Report No. 481508005

The Interactive Scenario Scanner (ISS): a Tool to Support the Dialogue between Science and Policy on Scenario Development Version 1.0

M.M. Berk and M.A. Janssen

November 1997

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RIJKSINSTITUUT VOOR VOLKSGEZONDHEID EN MILIEU
NATIONAL INSTITUTE OF PUBLIC HEALTH AND THE ENVIRONMENT

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BILTHOVEN, THE NETHERLANDS

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This research has been conducted on behalf and for the account of the National Institute of Public Health and the Environment (RIVM), the Ministry of Housing, Spatial Planning and Environment (VROM), and the Dutch National Research Programme on Global Air Pollution and Climate Change (NRP) within the framework of projects no. 481508 and 728001.

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ABSTRACT

In order to explore long-term policy options for controlling climate change, there is a need to develop and evaluate long-term emission scenarios. If these scenarios are to be policy relevant, they should, account for differences between world regions with respect to their contribution to the problem, their stage of economic development, their vulnerability to climate change and their ability to control emissions. The scenarios should also deal with the question of fair distribution of future emission budgets. Therefore it is important to involve policy makers in the development of these scenarios. On the basis of requests and comments from policy makers participating in the Delft Science Policy Dialogue workshops, a new software tool, called the Interactive Scenario Scanner (ISS), has been constructed at RIVM. ISS is a computer model that assists in the interactive construction and evaluation of long-term emission scenarios using the parameters of the Kaya Identity to define scenarios and the climate indicators of the Safe Landing Approach to scan their likely consequences for global climate change and its impacts. This tool can be used to construct proto-scenarios, which can then be further elaborated and analysed with such sophisticated energy and climate change models as IMAGE 2. Recent experiences with the application of ISS indicate that it indeed can be a useful tool to involve policy makers in the development of emission scenarios. Moreover, ISS has also been shown useful in educating policy makers on the complexity of the problem and enhancing communication between, and among, scientists and policy makers.

Keywords: Science/Policy Dialogue, Climate Change, Integrated Assessment Models, Scenario Development

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We thank Michel den Elzen for adapting his CYCLES model into a meta version of the climate system of IMAGE 2 and Rob Swart, Rik Leemans, Bert de Vries, Erik Kreileman, Henry Hengeveld, Leen Hordijk, Leo Meyer, the participants of the Delft workshops, and the sessions organised by Environment Canada for their comments and suggestions for improving the software and its application.

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1. INTRODUCTION

This report describes a new decision-support tool, the Interactive Scenario Scanner (ISS), recently developed at the National Institute of Public Health and the Environment (RIVM). The ISS is a computer model that allows the user to interactively construct and evaluate emission scenarios, and to scan their likely consequences for global climate change and its impacts. Emission scenarios are generated by using the Kaya identity, and climate change is simulated by a globally averaged meta model of the climate system. The ISS has been developed and already been used as a tool to facilitate a dialogue between scientists and policy makers on scenario development. Although the ISS will be described here in its current form (November 1997), this tool is likely to be further developed in response to new suggestions and comments by policy makers and other users. The current version should therefore not be considered as a final static product but as one under continuous development.

In the next section, we will describe the background to the development of this tool. In section 3, we will describe the structure of the ISS and guide you through its various views. Some of the experiences using the tool are described in section 4. Finally, in section 5 we will reflect on the further development of the ISS.

2. BACKGROUND

2.1 The role of science in climate change policy development

The Framework Convention on Climate Change (FCCC) of the United Nations (UNFCCC, 1992) states as its goal, the stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system (Article 2). However, translating this goal into concrete policies is not a straightforward task. This is due to the many scientific uncertainties limiting the understanding of the nature and extent of this complex climate change problem. Further, it is very likely that many of these uncertainties will remain. But, even if they were all to be resolved, the issue would still remain a difficult problem due to the regional differences in historical and present contributions, in levels of socio-economic development and in the nature of impacts, and in cultural value systems determining what changes are "dangerous", what contributions "fair" and what measures "acceptable". Meeting the goals of the FCCC is thus first and foremost a political process, where scientific knowledge may only help in clarifying the problem, assessing policy options and indicating interlinkages and trade-offs.

These tasks, however, are already very difficult because both among scientists of different disciplines and between scientist and policy makers many different views exists. This makes communication of clear scientific results extremely difficult. In response to complex environmental problems like acidification and climate change, a new branch of scientific activity has emerged: integrated assessment (IA). IA has been developed to bring together, link and evaluate different types of relevant scientific knowledge, often supported by (integrated) modelling activities. IA does not just aim at integrating scientific knowledge, but also at supporting policy making by communicating and providing insights into major policy issues (knowledge utilisation). In the area of climate change, various integrated assessment activities with different levels of scientific detail, scope and diversity, and with different time scales, are taking place (Bailey *et al.*, 1996; IPCC, 1996c; Parsons, 1996a). On one side of the spectrum there are the one- or two-day policy exercises (e.g. De Vries, 1995; Parsons, 1996b), while on the other side there is the IPCC assessment process, taking years (IPCC, 1996a,b,c). Moreover, the level and nature of the interaction between science and policy differ considerably between the various assessment activities. Whereas policy tends to dominate in policy exercises, science tends to dominate in scientific assessments, for example, in IPCC. In the former case, scientific knowledge is often insufficiently utilised; in the latter case, science tends to produce information insufficiently focused on the information needs of policy makers[1].

2.2 The Delft Science-Policy Dialogue workshops

One general insight emerges from the successful use of integrated assessment to generate and communicate relevant scientific knowledge to decision makers. This is the importance of stakeholder participation in the assessment process (participatory integrated assessment) (Baily *et al.*, 1996). For this reason, RIVM and the Faculty of Systems Engineering, Policy Analysis and Management of Delft University, set up a series of so-called science-policy dialogue workshops a few years ago on the basis of the integrated climate change model IMAGE 2 (Box 1) (Van Daalen *et al.*, in press). The aim of these workshops was to provide an informal platform for discussion and dialogue between policy makers and policy advisors involved in negotiations on a protocol to the FCCC and scientists, mainly from the IMAGE modelling team at RIVM. During these workshops, held in Delft in the Netherlands, the IMAGE team first presented and discussed the results of their scenario analysis with policy makers. This resulted in requests for new analyses. The results of these new analyses were presented during the next workshop.

One of the products of this iterative dialogue process was the so-called "safe landing approach". This safe landing approach allows for the evaluation of the compatibility of short and long-term emission profiles with intermediate and long-term climate targets. This approach was elaborated at RIVM into the Safe Landing Analysis software (see Alcamo and Kreileman, 1996a+b; Kreileman and Berk, 1997; Swart *et al.*, in press). Here, climate protection targets are defined by three mean impact indicators, notably, global temperature change, decadal rate of temperature change and sea-level rise. In addition, a constraint is set on the rate of global emission reductions as a proxy for technically and economically realistic future emission reduction levels. First, these four indicators were used to evaluate various scenarios and/or profiles of future global emissions. Later, when the interests of the policy makers shifted towards the short-term implications of long-term and intermediate-term climate protection targets, the Safe Landing Analysis was used to calculate so-called Safe Emission Corridors. These corridors indicate the maximum allowable emissions in the near future (e.g. 2010) compatible with long- and intermediate-term climate targets and constraints for emission reduction rates.

During the third and fourth Delft workshop policy makers indicated a renewed interest in the assessment of "realistic" long-term global emission scenarios, because the Safe Landing Analysis indicated the importance of also including a contribution of the developing countries in controlling future global emissions levels. To be policy relevant, such scenarios should consider the different position of industrialised (Annex 1) and developing countries (non-Annex 1) with respect to the feasibility of emission reduction targets and a fair distribution of future emission budgets among countries.

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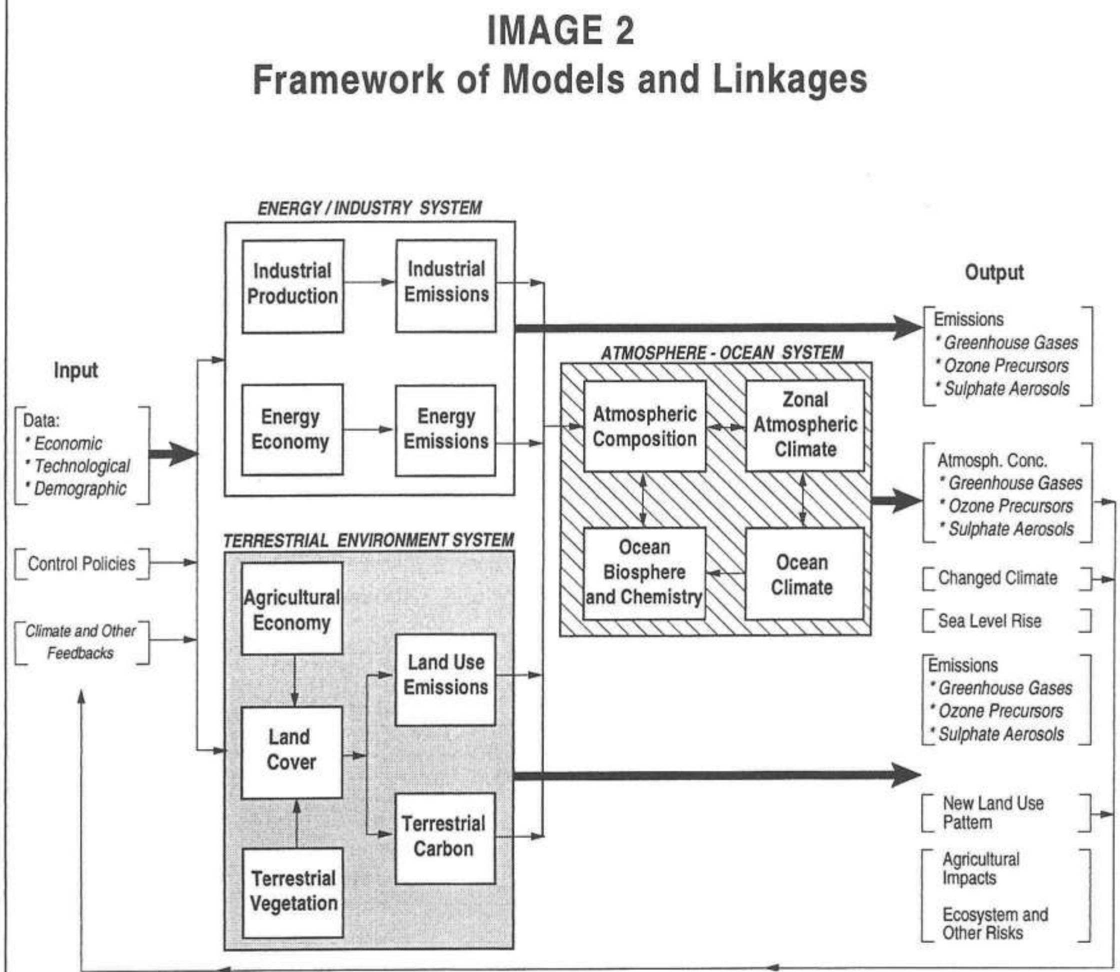
[1] It is acknowledged that policy makers often have different perceptions and interests, resulting in different information needs. This clearly hampers adjusting research priorities to policy makers needs (e.g. Vellinga et al., 1995, Hisschemöller et al., 1995)

