research for
man and environment

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

RIVM report no. 402001018

Descriptions of selected global models for scenario studies on environmentally sustainable development

J.A. Bakkes, J. Grosskurth (ICIS), A.M. Idenburg, D.S. Rothman (ICIS) and D.P. van Vuuren

October 2000

Global Dynamics and Sustainable Development Programme
GLOBO REPORT SERIES No. 30

With contributions by
N.-A. Braathen (OECD), R. Chipman (UN-DESA) and O. Dzioubinski (UN-DESA)

ICIS: International Centre for Integrative Studies, Maastricht
OECD: Organisation for Economic Co-operation and Development, Paris
UN-DESA: UN Department of Economic and Social Affairs, New York

This report been compiled by order and for the account of The Dutch Ministry of Housing, Spatial Planning and the Environment(VROM), the United Nations Environment Programme (UNEP) and the Organisation for Economic Co-operation and Development (OECD), within the framework of RIVM project 402001, contributions to the Global Environment Outlook.

RIVM, P.O. Box 1, 3720 BA Bilthoven, telephone: 31 - 30 - 274 91 11; telefax: 31 - 30 - 274 29 71

Acknowledgements

This report draws on the following four activities.

In early 1999, RIVM described by request of OECD a small number of world-wide models that could help to comprehensively evaluate global scenarios with respect to their impact on the environment. The selection of models was meant to specifically extend beyond the available energy-climate models. RIVM formatted its output as prefilled questionnaires to the modelling teams. This is the background of the material in Appendix I.

At the same time, UN-DESA was preparing a questionnaire to global modelling groups, in preparation for scenario-based reporting as input to the tenth session of the Commission of Sustainable Development, ten years after the Rio conference. This is the background of the material in Appendix II. As the DESA questionnaire was to have much in common with the OECD/RIVM exercise, the two activities were joined. The results of neither have been formally published.

Moreover, at approximately the same time, the European Environment Agency requested from ICIS an update of an earlier review of scenario studies. The review included a quick scan of European and global models useful for scenario development (van Asselt, Greeuw et al. 2000). This is the background of much of chapter 3 in the current document.

Finally, the collaborating centres for the UNEP Global Environment Outlook (GEO) are now preparing for the Outlook Chapter of GEO-3. Participants in this process also need concise background documentation on the available global modelling tools.

Disclaimer
The information in this paper is meant to describe the models as truthfully as possible. However, most of it has been collected from literature, not directly from the modelling teams. Therefore, it may not capture the latest developments.

CONTENTS

1. INTRODUCTION 5

2. CRITERIA FOR EVALUATION 6

3. GLOBAL MODELS FOR SCENARIO STUDIES ON ENVIRONMENTALLY SUSTAINABLE DEVELOPMENT 7

3.1. INTEGRATED MODELS FOR THE ASSESSMENT OF SUSTAINABILITY 7
3.1.1. World 3 7
3.1.2. International Futures (IF)..8
3.1.3. Tool to Assess Regional and Global Environmental and Health Targets for Sustainability (TARGETS)..8
3.1.4. Threshold 21 (T21) 9
3.1.5. POLESTAR 10
3.2. ENVIRONMENT-ENERGY MODELS 10
3.2.1. Atmospheric Stabilization Framework (ASF) 11
3.2.2. Multiregional Approach for Resource and Industry Allocation (MARIA)......................11
3.2.3. Model for Energy Supply Strategy Alternatives and their General Environmental Impact (MESSAGE) 12
3.2.4. Mini-Climate Assessment Model (MiniCAM) 12
3.3. GLOBAL CHANGE MODELS...13
3.3.1. Integrated Model to Assess the Global Environment (IMAGE)..............................13
3.3.2. Asian Pacific Integrated Model (AIM)...14
3.4. ECONOMIC-ENVIRONMENTAL MODELS 15
3.4.1. JOBS 15
3.4.2. Global Trade Analysis Project (GTAP) 15
3.4.3. World model for SCenario ANalysis (WorldScan)..16
3.4.4. World Model 17
3.4.5. Future Agricultural Resource Model (FARM)..18

4. CONCLUSIONS 18

5. BIBLIOGRAPHY 21

APPENDIX I: MODEL DESCRIPTIONS FROM RIVM PREPARED FOR OECD....................23

5.1. ASIAN-PACIFIC INTEGRATED MODEL (AIM) 24
5.2. POLESTAR...27
5.3. WORLD MODEL 32
5.4. IMAGE 2.2..36

APPENDIX II: MODEL DESCRIPTIONS FROM DESA SURVEY 42

5.5. MINI-CLIMATE ASSESSMENT MODEL (MINICAM)...43
5.6. JOBS 47
5.7. FUTURE AGRICULTURAL RESOURCES MODEL (FARM) 52

Summary

This report provides a survey of past and present integrated models that have been used for the generation and analysis of global scenarios. It examines the usefulness of the models for scenario studies on environmentally sustainable development. It does so by evaluating the models in terms of *inter alia* horizontal integration, vertical integration, and regional specificity. No single model is found to be ‘ideal’, but a judicious combination of currently existing models with narrative storylines can provide the basis for the development of global scenarios of environmentally sustainable development.

1. Introduction

This report provides a survey of past and present integrated models that have been used for the generation and analysis of global scenarios. We are specifically interested in the usefulness of the models for scenario studies on environmentally sustainable development. This is particularly timely with the recent publication of the Intergovernmental Panel on Climate Change's (IPCC) special report on emission scenarios (IPCC 2000), the preparation of the third Global Environment Outlook (GEO-3), which will have as a key chapter a 30 year prospective, and other events related to the run-up to Rio+10 process.

The models are clustered in four groups. The first group contains those models that have been built with the explicit objective of providing an integrated insight into a broad range of environmental, economic and socio-cultural aspects of sustainability. This group of models includes the legendary World 3 model and the more recent related models International Futures, TARGETS and Threshold 21, as well as the accounting based Polestar system. The second group contains models that put an emphasis on the link between the energy sector and the environment. These models usually concentrate on the issues of emissions, climate change or acid rain and depletion of resources. Here we include four of six models used in the recent IPCC *Emission Scenarios* study, namely ASF, MESSAGE-MACRO, MARIA and MiniCAM. The third group of models is a special class of the previous. These models – GCAM, AIM, and IMAGE – started out as energy-environment models, but have evolved to the point where they are now better characterised as global change models. The fourth group of models focuses on the link between the economy and the environment. It includes JOBS, GTAP, WorldScan, the WORLD Model, and FARM. Most models in this group support sophisticated and detailed scenarios of economic developments and translate these into rough sketches of possible environmental impacts.

The descriptions of the models focus on the breadth and depth of models as well as the modelling techniques used. Table 1 provides an overview of the main characteristics for the models described. The appendices present more detailed information on each model. At the end of this report, some preliminary conclusions are drawn concerning the general usefulness of existing models for a thorough and well balanced analysis and projection of developments related to sustainability. The next section describes the criteria for evaluation used in drawing these conclusions.

2. Criteria for Evaluation

The criteria for evaluating models need to reflect the goals which they are asked to achieve. The primary focus here is the ability of the models to help generate and analyse global scenarios of environmentally sustainable development. This implies the need for the models to be evaluated in terms of horizontal integration, vertical integration, geographic scope and specificity, and the ease with which they can be used and/or understood by persons other than the developers.

Horizontal integration refers to the integration between different aspects of a model's domain. Environmentally sustainable development rests on the three pillars of environment, economy, and society. Thus, the models must include integration between the environmental, the economic and the socio-cultural domains, as well as integration within each of these domains.

Vertical integration refers to the degree to which a model covers the complete cycle of human induced change, from driving forces to pressures to changes in state to impacts and finally to responses (DPSIR). Scenarios of environmentally sustainable development require descriptions of the evolution of strongly linked, complex, adaptive systems. Only by being vertically integrated can a model even hope to capture these dynamics.

Although this report focuses on global models, the regional specificity of modelling and scenario studies has been increasingly found to be crucial. The reasons for this include the following:

- Resource effects at more local levels that affect significant numbers of people, e.g. water shortages and land degradation, may be severely underestimated by aggregation to larger geographic scales;
- Differences in vulnerability are crucial in order to realistically assess impacts; and
- Involvement of regional expertise improves both the quality of assessments and their acceptance by the envisaged users.

The acceptability and influence of models, and the scenarios developed with their use, depends critically on the degree to which they are trusted by the end user. The more transparent are the processes by which the model operates and the scenarios developed, the more likely is it that the results will be accepted. It is not necessary that the end users actually be able to run the models, but they should have some level of comfort and understanding with how they work.

3. Global Models for Scenario Studies on Environmentally Sustainable Development

3.1. Integrated Models for the Assessment of Sustainability

The first group of models contains those that have been built with the explicit objective of providing an integrated insight into a broad range of environmental, economic and socio-cultural aspects of sustainability.

3.1.1. World 3

World 3 was the first comprehensive integrated global simulation model. It became known to a wide audience through the publication of *Limits to Growth* (Meadows, Meadows et al. 1972) and in its revised form through the publication of *Beyond the Limits* (Meadows, Meadows et al. 1991).

World 3 is a system dynamics model that covers a wide range of population, food, energy, environmental and economic issues. System dynamics models are based on sets of difference equations. These equations are used to express levels of stock variables and rates as a measure of change in the stock variables. Auxiliary variables, mostly parameters, quantitatively describe the relationships between the different stocks and flows. This modelling technique enables modellers to model complex interactions without having to tackle massive sets of time-series data. Scenarios can be forecasted and backcasted from a base year, which is the only year for which data is needed for a scenario run (for validation and calibration other data sets might be needed). In the case of the revised World 3 model, the base year is 1990. The forms of the equations, the interactions and the values for the auxiliaries and the constants are based on statistical analysis and scientific judgement without participative input. Scenario simulations run from 1900 until 2100. The so-called back-casting is used in order to validate and calibrate the model to actual history. A comprehensive technical description of the original World 3 model can be found in *Dynamics of Growth in a Finite World* (Meadows, Meadows et al. 1972).

World 3 is the first comprehensive example of horizontal integration. There is a plethora of feedbacks between the different domains of the models. However, the socio-cultural domain and the institutional domain are not represented in the model at all. The level of vertical integration is limited. It is not possible to trace clear cause-effect chains, as the descriptions of the different processes are too crude to allow for a detailed analysis. A major drawback of the model is the fact that it only provides scenarios on a global level, i.e. there is no regional disaggregation. The scenarios generated are of limited use for policy makers as they allow only very general conclusions about the possible effects of different policy strategies. As each new scenario run requires adjustments in the code of the program, the ease of use for people other than the developers is very limited.

3.1.2. International Futures (IF)

International Futures (IF) (Hughes 1999) is a global system dynamics model based on a similar methodology as World 3.[1] The model simulates population, food, energy, environmental, and economic developments for the period from 1992 until 2050 at a global as well as a regional level. The model includes fourteen regions. IF adds the domains of domestic and global social and political systems to the coverage of World 3. However, these aspects are covered more implicitly than explicitly in the model. An important feature of IF is the interactive way of developing scenarios, which allows users to efficiently adjust virtually all values of variables, parameters and constants in order to explore variations of a given base-line. However, the user can not adjust the form of the underlying equations. The IF base scenario draws on the extrapolation of current trends. The greater breadth of the model increases horizontal integration. However, the environmental domain is limited. With respect to vertical integration the model suffers from similar problems as World 3. The possibility to quickly create a set of partially custom-made scenarios is very valuable for policy analysis. The user is more likely to identify with the results as they are based on his/her own assumptions. The possibility to derive concrete underpinnings for policy analysis has not substantially improved.

3.1.3. Tool to Assess Regional and Global Environmental and Health Targets for Sustainability (TARGETS)

TARGETS is also a global system dynamics model (Rotmans and de Vries 1997).[2] As the title suggests, TARGETS puts its emphasis on the assessment of long-run environmental developments, taking into account biophysical, social and economic processes. Estimates of impacts on ecosystems and humans are the central results of the models. Like World 3, the model is restricted to the global level, with no regional disaggregation. Scenarios run from the year 1900 to 2100.

The explicit introduction of cause-effect chains differentiates the model from previous system dynamics models described in this overview. For this purpose the pressure-state-response approach developed by the OECD (1993) has been refined. The state part is split into state and impact to allow for a more detailed distinction between changes in the various functions of (sub)systems and the changes in the state of the system.

TARGETS consists of five sub-models and an economic scenario generator, which are integrated and interlinked with each other. The five highly aggregated sub-models are meta-models of expert models in the respective fields. The structures of the expert models have been simplified in order to make integration between the models possible. The result is a set of meta-models, that capture the behaviour of their "expert-parents" quite well, without describing the field concerned in infeasible detail.

[1] International Futures is available for downloading at http://w3.arizona.edu/~polisci/ifs/.
[2] TARGETS is available on CD-Rom from the authors.

