Integrated Assessment **1:** 253–266, 2000.

Exploring the use of computer models in participatory integrated assessment – experiences and recommendations for further steps

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Received 8 September 1999; revised 17 July 2000

Integrated assessment (IA) can be defined as a structured process of dealing with complex issues, using knowledge from various scientific disciplines and/or stakeholders, such that integrated insights are made available to decision makers (J. Rotmans, Enviromental Modelling and Assessment 3 (1998) 155). There is a growing recognition that the participation of stakeholders is a vital element of IA. However, only little is known about methodological requirements for such participatory IA and possible insights to be gained from these approaches. This paper summarizes some of the experiences gathered in the ULYSSES project, which aims at developing procedures that are able to bridge the gap between environmental science and democratic policy making for the issue of climate change. The discussion is based on a total of 52 IA focus groups with citizens, run in six European and one US city. In these groups, different computer models were used, ranging from complex and dynamic global models to simple accounting tools. The analysis in this paper focuses on the role of the computer models. The findings suggest that the computer models were successful at conveying to participants the temporal and spatial scale of climate change, the complexity of the system and the uncertainties in our understanding of it. However, most participants felt that the computer models were less instrumental for the exploration of policy options. Furthermore, both research teams and participants agreed that despite considerable efforts, most models were not sufficiently user-friendly and transparent for being accessed in an IA focus group. With that background, some methodological conclusions are drawn about the inclusion of the computer models in the deliberation process. Furthermore, some suggestions are made about how given models should be adapted and new ones developed in order to be helpful for participatory IA.

Keywords: participatory integrated assessment, methodology, focus groups, computer models, uncertainty

1. Introduction

As Funtowicz and Ravetz have pointed out [2], issues of global environmental change, such as the issue of global climatic change as a result of human activities, differ from "traditional scientific issues", because they are global in scale and have long-term impacts, data are generally inadequate and the phenomena are complex and not well understood. They concluded that a new methodology is required for science to provide support for decisions on global environmental problems.

One methodology that has received increasing attention in recent years is "integrated assessment" or "integrated environmental assessment" [3]. There are numerous definitions of "integrated assessment" but they have in common that "integrated" refers to the fact that knowledge from various disciplines must be brought together and "assessment" is a process that bridges the scientific and policy realms. Thus, for example, Rotmans describes integrated assessment as

> *A structured process of dealing with complex issues, using knowledge from various scientific disciplines and/or stakeholders, such that integrated insights are made available to decision makers [1].*

In addition to the numerous definitions of "integrated assessment", there are also many ways of doing it. Parson distinguishes two basic methods of integration: formal models and expert panels [4]. Formal models or computer models have indeed become a popular way of integrating knowledge on global environmental issues, particularly the issue of global climatic change and there have been numerous appraisals of their use.

This paper looks at how some of these computer models have been used in a process designed to allow informed citizens to explore and express their judgements on the issues of climatic change and sustainable development. This process has been developed within the ULYSSES project [5], which is a three-year effort funded by the European Commission and involving research teams from eight countries.

The project responds to a growing recognition that the participation of stakeholders is a vital element of integrated assessment [1,6,7]. The response has been to design a procedure for the participation of stakeholders. This procedure for participatory integrated assessment is referred to here as integrated assessment focus groups (IA focus groups). This paper summarises some of the experiences gathered in the ULYSSES project in IA focus groups in which computer models were used as a source of information and to stimulate the discussion. Selected empirical results are presented, focusing on the added value of using computer models during the meetings of the IA focus groups, the lessons learned about the models themselves and the ways that they are used.

The terminology in this field is far from clear. For the purpose of this paper, we define computer models as all kind of software tools that include a mathematical representation of some social, economic or environmental processes. This definition includes all computer models with a claim for representing reality (in a more or less restricted, but nevertheless direct sense). which is the case for all the software tools used in this project. Nevertheless, there has been a considerable diversity of models in the project, ranging from integrated assessment models (IAM) to simpler and non-dynamic tools. On the other hand, we are excluding by this definition computer games (SimCity and the like) and educational software with text only. The reasons for these exclusions are not that we would consider computer games or educational software as useless or inferior to what we define as computer models, but rather because reality is represented in these models only in a metaphorical way of ideal types (e.g., "the" generalized city, not a specific one).

Why use computer models in participatory IA? We hypothesise that computer models are powerful tools for promoting a numbers of insights about a complex issue like climate change. Computer models provide direct access to expertise and due to their flexibility and interactivity might be better able to support learning processes and decision making. In particular computer models might help in understanding the *spatial dimensions* of climate change and the links between the global and the regional level, the *temporal dimension* (long-term perspective), the *complexity* of the entire climate system, the *uncertainty* involved in the science and modeling and possible *policy options*. In order to fulfill these tasks in participatory IA, we assume that computer models must be user-friendly. If the model cannot be used easily by non-experts, it will be of limited use in a participatory process. We hypothesize that a further important characteristic is transparency. If the model remains a black box spitting out results without any further explanations, it can hardly inform learning processes. Finally, we believe that if users do not attribute any *credibility* to a model, it is unlikely to be accepted as a support for decision making.

Section 2 of this paper describes the methodology of this research, which included IA focus groups and a number of computer models used in these groups. Section 3 presents the empirical findings, testing the assumptions and hypotheses outlined in the previous paragraph. In section 4, suggestions are made for how IA procedures that plan to integrate computer models should be designed, and how computer tools should be adapted or built in order to be helpful for participatory IA. General conclusions are presented in section 5.

2. Method: integrated assessment focus groups and computer models

2.1. Integrated assessment focus groups

The ULYSSES project has developed a particular method in order to allow informed citizens to express their judgments on climate policy. Within the project, there is some diversity in the terminology of this approach: The Venice team uses the term "In-Depth Groups", the Manchester team "citizen's panel". However, most teams in the project use the term "Integraded Assessment focus groups" (IA focus groups) for their work and we will follow that line in this paper.

An IA focus group consists of a mixed group of citizens, who are provided with basic information, have access to one or several computer models during their deliberations and reach a collective conclusion, say a policy recommendation for the issue under consideration. The basic methodology has been used in the following seven urban regions throughout Europe: Athens (Greece), Barcelona (Spain), Frankfurt (Germany), Manchester (UK), Stockholm (Sweden), Venice (Italy), Zurich (Switzerland). Furthermore, one partner project with a similar approach has been carried out in Pittsburgh, Pennsylvania (USA). An overview on which models where used in which regions is given below in table 1.

There were some methodological variations between the regions, e.g., with regard to the selection of models, or the application of specific elements (e.g., the citizen report). We discuss the implications of this diversity for the findings under 2.4. However, the following main elements of the group design are the methodological template followed by most research teams [8]:

- *Recruitment*: All participants of one focus group had their place of residence in the same region. However, selection criteria were applied during the recruitment process in order to get a heterogeneous group composition as to age, gender, occupation and education, and income as well as to attitudes towards the environment.
- *Non-verbal assessments*: In some groups, in the first meeting the participants produced collages on the future of their region under different assumptions for the development of energy use.
- *Discussions on global change*: The participants discussed about global change with a focus on climate and energy issues. During this process, the participants were able to look at one or several computer models on global change. A model moderator helped the group to use the model as a support in the discussions.
- *Discussions on regional goals and policy options*: The participants also discussed about regional policy goals

Table 1
Model description and model use in IA focus groups.