Box 1. Information on the IMAGE 2 model.



The IMAGE 2 model is a multi-disciplinary, integrated assessment model designed to simulate the dynamics of the global society-biosphere-climate system. The objectives of the model are to investigate linkages and feedbacks in the system, and to evaluate consequences of climate policies. Dynamic calculations are performed from 1970 to 2100, with a spatial scale, depending on the submodel, ranging from grid (0.5° x 0.5° latitude-longitude) to 13 world regions.

The model consists of three fully linked subsystems: Energy/Industry, Terrestrial Environment and Atmospheric-Ocean. The *Energy/Industry* models compute the emissions of greenhouse gases in the world regions as a function of energy consumption and industrial production. End-use energy consumption is computed from various economic/demographic driving forces. The *Terrestrial Environment* models simulate the changes in global land cover on a grid scale based on climatic and economic factors, and the flux of carbon dioxide and other greenhouse gases between the biosphere and the atmosphere. The *Atmosphere-Ocean* models compute the build-up of greenhouse gases in the atmosphere, as well as resulting zonal-average temperature and precipitation patterns.

The fully linked model has been calibrated and tested against data from 1970 to 1990, and can reproduce the following observed trends: regional energy consumption and energy-related emissions, terrestrial flux of carbon dioxide and emissions of greenhouse gases, concentrations of greenhouse gases in the atmosphere and transformation of land cover. The model can also simulate current zonal average surface and vertical temperatures.

For further information we refer to Alcamo (1994) and Alcamo *et al.* (1996)

2.3 The origin of the Interactive Scenario Scanner

Defining acceptable levels of climate change and criteria for burden-sharing is a matter of political choice. Modellers can therefore not develop any objective set of emission control scenarios. It is thus essential to involve policy makers in the selection of the scenarios types to be developed. Moreover, as the range of possible scenarios is very large and as the development and analysis of scenarios with comprehensive integrated climate change models like IMAGE 2 laborious, a (pre)selection of policy relevant scenarios is needed. This insight has resulted in the development of a tool that during a science–policy dialogue could facilitate the search for and selection of policy-relevant scenarios. The full set of consequences on these scenarios could then further be elaborated with comprehensive integrated assessment models in order to evaluate their feasibility, plausibility and analyse the underlying assumptions and policies needed to realise them.
For this purpose the tool needed had to be simple, interactive, scientifically acceptable and encompassing important climate policy dimensions. At the same time we also wanted to keep a link with the safe landing approach. The result, the so-called Interactive Scenario Scanner (ISS), therefore adopts features of the earlier evaluation of global emission profiles within the Safe Landing Analysis (Alcamo and Kreileman, 1996 a+b). It allows for the construction and evaluation of emission profiles and differentiation between the development of emissions from industrialised and developing countries. Its interactive character enables users to assess the interactions, feedbacks and trade-offs between socio-economic welfare, technological change, international equity and climate change. In this way, the ISS not only helps to select policy relevant scenarios, but also to communicate important insights on the climate problem. Moreover, the tool facilitates discussions on the underlying scenario assumptions. In this process, important differences in perceptions and opinions may be revealed.

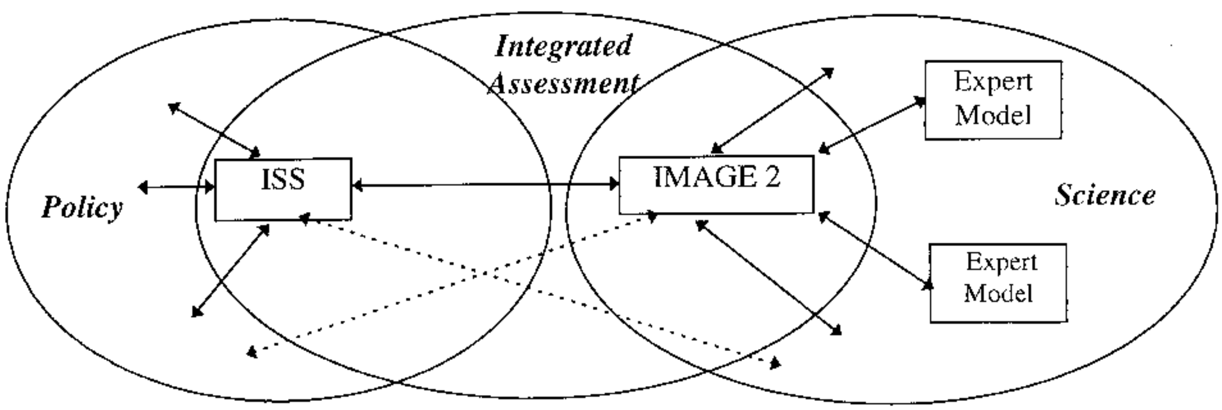
2.4 Modelling the philosophy behind the ISS

Computer models are increasingly used to assess long-term developments in economic, social and ecological systems. One type is formed by the so-called Integrated Assessment (IA) models. These usually consist of simplified parameterisations of detailed expert or disciplinary models so that an integrated and consistent picture can be given of the key dynamics, and interactions of the total system (Weyant *et al.*, 1996; Janssen, 1998). These tools do not provide accurate predictions but can only illustrate plausible consequences of different comprehensive sets of assumptions. Each set is a scenario. Such analyses can be used to support policy making on various levels.

Building a comprehensive Integrated Assessment model requires scientific input and acceptance from many disciplines. That is why developers of IA models usually pay more attention to the involvement and views of their scientific peers than to the views and needs of policy makers. The resulting structural complexity and longer computing time of most state-of-the-art IA models make them less suitable for an interactive communication mode for use with policy makers.

In communicating information to policy makers, most of the current IA models are used passively i.e. only results of scenarios are presented. Although graphs, tables and diagrams depict differences between scenarios and provide useful insights, information exchange could be much more effective if models were used interactively. We believe therefore that there is a need for developing more simple, interactive tools. Such a tool does not intend to replace the current IA models but provides a niche to improve the communication between policy makers and scientists. It further provides an educational need. The ISS is created specifically to serve the science-policy dialogue and has few or no scientific goals (as in the case of other IA models). Only the most important parameters and relationships are included in the ISS. The ISS can also be focused on a distinct policy process - such as the climate policy negotiations. Visualisation of the information is focused on. An important aspect of the ISS is its flexibility: the structure of the model, use of indicators and way of visualisation can be easily adapted to alternative requirements of policy makers.

The art of successful communicating insights between science and policy is based on finding the balance between relevance, comprehensiveness, transparency, robustness and reliability. Usually, simpler computer models evoke such a reaction from the scientific community that many important aspects of the issue are ignored, and such models tend to blur the uncertainties surrounding the issue. However, as indicated, a comprehensive scientific model is not suited for interactive use. In our view, the communication between science and policy can be enhanced by using not just one type of model, but a set of different, but related models (Figure 1), combining the strengths of each type of model. The parameters in the ISS have been tuned on the outcomes of the more complex IA model, IMAGE 2. ISS and IMAGE 2 are thus two complementary IA models. The first screens possible plausible scenarios, while the latter provides a much more detailed analysis.



Type of Model	Aim of Model	Type of Communication to Policy Makers	Basis for Credibility
Comprehensive IAM (like IMAGE 2)	gain scientific knowledge, provide expert advice to policy makers	one-way, presentation of results, expert statements	acceptance in scientific community
Scanner (like ISS)	support policy and development, explore possible futures, education	dialogue, input from both policy makers and experts, insights by interactive use and discussion	based on accepted models, transparency, own judgement

Figure 1: Borders on the spectrum of models which can be used for the interaction between science and policy: on the one hand, a heuristic tool like the ISS, and on the other, a more comprehensive integrated assessment model such as IMAGE 2.

This linking of simple and comprehensive models is also important from a modelling point of view. The process of developing computer models usually starts with a simple parameterisation of the most important components. Over time, more and more details, in terms of components, processes, interactions and resolution in space and time are added to improve the capture of the complexity and diversity of the real world and enhance its scientific credibility. Later, when the behaviour of the system is approximately understood, one is faced with the need of simplifying the model again to speed up computation, decrease data dependence and enhance the communication of results to others. This process is essential for the development of simple models. Therefore the development of tools such as the ISS can best be based on experiences with more sophisticated IA models, like the IMAGE 2 model.