The sub-models cover the aspects of population and health, land and food, energy, water, and global bio-geo-chemical cycles.
The economic scenario generator is a relatively primitive tool to feed exogenous GWP (Gross World Product) trajectories into the model. TARGETS has a unique way of dealing with uncertainty. The model uses a generic description of the users world view and management style in order to adjust the underlying assumptions to that persons probable convictions. The options offered for both choices are egalitarian, hierarchist and individualist. The choices made influence the way in which adjustment in behaviour, learning and other aspects takes its effect during the run of the model. The three categories are derived from cultural theory (Thompson, Ellis et al. 1990).

TARGETS focuses on the assessment of the environmental and health effects of sustainability. Within these fields there is interaction between the different sub-models. There is no further horizontal integration with other sectors. Within the coverage of the model, horizontal integration through the consequent application of the pressure-state-impact-response approach (PSIR), vertical integration within the domain of environmental assessment is rather advanced. On a European level, the model has little use for concrete policy analysis or advice other than to quantify the urge for a reduction in resource use and emissions.

3.1.4. Threshold 21 (T21)

Threshold 21 (T21) is a system dynamics model that covers the domains of the three previous models[3] . It combines the social, economic and environmental domains in an extremely transparent model. Within the structure of the model, market and government behaviour plays a key role, which allows users to easily adjust political strategies and view its impacts. These adjustments can be introduced in the form of changes in the otherwise static parameters that quantify the relationship between the different stock and flow variables. The model is generally adjusted for use on the national level and has already been used in a number of developing countries, as well as in Italy and the US. Global influences in issues such as GHG emissions are also included in T21. The level of detail in the output variables is impressive. However, this level of detail is not applied in the description of the cause-effect chains.

Horizontal integration in T21 is very elaborate. All the sectors directly influence each other through a plethora of feedback cycles and other linkages. Vertical integration is also implemented, but less detailed. The high accessibility of the model and the ease with which every link can be adjusted allows the fast analysis of a large number of different policy options under changing assumptions. One should, however take care that the model is calibrated only for a given reference data set. Playing with the model in itself does not provide substantive input for policy analysis, but communicates a feeling for the complexity and integrated nature of sustainable development.

[3] A demo-version of Polestar is available for download at www.tellus.org.

3.1.5. POLESTAR

Polestar is an integrated accounting framework developed by the SEI Boston Center (SEI Boston Center 1999).[4] Its best known application has been in conjunction with the Global Scenarios Group (Gallopin, Hammond et al. 1997). The backbone of the model is an extensive data set containing a wide range of social, economic and environmental variables. Some political and cultural variables are also included. Base year data is available for the year 1995. In a stepwise procedure the user can introduce assumptions from other studies and/or models and check these against the values of indicators of sustainable development for future years. The first step of the scenario building process contains the external development of scenarios for population change and economic development. Based on these scenarios, the model calculates the consequences for the environment and world resource availability based on standard parameters. Societal responses to certain developments can be introduced externally to explore a set of different pathways. The geographical focus of the model is rather flexible; it has been used from the very local to the very global level. Most recently, it has been applied at the level of 22 regions (Raskin, 2000). There is also the option to introduce new variables or to ignore existing ones. These options make Polestar a very flexible accounting tool (SEI Boston Center 1999).

Polestar exhibits a very low level of horizontal and vertical integration. Horizontal integration is restricted to a minimum of strictly necessary interactions, vertical integration is lacking on the whole. This limits the possibility to derive integrated and balanced answers for issues related to political decision making from the model. For the analysis of very specific rather short-term questions the model provides a useful first insight.

3.2. Environment-Energy Models

In this second group of models, the emphasis is placed on the relationships between energy and the environment. Many of these grew out of the energy models that were first developed in the wake of the 1970s oil shocks.

In a recent study, the IPCC (2000) made use of six of these models for developing new GHG emission scenarios. The IPCC considered the selected models as representative of current modelling techniques in this field. The six models are: The *Asian Pacific Integrated Model* (AIM), the *Atmospheric Stabilization Framework* (ASF), the *Integrated Model to Assess the Greenhouse Effect* (IMAGE), the *Multiregional Approach for Resource and Industry Allocation* (MARIA), the *Model for Energy Supply Strategy Alternatives and their General Environmental Impact* (MESSAGE) and the *Mini-Climate Assessment Model* (MiniCAM).[5] ASF, MARIA, MESSAGE, and MiniCAM are discussed in this section; AIM and IMAGE are described in the following section.

---

[4] A demo-version of Polestar is available for download at www.tellus.org.

[5] The following descriptions are based on IPCC (2000), App. IV and additional information available at the indicated websites unless otherwise noted.

3.2.1. Atmospheric Stabilization Framework (ASF)

ASF is an accounting framework covering the fields of energy, agriculture, deforestation, GHG emissions and an atmospheric model. Emission estimates are provided for nine world regions. ASF consists of a cluster of five sub-models. The energy model contains four sectors: residential, commercial, industrial and transportation. Equilibrium for the energy market is based on prices, which differ by region, type of energy and conversion costs. An agricultural model is linked to a deforestation model. Interactively, these two models calculate the agricultural production and the area of deforestation based on population and GNP developments. The emissions model uses the output of the three previous models to estimate GHG emissions. The atmospheric model uses this as an input to calculate the effects with respect to temperature and CO_2 concentration.

Integration in the ASF model is limited horizontally by the narrow focus of the model. Within this focus the level of integration between the different modules is actually quite high. The model does not represent any socio-economic factors. The horizontal integration of economic and environmental issues is very limited. Vertically, there are some gaps in the PSIR causal chain, especially concerning responses. The possibility to derive substantial input for policy analysis from the model is limited by these factors.

3.2.2. Multiregional Approach for Resource and Industry Allocation (MARIA)

MARIA is an inter-temporal non-linear optimisation model focusing on the assessment of technology and policy options available to address global warming. The model is based on the DICE model (Nordhaus 1994) and covers aspects of economics (consumption and trade), land use, natural resources, and energy. MARIA divides the world into eleven regions. The model requires the exogenous input of population and potential per capita GDP growth rates. The simulation of economic activities is then modelled under the assumption of constant substitution elasticities. The analysis of emissions is limited to global carbon emissions.

The level of horizontal integration of the model is limited by its narrow focus. Vertical integration is limited by the exogeneity of key economic indicators. With respect to policy relevance there is a lack of detail concerning the policy options available. The effects of specific policy choices are hard to evaluate. The strength of the model lies in the general macro-level evaluation of various consistent options.

3.2.3. Model for Energy Supply Strategy Alternatives and their General Environmental Impact (MESSAGE)

MESSAGE is a dynamic linear programming model. It is a sub-model of the IIASA integrated modelling framework and is generally used in a tandem with the MACRO macro-economic model.[6] The two models are a combination of top-down and bottom-up modelling techniques. MACRO (top-down) calculates the maximal utility of a representative consumer for each region and its relations with macro-economic development and energy use. MESSAGE (bottom-up) calculates energy demand, supply and emission patterns on the basis of economic input. The model requires the exogenous input of population and GNP scenarios on a regional level. From this, the *Scenario Generator* (SG) derives scenarios for future energy demand that are consistent with empirical results derived from historical data stored within the SG. The model divides the world into eleven regions. In the IIASA integrated modelling framework MESSAGE is also used in combination with RAINS, MAGICC and other specific models.

The MESSAGE-MACRO tandem lacks vertical as well as horizontal integration. Horizontal integration can be improved through the interaction with other models, but is then limited to the highest scale level and does not directly affect sub-sections of the model. Vertical integration is also a problem because effect chains have to be limited to rather general descriptions. As such the model is more a tool for the analysis of the consistency of given scenarios rather than a relevant basis for political decision-making.

3.2.4. Mini-Climate Assessment Model (MiniCAM)

MiniCAM is an integrated model developed at Battelle Pacific Northwest Laboratories.[7] The model consists of a combination of the Edmonds-Reilly-Barnes (ERB) energy model and the Model for the Assessment of Greenhouse-Gas Induced Climate Change (MAGICC) atmospheric global climate model. The ERB model describes long-term trends in economic output, energy use, and greenhouse gas emissions for nine world regions through detailed sub-modules representing energy resources, primary energy supply and demand, energy markets including world trade and electricity conversion, and fuel-specific emissions factors. An exogenous economic scenario is fed into the ERB model, which calculates the energy supply, demand, balance and resulting GHG emissions. This output is used as input into MAGICC where the gas-cycle module feeds into the climate module and the sea-level module. The atmospheric composition, radiative forcing, mean global temperature rise and sea level rise are then fed back into the ERB model. Some applications use the MERGE model to translate the output from MAGICC into input for the adjustment of the economic scenarios in the form of market and non-market damages using simple damage functions.

[6] Further information about the IIASA integrated modelling framework and MESSAGE is available at http://www.iiasa.ac.at/Research/ECS/.
[7] Further information about MiniCAM is available at http://sedac.ciesin.org/mva/.

A simple graphical spreadsheet-based interface allows the fast exploration of different scenario runs. The geographical focus of the model output distinguishes fourteen regions.

MiniCAM exhibits low levels of horizontal and vertical integration. Horizontally, the economic and environmental issues addressed are very limited. There is a complete lack of socio-cultural aspects. Vertically, there are no feedback mechanisms other than the final link of output to input, which is one of the weakest links of the model. A full-feedback version including the link between climate change and the economy is under development. The purpose of MiniCAM lies more with the quick exploration of a set of possibilities rather than a detailed description of the domains involved.

3.3. Global Change Models

The models in this group are similar to the previous in that the emphasis is placed on the relationships between energy and the environment. However, reflecting a trend in the past five years, the developers of these models have widened their scope to include other aspects than just the energy-environment links. For this reason, we have chosen to characterise them as global change models.

This section focuses on the IMAGE and AIM models. Conceivably, the Global Change Assessment Model (GCAM) could be counted in the same category. However, not enough and recent information could be found. GCAM was developed at the U.S. Pacific Northwest Laboratory (Edmonds, Pitcher et al. 1993; summary in Rotmans and Dowlatabadi 1998).

3.3.1. Integrated model to Assess the Global Environment (IMAGE)

IMAGE was developed at RIVM originally in order to assess the impact of anthropocentric climate change (Rotmans 1990)[8]. Later it was expanded to a more comprehensive coverage of global change issues, reflected in the current name of the model. The almost finished IMAGE 2.2 divides the world into nineteen regions (including Antarctica and Greenland), in order to match the regional grouping in the Global Environment Outlook. It is an integrated model consisting of three sub-models. The Energy-Industry System (EIS) calculates greenhouse gas emissions in each of these regions. Emissions from the energy sector are modelled with the TIMER simulation model, a system dynamics model for energy related information in 5 sectors of the economy. The Terrestrial Environment System (TES) simulates land-use and land-cover change and their consequences for biophysical processes. The Atmosphere-Ocean System (AOS) calculates the behaviour of greenhouse gases in the atmosphere and its effects on temperature and precipitation patterns.

[8] Further information about IMAGE is available at http://www.rivm.nl/image/.

Economic data, technological change, demographic developments and control policies are exogenous inputs into the model. Simulations run up to the year 2100; the historical database goes back to 1890. The geographical focus of the model ranges from a 0.5 degree x 0.5 degree latitude-longitude grid to world regional level. An overview of applications of IMAGE 2.1 can be found in Alcamo (1994) and Alcamo, Leemans and Kreileman (1998).

A special visualisation environment (M) supports a user support system containing results from a large set of scenarios off-line, as well as light meta-models for interactive use. Associated with but not integrated in IMAGE are CPB’s Worldscan (macro-economic projections, see section 3.4), PHOENIX (demography and population health), and EDGAR (historical emissions and related statistics on grid basis). Applications of IMAGE have initiated development of modules on water stress at drainage-basin level (now the Watergap model maintained at Kassel University), vulnerability to land degradation, and changes in an ecological capital index for terrestrial biodiversity.

IMAGE exhibits a lack of horizontal integration from the perspective of general sustainability analysis. However, within its narrow focus horizontal integration is exemplary. Horizontal integration is introduced at all computing levels of the model and not restricted to higher domains. There are a multitude of important feedbacks between models in the sub-systems, and between sub-systems. Vertical integration is more limited as there is a lack of feedback from the outcome of the model and the input. Only the output of land-use and climate data is used as input for the next round of calculations without affecting other exogenous inputs.

3.3.2 Asian Pacific Integrated Model (AIM)

AIM is a general equilibrium model developed by the National Institute of Environmental Studies in Japan.[9] The model focuses on the assessment of greenhouse gas emissions. It calculates the level and type of energy use on the basis of external socio-economic scenarios. The model consists of six sub-models. The *Socio-Economic Scenarios* sub-model is an input module for the external scenarios. It requires the exogenous input of GDP, population, resource base and lifestyle developments. The *Bottom-up Model* provides information about sectoral energy and resource efficiency. The *Energy-Economic Model* calculates a market equilibrium for energy markets. It does so for 17 world regions. The *Land Equilibrium Model* calculates the land use based on biomass energy demand, food consumption patterns and technological change. From the latter two sub-models GHG emissions are calculated which are in turn fed into the AIM *Climate Model* and subsequently the AIM *Impact Model*. Outputs from the latter model can be used to provide feedback concerning the socio-economic scenarios.