Model name, references	Model description					Model use
	Institution	Space	Time horizon (into the future)	Uncertainty	Policy options	(Interaction in IA focus groups)
IMAGE (integrated model to assess the greenhouse effect) [12]	RIVM,	Global, with regional information	100	Not explicit (several given scenarios)	Technology, lifestyle changes	Indirect access via model moderator way [13]
TARGETS (tool to assess regional and global environmental and health targets for sustainability) [14,15]	RIVM, Netherlands	Global	100	Explicit typology	Implicit in typology	Facilitated access
ICAM (for integrated climate assessment model) [12,17,18]	Carnegie Mellon University, Pittsburgh, USA	Global, with regional information	100	Explicit (stochastics)	Economic (CO_2-tax)	Facilitated access
Pole-Star [19]	Stockholm Environment Institute, Sweden	Regional	User defined (here: 30 years)	Not explicit (several user-defined scenarios)	Technology, lifestyle changes	Facilitated or indirect access
IMPACTS [13], OPTIONS [21]	EAWAG, Switzerland	Regional, with some global information	30 years	Explicit	Economic technology, lifestyle changes	Direct access by participants
Lifestyle indicators “CO_2-calculator” [14,15] (Zurich team)	EAWAG, Switzerland	Personal	User defined (here: not explicit)	Not explicit	Technology, lifestyle changes	Direct access by participants
“STELLA model for CO_2 personal accounts” [16,25] (Venice team)	ISPRA, Venice team					

and options, particularly with respect to climate issues. These discussions were backed up by the use of a computer model on regional or personal environmental accounts and corresponding scenarios.

- *Citizens’ report*: At the end of the process, some groups produced a written citizens’ report, giving their assessment in response to some questions on climate and energy issues.

The pilot phase of the ULYSSES project showed that it was advisable to have different persons to realise the tasks of “group moderation” and “model moderation”. The group moderator was in charge of guiding the focus group discussions, while the model moderator presented the computer model and guided the specific discussions during the computer interaction period. Considerable efforts were made in order to prepare the use of the models in the IA focus groups [9].

The placement of models within the overall IA focus groups process was the following: the process was normally split in five sessions of 2.5 h carried out on different days. Two computer models – one with a global perspective and one with a regional one – were generally used in two separate sessions. Most of the research teams presented an Integrated Assessment model of global scope (either IMAGE, TARGETS or ICAM) [9] in the second session, and a computer model of regional scope (either PoleStar or a CO_2-Lifestyle Calculator) in the third or fourth one. The selection of two models for each IA focus groups had the aim of complementing the global/local spatial dimensions with the impacts/measures dimensions in order to enhance debate on regional solutions for global environmental problems. Generally the presentation and debate on the models was between 1 and 1.5 h for each model. We estimate that the presentation and interaction with the two models did not exceed one third of the total discussion time.

The methodology and first findings have already been described with more details in other publications [8,10,11].

2.2. What models have been used?

The project teams used a number of computer models, addressing mainly global (IMAGE 2.0, TARGETS, ICAM 3.0) or mainly regional dimensions (PoleStar, IMPACTS, OPTIONS, Lifestyle-Indicators). It is important to note that most of these models were not specially developed for being used by lay people, but rather for assisting technically trained professionals in research and policy makers (like public officials, members of parliament, business representatives, NGO staff, etc.). This is true for IMAGE 2.0, TARGETS, ICAM 3 and PoleStar. Therefore, considerable ef-

Table 2
Model use by region (Number in cells: number of IA-groups with citizens) [11,18].

	Global model			Regional model			Model No.	Total of groups in region
	IMAGE	TARGETS	ICAM	PoleStar	CLEAR (IMPACTS OPTIONS)	Lifestyle indicators		
Athens	2	1		2				2
Barcelona	3	3		5		2		7
Darmstadt	5	5		8				9
Manchester							5	5
Pittsburgh			3			3	2	5
Stockholm	2	2		7				7
Venice	3	3				6		6
Zurich		4		4	6	1		11
Total of groups	15	18	3	26	6	12	7	52

forts were necessary to adapt the models for use in the IA focus groups.

On the other hand, some of these models (IMPACTS, OPTIONS, CO_2-Lifestyle-Indicators) have been designed in the course of the project to be used directly by lay citizens. Table 1 gives an overview of the models and their use (process design) in the IA focus groups. With regard to the model content described in table 1, two types of models can be distinguished that share some features [17]: One group includes the three global models IMAGE, TARGETS and ICAM. All of them have a long-term perspective, and two of them (TARGETS, ICAM) address uncertainties explicitly. The other group encompasses the three regional models (PoleStar, CLEAR-models, Lifestyle-Indicators) that have no specific time horizon (PoleStar, Lifestyle-Indicators) or a mid-term perspective only (CLEAR-models: 30 years). Furthermore, only one of the regional models (CLEAR-models) addresses uncertainties explicitly.

The classification of model use looks a bit different. As displayed in table 1, three categories of model use can be distinguished:

(a) *Indirect access*: These models were not accessible during the group session for technical reasons. The IMAGE model, for instance, cannot be run on a personal computer while the group is meeting, because it is a large model with many input and output variables. Similarly, some teams also felt that PoleStar was too cumbersome for a long online-presentation to a lay audience and gave only a brief introduction to the model, focusing on input data. Output (scenarios) was produced between two sessions, and presented at the next meeting of the group.

(b) *Facilitaded access*: These models (TARGETS, ICAM) could be run on a personal computer and the output be presented on the spot. However, the user interface was not so simple that an untrained individual could learn it within a few minutes. Therefore, a model moderator presented and operated the model, facilitating its understanding in accordance with the questions and demands of the participants.

(c) *Direct access by participants*: The CLEAR models were especially designed for lay users, and therefore did not need a model moderator as support. In the beginning of the model presentation, the few necessary technical hints were given by the group moderator. After that, participants were navigating through the models on their own, in small groups of 2–3 persons.

Model use by region

Table 2 gives an overview of which models were used in which regions. These groups were run in the years 1996–1998. Both pilot and main groups are included in this display. The total number of groups in a region (last column) is lower than the line total (groups working with a specific model), because most groups used more than one model.

The table provides some important information that has to be kept in mind in the data analysis and interpretation of the findings. First, the model selection is not independent of the region. Some models have been used in one region only (e.g., ICAM in Pittsburgh), others in several regions, but none in all regions. Therefore we do not focus on inter-regional comparisons (e.g., whether IMAGE was received differently in Barcelona than in Stockholm). Second, the total number of groups run with each model is not constant, but ranges from 3 (ICAM) to 26 (PoleStar). While these small numbers are too low for any kind of statistical analysis, they are nevertheless sufficient to meet the explorative intentions of this study, which is to identify tendencies and patterns in the model use. Furthermore, since many of the findings are not model-specific, but touch upon issues that are relevant for many, if not all the models, we can state that we have a quantitatively sound basis. Last but not least, we do not know of any other study that has empirically investigated the use of computer models in such a comprehensive way.

