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Modelling Tools

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Introduction

‘Models’, defined as a distinct tool group for integrated assessment in this project, are simplified representations of complex real–world phenomena. The focus in this group model tools lies on ‘applied’ models, i.e. models which try to simulate real–world processes based on or calibrated to empirical information and with some relevance to actual policy–making processes. The models considered here are models from exact sciences and do not include e.g. psychological models.

Models are based on scientific theory and have a formal, mathematical structure. The formal structure implies that models have well–defined input requirements as well as specific sets of outputs. With the exception of a rather small number of qualitative modelling tools, most models work on the basis of quantitative information, i.e. they require quantitative data as inputs and they provide quantitative data as outputs. Models can be applied to analyse complex chains of argumentation. The model developer is forced to structure the problem to be analysed, in order to facilitate an appropriate formulation in computer code. An important decision of the modeller is about endogenous and exogenous variables and processes in the model. Endogenous processes are described and simulated within the model, while exogenous information has to be taken as an input from external sources, e.g. other models, statistics or expert judgements.

Whether or not computer models are useful for the analysis of complex real–world phenomena, especially in an interdisciplinary setting, is subject to debate. Modellers would argue that the application of rigorous mathematical methods provides essential structure and transparency to the analysis of complex problems. It also makes it in some cases easier to communicate problem formulation, as compared to pure verbal descriptions of a research approach. Critics would argue that models have to make use of simplifications and exogenous assumptions to such an extent that in many cases it renders them useless for saying anything substantial about the problems to be analysed. The choice of the model structure may in many cases to a certain degree predetermine the outcomes. Moreover, while being simplifications of reality, many scientific models remain so complex that for non–scientists they may appear as black boxes instead of transparent research machines. Lastly, models tend to focus on the quantifiable elements of problems, as qualitative information is poorly dealt with by most models. Hence, some of the great strengths of modelling tools are felt as serious weaknesses by non–modellers.

The role of modelling tools in integrated assessment

Modelling exercises have to rely on inputs from raw data and statistics on the one hand, and on a well–framed problem or well–defined scenarios to be analysed on the other. Hence, in the first phase of an integrated assessment (problem framing), models will only play a limited role. Already existing model results from previous policy cycles or assessments can be useful for problem identification and problem framing. They can be used to construct sustainability indicators which are related to and justified by the problem under study and used throughout the integrated assessment.

As a part of the general pool of existing knowledge, model results will be used in the second integrated assessment phase (finding options) for defining scenarios, and in particular in defining realistic ranges for key aspects of scenarios. In this phase, models will contribute to knowledge generation and provide a necessary ‘reality check’.

Once a problem–related, well specified scenario setting has been developed, in Phase III of an integrated assessment models can be fully applied to explore the overall outcome, (e.g. impacts of policy options), specific outcomes of certain parts as well as their interactions, and sensitivities to a wide range of exogenous

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assumptions and uncertainties. Uncertainties can be systematically investigated by altering important parameters or providing ranges of these parameters instead of one single number. With increasing computer power, models can be run a large number of times in order to assess the ranges of possible outcomes. Models can provide counterfactual baselines, i.e. along the line of ‘what would have happened without any intervention’. Moreover, isolated effects and causal relationships ‘ceteris paribus’ can be analysed. The results of modelling exercises can become part of wider cost–benefit analysis or multi–criteria analysis.

Finally, models can be used to conduct ex–post assessments, in order to analyse detailed aspects of a broader policy measure in the past. This would in turn contribute to the generation of knowledge for the next policy and assessment cycle, as described earlier.

Choosing between models

When deciding to use model tools one needs to determine the required scientific domain(s), the desired geographical scale, level of detail et cetera. There are two important ‘trade–offs’ that are to be taken into account with respect to models:

1. Complexity versus transparency: the more complex a model becomes, the less transparent it becomes. Oversimplifying real and complex problems could make the model better understandable and transparent, but at the same time less reliable and realistic. Transparency of models is important, as the acceptance of model results for non–modellers very often depends on the acceptance and understanding of basic assumptions.
2. Specialisation versus integration: the more focussed a model is on a specific real–world process, the more appropriate will be the model representation with regard to this process. On the other hand, more external processes have to be ignored or treated as exogenous. Integrated models try to include many linkages between different domains in an explicit way, but in order to keep the overall complexity under control they will often have to rely on simplified representations of the single elements involved. Increasing computer power partly helps to make integrated models also more sophisticated, but the basic trade–off remains and has to be acknowledged by model developers and model users. There cannot – and should not – be a ‘one–size model that fits all purposes’.

Table 1. Examples of modelling tools for integrated assessment

Model category	Model examples
Biophysical models	
<u>Climate models</u>	General Circulation Models (HadCM, ECHAM); Earth–system Models of Intermediate Complexity (CLIMBER, MAGICC/SCENGEN)
<u>Hydrology models</u>	WaterGAP, SWIM, IRM–ABM
<u>Biogeochemistry models</u>	LPJ, VECODE, 4C, WOFOST, ACCESS
Socio–economic models	
<u>General economy models</u>	General equilibrium models (GEM–CCGT, GEM–E3, GTAP, WorldScan, SNI–AGE); Macroeconometric models (NEMESIS, QUEST–II, GINFORS)
<u>Partial economic sector models</u>	Energy sector models (POLES, PRIMES, MARKAL); Agricultural sector models (WATSIM, IMPACT, CAPRI, RAUMIS); Transport sector models (TREMOVE)
<u>Demography models</u>	PHOENIX, IIASA Population Project
<u>Public health models</u>	MIASMA, PHSF, TARGET
Integrated models	
<u>Land use models</u>	FARM, AgLU, CLUE, SFARMOD, CORMAS
<u>Qualitative systems analysis</u>	SYNDROMES, QSA–SCENE

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<u>Integrated assessment models</u>	IMAGE, ICLIPS, ICAM, FUND, MIND, DEMETER, RICE-FEEM, GENIE, IMPACT-WATER, QUEST
<u>Scenario building and planning tools</u>	POLESTAR, THRESHOLD-21

The evaluation of model tools in the SustainabilityA-Test project has not been carried out on the level of individual models or specific model types, as the available resources did not allow for that. Instead, the models have been categorised on the basis of the scientific domain for which they have been designed, as this is most likely the first argument for selecting a particular model. While many other forms of categorisation would also be plausible, the current approach was chosen, because:

- it reflects the development and application of models in their traditional disciplinary setting and, hence, will be most familiar to model developers and potential users, like policy makers and the wider public,
- it shows the relative position of available models, along the lines of increasing thematic integration, and
- it illustrates the challenges for more integrated modelling, which reflects the more general challenge of truly integrated research on sustainability impacts.

Those wanting to use a model can therefore first select a scientific domain and then see which models within that domain best correspond with the desired balance between complexity and transparency and between specialisation and integration. Table 1 (above) presents the model categories and models within each category.