[9] More information about AIM is available at http://www-cger.nies.go.jp/ipcc/aim/

Horizontal integration in AIM is limited by the extremely narrow focus of the model. The only interaction between the socio-economic module and the environmental module concerns climate related land-use patterns. AIM lacks horizontal integration with other aspects of environmental sustainability. Vertically, there is only a limited feedback mechanism between the environmental impact calculation and the socio-economic scenarios, which brakes the pressure-state-response cycle. The exogenous treatment of socio-economic developments limits the level of vertical integration. The geographical focus of the model is primarily meant to cover global issues rather than issues relevant on a regional scale. A very detailed version of the model exists for the Asian Pacific region where the model distinguishes 3200 regions.

3.4. Economic-Environmental Models

In the this fourth group of models, the focus is clearly on the economic system. With suitable modifications, however, they are able to shed some light on environmental consequences.

3.4.1. JOBS

JOBS is a rather simple simulation model developed by the OECD. It solves a sequence of static economic equilibria. It does so under the assumptions of national income accounting, where aggregate investment equals aggregate savings for each time step. Substitution elasticities are held constant throughout a model run. The time horizon of the model is limited to 2020. JOBS is a global model that divides the world into ten regions. The model uses the GTAP data base (see below) as a source.
The level of horizontal integration of the model is limited to a selected few ecological and economic indicators. The level of vertical integration is limited by the non-dynamic modelling technique. The breadth and width of the model are more limited than with the other economic-environmental models. The lack of accessibility to the model is a major drawback. It limits the possibilities of analysis to the simulation of isolated shocks and their effects in a very limited domain.

3.4.2. Global Trade Analysis Project (GTAP)

GTAP refers to both an extensive economic database as well as a general equilibrium model of the world economy (Hertel and Tsigas 1997). The model represents the developments and interactions between 50 sectors in 45 regions on the basis of the assumptions of perfect competition and constant returns to scale. It is a sophisticated tool for the simulation of global economic and trade patterns, but does not address environmental and socio-cultural aspects.

Within its domain, GTAP exhibits a strong degree of vertical integration. Horizontal integration is limited to the trade sector, however. Other economic perspectives of sustainability as well as environmental or socio-cultural aspects are lacking. However, GTAP might become relevant in the context of a modelling system for sustainability as a provider of economic scenarios, an aspect that has been rather neglected in many of the other models described here. In its own right the domain of the model is insufficient to address questions of sustainability.

The GTAP database covers a wide range of variables and is constantly extended according to the needs expressed by its users. Not all of the variables in the database are used in GTAP as the database is open to all users and has been used in other models as well.

3.4.3. World model for SCenario ANalysis (WorldScan)

WorldScan is an applied general equilibrium model (CPB 1999). The underlying assumptions of the model are based on neo-classical economic theory. Although it has a primary emphasis on economics, the model is also suitable for a wide range of applications in the fields of energy, transport, trade and environmental policy. For example, it has been used in conjunction with the IMAGE model for developing climate scenarios. Another recent application of WorldScan has been to analyse policy strategies for the implementation of the Kyoto protocol on climate change. For this purpose, the trade module of the model has been adjusted to incorporate the trade of different kinds of permits and the Clean Development Mechanism (CDM).[10] With respect to the environmental effects of globalisation and the related increase of transport, four scenarios for the transition towards the year 2020 and in some respects towards 2050 have been developed using WorldScan. The assumptions underlying these four quantitative scenarios are derived from the qualitative scenarios developed by Van Veen-Groot and Nijkamp for the GITAGE project. Future work with WorldScan is planned to be more explicit with respect to the effects of trade, consumption and production on international transport and the related environmental costs.

WorldScan divides the world into twelve regions. The economy is divided into 11 sectors with differing factor requirements. These are rather crudely defined to allow major shifts in production within sectors. Primary inputs in all sectors are low-skilled labour, high-skilled labour, capital and a fixed factor. Economic growth is predicted in line with neo-classical growth models on the basis of physical capital, labour and technology. Technology is allowed to differ between regions and can easily be adopted by developing countries. Labour is divided into low-skilled labour and high-skilled labour and in developing countries a fraction of the labour force works in low-productivity sectors, i.e. the subsistence sectors. Trade is modelled in such a way as to avoid abrupt specialisation patterns. Consumption is allocated over time, categories and regions. Consumption patterns generally tend to converge with OECD preferences and are assumed to change with changes in GDP per capita.

Richer societies spend relatively less on agricultural products and relatively more on services than poorer societies. These allocation decisions influence the amount of transport required and thus the level of emissions.

[10] A comprehensive overview of WorldScan applications can be found in WorldScan (CPB 1999) on page 128.

WorldScan is useful with respect to the analysis of global economic trends. Horizontal integration with environmental, institutional and socio-cultural factors is lacking. Vertical integration is insufficient due to a lack of feedback mechanisms. The lack of integration makes it difficult to derive balanced policy advice from WorldScan. For the economic domain, specific policy advice would be improved through a better access to different scenario runs, which would allow the analysis of the effects of different policy strategies concerning a specific question.

3.4.4. World Model

The World Model is based on the familiar, static input-output model, which has been extended by the explicit representation of investment and international exchanges. The World Model was designed by Wassily Leontief, and its initial implementation is described in Leontief, Carter and Petri (1997). The model has evolved over time into a dynamic form. A more recent version is described by Duchin and Lange (1994).

The model divides the world into sixteen geographic regions, each described in terms of about fifty interacting sectors. Regions are linked within each time period by the trade of commodities and flows of capital and economic aid; they are linked over the period 1980-2020 by the accumulation of capital and international debt or credit. Use of energy and materials is directly represented, and flows of pollutants have been incorporated. Public and private consumption and sector-level investment are also represented, both in terms of detailed goods and services and in the aggregate. The output of agricultural products and of minerals and emissions of pollutants are measured in physical units; most other quantities are measured in constant U.S. prices. It is highly integrated from an economic perspective; the environmental aspects are basically add-ons.

Duchin and Lange (1994) used the World Model to evaluate the Brundtland proposition that both economic and environmental objectives can be achieved if reasonable choices are made regarding technology and social organisation. For this exercise, they present both a Business as Usual scenario and a scenario based upon the recommendations of the report of the World Commission on Environment and Development – the Brundtland Report.

3.4.5. *Future Agricultural Resource Model (FARM)*[11]

FARM was developed by the U.S. Department of Agriculture in order to evaluate the effects of various global change phenomena on long-term agricultural and environmental sustainability (Darwin 1999). The modelling system links a GIS component, which simulates climate-induced changes in land and water resources, with a Computable General Equilibrium model, which models the economy. It divides the world into 12 production regions, which are aggregated into 8 economic regions. The GIS component having a spatial resolution of 0.5° x 0.5° latitude by longitude.

Because of its emphasis on agriculture, FARM has relatively more detail on the agricultural sector of the economy and less on other sectors than the other models in this category. The model currently exists in a static form, but a dynamic version is being developed.

4. Conclusions

From this overview it should be clear that there does not currently exist an 'ideal' global model for the development of scenarios of environmentally sustainable development. Nor is it realistic to expect such a model to exist. What is an appropriate model will always depend on the purpose of the particular study and the perspective from which it is approached. From a practical perspective, it will also depend upon available resources, i.e. time, money, and skills.

However, we can point to specific insights that can help us to think about what improvements can be made to existing models and to make practical choices about which models to use for particular purposes. For the purpose of exploring scenarios of environmentally sustainable development, the following list summarises our basic thoughts:

- *Models need to have greater regional specificity, i.e. be more spatially explicit. This is necessary for looking beyond averages and unveiling more localised, but significant patterns.*
- *Understanding interregional links will be more important as the world becomes increasingly more integrated.*
- *The demographic components of most models are weak, specifically the feedback from economic and environmental changes on fertility and mortality.*
- *The institutional components of most models are weak. This reflects a certain lack of understanding of the underlying processes among those building the models and a general lack of understanding of whether and how it is possible to model these processes.*

[11] More detail on FARM can be found at http://www.ers.usda.gov:80/briefing/globalresources/cceqa3.htm

- *Some parts of the environment almost systematically lacking, e.g. marine, coastal, and urban environments (with the notable exception of urban air pollution). Our representation of the parts that are included suffers from an incomplete understanding of the underlying processes.*
- *Among existing world-wide environmental modelling efforts, the climate community is ahead of most others. They have had to address important linkages between environmental and social systems on a global and long-term time scale. This has recently started to push them in the direction of treating climate issues from a broader sustainable development perspective.*
- *At this point in time, integrated analysis is still something that is achieved by a team thinking holistically, more than through a holistic model.*

The last comment above points to an important conclusion related to the use of models in developing and analysing scenarios. Models should be only one tool in this process, their main role being to generate and organise quantitative projections. In particular, descriptive narratives are powerful tools to convey the broader significance of scenarios. Among other things, narratives bring in qualitative elements that quantitative models cannot handle and help to understand that different scenarios constitute very different worlds and, therefore, strategies that will work in one future world may very well be out of place in another. Moreover, narratives allow a better understanding how coping capacity and, thereby, vulnerability changes in different scenarios.

Returning to practical choices, what can we conclude about the use of existing models in combination with descriptive narratives? In order to capture and make explicit the assumptions of a narrative, it is probably best to use a model that is fairly broad at the head of the causality chain and easy to use, e.g. Polestar, Threshold 21, or the International Futures model. However, these tend to be less suited for capturing the complex interactions of social and environmental systems and tracing assumptions to spatially explicit impacts. For this, we would recommend turning to the more detailed and less sector specific Integrated Assessment Models, such as IMAGE. For the near future, and perhaps even longer, the generation and evaluation of scenarios of environmentally sustainable development will require this form of hybrid approach.

Table I: Models

Model	Analytical Technique	Horizontal Integration[a]	Vertical Integration[b]	Key References	Key Existing Scenarios	Ease of Use by Non-Developers[c]
World 3	System Dynamics	Present	Limited	(Meadows, Meadows et al. 1972; Meadows, Meadows et al. 1991)	13 explorative scenarios	Limited
Int. Futures	System Dynamics	Advanced	Limited	(Hughes 1999)	base scenario	Very high
TARGETS	System Dynamics	Present	Present	(Rotmans and de Vries 1997)	reference case with varieties	High
Threshold 21	System Dynamics	Advanced	Present		several explorative scenarios	Very high
Polestar	Accounting	Present	Limited	(Raskin, Heaps et al. 1995; SEI Boston Center 1999)	two reference scenarios	Very high
ASF	Accounting	Limited	Advanced	(Lashof and Tirpak 1989; Sankovski, Barbour et al. 2000)	Four scenarios	Limited
MESSAGE-MACRO	Dynamic linear programming	Limited	Limited	(Messner and Strubegger 1995; Riahi and Roehrl 2000)	Nine scenarios	Limited
MARIA	Non-linear optimisation	Limited	Limited	(Mori and Takahashi 1999)	Five scenarios	Limited
MiniCAM	Partial Equilibrium	Limited	Limited	(Edmonds, Wise et al. 1996)	11 scenarios	High
AIM	General Equilibrium	Limited	Limited	(Morita, Matsuoka et al. 1994)	Seven scenarios	Limited
IMAGE	System Dynamics	Limited	Advanced	(Rotmans 1990) (Alcamo 1994)	Four scenarios	Limited
JOBS	Static equilibrium	Limited	Limited		Baseline and several explorative scenarios	Very limited
GTAP	General Equilibrium	Limited	Advanced	(Hertel and Tsigas 1997)	Several explorative scenarios	High
WorldScan	Applied General Equilibrium	Limited	Limited	(CPB 1999)	Four reference scenarios	Very limited
World Model	Dynamic Input-Output	Present	Present	(Duchin and Lange 1994; Leontief, Carter et al. 1997)	BAU and WCED scenarios	Very limited
FARM	GIS + Computable General Equilibrium	Limited	Present	(Darwin 1999)		Very limited

[a] *Very limited* indicates a lack of integration between different domains as well as within a domain. *Limited* refers to a lack in one of the two. *Present* indicates several domains are covered in an integrated manner. *Advanced* is used for models that include environmental, economic and socio-cultural aspects.

[b] *Limited* refers to models where several parts of the cause-effect chains modelled are missing or not explicit. *Present* refers to models where the causal chain is modelled, but there is a lack of feedback from the output of the model to the input. The term *advanced* is reserved for models where this final loop is also closed.

[c] *Very limited* refers to models that are not accessible to non-developers. *Limited* refers to models where the model can be used by outsiders after considerable training. The term *high* classifies models that are easy to grasp and use for non-developers. The term *very high* is reserved for models that exhibit an interface and a level transparency that makes it very easy for non-developers to apply the model and to adjust it to their own needs.

