates, plus additional information from other teams, led to a revision of these scenarios. Some assumptions were changed (e.g. about the extent of irrigated land), the storylines were revised, and the names of the scenarios changed from 'Sustainability' scenarios to 'Technology, economics and private sector' and 'Values and lifestyles'.
7. The preliminary scenarios (storylines plus quantifications) were posted on the Vision Unit website and widely discussed at several regional forums.
8. At the third meeting of the scenario panel the storylines were revised in accordance with public comments and further modelling results.
9. The final world water vision and scenarios were presented at the Second World Water Forum in the Hague (March, 2000), posted on the website of the world water vision, and published in various books (e.g. Cosgrove and Rijsberman, 2000) and reports (e.g. Alcamo et al., 2000).

The time span between the first scenario panel meeting and the presentation of the scenarios at the Second World Water Forum was about two years.

One deficiency of the scenarios was their narrowness. For instance, the single 'Business-as-usual' scenario provides a limited view of how the future could unfold if no action is taken to alleviate water scarcity. (On the other hand, the scenario panel pointed out that it did not have the capacity to develop more than one baseline scenario.) Others have also criticised the two policy scenarios — the technology-oriented one, and the lifestyles-oriented one — as too simplistic to be convincing.

But it can also be argued that the scenarios fulfilled the goal of the world water vision exercise by helping to raise public awareness about water issues. They did so by being an effective and credible method to communicate the main messages of the world water vision in numerous publications and public presentations (e.g. Anon, 2000; Cosgrove and Rijsberman, 2000). In the view of the author, the combined qualitative/ quantitative approach was an important factor in their success. The qualitative storylines were an effective device for communicating with the general public and non-experts, while the quantitative calculations provided the hard numbers preferred by many scientists and water experts.

3.5. Example 5: The SRES scenarios of the IPCC — 'Global greenhouse gas emissions'

3.5.1. Background

To assess the impacts of climate change it is obviously necessary to have a projection of future climate change and this will depend, among other things, on the future trend of greenhouse gas emissions. For this reason emission scenarios play a central role in the study of climate change and its impacts. In particular, estimates of future emissions are needed by climate models for simulating the future climate. But they are also needed by economists and engineers to assess the costs of mitigating climate change. Given the importance of greenhouse gas emission scenarios, the Intergovernmental Panel on Climate Change (IPCC) developed a set of these scenarios in 1992 (Leggett et al., 1992). Later the IPCC evaluated these scenarios and recommended improvements (Alcamo et al., 1995), and in January 1997 appointed a 'writing team' to develop new scenarios based on the recommendations. Since the writing team was supposed to produce a 'Special report on emission scenarios', the scenarios became known as the 'SRES' scenarios.

3.5.2. Elements of the scenarios

Each SRES scenario has the same two main elements as the world water scenarios, namely storylines and model calculations, but their importance is reversed. In the world water scenarios, the storylines were the main vehicle for carrying the scenario message, while model calculations played a supporting role. In the SRES scenarios, the model calculations were the main vehicle for carrying the message because the main objective of the scenarios was to produce numerical estimates of future emissions. Meanwhile, storylines provided a supporting role, mainly to explain the logic of selecting the driving forces of emissions. In the SRES scenarios each storyline expresses a different view of future world development, especially in the degree of globalisation versus regionalisation, in the relative emphasis on economic growth, and in the level of environmental protection. For example, the storyline of scenario family 'A1' describes a future of rapid technological progress and economic prosperity (Box 4). Based on this logic the scenario developers selected appropriate numerical estimates of driving forces of future emissions, such as trends in population, economic growth, and land-use distribution. These and other driving forces were used as input to six different models for producing estimates of the emissions of all important greenhouse gases and related substances.

Box 4: Excerpt of the A1 storyline from the IPCC–SRES scenarios

In the A1 scenario family, demographic and economic trends are closely related, as affluence is correlated with long life and small families (low mortality and low fertility). Global population grows to some nine billion by 2050 and declines to about seven billion by 2100. (...)

The global economy expands at an average annual rate of about 3 % to 2100. (...) While the high average level of income per capita contributes to a great improvement in the overall health and social conditions of the majority of people, this world is not necessarily devoid of problems. In particular, many communities could face some of the problems of social exclusion encountered in the wealthiest countries during the 20th century. (...)