This set of different, but related, models gives a research group complementary ways of dealing with (participatory) integrated assessment. The scanner type of model can be used to communicate basic insights, reveal problem perceptions and preferences of policy makers, and solicit more focused requests for further (scenario) analysis, using both expert knowledge and more sophisticated modelling tools. A continuous dialogue with policy makers on the subject of interactive tools may also lead to the inclusion of new, policy-relevant elements in the comprehensive IA model. At the same time, a well-organised dialogue between policy makers and experts using scanner models could avoid the development of inconsistent (policy) scenarios.

3. DESCRIPTION OF THE INTERACTIVE SCENARIO SCANNER

3.1 The set-up of the Interactive Scenario Scanner

The ISS consists of two parts:
(a) a system calculating future emission profiles of global CO_2-equivalent emissions for the 1990 -2100 period and
(b) a system evaluating the impacts of these profiles on climate change on the basis of the indicators used in the safe-landing approach.

Since the objective of the ISS software is to enable quick construction and screening of different types of emission scenarios, it therefore uses highly parameterised relations to calculate emissions and a globally averaged climate change model to simulate the climate change impacts. Here, we will summarise the different components used.

3.1.1 Constructing Emission Scenarios

Two regions are distinguished for constructing global emission scenarios : the industrialised countries (Annex-1) and the developing countries (non-Annex-1). This distinction is a consequence of the current discussions on international emission reduction protocols. Until 2010 non-Annex-1 countries do not have binding emission targets. For each of the two regions, profiles of future emissions are calculated on the basis of a simple equation, the so-called 'Kaya identity' (Kaya, 1989):

$$CO_2 = P * Y/P * E/Y * CO_2/E$$

where CO_2 represents the fossil CO_2 emissions from the region, P the population of the region, Y the Gross Regional Product (that Y/P represents the average GDP per capita), E stands for (primary) energy use (such that E/Y is the energy-intensity of Y) and CO_2/E is the carbon intensity of (primary) energy use.

The Kaya identity does not provide an explanatory model, but is only a descriptive model or accounting framework. While it can be argued that the variables in the Kaya identity are related, the values can be set independently. Including the Kaya identity in the ISS thus offers users the possibility to include their own perceptions of relationships between the Kaya variables. However, this does not provide information on the plausibility of the selected indicator values, nor how these may be obtained. The Kaya identity consistently and quantitatively relates various policy-relevant scenario indicators and in this way helps to search for scenarios which are interesting for more thorough exploration with the help of more sophisticated explanatory models. These models can then be used to assess the actual plausibility of the scenarios. The results of additional analyses can then be used for discussions on revisions of scenario assumptions.

The variables in the formula represent or approximate various possible developments in other background variables:
- *GNP/capita (Y/P):* by differentiating between industrialised and developing countries, this variable not only represents the overall welfare level, but also the level of interregional equity;
- *Energy intensity of the economy (E/Y)* : this variable represents two different components of energy demand: (1) (the change in) the energy intensity of an economy due to (a structural

change in) the sectoral composition of the economy and (2) the (general tendency of an improvement of) technical efficiencies of production and consumption processes. These efficiency improvements are assumed to have an autonomous component, apart from any price-induced component. The structural change component consists not only of a transition from a pre-industrial to a post-industrial society but also a transition of any future change in the energy intensity of an economy due to behavioural change, like shifts in diets, recreational behaviour and modes of transportation. Note that since energy intensity is defined here for primary energy use, energy conversion efficiencies (e.g. to produce electricity from coal) are also included in this parameter.
- *Carbon intensity of energy use (CO_2 /E):* this variable represents two different dimensions of (a change in) energy supply: (1) (the shift in) the relative use of different fossil fuel types (coal, oil, natural gas), and (2) (the change in) the share of non-fossil fuels (nuclear, hydropower, wind, solar, biomass). The structure of energy supply mix is related to the future availability and relative costs of various fossil and non-fossil energy resources, and developments in energy conversion and transportation technologies in the future.

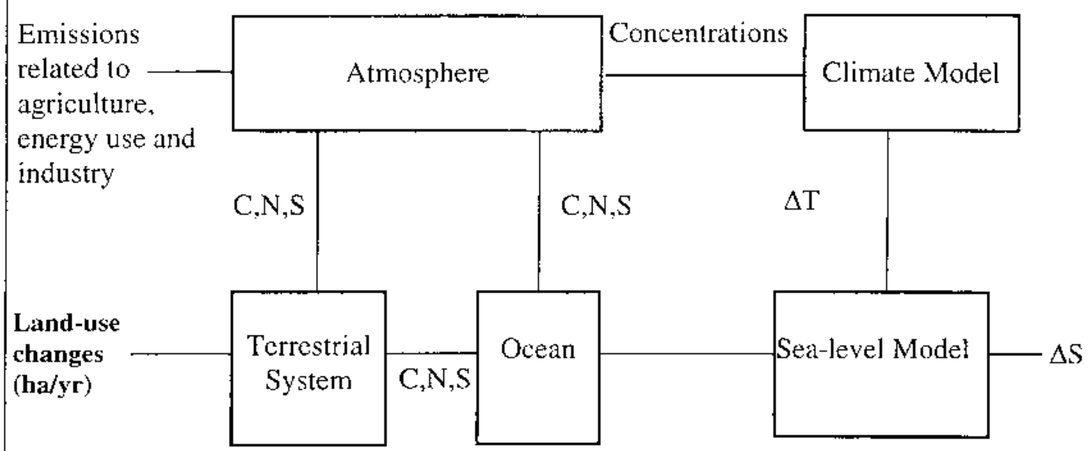
For the evaluation of the climate impacts of energy-related CH_4 and N_2O, emissions are modelled as a fraction of the energy-related CO_2 emissions. Their CO_2-equivalent values are calculated and added to the CO_2 emissions of the Kaya identity. Global SO_2 emissions are set as default values at their 1990 level but can be coupled to fossil CO_2 emissions. There is an additional option for constructing specific SO_2 emission profiles by changing the relative amount of SO_2 emitted per unit of CO_2 (to account for a shift in fossil fuel mix or policies aimed at reducing local air pollution or acidification). Land-use emissions for CO_2, CH_4 and N_2O are exogenous defined and default values are based on the IMAGE 2 medium baseline scenario (Baseline A) (Alcamo *et al.*, 1996). These values can be directly changed and compared to those of other IMAGE 2.1 scenarios.

3.1.2 Evaluation of Emission Scenarios

For the evaluation of the emission scenarios we used a global averaged climate model which has a short run time, thus allowing for interactive simulations. The original version of the model (CYCLES; Den Elzen *et al.*, 1997) is adapted in such a way that IMAGE 2.1 results are reproduced. This model thus acts as a meta model of the IMAGE 2 model. Its set-up also allows for assuming different climate sensitivities and global sulphur emissions (see Box 2). The constructed emission profiles are directly evaluated on the basis of a selected set of indicator values, the rate of temperature change, cumulative temperature change and sea level rise, also used in the safe-landing approach. This is shown by colouring the profiles. The profile becomes green if all indicator values are below 80% of the selected target level, while exceeding at least one of the limits by more than 20% turns it red. Yellow, used for the remaining profiles, indicates a zone of uncertainty of ± 20%. The colours are also marked for each indicator to see which one(s) determine(s) the colour of the profile.

Box 2. Information on the CYCLES model tuned on IMAGE 2.1 data.

Simplified climate-change-related view of the CYCLES model



The CYCLES model describes the long-term dynamics of the global biogeochemical cycles of carbon (C), nitrogen (N), phosphorus (P) and sulphur (S), their interactions and their impacts on climate change (Den Elzen *et al.*, 1997). The main input of the CYCLES model is formed by the emissions and fluxes of C, N and S compounds from the energy, industrial and agricultural sectors, biomass burning, fertilisers, etc. and the human-induced perturbations, land-use changes, fertiliser use, and harvesting. The model consists of simple box models for the atmosphere (one single, uniformly mixed box), the terrestrial biosphere (vegetation biomass, two organic and two inorganic soil layers, and groundwater and fresh surface water), and the oceans (a warm-water and cold-water column, with a surface layer (including marine biota) and four deep layers). The terrestrial biosphere is further subdivided into highly aggregated soil, climate and land-use classes. The model describes the fluxes between the compartments and their main internal processes: biological, chemical and physical (including the major terrestrial feedbacks). The CYCLES model includes a climate model, an energy balance model, accounting for changes in radiative forcing of greenhouse gases, stratospheric ozone and sulphate aerosols.

For the Interactive Scenario Scanner (ISS), a simplified version of the CYCLES model has been developed with the following main characteristics: (1) calibration of the atmospheric CO_2 concentration, and global temperature and sea-level rise towards the IMAGE 2.1 simulation results, and (2) a 99.99% run-time reduction from the IMAGE 2 model to the CYCLES of only a few seconds on a fast personal computer. To calibrate the CYCLES model towards IMAGE 2 results, the following model parameters have been changed: the CO_2 fertilisation growth parameters, the climate sensitivity, the Q_{10} value for the temperature feedback on soil respiration, the humidification fractions and the lifetimes of humus. Next, the ocean system is replaced by the convolution integral representation of the general ocean-circulation carbon cycle model of Maier-Reimer and Hasselman (1987). The decay times have been changed so as to simulate an oceanic carbon uptake similar to the IMAGE 2.1 results. As a consequence of the excluding the N-fertilisation feedback in the IMAGE 2.1 model, the nitrogen cycle model has been excluded. Regarding the second characteristic the 82 soil, climate and land cover classes have too been further aggregated to eight land- cover classes: forests, grasslands, agriculture and other land for the developing and industrialised world.