2.3. Other means of providing expert information

All research teams combined the use of the computer models with one or several other means of providing expert information, such as a fact sheet, a magazine article, a short expert hearing, etc.

In two regions, some of the focus groups were run without access to a computer model. In these teams, expert information was given either by oral presentations of an "expert"

(Manchester, quotation marks also in the original source) or by written information (Pittsburgh). The Pittsburgh research team used a brochure that was developed in an outreach project for informing lay people about climate change [19].

2.4. Diversity and robustness of the findings

Due to the explorative character of the project, a strict standardisation of the design was not considered to be a sound and feasible approach. Taking this into consideration, we have focused the analysis of results that were documented in several, if not all regions. These findings seem to be robust in particular because they were visible despite methodological and cultural differences between the regions.

International comparisons between the regions is not the focus of this paper. For such an endeavour, it would be necessary to discuss very carefully whether differences in the findings have their origin in cultural or methodological variations.

Robustness

To what extent are these findings robust? We have mentioned above that there was considerable variation in the selection of models and other information input and the way these tools were used in the IA focus groups. Therefore, a reader might ask to what extent our findings are sensitive, if not biased by these methodological changes.

Answering this question in detail would require an extended methodological study which is beyond the scope of this paper. Nevertheless, we want to express our judgment as authors that we share with many colleagues in the project, that the methodological and cultural variations were of minor importance for the kind of general findings presented here. Most colleagues shared the impression that despite the given methodological and cultural variations, the findings of each region are pretty similar to each other. The following points provide some evidence for that judgment.

> First, all teams were striving for a fair presentation of the models in the IA focus groups. In other words: No team was presenting a model that they considered as absolutely useless for the citizens. If a team reached that conclusion, it decided not to show the model, rather than “proving” its uselessness by presenting it in a bad way. This approach was motivated by both respect for the work of the modellers as well as a respect for the citizens that were not brought into this process in order to deliver empirical evidence to support the prejudices of the respective teams.
>
> Second, in order to check and increase the validity of the findings, a draft of this paper was circulated to all teams involved, giving them the opportunity to criticizes and comment on this synthesis. These comments have influenced the balance of evidence as presented here. Furthermore, most colleagues shared the impression of strong similarities between the regions.

What might be the reasons for these surprising similarities? We see at least two possible explanations. First, climate change is clearly an international issue. Cultural differences come into play to some extent in the perception and management of this issue, but several triggering events are international by definition (e.g., environmental conferences like Rio de Janeiro 1992 and Kyoto 1997). In other words, all regions are exposed to a similar stimulus, that is transmitted, perceived and responded to in culturally different ways.

Second, the regions included in this study are from a relatively homogenous background with regard to political and economic parameters. While there is some variation within the sample, all research teams are working in industrialized nations. In fact, most of them are members of the European Union with a shared policy approach on climate change.

In sum, it is plausible, but not trivial that citizens from a rather homogenous region discussing a truly global issue come to similar conclusions on a general level. On the other hand, in the following section we do not want to downplay findings of regional differences that were especially visible with regard to more detailed issues (e.g., policy options).

3. Findings

In the previous section, we have described the methodological approach of this study. In this section, we present some of the empirical findings. As documented in the methodological section, these findings and conclusions are synthesised from a considerable number of realisations, in different European cities, with different moderation techniques and different sets of models used. Therefore, it should be emphasised that the results presented here are tendencies and not unanimous conclusions. For this reason, we focus on the evaluation of features of models that we consider helpful, rather than comparing and evaluating models directly.

The section starts with what citizens were expecting from the model use before knowing in detail the options and limits of these tools. We then continue to present findings concerning the thematical issues to be illustrated by the computer models (global-local dimensions, temporal scale, uncertainty, complexity, exploration of policy options). Quotes from the discussion are included in this section in order to illustrate the way these topics were addressed. The quotes are complemented with pseudonyms in order to guarantee confidentiality of the findings. In the Venice groups no pseudonyms were added, because the statements are taken from the logbook, a kind of group diary which was approved by all members of the respective group. The section ends with a discussion of the extent to which key requirements of models (user-friendliness, transparency, credibility) have been met or not.

3.1. What do citizens expect concerning expert information and computer models?

Before presenting any model or expert information, the citizens were asked what they were expecting of a computer model, what they would like to know. First of all, they had no specific expectations and most of them were unable to answer the question. This is not very surprising, since they were usually learning about computer models for the first time, and had not yet developed any specific product preferences. Many said that they would like to listen first about what these models are and what they can do.

The list of topical questions brought up by participants is long and we will not present it here comprehensively. The questions were related to the following broad topics:

- General understanding of climate change (e.g., causes and effects of climate change)
- General understanding of related environmental problems (ozone depletion, deforestation, acid rain, etc.)
- Impacts of climate change (Global, regional and local, e.g., food production, demographics, health, sea level, migration, etc.)
- Determination of policy goals (e.g., risks of no intervention etc.)
- Determination of policy means (e.g., what would happen if petrol would not be used that much)

This condensed list of topics addressed in the questions illustrates that participants were not concentrating on a few and narrowly defined issues, but rather struggling for a broad understanding. Obviously, not all questions of the participants could be answered by the model or by the model moderator. However, there was at least some overlap between the citizens' questions and the model capabilities. E.g., the Barcelona research team counted that in their research region, roughly half of the participants' questions could be explored with the models used.

3.2. Global/regional and local scales

The computer models used in the ULYSSES project ranged in the geographical scale treated from the broad global scale that does not allow fine-scale differentiation, through the PoleStar accounting system that requires regional scale inputs particular to the region in question, to calculators that refer to an individual's lifestyle. Participants differed in whether they felt they needed to look at all scales and why. For instance, two participants from Barcelona thought it was good to look at the global scale model:

> I think it is alright in this way because the problem is a global problem, not a local one. It is good to know what happens at a global level. (Milagros, Barcelona)

It was also visible in the IA focus groups using the IMPACTS and OPTIONS models that the limitation on a regional perspective was not sufficient, but should be complemented with some information on how the regional puzzle stone fits into the larger, global picture.

> It is not only Switzerland that is responsible. This is such a little spot. We can't keep climate change out of our country. I doubt whether saving energy only here will be sufficient. (Barbara, Zurich)

The scale issue was also noted in the report of the Pittsburgh research team, which wrote that participants felt that models helped to some extent in taking the discussion of climate change beyond the personal and local to the global. In the Venice IA focus groups, it appears that the models that referred closely to daily experience were more appreciated and stimulated more active participation. Furthermore, when looking at the maps from the IMAGE model the Venice research team noted that people were looking for a better definition of what was happening in Italy and were very interested in these types of results for their own region. Participants liked the geographical approach of IMAGE, illustrating global trends and their regional variations. In fact, some said that they prefer maps to graphs and tables as means of communication. However, this approach also led to frustration, because the coarse geographical resolution of the output was not sufficiently detailed for providing enough regional information, as desired by the participants.

In a similar way, the Stockholm research team found that when the global-scale models were presented, it proved difficult to keep the discussion to the global perspective [20]. The Stockholm research team thus concluded that most people have much more to contribute when asked about local issues they experience in their lives than global issues.