Bibliography

Alcamo, J., Ed. (1994). IMAGE 2.0: Integrated Modeling of Global Climate Change. Dordrecht, The Netherlands, Kluwer Academic Publishers.

Alcamo, J., E. Kreileman, et al. (1998). Global modelling of environmental change: on overview of IMAGE 2.1. Global change scenarios of the 21st century. Results from the IMAGE 2.1 model. J. Alcamo, R. Leemans and E. Kreileman. London, Elseviers Science: 3-94.

Alcamo, J., R. Leemans, et al., Eds. (1998). Global change scenarios of the 21st century. Results from the IMAGE 2.1 model. London, Elseviers Science.

CPB (1999). Globalization, International Transport and the Global Environment: Four quantitative scenarios. The Hague, The Netherlands, CPB.

CPB (1999). WorldScan: the Core version. The Hague, The Netherlands, CPB.

Darwin, R. F. (1999). “A FARMer's View of the Ricardian Approach to Measuring the Effects of Climatic Change on Agriculture.” Climatic Change **41**(3-4): 371-411.

de Vries, H. J. M. and M. A. Janssen (1997). Global energy futures: an integrated perspective with the TIME-model. Bilthoven, RIVM.

den Elzen, M. G. J. (1998). The meta-IMAGE 2.1 model: an interactive tool to assess global climate change. Bilthoven, RIVM.

Duchin, F. and G.-M. Lange (1994). The Future of the Environment: Ecological Economics & Technological Change. New York, Oxford University Press.

Edmonds, J. A., H. Pitcher, et al. (1993). Design for the Global Change Assesment Model. Laxenburg, Austria, IIASA.

Edmonds, J. M., M. Wise, et al. (1996). “An integrated assessment of climate change and the accelerated introduction of advanced energy technologies: An application of MiniCAM 1.0.” Mitigation and Adaptation Strategies for Global Change(1(4)): 311-339.

Gallopin, G., A. Hammond, et al. (1997). Branch Points: Global Scenarios and Human Choice - A Resource Paper of the Global Scenario Group, Stockholm Environment Institute, Sweden.

Hertel, T. W. and M. E. Tsigas (1997). Structure of GTAP. Global Trade Analysis: Modeling and Applications. T. W. Hertel. Cambridge, Cambridge University Press.

Hughes, B. B. (1999). International Futures: Choices in the face of uncertainty. Oxford, UK, Westview Press.

IPCC, Ed. (2000). Emission Scenarios. Cambridge, Cambridge University Press.

Lashof, D. A. and D. A. Tirpak (1989). Policy Options for Stabilising Global Climate. Washington, USA, US Environmental Protection Agency.

Leemans, R., J. Bakkes, et al. (1999). History, current activities and future direction of the IMAGE-2 project: The briefing book for the 3rd meeting of the Ad-hoc IMAGE Advisory Board. Bilthoven, RIVM.

Leemans, R. and E. Kreileman (1999). The IMAGE-2 Model: Policy and Scientific Analysis. Bilthoven, RIVM.

Leemans, R., E. Kreileman, et al. (1998). The IMAGE User Support System: Global Change Scenarios from IMAGE 2.1. Bilthoven, RIVM.

Leemans, R. and G. J. van den Born (1994). “Determining the potential global distribution of natural vegetation, crops and agricultural productivity.” Water, Air and Soil Pollution **76**: 133-161.

Leontief, W., A. Carter, et al. (1997). Future of the World Economy. New York, Oxford University Press.

Meadows, D. H., D. L. Meadows, et al. (1991). Beyond the Limits. London, UK, Earthscan Publications Ltd.

Meadows, D. H., D. L. Meadows, et al. (1972). The Limits to Growth. New York, USA, Universe Books.
Meadows, D. L., D. H. Meadows, et al. (1972). Dynamics of Growth in a Finite World. Cambridge, UK, Wright-Allen Press.
Messner, S. and M. Strubegger (1995). User's Guide for MESSAGE III. Laxenburg, Austria, IIASA.
Mori, S. and M. Takahashi (1999). "An integrated assessment model for the evaluation of new energy technologies and food productivity." International Journal of Global Energy Issues **11**(1-4): 1-18.
Morita, T., Y. Matsuoka, et al. (1994). Global Carbon Dioxide Emission Scenarios and Their Basic Assumptions: 1994 Survey. Tsukuba, Japan, Center for Global Environmental Research.
Nordhaus, W. D. (1994). Managing the Global Commons: The Economics of Climate Change. Cambridge, USA, MIT Press.
OECD (1993). Environmental Indicators: Basic Concepts and Terminology. Indicators for use in environmental performance reviews, Paris, France.
Raskin, P., C. Heaps, et al. (1995). Polestar system manual. Stockholm, Stockholm Environment Institute.
Riahi, K. and R. A. Roehrl (2000). "Greenhouse gas emissions in a dynamics as usual scenarioof economic and energy development." Technological Forecasting & Social Change **63**(2-3).
Rotmans, J. (1990). IMAGE: An Integrated Model to Assess the Greenhouse Effect. Dordrecht, The Netherlands, Kluwer Academics.
Rotmans, J., H. de Boois, et al. (1990). "An integrated model for the assessment of the greenhouse effect: the Dutch approach." Climatic Change **16**: 331-356.
Rotmans, J. and H. J. M. de Vries, Eds. (1997). Perspectives on Global Change: The TARGETS approach. Cambridge, UK, Cambridge University Press.
Rotmans, J. and H. Dowlatabadi (1998). Integrated Assessment Modeling. Human Choices & Climate Change: Tools for Policy Analysis. S. Rayner and E. L. Malone. Columbus, OH, Batelle Press. **3:** 291-377.
Sankovski, A., W. Barbour, et al. (2000). "Quantification of the IS99 emission scenario storylines using the atmospheric stabilization framework (ASF)." Technological Forecasting & Social Change **63**(2-3).
SEI Boston Center (1999). PoleStar 2000, SEI Boston Center, Tellus.
Swart, R., M. M. Berk, et al. (1998). The safe landing analysis: risks and trade-offs in climate change. Global change scenarios of the 21st century. Results from the IMAGE 2.1 model. J. Alcamo, R. Leemans and E. Kreileman. London, Elseviers Science**:** 193-218.
Thompson, M., R. Ellis, et al. (1990). Cultural Theory. Boulder, USA, Westview Press.
van Asselt, M. B. A., S. C. H. Greeuw, et al. (2000). Cloudy crystal balls: An assessment of recent European and global scenario studies and models. Maastricht, The Netherlands, ICIS, Maastricht University.
van Daalen, C. E., W. A. H. Thissen, et al. (1998). Experiences with a dialogue between policy makers and global modellers. Global change scenarios of the 21st century. Results from the IMAGE 2.1 model. J. Alcamo, R. Leemans and E. Kreileman. London, Elseviers Science**:** 267-285.

Appendix I: Model Descriptions from RIVM prepared for OECD

A.I. 1 Asian-Pacific Integrated Model (AIM)

Source of prefilled information: March 1997 set of documentation (83 pp)

		Remarks
IDENTIFICATION		
What is the name and version of the model?	Asian-Pacific Integrated Model (AIM)	No indication of versions
SUMMARY DESCRIPTION		See figures AI.1-AI.2.
GENERAL		
<u>Approach</u>		
What is the main objective for which the model is being developed/recently used?	Climate change. However, the model structure allows in theory much broader evaluations.	This can be seen from an analogy with the IMAGE model, which has similar features.
If the model is part of a larger set-up, please describe.	National modules may be different from each other	
Is the model dynamic or static?	dynamic	
Is this an optimisation or simulation model?	simulation	
If it is an optimisation model, what is being optimised? And under which constrains?		
<u>Time</u>		
What is the temporal resolution of the model? • Social & economic parts • Environmental parts	Presumably five-year intervals or multiples of five	
For what period can the model be used?	Up to 2100	
Which year or period has been used for the model calibration?	1990	And periods for certain issues and areas, e.g, emission of sulphur oxides in Japan from 1960.
<u>Space</u>		
What is the spatial resolution of the model? • Social & economic parts • Environmental parts	Emission model combines 19 region world equilibrium model and bottom-up country models Environmental impacts calculated at very fine grids; sometimes down to 5x5 minute grid. The model database distinguishes 3200 ‘regions’in Asia Pacific.	

SOCIAL and ECONOMIC PARTS		
Production		
What type of production function is being used?	n.a.	
What types of economic activities are modelled?	Somewhat dependent on the country module. The focus is squarely on energy end-use.	See figures AI.1-AI.2.
Is production of these sectors endogenous or exogenous?	Exogenous	
Which factors of production have been distinguished?	n.a.	
How does the model deal with technological changes?	Through the scenarios. See scheme of the technology selection module. Bottom-up country models allow for detailed modelling taking into account specific technologies.	
Consumption		
What types of consumer categories have been distinguished?	n.a.	
Is consumption endogenous or exogenous?	exogenous	
What types of consumption categories have been distinguished?	energy	
How does the model deal with changing consumption patterns?	Not clear from the documentation	
Population		
Does the model include parameters on population?	Includes standard population growth module (cohort model). Uses age structure, fertility, life expectancy, fertility, birth-sex ratio, migration.	On size and structure
Is population endogenous or exogenous?	exogenous	
How does the model deal with changes in population?	As driver	
Trade: Is trade between the regions modelled? If so, how?	Not clear from the documentation; probably not except for agricultural products	
Land Use		.
What types of land uses are being modelled?	not clear from the documentation	
Is land use endogenous or exogenous?	endogenous, at least partly	
Feedback Does the socio-economic module include feedback from the environmental module?	On land use patterns, climate-related	

ENVIRONMENTAL OUTPUTS		
Please list (a) key environment concerns addressed and for each: (b) the estimation principle and (c) an example indicator. (Preferably use attached list of concerns.)	Nearly all climate-related : emission of GHG; impact on agricultural suitability (change in potential productivity for staple crops) water resources (% change in flood discharge) vector borne diseases (increase in area with population at risk). Estimation combines mixture of bottom-up (technologies & specific factors) and top-down (e.g. convergence of carbon intensity) approaches. Acidification: estimates time to buffer depletion due to acid deposition	
Does the model include costs and financing of environmental protection? If so, how?	Not documented	
APPLICATION		
How is the model normally applied in assessments?	In the climate domain: compilation of global and regional emission scenarios for IPCC. Evaluation of alternative policy scenarios for environmental policy in the region (Eco Asia) Evaluation of policy instruments at national scale.	
Does normal application make use of a standard set of scenarios?	Typically uses an extreme large variety of scenarios	
What types of policies can be studied with the model?	• Energy-related • Taxation and subsidies (according to claim from documentation) • Specific technology packages	
OTHER ASPECTS		
Who owns the model?	National Institute for Environmental Studies, Tsukuba, Japan	
Who is entitled to use it?	Collaborative agreements exist with seven institutes in Asia, and with Pacific North West Laboratory and IIASA	
Has the model been reviewed? By whom and when?		
Please list key publications on the model.		