The final integrated model is tested against data from 1970-1990, and simulates over the 1990-2100 period: global concentrations of the different greenhouse gases, global mean surface-area temperature change and global sea-level rise.

For further information please refer to Den Elzen *et al.* (1997) and Den Elzen (1998).

3.2 A guide to the views

The software of the interactive scenario scanner is written in the modelling environment and simulation language M (De Bruin *et al.*, 1996; www.m.rivm.nl) available from the authors who will provide a copy of the software and a user's manual. The software runs on a PC under Windows 95 or Windows NT and several Unix-based workstations. We will now describe the features of the ISS software. The user-friendly interface allows a fairly quick scan of different types of scenarios and assessment of the impacts of some key uncertainties. The software consist of one model which can be explored through different 'views', a view being a screen in which selected variables of the model are depicted. Changing one variable in one view, automatically leads to changes in other views. We use different views to keep the integrated view simple, while allowing the user to focus on specific facets and functions of the model.

The *Start-view* (Figure 2) view gives information about the authors and the version of the software. You have two options for continuing. If you are using the software for the first time, please click on the yellow button (right); otherwise use the red button (left).

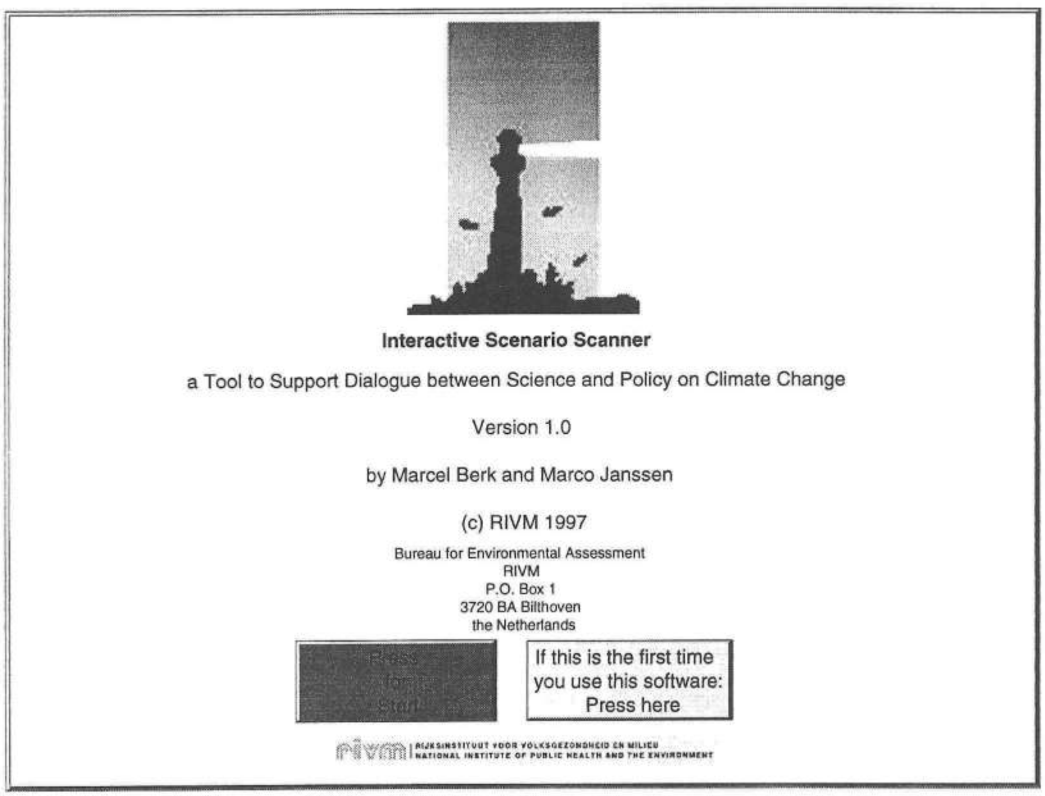


Figure 2: The *Start-view*.

Pressing the yellow button you will get you the *First-use-view*, which welcomes you and ask you to register at RIVM in order to receive updates of the software as they come available. Regular releases of new versions are expected since we intend to adapt the software to comments received from users.
Clicking on the red button (in the *Start-view* or *First-use-view*) will get you the *Disclaimer-view*. This view contains the necessary disclaimers for using the software.

The Main-view

Clicking now on the next red button, will get you the *Main-view* (Figure 3), which consists (on its first level) of four boxes:

- Scenario Construction: here you can change fossil CO_2 emissions in the Annex 1 and non-Annex 1 regions by changing the 4 indicators of the Kaya identity.
- Scenario Evaluation: here you can evaluate the resulting CO_2 equivalent emissions (CO_2, CH_4, and N_2O of both energy use and land-use changes) with respect to the climate-change policy targets selected.
- Options: open this box will reveal 6 buttons giving you access to special views focusing on uncertainty, energy emissions, the Kaya identity, the fuel mix, land-use emissions or other scenarios.
- Targets: opening this box will get you the 3 climate change indicators for selecting climate policy targets:
    - increase in global mean temperature compared to 1990 (Note that to account for the temperature increase since the last century about 0.5 °C should be added);
    - rate of global mean temperature change per decade;
    - the absolute sea-level rise (1990-2100).

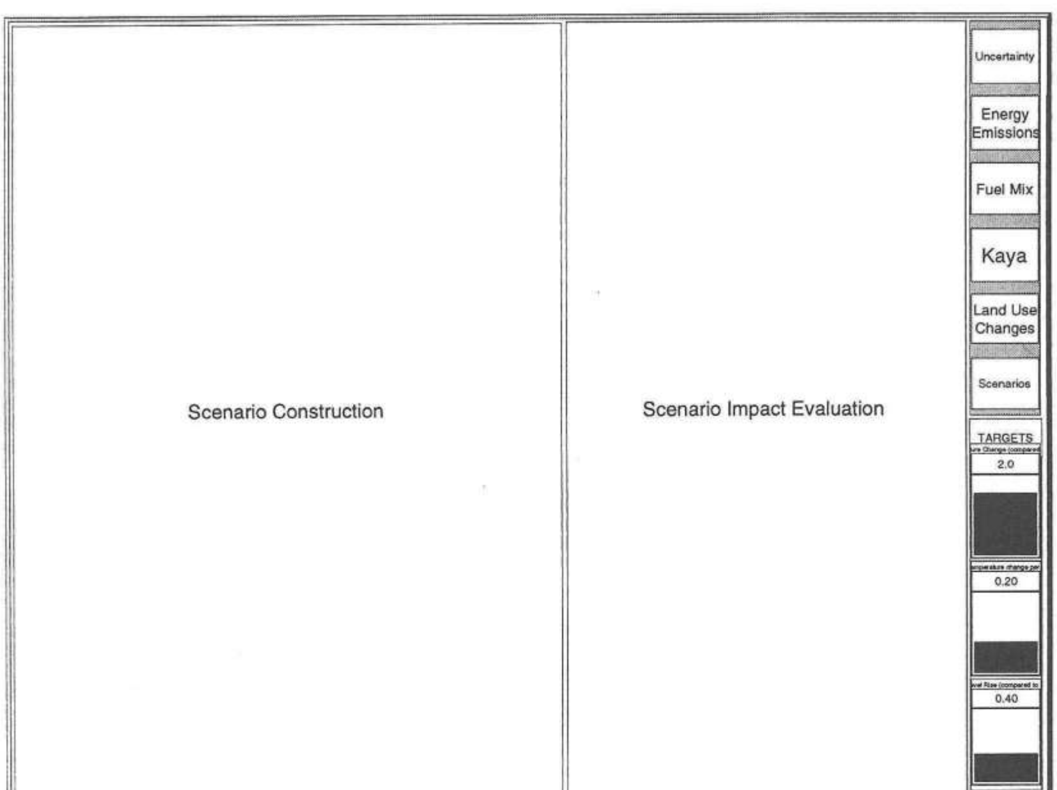


Figure 3: The *Main-view*.

We will now discuss the Scenario Construction (Figure 4) and Scenario Impact Evaluation (Figure 5) boxes in more detail.