Energy and mineral resources are abundant in this scenario because of rapid technical progress, which both reduces the resources needed to produce a given level of output and increases the economically recoverable reserves. Final energy intensity (energy use per unit GDP) decreases at an average annual rate of 1.3 %.

With the rapid increase in income, dietary patterns shift initially toward increased consumption of meat and dairy products, but may decrease subsequently with increasing emphasis on the health of an ageing society. High incomes also translate into high car ownership, sprawling suburbs, and dense transport networks.

Source: Nakicenovic et al. (2000).

Emission estimates have a base year of 1990, a time horizon of 2100, and 10 time steps in between. The resulting scenarios were clustered into four scenario 'families' and in this way they were also organised differently than the world water and other scenarios. Each family had its own storyline and scenario variants which add up a total of 40 scenarios. Since it was expected that such a large number of scenarios would overload potential users with information, the writing team identified a smaller set of four illustrative 'marker' scenarios to represent the variety found in the 40 scenarios. But as pointed out above, even four scenarios is a big number to handle, and it remains to be seen how users of the scenarios will make use of them.

3.5.3. Procedure for developing the scenarios

The writing team consisted of 28 lead authors and an additional 26 contributing authors. Six modelling teams quantified the scenarios. The huge number of actors would have been an unwieldy number had they all actively participated in the scenario development and report writing. As it was, meetings of the writing team were typically attended by around 10 to 15 authors, and only small numbers of authors were active in all phases of the report writing.

A new procedure was used to develop the scenarios, partly based on recommendations of the IPCC evaluation report (Alcamo et al., 1995), and partly on the existing expert and government review process of the IPCC. The procedure was made up of the following steps:

1. At the first lead authors' meeting the participants decided to develop four 'families' of scenarios. Each family of scenarios had similar demographic, societal, economic and technological change storylines. But it was also agreed that these similar storylines could lead to different trends of driving forces and diverging emission scenarios. Participants also selected the base year and time horizon of the scenarios (see above).
2. The writing team carried out a comprehensive review and analysis of the literature on emission scenarios and their driving forces. Results were published as a special issue of a scientific journal (Alcamo and Nakicenovic, 1998).
3. At the second lead authors meeting participants agreed on a set of driving forces of emissions. These included demographic, societal, economic and technical-change factors. The driving forces were based on the review and analysis of the literature.
4. The modelling teams began to quantify the scenarios based on the agreed-upon driving forces.
5. At the third lead authors meeting participants reviewed the first modelling results and revised the storylines accordingly.
6. Modelling teams continued with the modelling analyses.
7. Preliminary modelling results were posted on behalf of the IPCC on the website of the Centre for International Earth Science Information Network (CIESIN) and public comments were solicited. Two hundred sets of comments were received.
8. At the fourth lead authors meeting the public comments were reviewed, discussed, and plans were made to revise the scenarios accordingly.
9. A first order draft report was written and sent out by the Secretariat of the IPCC for worldwide expert review.
10. Expert comments were reviewed and incorporated into a second order draft report by a sub-team of lead authors.
11. A special issue of a scientific journal was prepared with the documentation of the scenarios (Nakicenovic, 2000).
12. The second order draft was sent out by the Secretariat of the IPCC for worldwide government review.
13. Government comments were reviewed and incorporated into a third order draft by a sub-team of lead authors.
14. The report was approved by Working Group III of the IPCC (the working group of the IPCC responsible for the report).
15. The report was approved by the Steering Committee of the IPCC.

In judging the effectiveness of this scenario exercise one has to take into account that these scenarios were hotly contested by the different global players in the climate change debate. It was argued that if baseline scenarios were high, then an enormous effort would be needed to keep emissions under control; if they were low then some parties insisted that climate policies were not needed at all to keep emissions low. Given this controversy it was a significant accomplishment that the writing team could develop a set of scenarios that passed through the rigorous public, scientific and governmental review process of the IPCC in only two-and-a-half years. Nevertheless, this consensus came at the cost of producing a very large number of scenarios that represented a very wide range of views. Even if only the four marker scenarios are used as reference points for policy analysis, this leads to a proliferation of policy scenarios.

An important aspect of this and the IIASA and IMAGE scenario exercises was that the scenarios were documented in special issues of scientific journals. In fact, the SRES writing team published two special issues of journals — one on their literature review and one on the new scenarios. These special issues both improved the scientific basis of these scenarios (because they had to pass an additional scientific peer review), and gave them a measure of scientific credibility and legitimacy.