3.3. Temporal scale

In addition to the spatial dimensions of climate change and climate policies, participants also discussed the temporal scale. As shown in table 1, the regional models had rather a "short-term" range (no specific time horizon given or the next 30 years only). In contrast to that, the global models generated scenarios even for the year 2100. This is beyond the life expectancy of all our participants, and therefore a challenging perspective. In fact, some older participants also mentioned that they would neither profit nor suffer from any of these scenarios. In general, this long time-horizon was seen as a problem by participants in a number of groups:

> Natalie: . . . Well, the problem may exist, but I myself don't suffer from it.
> Susi: Yes, but we suffer from it anyway. That is like radioactivity. You don't smell it, you don't taste it, but still it is harmful. . . . It is not like that we sweat more in summer, but the problem is that then the polar icecaps are melting. And then we have floodings. And this is what should frighten us. But I think these are things which are too far in to the future, they don't hurt us, we don't feel them at the moment. That is why nobody wants to tackle them really. (Darmstadt)

> ....there were a lot of hypotheses about what is going to happen in, for instance, one hundred years. That does not concern us as much as a closer time frame. (Lars, Stockholm)

In the Venice IA focus groups the time span over which the global models generated scenarios was greeted with scepticism: "anyway they wouldn't be here". Others commented on the need to have scenarios for the near future (within the time frame year of 10 years).

These findings concerning the interest in spatial and temporal scale support the hypothesis brought up by Meadows that most people focus their attention on processes that are close in time (next weeks and years) and space (family, neighbourhood, business, nation) [21]. In other words: Climate change as global and long-term risk lies beyond this horizon of "here and now" and thinking about it is unusual and challenging.

3.4. Complexity

The models varied to a great extent in their degree of complexity. While the life-style indicators included only a dozen or so variables, most of the global models include hundreds of variables and constants interacting with each other in a dynamic way. This high complexity was a problem for both participants and the model moderator. Due to the detailed information that some of the global models were providing, many specific questions about certain variables and their changes in different regions were asked, e.g., in the presentation of IMAGE outputs:

> Why is it raining so much in China?
> (Hilda, Stockholm)

Due to the high complexity of the model and the lack of comprehensive documentation, it was difficult for the model moderator to answer these detailed questions. The underlying complexity of the global models can mean that you get results that are difficult to explain at first. This was the case, for example, when the Venice research team noted a dip in emissions and concentrations that was ultimately explained by the IMAGE modelling team as a result of elimination of tropical forests by a certain date. Some participants also had the impression that not enough efforts had been made to explain complexity in a simple way. In contrast to that, the models with the lowest complexity (PoleStar, Lifestyle Indicators) were very well received. A number of reasons can be seen for that result. The models were easy to understand. There was no dynamics, no complex interactions, but just a few independent lifestyle areas that were added up.

> Lifestyle Indicator - the coloured squares- You just get it.
> (Jennifer, Pittsburgh)

In sum, the level of complexity given by most models was too high for the little time available and the given intellectual understanding of these lay participants.

3.5. Uncertainty

Only a few of the models deal with the issue of uncertainty in an explicit way. Furthermore, as shown in table 1, there was some variation in how this topic was dealt with. However, the general reactions towards uncertainty were similar, independent of the specific presentation: It was a shock for most participants.

> I'm scared by the uncertainty in science. I tought that science would know better. (Zurich, Veronika)

A typical reaction was that if uncertainties are so high, there was no justification for further discussion of this issue.

> The amount of uncertainty in the distribution in ICAM invalidates the model – you cannot predict the future. (Karen, Pittsburgh)

Comparing the reactions to the main approaches of dealing with uncertainties (typologically, as in TARGETS, vs. probabilistically, as in ICAM) participants seemed to have less difficulties with the latter approach. One explanation of this result might be that probability distributions are more familiar to a lay audience (e.g., from the weather forecast) than the typology of the cultural theory of risk [9].

The reactions towards the TARGETS approach of addressing uncertainties were mixed. Some participants reacted positively, appreciating the attempt to show multiple perspectives.

> Well, I found it very interesting and found it quite good that one had on the one side facts as background information, they are built in {the model}, as fix data or data assumed as fix. And that from the facts you draw conclusions for future developments based on the different assessments of possible points of view. (Stefan, Darmstadt)

However, many other participants had difficulties with the TARGETS approach. One difficulty was understanding what was meant by these three perspectives of the cultural theory of risk. Rather than taking them as ideal types of positions in the debate, they thought that each perspective is associated with specific, "real" scientists. Consequently, they were curious about the names and research sponsors of these individuals. Furthermore, some participants criticised that reducing social complexity by means of a typology with three categories was too rigid and too simplifying. They were rather reluctant about any attempts to classify human beings, and not willing to identify with one of the three perspectives.

In sum, the approach chosen in TARGETS to convey uncertainty was often misunderstood or rejected. The underlying subjectivism was seldomly appreciated as an attempt to promote an honest and pluralistic debate, but rather as an unwillingness of scientists to take sides and stick to (unpopular) positions. One participant criticised this approach as an indication of the opportunism of scientists producing a model that can confirm the view of everybody. Others were concerned that the model could be misused to support any political position.

> In my view, there are two types of experts: Those that are contacted by industry, that are certainly bringing in an other point of view than those experts, that are contacted by any environmental organization or even politicians. I think that, depending on where an expert comes from, different views and and predictions are given. (Kerstin, Darmstadt)

The quote shows that this concern was also raised as a more general problem of science, running the risk of being instrumentalized by specific interest groups.

3.6. Exploration of policy options

Several of the teams in the ULYSSES project noted that the participants found it difficult to explore the impacts of particular policy options with the available computer models. The Pittsburgh research team suggested on the basis of the analysis that participants felt that models can limit creative thinking about policy options. Further difficulties are indicated in the following quotations:

> I think it lacked a bit of . . . data on intervention from the population. (Lucia, Barcelona)
> It would be helpful if models could tell us the different impacts of different policies to help us decide which policy is best. (Daisy, Pittsburgh)

Many policy decisions concerning climate change are taken on a national or even regional level. Thus, it is not surprising that the regional models were better able to explore policy options. Participants had an active role in using the model. And even in the case of PoleStar, where the interaction with the model was indirect and mediated by a model moderator, they could develop their own scenarios, rather than being confronted with predefined expert runs. As the following quote illustrates, participants appreciated this tool function:

> If people are only reading something, they have a hard time imagining a specific scenario (. . .). This model (PoleStar) is good for me as an average citizen, because there are points of reference, visually and with numbers (. . .) One has to work with something: If you want to paint, you need a brush. (Hans, Zurich)

Despite the perception that the regional models were better suited for exploring policies option than the global models, participants critised that the former were not addressing this topic in a convincing manner. For example, in Stockholm, groups complained that PoleStar said nothing about feasibility, to what extent the measures suggested and tried are realistic, given economic, social and political constraints. Since the model is static and does not provide any quantitative barriers for scenario development, it is up to the users to critically evaluate their own selection of variables. This lack of restriction stimulated the discussion, because citizens had to evaluate the feasibility of certain measures themselves. On the other hand, they felt also a little bit left alone with that task. It was seen as crucial to have some kind of costing feature to find out what different measures are really possible.