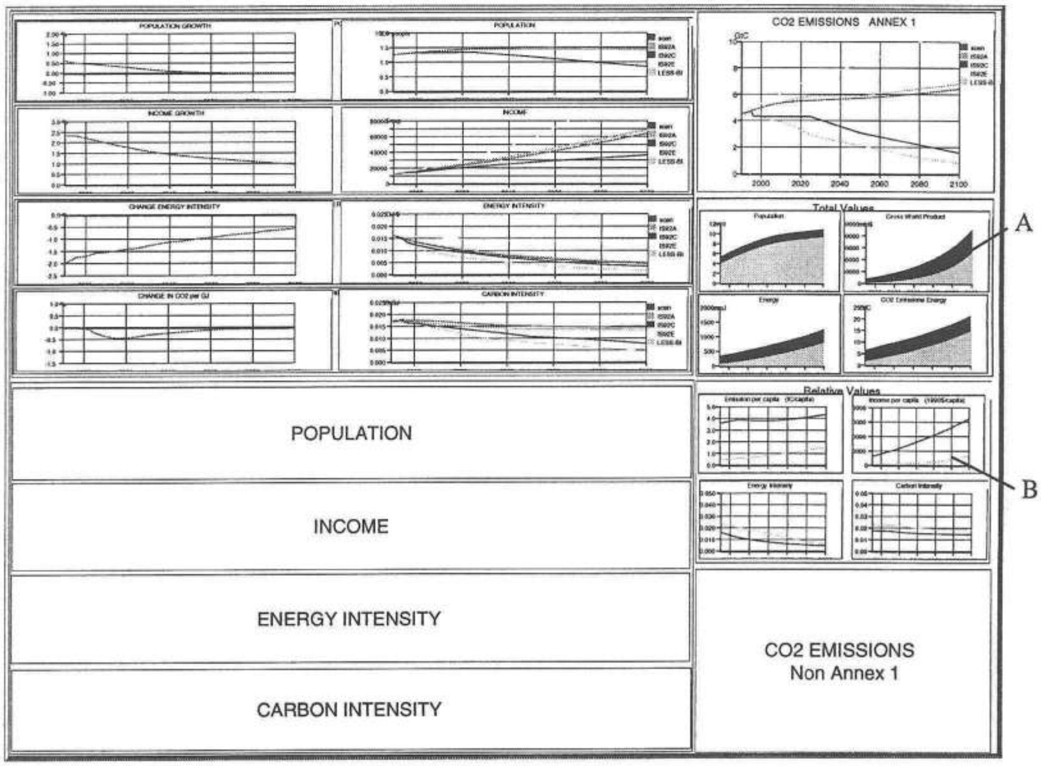


Figure 4: The Scenario Construction box of the *Main-view.*

Scenarios can be constructed by defining growth rates of population, income, energy intensity and carbon intensity in both the Annex 1 and non-Annex 1 regions. These growth rates are indicated in the 4 left-hand boxes in Figure 4. The (red) lines on the graphs can be changed by dragging them with the use of the mouse.

Next to the boxes (the right-hand column), you can view the consequences of the growth rates for: population size, per capita income, energy intensity and carbon intensity. Moreover, you can compare the absolute values of your own scenario (the red lines) with those of various other scenarios (IS92a, IS92c, IS92e and LESS-BI, as implemented in the IMAGE 2 model). By comparing your own values with these scenarios, you can get a feel of how they relate to assumptions in other well-known scenarios. However, as discussed above, this does not guarantee that your scenario assumptions are consistent or plausible, since the four indicators of the Kaya identity can be changed independently.

Some additional information on the scenarios is given in the right-hand column of Figure 4. First, the fossil CO_2 emissions of Annex 1 (upper right box) and non-Annex 1 (lower right box) of your own constructed scenario (the red line) can be compared to several other scenarios. Second, there are two boxes in the middle ((A) and (B)) that combine the scenario variables of both Annex-1 and non-Annex-1 in order to compare the results in a different way. Box (A) contains information on the absolute and aggregated values of population size, energy use, gross world product and fossil CO_2 emissions. Annex 1 is indicated by dark blue; non-Annex 1 by light blue. Box (B) contains four boxes that allow comparison of different values of emission per capita, income per capita, energy intensity and carbon intensity for Annex-1 and non-Annex-1 regions.

The scenario is then evaluated on the basis of the values chosen for the climate change target indicators (Figure 5). The colour of the upper box, the CO_2-equivalent emissions, results from the colour of the three individual climate indicator boxes: global mean temperature change compared to the 1990 level, decadal rate of temperature change and the sea-level rise compared to the 1990 level. Changing the policy targets for climate change may change the colour of the indicators.

We also included as an additional indicator the atmospheric CO_2 concentration since the stabilisation of the CO_2 concentration level is also often used as an important climate policy target. Such a stabilisation target is explicitly mentioned in the objective of FCCC.

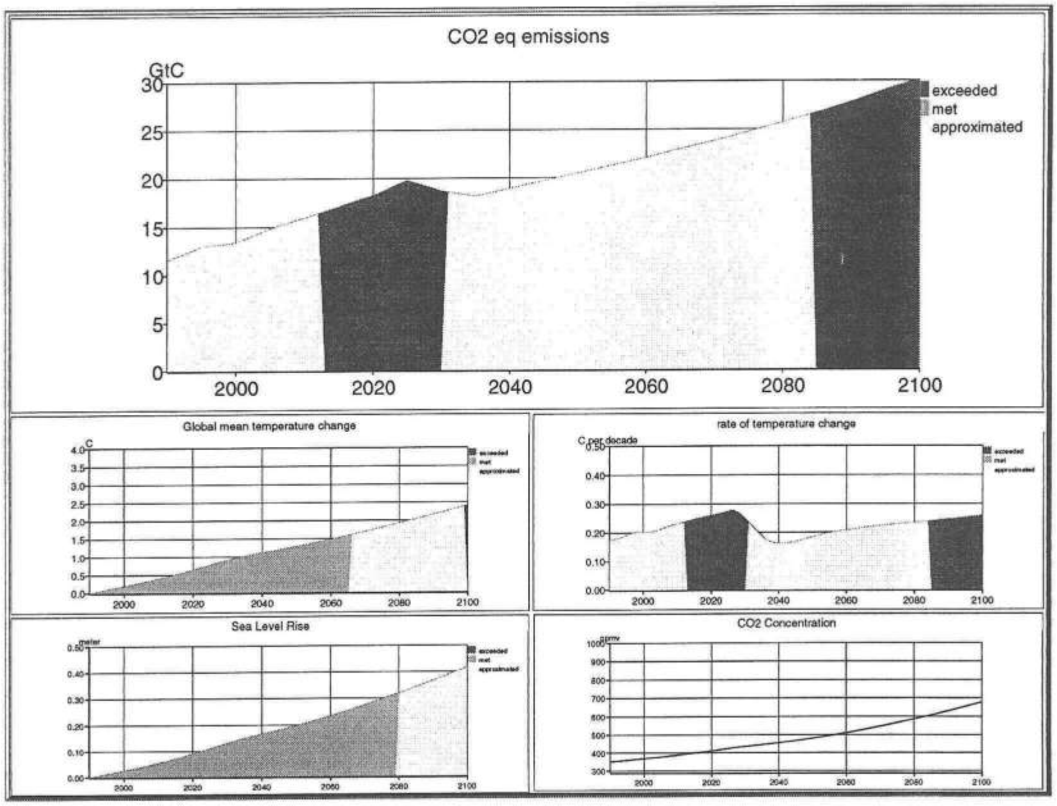


Figure 5: The Scenario Evaluation box in the *Main-view*.

The Uncertainty-view

Clicking on the *Uncertainty-view* (Figure 6) offers you the option of changing the assumptions for SO_2 emissions and the climate sensitivity, as well as to evaluate their impacts on the level of climate change and sea-level rise. The climate sensitivity is defined as the change in global mean temperature for a doubling of the CO_2 concentration. In the IPCC assessments its estimated change varies between 1.5 °C and 4.5 °C. One can change the value of the climate sensitivity by using the slider at the lower left side of the view. The default value is 2.37 °C, reflecting the climate sensitivity of the IMAGE 2 model. Changes will have a direct effect on the level of the (rate of) temperature change and sea-level rise and - thereby - on the colouring of the graphs (right side of the screen).

The SO_2 emissions make the climate cooler although this effect will show sharp regional variations because of regional differences in emission levels and relatively short lifetimes. In the default case, the emissions of SO_2 are assumed to remain stable at 1990 values (upper left box). However, you may couple the SO_2 emissions with fossil CO_2 emissions by assuming that the level of SO_2 emissions follow the CO_2 emissions. This coupling can be activated by changing the slider "SO2: 1990 level / related to CO2" from the "1990 level" to "SO2 related to CO2". The SO_2 emissions (upper left box) will change with time, and the climate impacts (right side of the view) will change due to the impact of SO_2 emissions on temperature change. A final option is to change the amount of SO_2 per unit of fossil CO_2 emission. This may reflect acid rain policies or an assumed shift from coal to oil and gas. This can be done by changing the level of the relative reduction of SO2/CO2 in the upper right box of the uncertainty box.