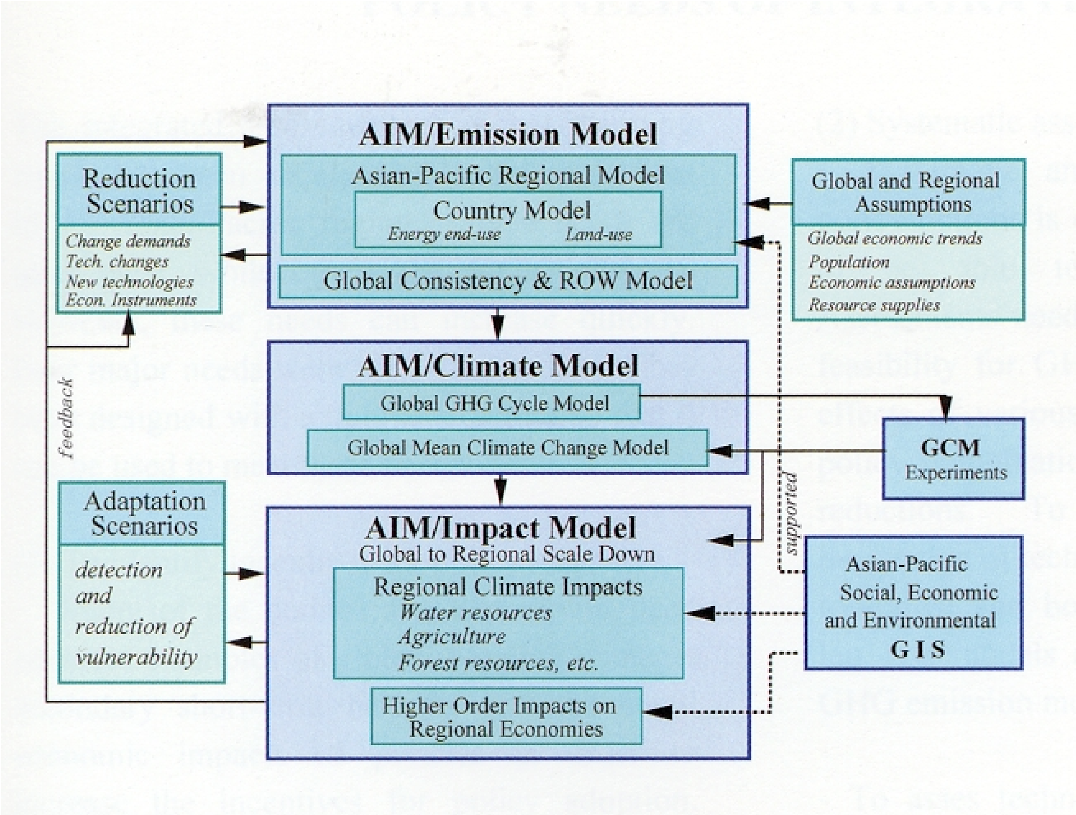

Figure AI.1: AIM Model Diagram

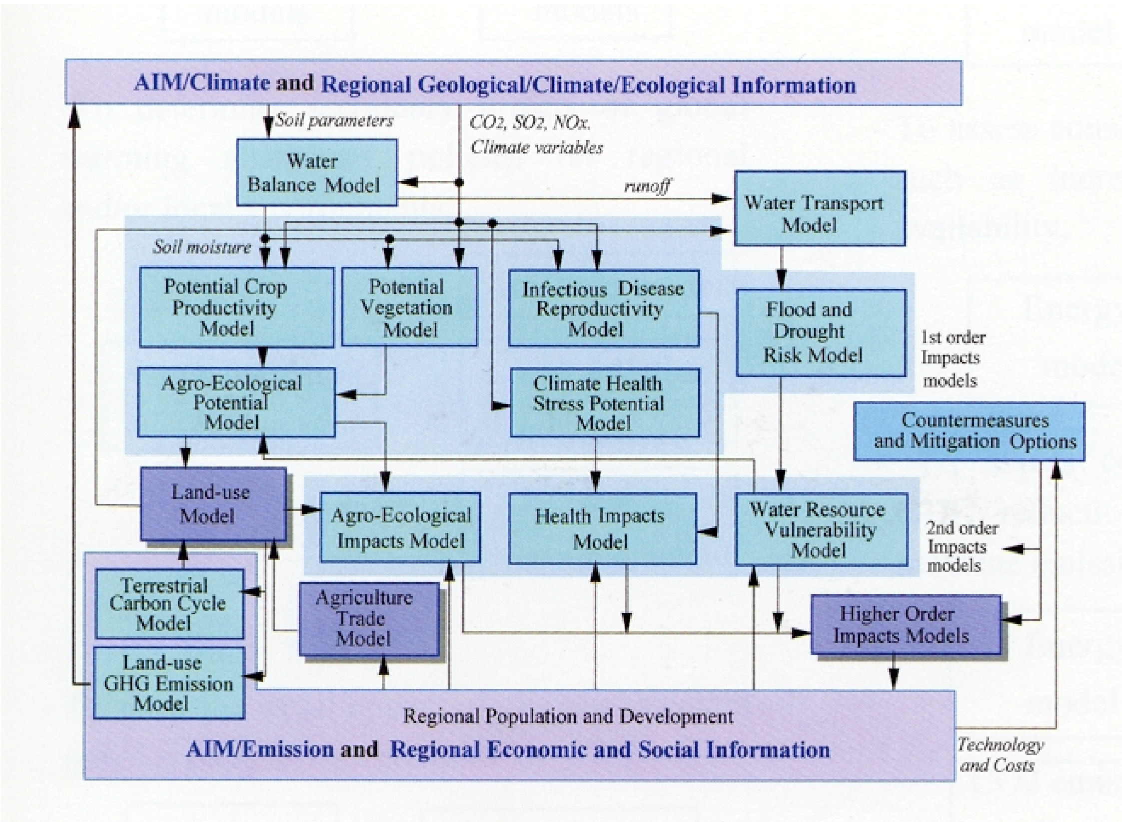

Figure AI.2: AIM Impact Model Diagram

A.I.2 POLESTAR

Source of prefilled information:
PoleStar System Manual for version 97.0. POLESTAR Series Report no. 2, July 1997

		Remarks
IDENTIFICATION		
What is the name and version of the model?	PoleStar version 97.0	
SUMMARY DESCRIPTION	Polestar is an adaptable accounting framework designed to assist the analyst engaged in sustainability studies.	See figure AI.3
GENERAL		
<u>Approach</u>		
What is the main objective for which the model is being developed/recently used?	High-level integration tool, to combine information from specialised analyses and models.	
If the model is part of a larger set-up, please describe.		
Is the model dynamic of static?	static	
Is this an optimisation or simulation model?	Neither; it is an accounting framework.	
If it is an optimisation model, what is being optimised? And under which constrains?		
<u>Time</u>		
What is the temporal resolution of the model? • Social & economic parts • Environmental parts	user-defined	
For what period can the model be used?	No intrinsic limitation, i.e. depends on the user's belief in future sectoral structure of the economy and efficiencies	
Which year or period has been used for the model calibration?	For world regions: up to 2050	
<u>Space</u>		
What is the spatial resolution of the model? • Social & economic parts • Environmental parts	This is a generic framework. No spatial subdivision prescribed; the analysts can set number and types of regions but has to supply the data..	

SOCIAL and ECONOMIC PARTS		
Production		
What type of production function is being used?	none	
What types of economic activities are modelled?	Households Transport Services Industry Energy conversion	
Is production of these sectors endogenous or exogenous?	exogenous	
Which factors of production have been distinguished?	n.a.	
How does the model deal with technological changes?	efficiency factors can be set	
Consumption		
What types of consumer categories have been distinguished?	Household sector only; could be subdivided by the analyst into subsectors and processes	
Is consumption endogenous or exogenous?	exogenous	
What types of consumption categories have been distinguished?	Resource use is modelled as environmental pressure; see below	
How does the model deal with changing consumption patterns?	By setting a 'scenario' (in fact a future situation of the accounts)	
Population		
Does the model include parameters on population?	Population growth can be set	
Is population endogenous or exogenous?	Exogenous	
How does the model deal with changes in population?	Exogenous; population size is one of the 'macro drivers' of environmental pressure	
Trade: Is trade between the regions modelled? If so, how?	Trade assumptions are implied the in self-sufficiency ratios of the spatial units according to the 'scenario'	
Land Use		
What types of land uses are being modelled?	default: cropland pastureland forest land built env. protected other	
Is land use endogenous or exogenous?	exogenous, within accounting framework	
Feedback Does the socio-economic module include feedback from the environmental module?	No	

ENVIRONMENTAL OUTPUTS		
Please list (a) key environment concerns addressed and for each: (b) the estimation principle and (c) an example indicator. (Preferably use attached list of concerns.)	<u>Resource pressure:</u> fossil fuel reserves hydropower& geothermal water stress cultivable land in use mineral reserves Environmental loads greenhouse gases ground-level pollutants ozone-depleting gases Water pollution Toxics Agricultural chemicals Municipal solid waste	
Does the model include costs and financing of environmental protection. If so, how?	No	
APPLICATION		
How is the model normally applied in assessments?	As a means to combine outcomes of specialised models and analyses	
Does normal application make use of a standard set of scenarios?	No	
What types of policies can be studied with the model?	Environment in a larger context	
OTHER ASPECTS		
Who owns the model?	The Stockholm Environment Institute contact: Stockholm Environment Institute – Boston Center	
Who is entitled to use it?	Can be ordered. Can be downloaded for review	http://www.seib.org
Has the model been reviewed? By whom and when?		
Please list key publications on the model.	See reference to manual, above. Reports on SEI-related studies using PoleStar are published in the POLESTAR report series.	

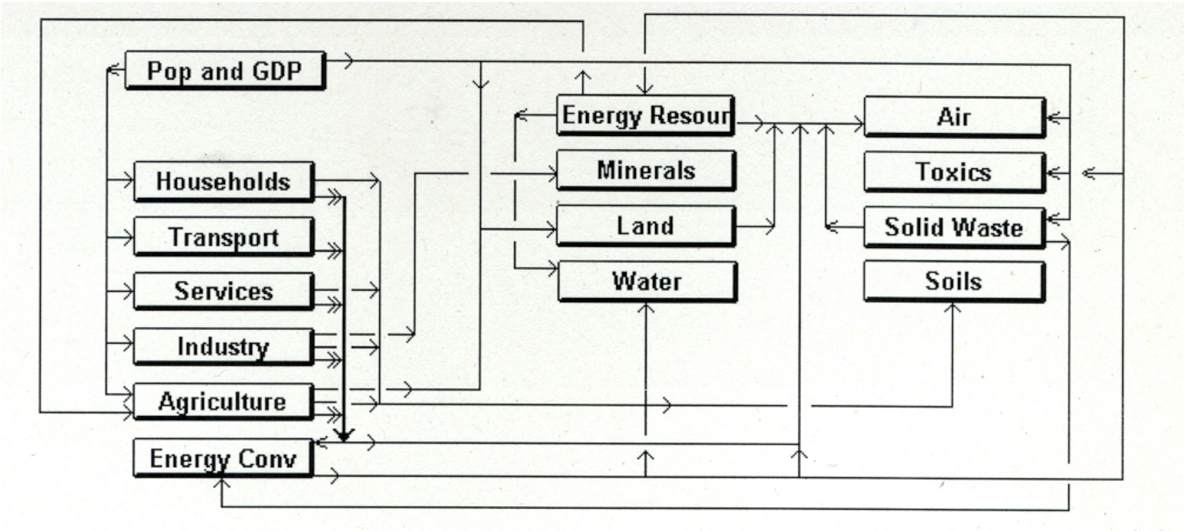

Figure A1.3: POLESTAR Model Diagram

A.I. 3 WORLD MODEL

Source of prefilled information:

Leontief, W., A. Carter and P. Petri, 1977, “Future of the World Economy”, New York, Oxford University Press
Duchin F. and G.-M. Lange, 1994, “The Future of the Environment: Ecological Economics & Technological Change,” New York, Oxford University Press

		Remarks
IDENTIFICATION		
What is the name and version of the model?	World Model	
SUMMARY DESCRIPTION		
The World Model is based on the familiar, static input-output model, which has been extended by the explicit representation of investment and international exchanges. The World Model was designed by Wassily Leontief, and its initial implementation is described in Leontief, Carter and Petri (1977). The current version of the model is implemented and described by Duchin and Lange (1994). The model divides the world into sixteen geographic regions, each described in terms of about fifty interacting sectors. Regions are linked within each time period by the trade of commodities and flows of capital and economic aid; they are linked over the period 1980-2020 by the accumulation of capital and international debt or credit. Use of energy and materials is directly represented, and flows of pollutants have been incorporated. Public and private consumption and sector-level investment are also represented, both in terms of detailed goods and services and in the aggregate. The output of agricultural products and of minerals and emissions of pollutants are measured in physical units; most other quantities are measured in constant U.S. prices.		
GENERAL		
Approach		
What is the main objective for which the model is being developed/recently used?	To evaluate the Brundtland proposition that both economic and environmental objectives can be achieved if reasonable choices are made regarding technology and social organisation.	
If the model is part of a larger set-up, please describe.	The model was designed, and has been used, to explore a wide variety of other questions.	
Is the model dynamic or static?	The model covers several decade-long periods, but the inter-temporal linkage is very simple. The transition from one period to another is exogenous.	

Is this an optimisation or simulation model?	simulation	
If it is an optimisation model, what is being optimised? And under which constrains?		
Time		
What is the temporal resolution of the model? • Social & economic parts • Environmental parts	ten year steps	
For what period can the model be used?	1970-2020	
Which year or period has been used for the model calibration?	1970-1990	
Space		
What is the spatial resolution of the model? • Social & economic parts • Environmental parts	16 geographical regions: High-income North America Newly industrialising Latin America Low-income Latin America High-income Western Europe Medium-income Western Europe Eastern Europe Former Soviet Union Centrally planned Asia Japan Newly industrialising Asia Low-income Asia Major oil producers Northern Africa and other Middle East Sub-Saharan Africa Southern Africa Oceania	
SOCIAL and ECONOMIC PARTS		
Production		
What type of production function is being used?	input-output model / Leontief production function, the technical coefficients change for different time periods and for different scenarios	
What types of economic activities are modelled?	Motor vehicles Aircraft and parts Other transportation equipment Metal products Machinery Electrical and electronic machinery and equipment Professional and scientific instruments Miscellaneous manufacturing Electric utilities Construction Trade Transportation services Communication services Other services.	