Another noteworthy aspect of this and the world water exercise was the successful use of the Internet to inform and solicit comments from a wide audience of stakeholders.

4. Characteristics of good scenarios

What can we say about the characteristics of 'good' scenarios based on experience presented here and elsewhere?

The first and foremost characteristic of a good scenario is that it fulfills the objectives of the scenario exercise. The IMAGE scenarios aimed to provide scientific information for the climate negotiations, while the world water vision scenarios were meant to educate a wide audience about the global water situation. It is against these different yardsticks that the scenarios must be judged. A more pragmatic trait of a good scenario is that it should be sufficiently documented so that reviewers and users of the scenario have sufficient information to understand its assumptions and messages. But understanding comes not only from the amount of documentation but also from the transparency of a scenario, which is another mark of a good scenario.

A good scenario is also a plausible scenario, or at least 'not implausible' as IIASA researchers preferred to say (Stigliani et al., 1989; Anderberg, 1989). In other words, a scenario should not be easily dismissed by experts and policymakers. The plausibility of a scenario depends among other things on its internal consistency and this is another trait of a good scenario. One way to test and perhaps enhance this consistency is to use models in the way they were used in the world water scenario exercise.

Although a good scenario is plausible, there are also situations in which a good scenario should challenge the beliefs and broaden the understanding of experts and policymakers. For example, one of the objectives of the IIASA scenarios was to alert experts and policymakers about unexpected but possible developments in Europe's natural environment. To do so, the IIASA team prepared scenarios that were 'low in probability but high in consequence'. In an associated IIASA study these were dubbed 'surprise scenarios' (Anderberg, 1989). An example is the 'Big shift' scenario in which the centre of world economic activity shifts from Europe and other OECD regions to South and East Asia (Anderberg, 1989). Another example is the 'Ocean realignment' case developed by the IMAGE team (Alcamo, 1994) which describes possible consequences of a future cooling rather than warming of ocean and air temperatures.

Scenarios of this type are sometimes called 'rich' scenarios in that they convey a rich amount of diverse information, and provide insights into non-linear or interrupted trends. Rich scenarios challenge the thinking behind slow and smoothly changing scenarios, and encourage stakeholders and policymakers to think about policies robust enough to contend with such surprises.

5. The SAS (story-and-simulation) approach to scenario development

Now that we have noted some of the attributes of good scenarios, how do we develop these scenarios? Here we build on the positive aspects of the exercises reviewed above, and propose a 'story-and-simulation' (SAS) approach to scenario development.

The SAS approach is partly built on the idea of 'policy exercises', but even more so on experience in developing the SRES and world water scenarios described earlier. The main parts of this approach are:

- the development of qualitative 'storylines' by a group of stakeholders and experts;
- the use of models to quantify the storylines;
- the use of an iterative process to develop the scenarios based on the interaction between scenario writers, experts, global modellers and stakeholders;
- the 'openness' of the process in that stakeholders are involved in the development of the scenarios, and all interested parties can comment on and contribute to the scenarios;
- the use of a variety of means, including the Internet, to solicit comments and contributions to the scenarios, and to communicate scenario results.

Every scenario approach has to have some main actors, and in this approach they are:

- the scenario team which coordinates the exercise;
- the scenario panel which provides the creative input and ensures that a wide range of views are represented in the scenarios; and
- the modelling team which quantifies the scenarios.

More on each of these is given below.

The steps of the SAS approach are summarised in Box 5, and a sample estimate of its time requirements is given in Table 3. Below we elaborate on each of these steps. Note, however, that this procedure is offered only as a guideline to scenario building. It is not necessary to follow the procedure literally step by step in every scenario exercise. Indeed, the method used for building scenarios should be adapted to the aims and conditions of the particular exercise.

Box 5: Overview of the SAS (story-and-simulation) approach

1. The scenario team and scenario panel are established.
2. The scenario team proposes goals and outline of scenarios.
3. The scenario panel revises goals and outline of scenarios, and constructs zero order draft of storylines.
4. Based on the draft storyline, the scenario team quantifies the driving forces of scenarios.
5. Based on the assigned driving forces, the modelling teams quantify the indicators of the scenarios.
6. At the next meeting of the scenario panel, the modelling team reports on the quantification of the scenarios and the panel revises the storylines.
7. Steps 4, 5 and 6 are repeated until an acceptable draft of storylines and quantification is achieved.
8. The draft scenarios are distributed for general review.
9. The scenario team and panel revise the scenarios based on results of the general review.
10. The final scenarios are published and distributed.