Some research teams found that the lay participants mostly wanted a tool that would directly relate to their own consumption and lifestyle, including issues such as recycling of waste, what kind of food we buy, and packaging. The Lifestyle-Indicators met this demand in many respects. Policy decisions were translated into individual lifestyle choices. This representation of policy choices was understandable and accessible to each participant. In fact, the policy problem was translated into a moral problem: What are my options for addressing climate change policy? While a model of individual behaviour only, it also stimulated discussion on collective choices and changes. For example, in the transportation sector, participants wondered how public transport could be promoted relative to individual driving. The model stimulated also discussions on equity, simply by international comparisons of per capita emissions (e.g., the USA and India).

Overall, however, there was a sense that it was not possible to explore policy options with the models used in the ULYSSES process and thus to explore how one could contribute on a regional, or even very local scale to respond to the issues of climatic change and sustainable development.

3.7. Credibility

Unlike the model features discussed up to now, credibility is a result of the interaction with a model, rather than a property that can be easily and directly tuned by the model author. Credibility in this sense is not the lay judgement of the scientific quality of the model, which would not make sense, but rather the empirical description of the subjective perception of he IA model. It is well known that lay people have specific mental models [22–24] of complex issues and apply a number of heuristics and biases [25,26] for risk assessment. Irrespective of the simplifying or even biasing character of these heuristics, it is important to get to know them and to be aware of them in the communication about the IA models. Therefore, we will sketch some features of the model that did promote or hinder credibility.

Most teams experienced occasions where participants found that something related to a particular model was not credible – e.g., the rate of economic growth in the future, the amount of sea-level rise by a particular date. Sometimes the participants compared the credibility of two models that they had seen. For example, one participant in Barcelona said:

> I found the second {PoleStar} more credible, the first one {TARGETS} looked more superficial. (Montserrat, Barcelona)

Credibility is enhanced if participants can associate what they see with own experiences. The Venice research team noted, however, that “People had difficulties relating the results of the IMAGE model to their own lifestyles. In fact, while exploring the IMAGE scenarios they did not relate the possible futures to their current choices for energy consumption and transportation modes” [27]. Thus, the Venice research team notes that participants often suggested that the credibility of the IMAGE scenarios could be improved by providing results for the year of 1997.

While some teams sensed that the participants distrusted the models, especially in the cases where there was an awareness of the inherent uncertainties, there were some other interesting perspectives. For instance, the Pittsburgh research team [18] noted that participants thought that

> the information we get from models is not coloured by emotion. (Ronald, Pittsburgh)
> . . . people who hold extreme views on the climate question will not believe the models. (Tamara, Pittsburgh)

Both of these comments suggest that the participants felt that models were objective and from that point of view trustworthy.

An open discussion of uncertainty and complexity has had both positive and negative impacts on the credibility of the respective models. The following quote shows that TARGETS was rather increasing its credibility:

> Though I’m a citizen who has no idea, it seemed to me that scientists share some of my doubts. (Milagros, Barcelona)

However, for other participants, this transparency in TARGETS promoted doubts and scepticism and they did not trust the results. In a similar sense the complexity of ICAM and the amount of information in available was a hindrance for understanding and trusting the model.

> Plugging in 2000 parameters will not give us answers to what will happen in 2025 or 2050. (Ronald, Pittsburgh)

The following quote illustrates that the regional models were generally considered to be more credible:

> I consider the first model (TARGETS) as more attractive, but I found the second one (PoleStar) more real because it contained more specific things from which to draw conclusions. (Beatriz, Barcelona)

A number of reasons can be seen to lead to that judgement. As shown in the presentation of the models, most regional models were less complex than the global models and did not explicitly discuss uncertainties. Furthermore, participants seemed to develop more trust into the highly detailed regional data than the abstract aggregations, long causal chains and dynamic feedbacks in the global models.

3.8. Models in comparison with other input

Many participants believed that if greatly simplified and adjusted to the preferences of lay audience, the models could become a useful tool in climate change discussions among lay citizens. Despite the obstacles that had to be overcome with the currently available models, some participants had the feeling that the computer models were better able to support a systematic and analytical discussion of climate change issues than other, possibly more attractive means of information:

> Yes, it might have been more delightful {a video}, but to have the data to be able to compare, or to analyse or to see; I think it is better have numbers or a graphic. (Ferran, Barcelona)

However, few of them thought that they themselves would prefer to use the currently available models in order to get acquainted with climate change issues.

Some groups were designed to experiment also with other scientific information input (participant interaction with invited climate experts, video show, fact sheet). In the Stockholm IA focus groups, the citizens praised direct interaction with experts as preferable to any other type of scientific information. In this group, everybody agreed that the presence of an expert with pedagogical skills was way better for a rapid and efficient learning process than the use of computer models. Although the model interaction did spur the debate around the relevant issues, it is also possible that such a productive discussion would have taken place simply by bringing the topic to the table with some overheads or by talking.

In Manchester and Pittsburgh some focus groups were run without using any computer models. In Pittsburgh, the participants in those non-model focus groups were asked explicitly whether they would have liked to work with a computer model. They showed some interest. The findings from Manchester look somewhat different. Computer models were not the chosen option, no matter whether they were explicitly offered or not. Rather, participants had no strong opinion either for or against computer models.

A first explanation for these contrasting findings could be that trust in science is the key variable that determines whether participants showed some interest in scientific information, irespective of the form (paper, computer models, etc.) or not. This trust in science seemed to be higher in the Pittsburgh IA focus groups than in those run in Manchester.

However, as a second explanation for these contrasting findings, the Manchester team notes that the issue of trust might not be limited to science, but encompass further public institutions:

> An explanation for these contrasting findings could be located in the different levels of public trust in the various cities/countries, not only about level of (dis)trust in ‘science’ per se but also (dis)trust in ‘government’, (dis)trust in ‘public participatory processes’ and also (dis)trust of individual agency. (Eric Darier, personal communication).

A third, more general explanation is that a scientific perspective on the issue of climate change is of limited relevance for most participants. This is consistent with the findings of several teams and cross-regional comparisons that found that participants tended to want to debate the climate change issue from within a much broader range of perspectives (ethical, political, moral, economic, inter-personel) rather than exclusively from a narrow "scientific" perspective [28,29].

3.9. Evaluation of the IA focus group process by the participants

The inclusion of a computer model within IA focus groups was organised in concordance with the general IA focus group design. That is, for any issue that was to be debated a time period was always included before any expert input or model presentation was provided, for participants to express their own concepts and what they thought to be relevant. As the quote below shows, some participants realised this fact and appreciated it:

> What I have found very interesting and very well prepared, is that first we talked – we said all that came into our minds – and afterwards we got some data on which we talked again. (...) It is very important to know what we think before seeing the data, because otherwise it could be that automatically after seeing the data we make all our approach to the issue depending on what we have seen. (Beatriz, Barcelona)

How many models in one IA focus groups?