Is production of these sectors endogenous or exogenous?	endogenous	
Which factors of production have been distinguished?	labour and capital	water and land are easily added
How does the model deal with technological changes?	Technological changes are exogenous and based on case studies and scenario assumptions. The technical assumptions cover the direct changes in inputs per unit of output in a given sector. The case studies cover the likely future changes in the use of energy in households, transportation, electricity generation, and industrial production and also examine pollution control options. Assumptions have been made about the changing use of materials in processing and fabricating industries, as well as for construction.	
<u>Consumption</u>		
What types of consumer categories have been distinguished?	urban and rural population government spending import export plant and equipment investment	
Is consumption endogenous or exogenous?	endogenous	
What types of consumption categories have been distinguished?	see type of activities modelled livestock, oil crops etc.	
How does the model deal with changing consumption patterns?	exogenous-based on case studies and scenario assumptions	
<u>Population</u>		
Does the model include parameters on population?	size per region, urban and rural populations are distinguished	
Is population endogenous or exogenous?	exogenous	
How does the model deal with changes in population?	scenario	
<u>Trade:</u> Is trade between the regions modelled? If so, how?	All regions' imports of a given commodity are delivered from a single world trade pool rather than being specified by bilateral trade arrangements. Imports are computed as a share of domestic production, and region's exports are a share of the total pool. In the case of non-competitive imports, level of imports is exogenous. (F. Duchin has developed a new algorithm for trade base on comparative advantage. It has not yet been implemented on the full world model system.)	

Land Use		
What types of land uses are being modelled?	not included	
Is land use endogenous or exogenous?		
Feedback Does the socio-economic module include feedback from the environmental module?	no	
ENVIRONMENTAL OUTPUTS		
Please list (a) key environment concerns addressed and for each: (b) the estimation principle and (c) an example indicator. (Preferably use attached list of concerns.)	(a) Emissions of carbon dioxide, sulphur oxides and nitrogen oxides. (b) Deterministic on basis of coefficients for (fossil fuels; oil, gas and coal) and technologies in use. (c) regional emissions of carbon dioxide, sulphur oxides and nitrogen oxides	
Does the model include costs and financing of environmental protection? If so, how?	Abatement activities are included as sectoral technical change. Costs for abatement and protection are therefore included but have not been shown separately.	
APPLICATION		
How is the model normally applied in assessments?	case studies are carried out to develop data	
Does normal application make use of a standard set of scenarios ?	No	
What types of policies can be studied with the model?	Technology in specific sectors Economic aid Trade Employment etc.	
OTHER ASPECTS		
Who owns the model?	F. Duchin and G. Lange	
Who is entitled to use it?		
Has the model been reviewed? By whom and when?	Yes	
Please list key publications on the model.	Duchin F. and G.-M. Lange, 1994, “The Future of the Environment: Ecological Economics & Technological Change”, New York, Oxford University Press	

Information about the provider of this information:

Name	Prof. Faye Duchin
Function	Dean, School of Humanities and Social Sciences
Name of the organization	Rensselaer Polytechnic Institute
Postal address	110 8th St., Troy, NY 12180-3590
Telephone	(518) 276-6575
Fax	(518) 276-4871
E-mail	duchin@rpi.edu

A.I.4 IMAGE 2.2

		Remarks	Source of prefilled information
IDENTIFICATION			
What is the name and version of the model?	IMAGE 2.2 (Integrated Model to Address the Global Environment)	IMAGE 2.2 will be available early summer 2001. The current version is 2.1.2	See reference list
SUMMARY DESCRIPTION0	IMAGE has been developed over the last decade at RIVM in collaboration with many other institutes and groups (Rotmans, de Boois et al. 1990; Alcamo 1994; Alcamo, Leemans et al. 1998; Leemans, Kreileman et al. 1998). IMAGE 2 is an integrated assessment model for global environmental change. The dynamics and consequences of climate change are a central part of the model. The scientific goals of IMAGE 2 are to evaluate the relative importance of major processes, interactions and feedbacks in the society-biosphere-climate system, and to estimate the most important sources of uncertainty in such complex system. The policy goals are to provide a dynamic and long-term perspective about the consequences of environmental change, to provide insight into the side effects of various policy measures and to provide a quantitative basis for analysing the effectiveness of various measures to address environmental change. The IMAGE 2 modelling efforts thus aim to link scientific and policy aspects of global environmental change in order to assist decision-making. These objectives have governed the design, the development and the application of the model (c.f. Diagram below). The resulting model consists of three fully linked sub-systems of models: the Energy-Industry System (EIS), the Terrestrial Environment System (TES) and the Atmosphere-Ocean System (AOS). EIS computes the emissions of GHGs and ozone precursors from 13 world regions as a function of energy consumption and industrial production. The EIS models are especially designed to investigate the GHG emissions resulting from the dynamic interplay of scenario-based energy efficiency improvements, fossil-fuel supply, secondary fuel substitution, and renewable energy-supply technologies. TES simulates changes in land use and land cover as influenced by local climatic, soil and terrain properties and regional consumption of food, fodder, fibre, fuelwood and biomass. The resulting land-cover changes are used to calculate natural and land-use fluxes of CO_2 between the biosphere and the atmosphere. All land-use activities also contribute to emissions of non-CO_2 GHGs. AOS calculates from all the GHG emissions, their final atmospheric concentrations considering oceanic uptake of CO_2 and atmospheric chemistry and the resulting changes in climatic patterns. These patterns are corrected for oceanic heat transport and S-aerosols. Historic data from the period 1970 to 1990 is used to calibrate, test and initialise the model. Scenario assumptions on, for example, demographic, technology, trade and fuel mix developments have to be provided for the simulated period, which extends to the year 2100. The time steps of different submodels vary, depending on their mathematical and computational requirements, but ranges typically from one day to one year. IMAGE 2 covers the entire globe but performs many of its calculations either on a high-resolution terrestrial grid, for 13 world regions or for latitudinal bands. This spatial resolution increases model testability against measurements, allows an improved representation of feedbacks and provides more appropriate information for climate impact analysis. Moreover, most submodels are process-oriented and contain fewer empirical parameterisations than other integrated assessment models. This should enhance the scientific credibility and reliability of the calculations.		
Diagram	See Figure I.4. The model structure, input and output data can be evaluated form the IMAGE CD-ROM (Leemans, Kreileman et al. 1998).		

GENERAL			
<u>Approach</u>			
What is the main objective for which the model is being developed/recently used?	Climate change research and policy support. IMAGE 2.2 calculated dynamically the emissions of all greenhouse gases and ozone precursors as a consequence of land use, energy use and industrial activities.	The model has contributed to support IGBP/IHDP research. The IMAGE team is actively involved in IPCC activities. Finally, an active dialogue is evolving between FCCC negotiators and the IMAGE team.	(Alcamo, Kreileman et al. 1998; van Daalen, Thissen et al. 1998; Leemans, Bakkes et al. 1999; Leemans and Kreileman 1999)
If the model is part of a larger set-up, please describe.	IMAGE 2.2 is the core model that has a long computation time and provides detailed output, but simpler interactive tools for specific research and policy questions have been developed.	See Figure I.4	(Swart, Berk et al. 1998; Leemans, Bakkes et al. 1999; Leemans and Kreileman 1999)
Is the model dynamic of static?	Dynamic model	I.e. is the transition from one period to another endogenous or exogenous?	
Is this an optimisation or simulation model?	Simulation model		
If it is an optimisation model, what is being optimised? And under which constrains?	n.a.		
<u>Time</u>			
What is the temporal resolution of the model? • Social & economic parts • Environmental parts	1970 – 2100 with seasonal to 5 years time steps.	• The socio-economic aspects are simulated with annual time steps • Crop and ecosystem productivities are simulated with seasonal time steps • Land use is updated each half decade. Ocean and Climate dynamics are simulated with annual time steps with relatively coarse parameterisations.	(Alcamo, Kreileman et al. 1998)
For what period can the model be used?	Up to 2100		
Which year or period has been used for the model calibration?	1970 – 1995		
<u>Space</u>			
What is the spatial resolution of the model? • Social & economic parts • Environmental parts	• 17 socio-economic regions • calculation at 0.5 x 0.5 degree grid • climate model in 19 latitudinal zones • Ocean in several major ocean basins		

SOCIAL and ECONOMIC PARTS			
<u>Production</u>			
What type of production function is being used?	Different for the different parts of the model.		
What types of economic activities are modelled?	• Energy use • Industrial activities • Land use (forestry, arable land, grazing, modern biomass and C-sequestration)		(Leemans and van den Born 1994; de Vries and Janssen 1997)
Is production of these sectors endogenous or exogenous?	Endogenous		
Which factors of production have been distinguished?	• Energy: technology, resource availability, energy efficiency • Industry: highly aggregated productivity function for energy use and GHG emissions • Agriculture and forestry: depending on local climate and soil, linked to management		
How does the model deal with technological changes?	Partly described as an scenario assumption, partly endogenous		
<u>Consumption</u>			
What types of consumer categories have been distinguished?	• Primary & secondary energy • Energy carriers • Food, fodder, fibre & biomass		
Is consumption endogenous or exogenous?	Partly described as an scenario assumption, partly endogenous		
What types of consumption categories have been distinguished?	Energy: Transport, Households, Industry & Others Industry: Cement & Others Agriculture: Food, fodder, fibre & biomass		
How does the model deal with changing consumption patterns?	Determines the environmental consequences of changing consumption patterns		
<u>Population</u>			
Does the model include parameters on population?	Yes	Regional rural and urban population figures	
Is population endogenous or exogenous?	Exogenous		
How does the model deal with changes in population?	Population dynamics is a scenario assumption. Each capita uses the energy and food characteristic for the region	The environmental consequences of changing population is determined	
<u>Trade:</u> Is trade between the regions modelled? If so, how?	Yes, trade patterns are generally scenario descriptions. Within these pre-set scenario limits, the model calculated species specific trade patterns.		

Land Use			
What types of land uses are being modelled?	Forestry, arable land (12 crops for human food and fodder), grazing land (cattle, goats), biomass plantations, c-sequestration and natural ecosystems (17 classes)	The land-use and land-cover change is dynamically simulated in IMAGE 2.2.	
Is land use endogenous or exogenous?	Endogenous, initiated by FAO and land-cover data.	Land use is simulated regionally, the consequent land cover on the 0.5 x 0.5 degree grid.	
Feedback Does the socio-economic module include feedback from the environmental module?	Yes. Land use changes influences the carbon cycle. Climate change influences land use. IMAGE 2.2 is a fully integrated system (c.f. diagram)	E.g. on: • quality and quantity of factors of production; • quality and quantity of commodities for consumption: • size and structure of population: • land use patterns.	
ENVIRONMENTAL OUTPUTS			
Please list (a) key environment concerns addressed and for each: (b) the estimation principle and (c) an example indicator. (Preferably use attached list of concerns.)	• Changes in land use (patterns and deviation from preferred diet) • Change in climate on basis of a full array of greenhouse gas emissions and concentrations. • Changes in crop productivity (climatic and soil's influences on distribution and productivity) • Changes in land degradation (as a function of climate, soil and land use) • Changes in biodiversity (coarse proxies and nature reserves and ecosystems) • Potential for renewable energy (modern biomass productivity and the consequences for land use) • Potential for C-sequestration (Kyoto forests) • Sea level rise (impact on coastal zones as driven by climate change)		Depending on user additions out put can be defined. Examples are given by (Leemans, Kreileman et al. 1998).
Does the model include costs and financing of environmental protection. If so, how?	No		
APPLICATION			
How is the model normally applied in assessments?	Through scenario analysis. The derived tools in an interactive mode.		(van Daalen, Thissen et al. 1998)
Does normal application make use of a standard set of scenarios ?	Yes and dedicated scenarios and sensitivity analysis		
What types of policies can be studied with the model?	• Environment issues proper • Taxation and subsidies • Technology • Specific sectors		

OTHER ASPECTS			
Who owns the model	RIVM		
Who is entitled to use it?	In principle free asses to the model but a licence agreement is required. The IMAGE CD-ROM id broadly available but no new model runs can be made. Only model outputs can be viewed.	The model is UNIX based and requires large workstations. Setting up the model and its scenarios is complex and requires much computer skills and resources. We further do not have the resources for an advanced user-support. Therefore we only licence the model to other strongly interested research institutes in a collaborative mode, either scientifically or regionally.	(Leemans, Kreileman et al. 1998)
Has the model been reviewed? By whom and when?	Yes, by IGBP en in many peer-reviewed publications in the literature.	Additionally, an international advisory board has been established which reviews progress and advises on important future directions. The last meeting was November 1999.	(Leemans, Bakkes et al. 1999)
Please list key publications on the model.	See reference list	The total list (updated until 1999) is presented in (Leemans and Kreileman 1999)	

Information about the provider of this information:

Name: Dr. Rik Leemans
Function: IMAGE project leader
Name of the organisation: RIVM
Postal address: POBox 1, 3720 BA Bilthoven, The Netherlands
Telephone: +31 30 274 3377
Fax: +31 30 274 4437
E-mail: image-info@RIVM.nl or Rik.Leemans@RIVM.nl