Table 3. **Example of time planning for an international scenario project assuming a total time of three years**

Scenario development step	Months from start of project					
	t+6	t+12	t+18	t+24	t+30	t+36
1. Establish scenario team and scenario panel						
2. Scenario team proposes goals and a first outline of scenarios.						
3. Convene first meeting of the scenario panel and construct zero order storylines	X					
4. Scenario team quantifies the driving forces of scenarios						
5. Modelling teams quantify the indicators of the scenarios						
6. Convene meeting of scenario panel, and storylines are revised		X				
7. Iteration of steps 4, 5 and 6 until acceptable draft of scenarios agreed upon						
8. Draft scenarios distributed for general review						
9. Scenario team and panel revise scenarios based on general review						
10. Publication and distribution of final scenarios						X

Step 1. Scenario team and scenario panel are established

As a first step in the procedure, the institution sponsoring the scenarios (e.g. the European Environmental Agency) establishes a scenario team, whose goal is to coordinate the construction of the scenarios. The team includes at a minimum:

- representatives of the institution responsible for the scenarios;
- a selection of experts outside the institution including representatives of the modelling team(s) responsible for quantifying the scenarios.

Experience suggests that the scenario team should have about three to six members.

An important initial task of the team is to organise a scenario panel, consisting of stakeholders in the scenario process and experts. To put it more plainly, the panel should include individuals or organisations who have a special interest in the outcome of these scenarios, for example, representatives from different European agencies involved in environmental issues, members of environmental organisations, and members of industries especially affected by environmental regulations. The scenario panel should also include experts needed to construct the scenarios, e.g. individuals with either special environmental expertise or experience in building scenarios, or both. What size should the panel be? On the one hand, the more representatives of different interests the better, but on the other hand, the larger the group the more unwieldy the discussions. Experience suggests that a workable size of the panel is between 15 and 25 members ([3]).

Step 2. Scenario team proposes goals and outline of scenarios

One of the first tasks of the scenario team is to propose the fundamental goals and outline of the scenarios. For example, what should the scenarios achieve? What subjects should they cover? What is their time horizon? To develop their ideas it is advisable that they consult with a number of colleagues inside and outside their institution.

The general aim of this task is to narrow the huge possible scope of the scenario exercise and in this way to utilise the time of the scenario panel most efficiently. It is not, however, intended to limit the creative input of the panel. Therefore, the scenario team should present the panel with a proposed outline, not a *fait accompli.*

(3) By way of illustration, the 'Scenarios Europe 2010' exercise involved five separate panels with 12 to 15 members each, the world water vision exercise had a panel with 17 members, and the SRES–IPCC exercise had a panel with 28 members (not all active). (Note that, although they functioned like scenario panels, these groups were not called 'scenario panels' in either the 'Scenarios Europe 2010' exercise or the SRES–IPCC exercise.)

Step 3. Scenario panel revises goals and outline of scenarios, and constructs zero order draft of storylines
After the outline of the scenarios has been drafted, the scenario team convenes the first meeting of the scenario panel. This meeting has two main objectives. The first is to discuss and revise the scenario goals and outline proposed by the scenario team. Accordingly, agreement is needed on the following details:

- the number of scenarios;
- the main themes of the scenarios (both baseline and policy scenarios);
- the main messages of the scenarios;
- the indicators to be used in the scenarios;
- the time horizon of the scenarios.

The second goal of the meeting is to construct a 'zero order draft' of the storylines. These consist of very preliminary sketches of the sequences of main events in the scenarios. (Calling it a 'zero order draft' emphasises its preliminary character and may encourage participants to be more experimental and creative.)

Step 4. Scenario team quantifies the driving forces of scenarios
After preparing the zero order draft of the storylines, the scenario team assigns numerical values to the driving forces of the scenarios based on the best information available. Typically, these data are taken from previous studies. For example, a main driving force of the world water, SRES and IMAGE scenarios were population trends, and these were taken from studies of the United Nations and other international organisations.

Step 5. Modelling teams quantify the indicators of the scenarios
The driving force assumptions are then used by the modelling team or teams to compute the basic indicators of the scenarios. For the world water scenarios, the main indicators were the use and availability of water in different river basins around the world. In the SRES scenarios, the main indicators were different types of greenhouse gas emissions (carbon dioxide, methane, and so on) in different world regions.