In the Barcelona IA focus groups this issue was explicitly addressed by participants during the process evaluation session. The majority of participants felt that the amount of models they had experienced – two models for five sessions – was appropriate. The point they made was that although one model alone would have permitted them insights in more detail, seeing two models provided them with a more diversified understanding of the possible variety of approximations towards the climate change problem (local/global, lifestyle change/policy measures).

3.10. Evaluation of the added value of models by the participants

Participants were asked for their own evaluation of the process, i.e., whether they considered the models to be helpful for their discussion and judgement formation or not. Before we start discussing this question systematically, we include a number of other comments made about the computer models used in the IA focus group activities that are worth noting in this context. For example, the participants in Pittsburgh felt that many of the important questions to be wrestled with in the climate change debate are moral in nature and that models are of limited value in helping with moral questions, because they do not provide information relevant for moral issues (e.g., on intergenerational or international equity). They also thought that subjective things, such as quality of life, can not be modelled. Similar points were made by participants in the Venice IA focus groups as shown in the following quotations [27]:

> Mr. Computer has a brain, but not a soul.... (Venice)
> Human value is lost with the computer. The machine is cold. (Venice)

In Darmstadt one participant asked:

> Where is man in the models? Where are societal scenarios? (Gerhard, Darmstadt)

The results of this evaluation were mainly positive, but also ambivalent or negative. On the positive side, many participants supported the use of models because they had experienced them as interesting, providing new information in an attractive format. They appreciated that in most models, a range of possible outcomes was given, not just one – potentially biased – result. However, there were also sceptical remarks like the following one:

> The models were informative, but not really helpful. (Cornelia, Zurich)

This quote illustrates that participants acknowledged the new information that they got from the model. But some clearly felt that this information was also disappointing, indicating areas of uncertainties and limited understanding. People learned about collective ignorance, which comes close to Aristoteles definition of wisdom: I know that I don't know.

Some concluded that there was nothing to be learned from the models, while others developed an attitude of sceptical trust [1]. The other extreme was not found in the IA focus groups: Participants did not show blind trust in the models and did not treat them as "truth machines" but were aware of the shortcomings and uncertainties. This is true for those models that were explicitly addressing uncertainties (TARGETS, ICAM, IMPACTS, OPTIONS) and to a lesser extent also for the other models (IMAGE, PoleStar, Lifestyle Indicators).

> You can't take the model output as gospel truth. (Donald, Pittsburgh)

The quote above expresses some healthy skepticism toward the models used in this group. In this context, it is important to note that it was not the intention of the modellers to promote some kind of blind trust, but – to a greater or lesser extent – an attitude of informed skepticism. The quote illustrates, that at least in this case, the message of the modeller was communicated successfully to the user.

Last but not least, several teams observed that previous experience with computer technology definitely influenced the way that participants reacted to the use of computer models. For instance, the Venice research team noted a variety of reactions according to previous experience with this type of technology, from those who knew the finer details of computer models to those who had never seen a computer at work [27]. People that were more familiar with these types of technologies were more willing and active when using them. This group also noted that the age of the participants was a significant variable in the acceptance of computer models. Similarly, the Stockholm group found that when they asked whether any of the participants wanted to use the computer mouse during two of the demonstrations, on both occasions the volunteers was the youngest male in the group.

4. Synthesis and suggestions

4.1. Feasibility of the approach

As a first and general synthesis, it is fair to say that these findings provide evidence for the feasibility of integrating computer models with citizen deliberation. Keeping in mind that most of these models were not designed for non-experts, this is not a trivial result. This indicates that computer models per se are not a barrier in such participation processes. We are aware that feasibility is only a necessary, but not sufficient requirement for suggesting the wider use of IA focus groups. Other criteria would include an evaluation of the process by the participants, scientist (here: the modellers) and also policy makers. For obvious reasons, we are focusing on the evaluation by the participants.

4.2. Suggestions for IA focus group process design and model moderation

We consider the following three points as essential for a successful facilitation of the interaction with the models. First, the model moderator should be fully prepared and have access to proper support material. Possibilities for satisfying these demands could be either a "hot-line" to a model developer or model expert during the sessions, or to have detailed backup materials available during the presentation to satisfy the more curious participants

Second, she/he should be able to stimulate discussions. This requires on the one hand an indepth understandig of the model to be presented, and on the other hand the ability to communicate and translate key messages of the model into a non-expert language.

Third, participants should perceive the facilitator as neutral with regard to the model and its messages. If the model moderator is an overenthusiastic model developer or a too negative model facilitator, the exercise outcome will be less valid than if a careful, respectful, and unbiased one takes part.

These suggestions may sound obvious and trivial, but they can only be realized under the condition of a close and good contact with the model developers which was the case in this project.

4.3. Suggestions for computer model design

On the basis of our findings, we see the following suggestions important for redesigning given or developing new models for participatory IA:

Space: For a global issue like climate change, a model should provide some global information, however, the focus should be on the region where participants come from. Regarding *time*, participants were more interested in short-term than long-term perspectives.

> A shorter time-span in scenarios, such as 20 years, would make it more concrete. (Agnes, Stockholm)

The *complexity* of climate change and its representation was certainly challenging for most participants. In that respect, model presentations should be kept as simple as possible, focusing on a few key processes that are modelled and explained very carefully.

As described in the findings section, participants reacted strongly and negatively towards the explicit discussion of uncertainty.

> If science is unable to agree, how should we be able to make any statement about climate futures? (Veronika, Zurich)

Despite these reactions, we suggest that *uncertainty* should be addressed explicitly in every model. Funtowicz and Ravetz have suggested the NUSAP notation scheme for dealing with uncertainty in quantitative information, that can be considered as a good start. The notation consists of five qualifiers: numeral, unit, spread, assessment and pedigree (NUSAP). The last three qualifiers address various aspects of uncertainty: Spread conveys an impression of the inexactness. Assessment expresses a judgement on the reliability and indicates the strength of the data. Pedigree conveys an evaluative account of the production process of the information and indicates the scientific status of the knowledge [2]. Besides the communication of uncertainty in quantities, more efforts are necessary to explain the qualities of uncertainty, its various sources and the approaches to deal with them.

Participants had a strong interest in exploring *policy options*. The findings with regard to that point were mixed: On the one hand, we had the impression that in some groups the interaction with the computer models did increase a sense of agency. Manipulating the models and visualising a diversity of scenarios conveyed the impression that the real world can be modified, too. This is especially true for those scenarios with policy interventions, supporting the view that collective action could make a difference for the future. (It remains open whether this sense of agency is a strong motivation for real word action or whether it is a virtual experience only with little impact.) On the other hand, the models often created a sense of gap between their own (lay) understanding and the models (scientific knowledge), giving people an impression that little can be done to combat climatic risks.

Furthermore, most models were only of limited help for evaluating the feasibility of the suggested policy interventions, for instance with regard to the political and societal institutions involved. The following quote illustrates this view:

> The greenhouse effect is certainly a frightful problem, but for our group, the model made us confused more than anything else. To accept that the world will go under or

persist in believing that freedom resolves all problems are both naive attitudes. But the big questions are *what* can we do and *how*? (Bodil, Stockholm)

Basically, I consider it as sound to approach the issue top-down. Whether this is feasible is an other story. It is certainly easier to address such a topic in the Landtag (regional parliament) than at the European level. (Ingo, Darmstadt)

Most of these questions had to be left to the consideration of the participants. Although quantitative modelling of regional policy options is a relatively new research area, IA-processes that are provided with more information on this issue would certainly be better able to meet the demands of the users.