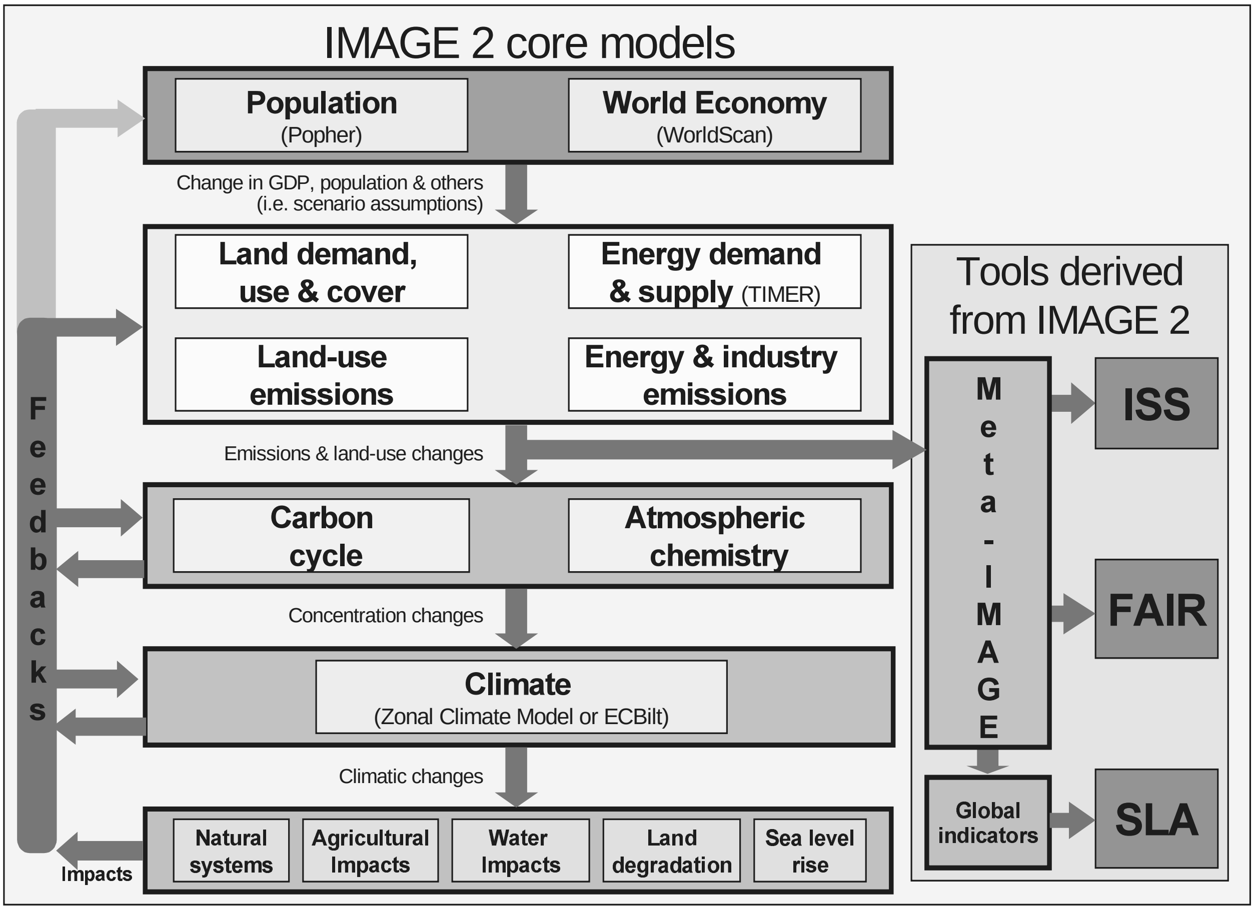

Figure A1.4: flow diagram of IMAGE 2 and related models

The derived tools are especially designed to address specific FCCC-policy issues. The meta-IMAGE is a simplified model that still mimics the behaviour of the IMAGE 2.2 (den Elzen 1998). ISS is the interactive scenario scanner, FAIR is the Framework to Address International Emissions reduction schemes; the SLA is the safe landing analysis. IMAGE 2.2 and its derived tools are complementary (Leemans and Kreileman 1999).

Appendix II: Model Descriptions from DESA Survey

A.II.1 Mini-Climate Assessment Model (MINICAM)

Name and version of model: Minicam Version 99-14. The model is under very active development, with a new transport sector, a full suite of green house gases, and new regions presently under development or in advanced planning stages. Ancillary models to derive inputs, to model sulphur emissions, and to estimate stream flows are presently being incorporated into the model. A substantially revised and extend version of the model should be available by next summer.

What is the primary purpose/focus of model (climate change, sustainable development, energy, etc.): Climate change, with subsidiary models that focus on sustainability and vulnerability

Names of component modules and/or associated models:
Edmonds, Reilly, Barns energy/emissions model
Ag/Land Use model (Edmonds, Wise)
MAGICC climate model (Wigley, Raper)
SCENGEN regional climate tool (Hulme, Wigley)
ISAM integrated science model (Jain et al.)
Global Stream Flow (Bandy Strzepek, Yates)
SusVul (Pitcher, Moss,)
Sulphur (Smith)

Is the model fully dynamic? The system uses a partial equilibrium price model to solve for energy and agriculture prices given an aggregate level of output, which is determined by a population, labour productivity equation. The model does not incorporate expectations, so the issue of consistent expectations does not arise. The model does not compute capital stocks.

We have a larger model, the SGM, which is a full CGE model, including vintaged capital stocks and expectations. We normally do not run this model to ensure consistent expectations, although it is possible to exercise the model in this model.

Is it a simulation or optimisation model? If optimisation, what is optimised and what is the discount rate? Is it a policy evaluation model or a policy optimisation model (according to the IPCC-classification of Integrated Assessment models)?
The Minicam is a simulation model. It is a policy evaluation model, although in combination with a climate model and a variant of the model which computes consistent long term prices, it can be used to select least cost trajectories to achieve given concentrations.

What is the base year/period for which the model has been calibrated?
The model is calibrated to 1990

What is the time step and simulation period of the model (e.g., five-year steps to 2050)?
The model uses 15-year time steps and simulates to 2095. For the IPCC SRES report, we have developing reporting frameworks, which give output every ten years from 1990 to 2100

What is the spatial resolution of the model?
The model presently comprises 14 regions. These include the US, Canada, Western Europe, Japan, Australia, New Zealand, The former Soviet Union, Eastern Europe, China and other centrally planned economies, India, Korea, Other Asia, Middle East, Latin American, and Africa. We have received funding which will enable us to disaggregate Latin America into three or four regions.

Regional climate model outputs are available on a one-degree gridded basis.
Stream flow will be on a roughly 180 river basin basis or on a regional basis.

Which are the main data sources used for the calibration of the model?
IEA energy data, UN population data, FAO agriculture and land use data.

What type of production function is being used for the economic parts of the model?
Leontief with varying conversion efficiency for energy inputs.

How is technological change modelled?
Ancillary models determine labour productivity, while energy and ag technical change are exogenous assumptions, driven by spread sheet tools.

Is trade between the regions modelled? If so, how?
The model balances global production and demand, taking account of transportation costs. Trade is the residual between local production and demand. Bilateral trade is not modelled.

How does the model deal with changing consumption patterns?
Agriculture and energy demands are assumed to reach regionally specific asymptotes as per capita income rises.

How does the model cope with uncertainty?
We have developed a full-scale Monte Carlo front end for the model. In addition, we are developing SUM, a simple uncertainty model, for assessing long-term scenario outcomes for the important climate variables. This modelling technology could be readily extended to other aspects of the model.

Does the model include any feedbacks from the environment to, for example, the economy or population developments?
The model can incorporate feedbacks from climate to agricultural productivity, and to water availability (under development). We are developing a version, which will run the climate model contemporaneously with the economic model, so that full feedbacks are available

What types of policies can be studied with the model (financial, regulatory, education, climate-related, etc.)?
We can model a variety of policies, including taxes, availability times for technologies, retirement times for technologies, carbon sequestration, etc. These policy tools are focused on climate rather than development issues. It would be straightforward to modify the ancillary model which drives overall economic growth to reflect critical development tools such as education and savings rates.

Is it available for installation/use by others? On what terms? What are the technical requirements?
We make the model freely available (data code and executables). There is a simple version of the model, which has an Excel front end for use in educational situations. We will be developing a user environment that includes extensive data base capability over the next nine months. We do not have the staff to provide more than nominal technical support to users who are not sponsors. The model runs on any Intel Pentium class system that can support windows and Microsoft Office. We assume the presence of Excel in all of the ancillary data files and processing, although this is not strictly a necessity.

Are the following variables included in the model? Can they be specified exogenously? Can they be projected endogenously?

	Exog.	Endog.	Comments
Agriculture and land use			
Crop land		x	
Irrigated land			under development
Food production		x	
Other agricultural production		x	
Fertilizer use			under consideration
Pesticide use			
Soil fertility/degradation			
Pasture land		x	
Rangeland			
Animal stocks			
Meat/dairy production		x	
Forested land		x	
Forest stocks			
Forest production		x	
Fish harvest			possible
Urban land/settlements	x		
Protected ecosystem area	x		
Other/waste land		x	
Water			
Surface water availability/use	x		
Groundwater availability/use			
Water use, agriculture			in planning
Water use, non-agricultural			in planning
Water pollution			
Water treatment/sanitation			
Health impacts of water pollution			
Ecosystem impacts of pollution			
Air pollution			
Particulates (urban/regional)			in planning
SO_2 (urban/regional)		x	
NO_X (urban/regional)			in planning
Ozone (urban/regional)			in planning
Health impacts of air pollution			in planning
Transport			
Number of motor vehicles			this sector is under development—anticipated completion is mid 2000
Motor vehicle use			
Cars			
Trucks/buses			
Alternative motor vehicles			
Rail transport			
Air transport			
Ship transport			

Trade and investment			
Exports/imports	x		
Domestic investment			
Foreign investment			
Demographics/poverty			
Population, urban/rural		x	we have age cohort model — urban population is estimated separately
Poverty/inequality			ex post estimates
Energy/CO_2/Greenhouse gases			
Fossil fuel consumption	x		
Fossil fuel depletion	x		
Renewable energy sources		x	
Greenhouse gas emissions/levels		x	
CO_2		x	
CH_4		x	
N_2O		x	
Other		x	HFC, PFC, SF6, SO2
Climate change impacts		x	a major focus over the next year

How many sectors and regions does the model have?

	Number	Comments
Number of industrial sectors	4	energy, agriculture, biomass, other
Number of service sectors	NA	
Number of consumption goods	7	three kinds of agriculture, three kinds of energy, all other
Number of household categories	NA	
Developed country regions	5	
Developing country regions	9	with more to come

(It would be helpful if you could list all sectors and regions at the level of detail used in the model).
Energy sectors: solid, liquid, gas, electricity. Electric technologies include conventional coal, atmospheric fluidised bed, combined cycle gas turbine, nuclear, solar, hydroelectric. Synthetic fuels include coal to gas, coal to liquid, gas to liquid, biomass, etc.

What are the costs and timeframe to develop and run a new scenario and to analyse the outcomes?
We have developed an extensive set of tools to create new scenarios, and are actively involved in this work at the moment. To develop and analyse a scenario close to the set of scenarios we have run for the IPCC is a matter of a week or so. Really new scenarios may take considerably longer, depending on what the specifications are, and how much new input and output are required.

Contact for further information

Name: Hugh M. Pitcher
Title: Staff Scientist
Organisation: Global Change Group, Pacific Northwest National Lab
Mailing address: 901 D. St SW, Washington, DC, 20024
Phone: 01 202 646-7815
Fax: 01 202 646-5233
E-mail: hugh.pitcher@pnl.gov

A.II.2 JOBS

Name and version of model:
JOBS (We might change the name, as we do not focus on any labour market issues in the current project.)

What is the primary purpose/focus of model (climate change, sustainable development, energy, etc.):
Assessment of economic impacts of globalisation on individual regions of the world

Names of component modules and/or associated models:

Is the model fully dynamic?
There is no forward-looking behaviour incorporated in the model. Instead, the model is solved as a sequence of static equilibria, where the value of investment in each year and region is equal to the value of aggregate saving in the region.

Is it a simulation or optimisation model? If optimisation, what is optimised and what is the discount rate? Is it a policy evaluation model or a policy optimisation model (according to the IPCC-classification of Integrated Assessment models)? Simulation

What is the base year/period for which the model has been calibrated?
1995

What is the time step and simulation period of the model (e.g., five-year steps to 2050)?
This can in principle easily be varied, but due to some convergence problems, the model is most often solved for each year. The simulations for the “Environmental Outlook and Strategy” (EOS) project go to 2020.

What is the spatial resolution of the model?
This can also easily be varied, but in the EOS project, 10 regions are used. (USA, Canada and Mexico, Western Europe, Central and Eastern Europe, Japan and Korea, Australia and New Zealand, Former Soviet Union, China, East Asia, Latin America, Rest of the World.)

Which are the main data sources used for the calibration of the model?
GTAP database

What type of production function is being used for the economic parts of the model?
In each sector in each region, the production is determined through a set of nested Constant Elasticity of Substitution (CES) production functions.