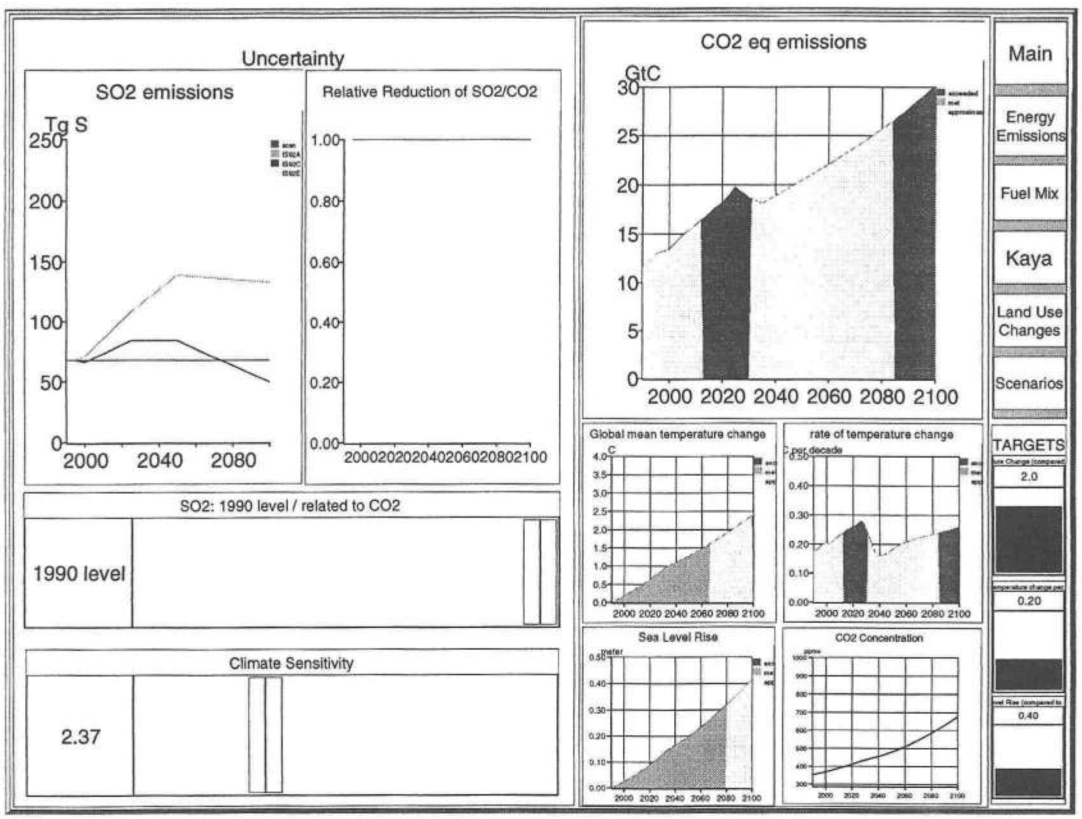


Figure 6: The *Uncertainty-view.*

The Energy emissions-view

Clicking to the *Energy emissions-view* will get you the ability to directly change the level of energy-use-related emissions for the Annex 1 and the non-Annex 1 region (Figure 7). In this way, this option allows for directly evaluating the effects of various emission reduction schemes. The *Energy emissions-view* consists of a construction part (left side) and an evaluation part (right side). Note that in this climate impact evaluation the same policy targets, SO_2 emissions, land-use change emissions and climate sensitivity as in the other views are used. Only the energy-related emissions are changed. The construction part contains two boxes where emissions from Annex-1 and non-Annex 1 can be specified as a percentage change in fossil CO_2-emission levels (the left boxes). The right-hand boxes of the construction part show the resulting emission levels as compared to their 1990 levels. The lower box shows the sum of the Annex 1 and non-Annex 1 energy-related CO_2 emissions.

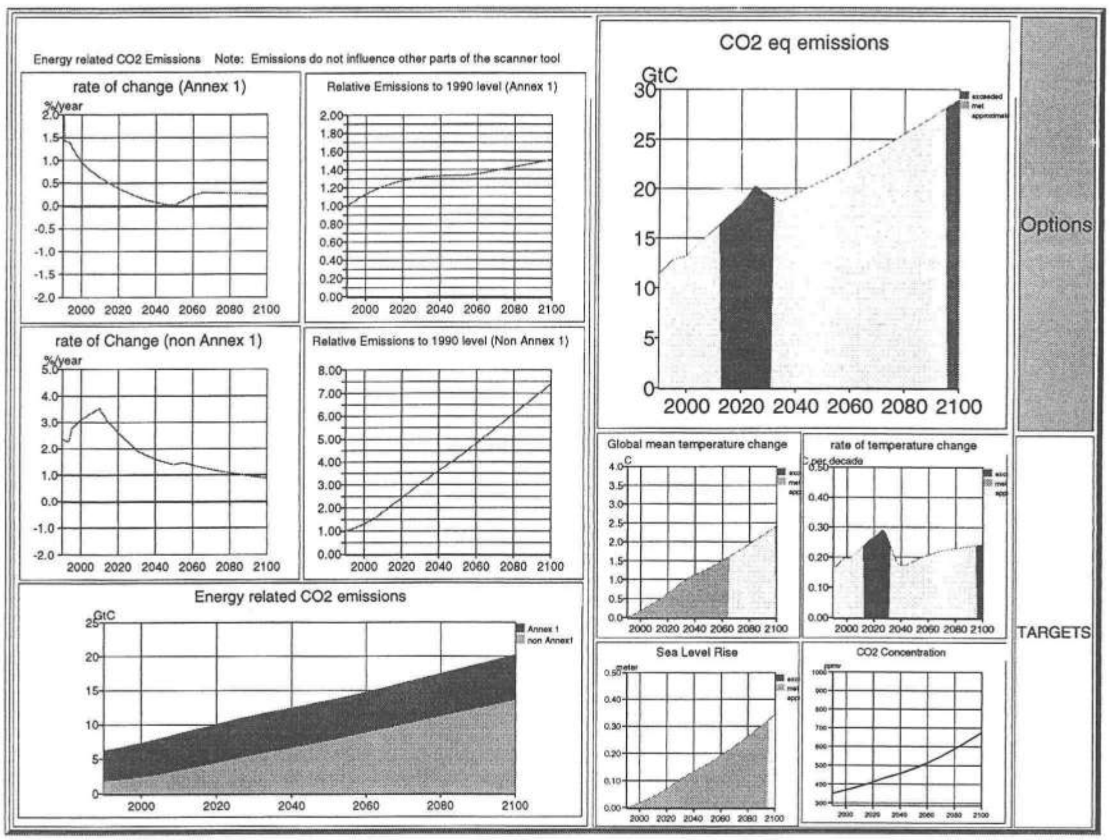


Figure 7: The *Energy-emissions-view.*

The Kaya-view

Choosing the *Kaya-view* (Figure 8), provides you with the opportunity to select the Kaya indicator values in such a way that the resulting scenario (red line) mimics the emission profile constructed by changing energy-related emissions directly (green line) using the *Energy-view*. This allows for exploring various settings of the Kaya indicators, resulting in the same emission profiles (e.g. scenarios with different assumptions for population and income growth).

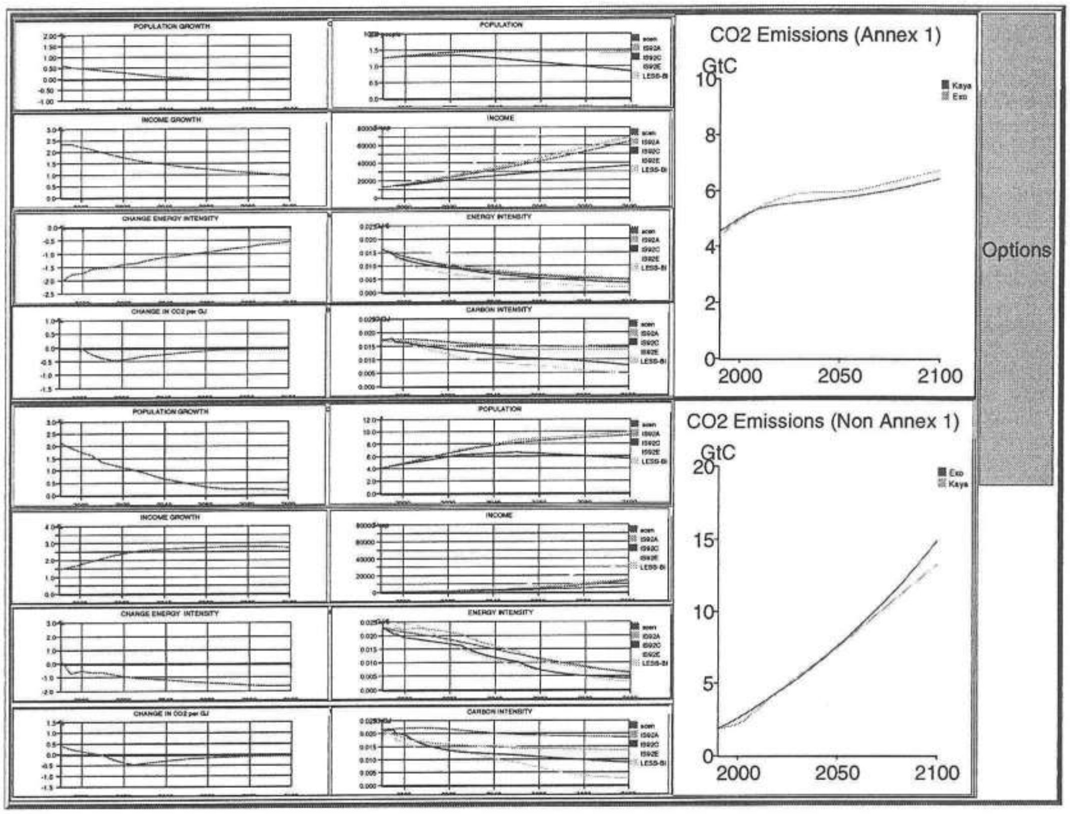


Figure 8: The *Kaya-view*.

The Fuel Mix-view

The Fuel Mix-view enables you to construct a fuel mix mimicking the desired development of carbon intensity (Figure 9). You may change the percentage use of oil, gas and non-fossils (left-hand side); together with the leftover (coal), the fuel mix and carbon intensity of the energy supply are calculated. Given the total energy use, the use of the different fuel types can also be expressed in EJ. You may use this view in two different ways: (1) reproduce a previously defined carbon intensity profile in the Kaya formula by adjusting the fuel mix, or (2) construct a fuel-mix scenario and change the carbon intensity in the Kaya formula in accordance with the resulting carbon intensity profile.