With regard to the rather technical requirements of *user-friendliness* and *transparency*, we can rely on a number of suggestions given directly by the participants. The responses reflected some high expectations, especially with regard to the use of multi-media techniques (e.g., sound, music, video clips, etc.) and the wish for interactive approaches.

The following quotations illustrate the desire for colour, sound and graphic illustrations:

We are lay people. We need clear, simple and 100% pedagogical information to be able to understand why we are doing this. And these are graphs and tables that we do not understand ... but if we get it presented in a clear-cut way which stimulates our fantasy ... because we cannot understand at all what is said there. (Per, Stockholm)

... with graphics and colours, because one image is worth more than a thousand words (Monica, Barcelona)

... I would like to see an industry or a factory and see how it emits CO_2... a visual practical example (Victor, Barcelona)

Participants in the Venice In-depth Groups also suggested the use of animation, more interactive methods, pictorial interfaces and multi-media resources.

Insert a musical background. (Venice)

For non-experts you need many explanatory windows (sentences, examples, images...). (Venice)

The wish for more possibilities for interaction with the computer was expressed, for example, by participants from Stockholm, where it was generally felt, amongst those with computer experience, that they would want to sit down and try it out themselves, instead of watching. They wanted to have a more interactive model, where you could go in and change, for instance, the temperature and see what happens to the sea level. By being able to isolate such steps in the complex causal chain in climate change, it would become easier to understand the relationships. Then, it would be easier to grasp what the model is trying to show.

Furthermore, participants in Stockholm suggested that an interactive model for focus group use would likely benefit from features such as selection buttons of multiple-choice character. This would compromise the transparency but increase user-friendliness. Transparency is absolutely necessary in scientific work, but may be less useful in focus groups, where there will be no time to check background data and assumptions anyway.

A number of teams reported that the call for more interactive computer use was also put in terms of the use of computer games. Participants in both Barcelona and Pittsburgh referred to the game SimCity and thought that something similar for climate change and sustainability issues would be useful in an IA focus group setting.

Interestingly, a number of groups also expressed the wish to be able to "work backwards". As the report on the Pittsburgh IA focus groups states:

Models would be helpful if we could work backwards ... if we could decide what kind of world we want to leave our grandchildren and look to the model to tell us how to get there. (Curtis, Pittsburgh)

Other participants thought that it would be good to have the possibility of looking at scenarios from the past, e.g., sea-level a hundred years ago, since this would enhance the awareness about some issues. One group was particularly interested in more detailed information on economic impacts and possible ranges of impacts (worst and best).

Last, but not least we as researchers have also some suggestions based on our experiences with the models [17]:

User-friendliness can hardly be underestimated as a criterion. Keeping the user of a software in mind also means distinguishing between different levels of expertise. We have the impression that many model developers focus on the highest level of expertise only. In contrast to that, we suggest to plan for at least three levels of model use:

(1) Beginners: Lay people with limited knowledge and time. Provide quick-tours and demoviews that give a first impression.

(2) Advanced: Students with some background understanding, more time available, but not experts in any of the fields. Provide comprehensive documentation.

(3) Experts: Peers that might invest only little time, but care about details. Provide possibilities for digging deep.

Another element of user-friendliness is the availability of demoviews. The ULYSSES experience brings us to recommend the use of models – or demoviews – specifically configured for these kind of exercises in IA focus groups. Nevertheless, even if the characteristics of the computer model were ideal for the use in IA focus group discussions, its usage could be sub-optimal if the model presentation and moderation are unsatisfactory. To avoid both dissatisfaction of participants and failure to achieving the participatory IA aims, we found that it is necessary to have an appropriate preparation of the model facilitator before the IA focus groups exercise, an adequate design of the variables of the model to display, as well as proper adaptation of the model screen interface.

Finally, we feel that many of these models focus too much on quantitative aspects and give too little information about qualitative aspects. For the model development, this means that more context has to be added to the models, say documentation of definitions of variables, ranges of variables discussed in the literature, sensitivity of variables, outputs with interpretation etc.

5. Conclusions

What have we learned about the usefulness of computer models for a participatory process like IA focus groups? Despite the variety of models used and empirical designs applied, we see the following general lessons to be learned from that project:

The computer models were instrumental in stimulating the discussion on scientific aspects like complexity, globality and uncertainty. This stimulation was not always equivalent with clarification, but included processes of introducing unknown topics and raising the awareness for the limits of science. We have given some suggestions on how models can be improved with regard to these dimensions.

On the other hand, the computer models were less helpful for the discussion of regional policy issues which was the core interest of most participants. A number of explanations can be given for that finding: First, regional modeling is a relatively new field of investigation, and we have learned in the project that the adaption of a general regional model to a specific region is difficult. Second, modeling of policy processes is less developed than modeling of (natural) science phenomenon.

We are aware that several of these models have not been developed for lay people, but for a more informed and specialised audience, e.g., negotiators involved in national and international climate policy. However, it is important to keep in mind that in an interdisciplinary field as IA, the distinction between experts and lay people is not as clear cut as one might think, but rather a continuum that is contingent on the issue under consideration. Experts are usually specialists in a narrow disciplinary field, but for issues outside that field, they have to be considered as lay people that have to undergo the same learning processes. Therefore, we are convinced that the lessons to be learned about the usefulness of these computer models for normal citizens are also relevant for expert users.

Only a few of the models were specifically designed for this kind of activity. It is therefore not surprising that the research teams generally concluded that most of the models used were not very suitable for focus group discussions. On the background of these experiences we are rather skeptical whether an even more ambitious aim of these models can be reached, namely to be used individually without any social support of a model moderator.

What are areas for further research? Concerning model development, we consider it as very important to keep the user in mind. Some models are developed and used by the same individual or team as scientific think tool. However, many of these models make a claim of being accessible to a wider audience of educated users and for this purpose, the computer models should be smaller, simpler and better documented. This can be done by either improving the models themselves or by creating additional electronic documentation (e.g., a few model runs with interpretation or a hypertext glossary on a CD).

Having talked so much about computer models, it is important to keep in mind that in contrast to other scientific fields, computer models in IA are not a goal on its own, but a mean for providing expert information to a policy process. From our experience with developing participatory IA procedures, we would like to stress that computer models should serve as catalysts supporting the discussion, providing new information and insights, but not dominate the discussion, because the main intention in participatory IA is not to test a software, but to launch a learning process and to elicit views and values of the participants.

Concerning the social design of the participation procedure, we see the following areas for further research: While ULYSSES has followed an experimental approach of creating and analyzing interactions of users and models it would be interesting to take stock of the model use as it is happening outside these social science laboratories, say without scientific observation or control. For this purpose, an expert survey or a participant observation of model presentation workshops would be appropriate methodological approaches. A other and less costly method would be that model authors were to include in every publication about their models a report on the experiences of direct and indirect use of the model by individuals not involved in the model development.