How is technological change modelled?
Old and new vintages of capital are included, and technology changes as the composition of “old” capital changes. Otherwise, technological change is explicitly included through a number of technology shifters that can be modified exogenously.

Is trade between the regions modelled? If so, how?
Yes, through bilateral trade flows between all regions.

How does the model deal with changing consumption patterns?
Household consumption demand is modelled through the use of a so-called "extended linear expenditure system" (ELES). This consumption demand includes a demand for future goods, which is represented through the demand for savings, which in turn is determined as a residual, as the difference between household disposable income and expenditures. The demand for each category of goods and services consists of two components: a population-adjusted subsistence minimum and a component reflecting *inter alia* the relative prices of the different categories.

How does the model cope with uncertainty?

Does the model include any feedbacks from the environment to, for example, the economy or population developments?
No.

What types of policies can be studied with the model (financial, regulatory, education, climate-related, etc.)?
Tax changes, tariff changes, quantitative demand limitations, CO_2 emission limitations.

Is it available for installation/use by others? On what terms? What are the technical requirements?
No.

Are the following variables included in the model? Can they be specified exogenously? Can they be projected endogenously?

	Exog.	Endog.	Comments
Agriculture and land use			
Crop land	x		
Irrigated land			
Food production		x	
Other agricultural production		x	
Fertiliser use	x		
Pesticide use			
Soil fertility/degradation			
Pasture land			
Rangeland			
Animal stocks			
Meat/dairy production		x	
Forested land			
Forest stocks			
Forest production		x	
Fish harvest		x	
Urban land/settlements			
Protected ecosystem area			
Other/waste land			
Water			
Surface water availability/use	x		We are trying to implement this
Groundwater availability/use			
Water use, agriculture		x	Input demand for “water” according to GTAP
Water use, non-agricultural		x	Input demand for “water” according to GTAP
Water pollution			
Water treatment/sanitation			
Health impacts of water pollution			
Ecosystem impacts of pollution			
Air pollution			
Particulates (urban/regional)			
SO_2 (urban/regional)			
NO_X (urban/regional)			
Ozone (urban/regional)			
Health impacts of air pollution			
Transport			
Number of motor vehicles			
Motor vehicle use			
Cars			
Trucks/buses			
Alternative motor vehicles			
Rail transport			
Air transport			
Ship transport			
Trade and investment			
Exports/imports		x	
Domestic investment		x	
Foreign investment			

Demographics/poverty			
Population, urban/rural	x		Only total population, using medium UN projections
Poverty/inequality			
Energy/CO_2/Greenhouse gases			
Fossil fuel consumption		x	
Fossil fuel depletion		x	
Renewable energy sources			
Greenhouse gas emissions/levels			
CO_2		x	Only emissions related to energy use
CH_4			
N_2O			
Other			
Climate change impacts			

How many sectors and regions does the model have?

	Number	Comments
Number of economic sectors	22	Can fairly easily be modified
Number of industrial sectors		
Number of service sectors		
Number of consumption goods		
Number of household categories		
Developed country regions	6	- Canada, Mexico and United States - Western Europe - Japan and Korea - Central and Eastern Europe - Australia and New Zealand - Former Soviet Union
Developing country regions	4	- China - East Asia - Latin America (excluding Mexico) - Rest of the World
Economic sectors:	22	- Rice - All other crops - Livestock, including milk and wool - Forestry - Fisheries - Minerals - Coal - Oil - Natural gas - Refined oil - Electricity generation and distribution - Light industry (including food processing, textiles and apparel and electronic equipment) - Chemicals - Metals - Other intermediate goods (including wood products, pulp and paper, metal products) - Motor vehicles - Other transport equipment - Other manufacturing - Construction - Water supply - Trade and international transport services - Other services (including other private services, public services and dwellings)

What are the costs and timeframe to develop and run a new scenario and to analyse the outcomes?
We use the model primarily to simulate isolated “shocks” compared to a baseline scenario, based on other OECD work. There are no plans to develop “alternative” baseline scenarios, but several shocks will eventually be combined into one or more “policy scenarios”. The cost of running a given shock is limited (the model solves for every year up to 2020 in about one hour), - once a “correct” formulation of the shock has been developed.

Contact for further information

Name: Nils Axel Braathen
Title: Administrator
Organisation: OECD
Mailing address: 2, rue André-Pascal, 75775 Paris CEDEX 16
Phone: + 33 1 45 24 76 97
Fax: + 33 1 45 24 76 97
E-mail: nils-axel.braathen@oecd.org

A.II.3 Future Agricultural Resources Model (FARM)

Name and version of model:
Future Agricultural Resources Model (FARM). Have a version developed in 1995. Currently developing a dynamic version.

What is the primary purpose/focus of model (climate change, sustainable development, energy, etc.):
To evaluate the effects of various global change phenomena (i.e., population growth, trade liberalisation, ecosystem protection, and climate change) on long-term agricultural and environmental sustainability.

Names of component modules and/or associated models:
A geographical information system (GIS), which describes land and water resources, is linked with a global computable general equilibrium (CGE) economic model, which estimates the economic effects of various phenomena.

Is the model fully dynamic?
The 1995 version is comparative static model.

Is it a simulation or optimisation model? If optimisation, what is optimised and what is the discount rate? Is it a policy evaluation model or a policy optimisation model (according to the IPCC-classification of Integrated Assessment models)?
The GIS simulates climate-induced changes in land and water resources. The CGE economic model optimises firm profits and household utility. The discount rate in the comparative static and dynamic models is 0. The model can be used for either policy evaluation or policy optimisation.

What is the base year/period for which the model has been calibrated?
The 1995 version is calibrated to 1990. The dynamic version is calibrated to 1995.

What is the time step and simulation period of the model (e.g., five-year steps to 2050)?
The comparative static model is a one-step model. The time period can be up to 60 years (through 2050). The dynamic version takes 12 one-year steps from 1995 to 2007.

What is the spatial resolution of the model?
The spatial resolution of the GIS is 0.5° grids aggregated to 12 economic regions. The CGE of the 1995 version has 8 economic regions. The dynamic version has 12 economic regions.

Which are the main data sources used for the calibration of the model?
Data for 1995 version:
Food and Agriculture Organisation of the United Nations. Agrostat. Rome, 1993.

Global Trade Analysis Project's GTAP 1 Data Base (see Hertel, T.W., compiler. 1993. *Notebook for Short Course in Global Trade Analysis*. Department of Agricultural Economics, Purdue University, West Lafayette, IN.)

Leemans, R. and W.P. Cramer. 1991. *The IIASA Database for Mean Monthly Values of Temperature, Precipitation, and Cloudiness on a Global Terrestrial Grid*. Digital Raster Data on a 30-minute Geographic (lat/long) 360x720 grid. International Institute for Applied Systems Analysis, Laxenburg, Austria

Olson, J. S. 1989-91. World Ecosystems (WE1.3). Digital Raster Data on a 1-degree Geographic (lat/long) 360x720 grid. National Center for Atmospheric Research, Boulder, CO.

Data for dynamic version:
Global Trade Analysis Project's GTAP 4 Data Base (Energy Version)

What type of production function is being used for the economic parts of the model?
Constant elasticity of substitution for primary factors, Leontiev for intermediate goods and services.

How is technological change modelled?
Uses structural parameters for firm inputs and household goods and services that may be exogenously set or endogenously determined to meet specific output or consumption levels.

Is trade between the regions modelled? If so, how?
Trade between regions is modelled with an Armington structure.

How does the model deal with changing consumption patterns?
Can be determined endogenously or exogenously set.

How does the model cope with uncertainty?
Use multiple sets of shocks coupled with sensitivity analysis of parameters.

Does the model include any feedbacks from the environment to, for example, the economy or population developments?
Climate change, for example, affects land and water resources which in turn affect economic activity.

What types of policies can be studied with the model (financial, regulatory, education, climate-related, etc.)?
Financial (e.g., taxes, subsidies, and tariffs) and regulatory (e.g., production inputs or outputs) related to climate and many other changes.

Is it available for installation/use by others? On what terms? *What are the technical requirements?*
Both models are prototypes at present. Their specialised features will be made available through the Global Trade Analysis Project at Purdue University at some time in the future. Require FORTRAN and GEMPACK software for full utilisation.

Are the following variables included in the model? Can they be specified exogenously? Can they be projected endogenously?
Answers pertain to both the comparative static and dynamic versions unless otherwise noted.

	Exog.	Endog.	Comments
Agriculture and land use			
Crop land	Yes	Yes	Includes irrigated cropland
Irrigated land			
Food production	Yes	Yes	
Other agricultural production	Yes	Yes	
Fertiliser use			Aggregated with non-metallic manufactured inputs
Pesticide use			Aggregated with non-metallic manufactured inputs
Soil fertility/degradation			
Pasture land	Yes	Yes	Includes rangeland
Rangeland			
Animal stocks	Yes	Yes	Aggregated livestock
Meat/dairy production	Yes	Yes	Aggregated with fish
Forested land	Yes	Yes	
Forest stocks			Separate variable in dynamic version
Forest production	Yes	Yes	
Fish harvest			Aggregated with meat and dairy
Urban land/settlements	Yes	Yes	
Protected ecosystem area			
Other/waste land	Yes	Yes	

Water			
Surface water availability/use	Yes	Yes	Aggregated with groundwater availability/use
Groundwater availability/use			
Water use, agriculture	Yes	Yes	
Water use, non-agricultural	Yes	Yes	
Water pollution			
Water treatment/sanitation			
Health impacts of water pollution			
Ecosystem impacts of pollution			
Air pollution			
Particulates (urban/regional)			
SO_2 (urban/regional)			
NO_X (urban/regional)			
Ozone (urban/regional)			
Health impacts of air pollution			
Transport			
Number of motor vehicles			
Motor vehicle use			
Cars			
Trucks/buses			
Alternative motor vehicles			
Rail transport			
Air transport			
Ship transport			
Trade and investment			
Exports/imports	Yes	Yes	
Domestic investment	Yes	Yes	Especially in the dynamic version
Foreign investment	Yes	Yes	Especially in the dynamic version
Demographics/poverty			
Population, urban/rural	Yes	Yes	Urban and rural aggregated together
Poverty/inequality			
Energy/CO_2/Greenhouse gases			
Fossil fuel consumption	Yes	Yes	
Fossil fuel depletion			
Renewable energy sources			
Greenhouse gas emissions/levels			
CO_2			
CH_4			
N_2O			
Other			
Climate change impacts	Yes		

How many sectors and regions does the model have?

	Number	Comments
Number of sectors	13/18	Static/Dynamic. Dynamic version has 5 new crop sectors
Number of industrial sectors	7/7	Includes coal-oil-gas and other-minerals sectors
Number of service sectors	1/1	
Number of consumption goods		
Number of household categories		
Developed country regions	5/7	
Developing country regions	3/5	

(It would be helpful if you could list all sectors and regions at the level of detail used in the model).

1995 Version
GIS Regions: the United States, Canada, the European Community (as of 1990), Japan, other East Asia (South Korea and China, including Taiwan and Hong Kong), southeast Asia (Indonesia, Malaysia, Philippines, Singapore, and Thailand), Australia and New Zealand, the former Soviet Union plus Mongolia, eastern and northern Europe plus Greenland, western and southern Asia, Latin America, and Africa.

CGE Regions: the United States, Canada, the European Community (as of 1990), Japan, other East Asia (South Korea and China, including Taiwan and Hong Kong), southeast Asia (Indonesia, Malaysia, Philippines, Singapore, and Thailand), Australia and New Zealand, and Rest of World.

Sectors: wheat, other grains, non-grains, livestock, forestry, coal-oil-gas, other minerals, fish-meat-milk, other processed foods, textiles-clothing-footwear, non-metallic manufactures, other manufactures, and services.

Dynamic Version
Regions: the United States, Canada, the European Community (as of 1990), Japan, other East Asia (South Korea and China, including Taiwan and Hong Kong), southeast Asia (Indonesia, Malaysia, Philippines, Singapore, and Thailand), Australia and New Zealand, the former Soviet Union plus Mongolia, eastern and northern Europe plus Greenland, western and southern Asia, Latin America, and Africa.

Sectors: paddy rice, wheat, other grains, vegetables-fruits-nuts, oilseeds, sugar crops, plant fibres, and other crops, livestock, forestry, coal-oil-gas, other minerals, fish-meat-milk, other processed foods, textiles-clothing-footwear, non-metallic manufactures, other manufactures, and services.

What are the costs and timeframe to develop and run a new scenario and to analyse the outcomes?
From one or two days to two weeks depending on the complexity of the shocks and/or the scope of analysis desired.

Contact for further information
Name: Roy Darwin
Title: Agricultural Economist
Organisation: USDA\ERS
Mailing address: 1800 18th St., NW, Room 4180; Washington, DC 20036-5831
Phone: 202 694-5513
Fax: 202 694-5774
E-mail: rdarwin@econ.ag.gov