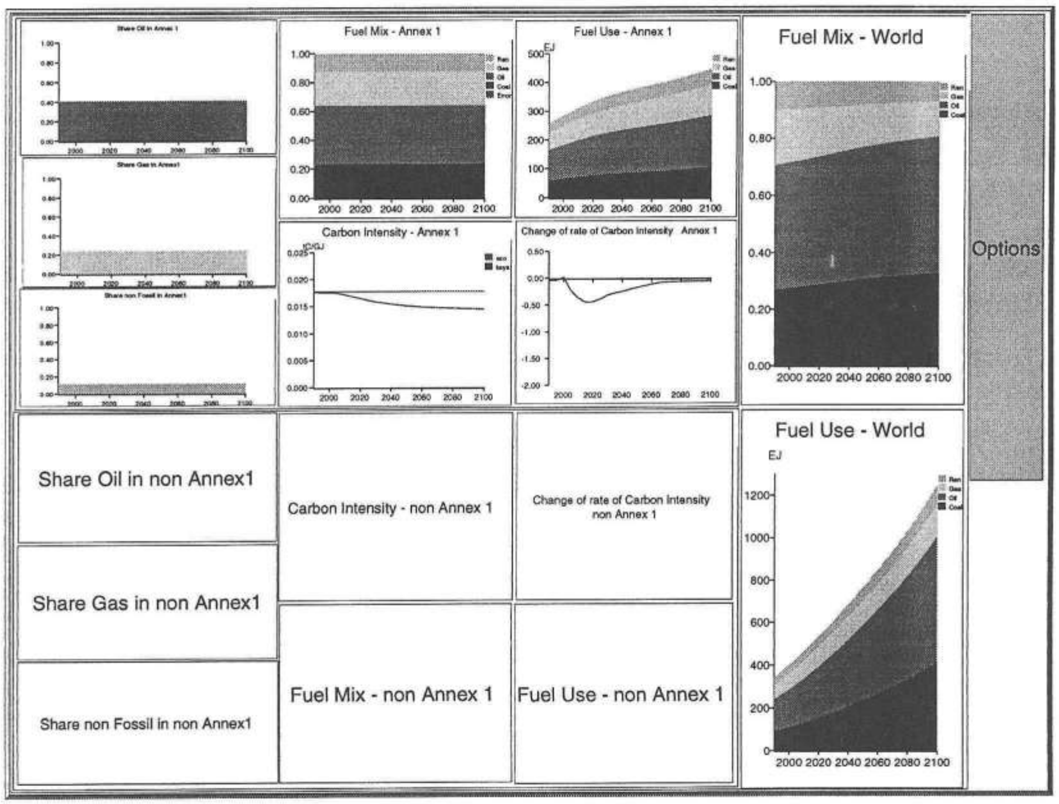


Figure 9: The *Fuel mix - view.*

The Land-use emission-view

Land-use changes are exceptionally difficult to capture in simple modelling frameworks. To keep the ISS simple and transparent we therefore did not model land-use emissions, but used emissions from the IMAGE 2 model. To account for options to control also land-use emissions, we allow the user to change land-use emissions directly. Clearly, this requires substantial expertise of reasonable assumptions are to be made. The *Land-use emission-view* (Figure 10) consists of a constructions part and an evaluation part. The construction part consists of absolute emission levels of CO_2, CH_4 and N_2O, which can be changed in the left-hand boxes. In the right-hand boxes you will find the constructed emission levels (the red line) along with a number of scenarios (IMAGE scenarios Baselines A, B and C, and the IS92a scenario). The default scenario of land-use emissions follows the IMAGE 2 Baseline A projections (Alcamo *et al.*, 1996). The comparison with other scenarios may give an impression of the order of magnitude, but cannot avoid the user possibly creating inconsistent scenario assumptions. The impact of changes in land use emissions can be directly evaluated in the right-hand part of the *Land-use emissions-view.*

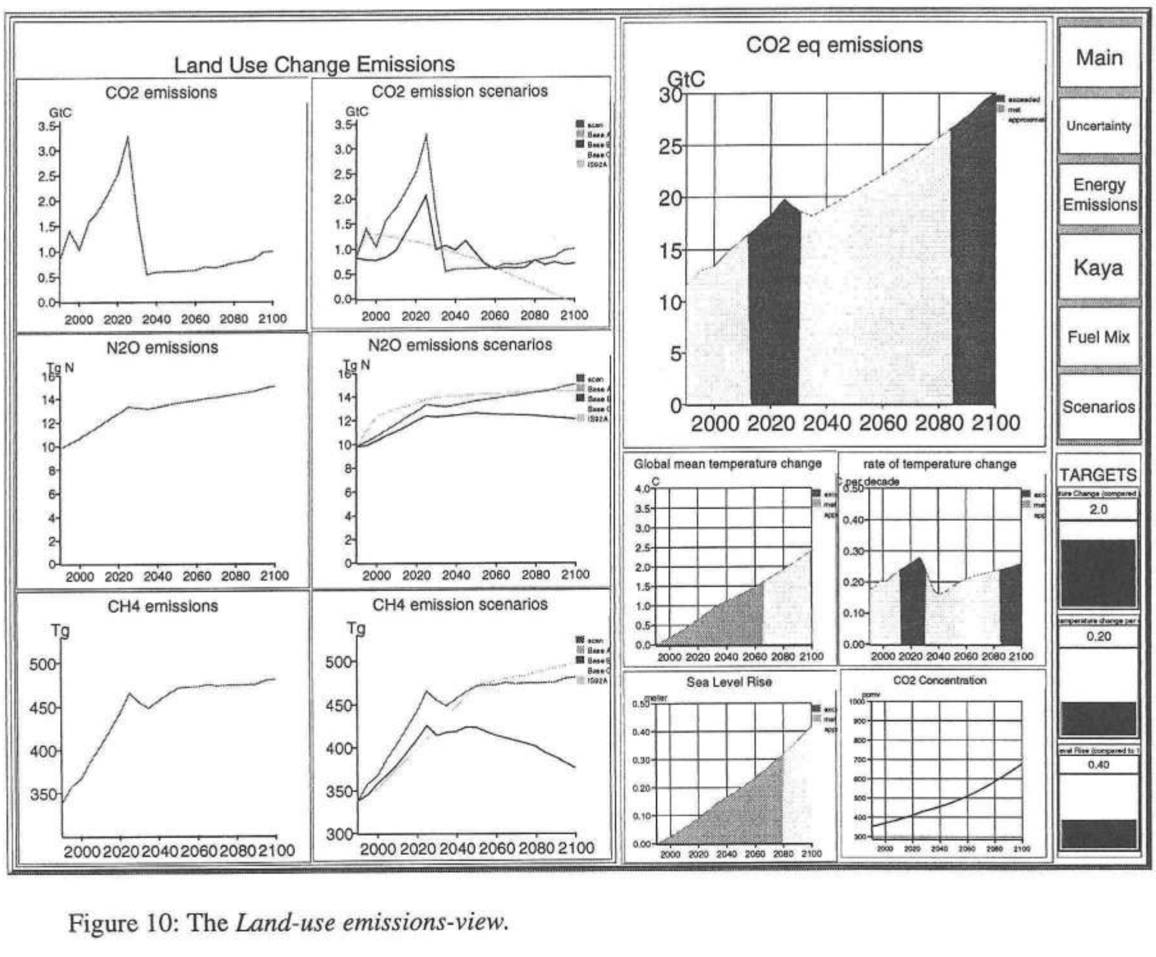


Figure 10: The *Land-use emissions-view.*

The Scenario-view

The *Scenario-view* of the ISS software allows for the comparison of the climate impacts of the constructed scenario with those of various existing scenarios (Figure 11). The view consists of two parts. The left side depicts the climate change evaluation of existing scenarios, where one can choose between different scenarios by adjusting the slider vertically. The right side of the view shows the climate change evaluation of the scenario, constructed by changing the growth rates of the indicators of the Kaya identity. Note that scenarios as in the IPCC have increasing and not constant (1990) SO_2 emissions - as in the default scenario - which leads to different impacts with similar levels of CO_2 equivalent emissions.

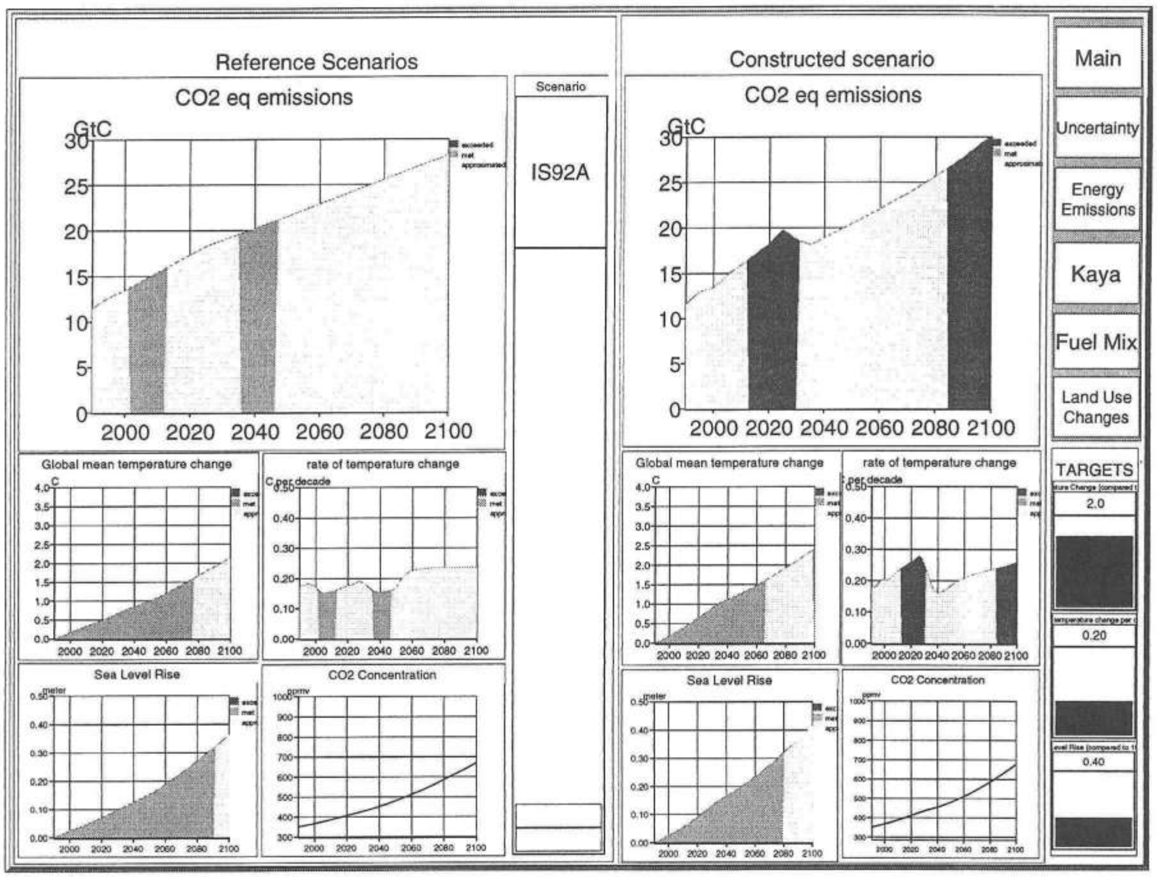


Figure 11: The *Scenario-view*.