Step 6. Storylines are revised
At the next meeting of the scenario panel, the modelling teams present the quantification of the draft storylines. The team points out where the model calculations provided new information that could be included in the scenarios, and where they identified possible inconsistencies. As an example of identifying inconsistencies, recall from the example of the world water scenarios that model calculations raised some questions about the sustainability of the original 'sustainability' scenarios.

Based on the results of the quantification together with further discussion at the scenario panel meeting, the draft storylines are revised by the scenario panel and scenario team.

Step 7. Iteration of steps 4, 5 and 6 as necessary
It is likely that the discussions in step 6 will lead to revised storylines. If the changes are significant then steps 4, 5 and 6 must be repeated until the scenario panel and Team agree on an acceptable draft of the storylines and their quantification.

Step 8. Draft scenarios distributed for general review
The draft scenarios from step 7 are distributed widely for the broadest possible review by experts and all stakeholders in the scenarios. This can be accomplished by posting and publicising the scenarios on the Internet, by distributing the scenarios in paper report form, and/or holding workshops to solicit comments and input.

Step 9. Scenarios are revised based on results of general review
Taking into account the comments of stakeholders and experts, the scenario team and scenario panel revise the storylines and driving forces. The modelling teams then produce the final quantifications of the scenarios.

Step 10. Publication and distribution of final scenarios
The final scenarios are published and distributed through the Internet, in the form of paper reports, at meetings, and/or by other means.

5.1. Disadvantages/advantages of the SAS approach

Like every method, the SAS approach has its drawbacks. For example, an important component of this approach is the use of models for quantifying storylines — but good models are not always available; and even when they are available there is often a shortage of personnel to run them or interpret their output. The SAS is also a costly approach since it requires the organisation of many meetings, and the participation costs of many scenario builders. It is also a time-consuming approach because it calls for multiple cycles of storyline writing, quantification and scenario review.

But this approach has its positive aspects, especially because it combines qualitative and quantitative scenario-building methods and also their advantages. The qualitative storylines can represent the views of many different stakeholders and experts, and can be an interesting and understandable way to convey many messages about future developments. Meanwhile, model calculations provide the need for numerical information about environmental changes and their driving forces. Model calculations also complement the storylines by helping to maintain their consistency. Moreover the iterative approach of review and revision involving stakeholders and experts enhances the credibility and legitimacy of the resulting scenarios.

6. Recommendations and final comments

At this juncture some specific recommendations are made for developing scenarios in international environmental assessments of the type carried out by the European Environment Agency.

- It is advisable to slowly build up the internal capacity of the Agency to develop scenarios. Specifically, the Agency should consider beginning with a scenario exercise covering only one or two environmental issues. This would allow the Agency to gain experience in developing scenarios instead of having to deal right away with the complication of multiple environmental issues. More environmental issues can be added once the Agency has settled on an appropriate scenario-building procedure.
- The Agency should consider beginning its scenario activity with the SAS approach which has the advantages and disadvantages noted above. But it is important to emphasise that the SAS procedure is offered as a general guideline to scenario development, not as a strict model building protocol that needs to be followed to the letter. It is the view of the author that the procedure for building scenarios should be tailored to the goals of the scenarios and the situation under which they are being developed.
- Storylines in new scenarios should be based, if possible, on existing storylines. This would save a great amount of time, effort and cost, and the new scenarios might benefit from the acceptance already achieved by these storylines.
- Experience suggests that a scenario team appropriate for an international scenario-building exercise should have around three to six members, and a scenario panel 15 to 25 members.

To sum up, one of the main messages of this report is that scenarios and scenario analysis can be helpful tools for assessing international environmental problems. In particular, scenarios are handy devices for organising and communicating large amounts of complex information, and they can do so in both a qualitative and quantitative fashion. They also help address a basic problem of assessments, namely, how to assess a future that does not yet exist. They help to visualise the consequences of neglecting environmental problems and at the same time provide insight into the policy steps needed to cope with an environmental problem.

Scenarios also perform a crucial function as a bridge between environmental science and policy. They are effective tools for summarising and synthesising scientific knowledge in a shape that can be used by policy-makers to develop policies. They help policy-makers visualise the different aspects and connections of an environmental problem, as well as its large time and space scales. In this way they are a valuable asset for helping us contend with increasingly complex problems.

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