Computer technology is rapidly developing and raises hopes to make almost every thing more easy, including participatory IA. In contrast to that euphoria, we are convinced that great care and effort has to be taken in the preparation and implementation of this kind of IA focus group. Nevertheless we would encourage continued exploration and development of this and other participatory techniques.

Acknowledgement

This paper is based on research performed in the European project ULYSSES – Urban Lifestyles, Sustainability and Integrated Environmental Assessment, financed by DG XII of the European Commission (Fourth Framework Programme – RTD Programme Environment and Climate) and in case of the Swiss team by the Swiss Federal Office for Education and Science (BBW). Partners of ULYSSES are Carlo Jaeger, Silvio Funtowicz, Brian Wynne, Salvador Giner, Asa Gerger, Maria Giaoutzi, Ferenc Toth, Jill Jäger, Jerry Ravetz and Bernd Kasemir. Furthermore, this research was supported by the Swiss National Science Foundation within the CLEAR project (Climate and Environment in Alpine Regions). The partner project from Pittsburgh was sponsored by the "Center for the Integrated Study of the Human Dimensions of Global Change", Carnegie Mellon University, Pittsburgh, which is supported by the US National Science Foundation.

The opinions expressed in this paper are those of the authors. We are very grateful to all our colleagues working in the project for sharing their thoughts and data with us. Special thanks goes to Janet Stocks and Ralf Schüle, who specifically prepared input for this paper (Stocks, 1998, Schüle, 1998) and to Eric Darier, Asa Gerger, Hadi Dowlatabadi, Paul Raskin, Christoph Schlumpf, Jerry Ravetz, Chris Hope and an anonymous reviewer for their invaluable comments and criticism on earlier versions of this paper. The responsibility for any remaining errors is ours. Last but not least, we want to express our gratitude to the participants in the focus groups that were willing to embark on that endeavour.

References

[1] J. Rotmans, Environmental Modelling and Assessment 3 (1998) 155.

[2] S.O. Funtovicz and J.R. Ravetz, *Uncertainty and Quality in Science for Policy* (Kluwer, Dordrecht, 1990).

[3] F.L. Toth and E. Hizsnyik, Environmental Modelling and Assessment 3 (1998) 193.

[4] E.A. Parson, Environmental Modelling and Assessment 2 (1997) 267.

[5] http://www.zit.th-darmstadt.de/ulysses

[6] J. Jäger, Environmental Modelling and Assessment 3 (1998) 143.

[7] R.S.J. Tol, Vellinga and Pier, Environmental Modelling and Assessment 3 (1998) 181.

[8] B. Kasemir, Behringer, Jeannette, De Marchi, Bruna, Deuker, Christoph, Dürrenberger, Gregor, Funtowicz, Silvio, Gerger, Asa, Giaoutzi, Maria, Haffner, Yvonne, Nilsson, Mans, Querol, Cristina, Schüle, Ralf, Tabara, David, van Asselt, Marjolein, Vassilarou and W. Demetra, Focus Groups in Integrated Assessment – The ULYSSES pilot Experience, Technical University of Darmstadt, ZIT Center for Interdisciplinary Studies in Technology, Darmstadt (1997).

[9] U. Dahinden, Querol, Cristina, Jäger, Jill, Nilsson and Mans, Using computer models in participatory integrated assessment – Experiences gathered in the ULYSSES project and recommendations for further steps, ULYSSES working paper WP-99-2, Technical University of Darmstadt, Sociological Institute, Darmstadt (1999).

[10] G. Dürrenberger, Behringer, Jeannette, Dahinden, Urs, Gerger, Asa, Kasemir, Bernd, Querol, Cristina, Schüle, Ralf, Tabara, David, Toth, Ferenc, van Asselt, Marjolein, Vassilarou, Demetra, Willi, Nicole, Jaeger and Carlo (1997), Focus Groups in Integrated Assessment. A manual for a participatory tool, ULYSSES working paper WP-97-2, Technical University of Darmstadt, ZIT Center for Interdisciplinary Studies in Technology, Darmstadt, 1997.

[11] ULYSSES, Technical University of Darmstadt, ZIT Center for Interdisciplinary Studies in Technology, Darmstadt, 1998.

[12] http://hdgc.epp.cmu.edu/public/icam/icam.html

[13] http://CLEAR.eawag.ch/models/impactsE.html

[14] C. Schlumpf, Behringer, Jeannette, Dürrenberger, Gregor, Pahl-Wostl and Claudia, Environmental Modelling and Assessment 4 (1998) 1.

[15] http://CLEAR.eawag.ch/models/cozweiE.html

[16] B. De Marchi, S. Funtowicz, C. Gough, A. Guimarães Pereira and E. Rota, The ULYSSES Voyage: The ULYSSES project at the JRC. EUR 17760EN (Joint Research Centre – European Commission, Ispra, 1998).

[17] J. van der Sluijs, Jaeger and Jill, Towards a Typology for Computer Tools for participatory Integrated Assessment, Working paper, University of Utrecht, Utrecht (1998).

[18] J. Stocks, Citizen discussions of computer models in global climate change focus groups, Working paper, Carnegie Mellon University, Pittsburgh, Pennsylvania, USA (1998).

[19] M.G. Morgan, Smuts, Tom, Dowlatabadi, Hadi, Fischhoff, Baruch, Lave, Lester, Rubin, eds., *Brochure: Global Warming and Climate Change* (Carnegie Mellon University, Pittsburgh, 1994).

[20] M. Nilsson, *Computer Tool Experiences in ULYSSES* (Stockholm Environment Institute, Stockholm, 1998).

[21] D.H. Meadows, D.L. Meadows, J. Randers and W.W. Behrens, *The Limits to Growth* (Universe Books, New York, 1972).

[22] J. Oakhill, *Mental Models in Cognitive Science* (Taylor and Francis, London, 1996).

[23] A. Bostrom, M.G. Morgan, B. Fischhoff and D. Read, Risk Analysis 14 (1994) 959.

[24] P.N. Johnson-Laird, *Mental Models* (Cambridge University Press, Cambridge, 1983).

[25] D. Kahneman, Slovic, Paul, Tversky and Amos, *Judgment under Uncertainty: Heuristics and Biases* (Cambridge University Press, 1991) (first published: 1982).

[26] G. Gigerenzer, Todd and M. Peter, *Simple Heuristics that Make us Smart* (Oxford University Press, New York, NY, 1999).

[27] A. Guimaraes, Gough, Clair, De Marchi and Bruna, International Journal of Environment and Pollution (1998), accepted.

[28] E. Darier, Schuele and Ralf, "Think Globally, Act Locally?" Climate Change and Public Participation in Manchester and Frankfurt, Local Environment (1998), submitted.

[29] E. Darier, Gough, Clair, De Marchi, Bruna, Funtowicz, Silvio, R. Grove-White, Kitchener, Dryan, Pereira, Angela, Wynne and Brian, Between Democracy and Expertise? Citizens' Participation and Environmental Integrated Assessment in Venice (Italy) and St. Helens (UK), Journal of Environmental Policy and Planning (1998), submitted.