4. EXPERIENCES USING THE ISS

The ISS has been demonstrated to and used by various scientists, policy analysts and policy makers. We will discuss two important events where the use of this tool, along with insights gained to date from its application, were shown. These are (1) the fifth Delft Dialogue workshop (June 1997) and (2) the sessions held at Environment Canada (July 1997).

4.1 The Delft Dialogue scenario session

As indicated in section 2, the ISS, originally developed for the Delft Dialogue workshop (Van Daalen *et al.*, in press), was used during the second day of the workshop. During the first day, there were presentations on rates of technological change and economic analysis of EMF-14 emission mitigation scenarios. We asked the speakers for that day to present their scenario assumptions and results in the same way as in the ISS by using the indicators of the Kaya identity. In this way, the participants would get a better feeling for the implications of various indicator values. On the second day, the ISS was first presented and demonstrated, after which it was used in a scenario development session. The aim of the scenario exercise was to develop a set of proto-scenarios that might be further elaborated by the IMAGE team either within the context of the so-called COOL project[2] or scenario development activities or within the context of IPCC's Third Assessment Report (TAR). The participants were split up into three subgroups: a group with participants from developing countries, a group with participants from Europe and a group dominated by participants from North America. All groups were asked to construct three scenarios: a most likely scenario, a most desirable scenario and a feasible scenario. As a starting or reference point, an IS92A type of assumptions was given. The groups, supported by a moderator and a computer operator, had about two hours for the scenario construction. The results were reported back during a plenary session. Since the two hours was not enough for all groups to develop three scenarios, two groups did not construct a feasible scenario.

With respect to the outcome of the session it was interesting to see that the various groups had developed largely different scenarios, not only in the case of desirable futures, but also in the case of the most probable futures. While all groups expected that both emissions and GHG concentrations would continue to rise strongly and would lead to substantial warming, total CO_2 equivalent emissions in 2100 diverged due to different assumptions for the Kaya parameters by a factor of two. This clearly indicates that there can be important differences in perceptions policy makers have of baseline developments.

As to the desirable futures there were also significant differences between the various groups with respect to the climate targets selected. These reflected different interests and perceptions of vulnerability (for example, for sea-level rise or overall temperature change). Some groups experienced difficulty in meeting their selected climate targets, while at the same time achieving convergence in both per capita emissions and income. Perceptions of possible rates of technological change diverged considerably.

[2] The COOL project is a planned participatory integrated assessment project in the Netherlands. The project will form part of the Dutch National Research Programme on Climate Change (NRP) and focus on the identification of long-term climate policy options for various sectors of society in a European and global scenario context. A follow-up to the Delft dialogue workshops is envisioned for the development of global scenarios .

In evaluating the scenario session participants indicated the Interactive Scenario Scanner as being an interesting and useful tool, both from an educational and policy-development point of view. The tool was viewed to be especially useful in dealing with post-Kyoto issues like differentiation and graduation, fairness and equity, and technological change/transfer.

From this first session with this ISS tool we learned that:

1) the ISS could indeed facilitate the involvement of policy makers in the development of emission scenarios. Its structure and visualisation are both simple and transparent enough to enable policy makers to work with the tool, and comprehensive enough to allow generation of proto-scenarios that can be used for further scenario development. However, to realise this the elaboration of the story lines (the grand logic behind the numbers) will be as important as specifying the values of the Kaya parameters, requiring substantial availability and moderation of expert knowledge to guide the process.
2) considering the importance of acessible knowledge, a moderator, well informed and experienced in both the scientific and political dimensions of the climate change debate, is essential to structure the discussion of the policy makers. If extreme settings are proposed, the moderator should get behind the assumptions. The moderator can, furthermore, indicate cross-linkages between issues and check for the consistency in assumptions used.
3) the process of using the ISS is as valuable as its outcome. The ISS has both educational and communicative value for policy makers and scientists. Even those well informed indicated that the tool in helping to consistently and quantitatively link existing insights sometimes leads to new insights. Moreover, the ISS also proved to be an interesting tool to enhance the communication between policy makers, especially by revealing (causes for) differences in perceptions and opinions.
4) it would be very helpful if someone who is experienced with the ISS software could make the actual changes in the desired input. This would prevent policy makers struggling with the soft- and hardware.
5) it is important for participants to be willing and able to spend a number of hours on the scenario exercise. Less time spent is likely to be at the expense of story-line development and group discussion, making both the process and outcome less valuable. Policy makers should avoid being disturbed by 'very important calls and faxes' so that they will have time enough to spend on the exercises with the whole group.
6) if more than one group is doing the exercise, an evaluation of the results of each group in a plenary session would be very useful.

4.2 The sessions at Environment Canada

On invitation of Environment Canada, one of the authors (M.A. Janssen) had the opportunity of giving several presentations and demonstrations in Toronto and Ottawa at the end of July 1997. Environment Canada wanted to use the Safe Landing Analysis software and the ISS to facilitate improved communication to senior policy makers and politicians about possible implications of climate change and different mitigation scenarios. Three sessions were organised to demonstrate the tools scientists, policy analysts and policy makers use. Each session was introduced by Henry Hengeveld, a scientific advisor of Environment Canada on climate change, who gave an introduction on the Kyoto discussion. He stressed the balance of emission reductions and climate change impacts. Janssen presented the background of the Interactive Scenario Scanner and gave a demonstration of the software. After that there was room for discussion and the actual demonstrations. The first session was held in Toronto for a group of scientists in the field of climate change. The discussion was mainly focused on the treatment of uncertainty, the influence of sulphate aerosols and the meaning of the selected threshold values. The next day, two sessions were held in Ottawa. The morning session was held for a group of policy analysts of Environment Canada. The role of uncertainties and critical values for the climate indicators were the main issues of discussion. The session in the afternoon was held for senior policy makers. The discussion led to the evaluation of alternative proposals, the role of non-Annex 1 countries and threshold values of global indicators for the evaluation of climate impacts.

The experiences in Canada confirmed earlier experiences with interactive tools. The ISS cannot be used without the help of experts with a good general overview of the subject. During the sessions questions were raised on issues which were not explicitly included in the software, requiring additional explanations by scientific experts. Here it was found that although the ISS was developed for the construction of proto-scenarios, it can also be fruitfully used to stimulate discussion and dialogue between scientists and policy makers. In more such instances ISS serves as an effective educational tool. There were as well many suggestions for additional views and functions. This indicates that the tool is likely to be further developed and that future versions of the ISS software will surely be updated to tackle ever-occurring timely issues in the FCCC negotiations. These experiences have confirmed flexibility in modelling and visualisation to be important features for supporting policy development.

5. FUTURE DEVELOPMENTS

The experiences with the IMAGE science–policy dialogue workshops have made clear the interaction between science and policy as one of mutual learning (Van Daalen *et al.*, in press). Without the interactions during the dialogue workshops it is unlikely that tools like the Safe Landing Analysis and the Interactive Scenario Scanner would have been developed. We learned that in addition to comprehensive scientific models, simpler tools will be needed to help improve the communication between scientists and policy makers on issues that have complex scientific and political dimensions. From the various sessions held with the ISS, we can conclude that it is indeed a fruitful tool in stimulating the dialogue between science and policy on scenario development. It helps in communicating important scientific insights to policy makers, while providing scientists with a better understanding of policy makers' concerns, requirements and dilemmas. Because a simple computer model does not make the problem at hand easier to solve, it is obvious that a need for expert support to provide detailed background information remains. Only with all this information and understanding can policy makers arrive at sensible results.

From our experiences, it is also clear that the present version of the Interactive Scenario Scanner is likely to evolve over time in response to new suggestions and demands from policy makers[3]. There are many ways to further improve and expand the ISS software. There have been suggestions for inclusion of, for example, more regions, the visualisation of possible climate change impacts, ranges of economic costs and more information on technological options. However, when considering further revisions and extensions we will always have to find a balance between the model's functionality, transparency, reliability and interactive use. For example, the economic costs of various emission profiles cannot be modelled in any simple way. Likewise, it is not feasible to model regional climate impacts. Instead we propose linking the ISS to a library of directly accessible background information. This information can then be used by policy makers in selecting climate targets and making assumptions on the settings of the Kaya variables. A further regionalisation of the ISS would necessitate users specifying many more assumptions, which would make the system much more complex thus reducing the transparency and limiting interactive use. However, it may become desirable to facilitate discussions on diverse post-Kyoto issues, such as graduation, differentiation of commitments or distribution of emission budgets. In this case, it may be better to develop a separate ISS version instead of including all features in one new version. In any case, we will continue to discuss these extensions of the ISS with policy makers and therefore believe that many opportunities for using the ISS in science–policy dialogues remain. In our opinion, an interactive and iterative process is the best way to improve the science–policy dialogue, leading to both better informed policy makers and a better utilisation of scientific knowledge.

[3] The Dialogue workshops could continue in the context of the COOL project (participatory integrated assessment) and the FRED project (a framework of models and information systems on global change). These projects are currently being proposed.

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