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The relevance of participatory approaches in integrated environmental assessment

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1. Introduction

Integrated environmental assessment is a booming field. Its intellectual challenges, its relevance for real life problems, and its generous financial support have attracted many researchers who either assess the environment in an integrated manner, or purport or pretend to do so. This has led to a wide and diverse range of research and policy activities, all sharing the nominator of integrated environmental assessment.

This paper has a twofold objective. Firstly, it discusses the main approaches to Integrated Environmental Assessment (IEA). IEA is meant to deliver usable (scientific) knowledge to environmental policy making. In order to achieve its goal, IEA frequently uses an integrated assessment modelling approach, but it may also use a participatory approach. Modelling and participatory approaches are sometimes considered irreconcilable, since they are different in scope, use different kinds of methods and may even be based on conflicting epistemologies. However, as this paper will argue, they are increasingly recognised as mutual reinforcing approaches. They need each other in order to improve decision making on complex environmental issues by identifying, using and integrating a broad body of knowledge available from different sources. Therefore, the second objective of this paper is to show the mutual interdependence of participatory and modelling approaches in assisting policy-making. It thereby gives special attention to the various goals and functions of IEA. The contributions of IEA to science are beyond the scope of this paper.

Section 2 defines the concept of integrated assessment and explores its possible goals and functions in assisting environmental policy-making. Sections 3 and 4 succinctly provide an overview of approaches to integrated assessment. The authors, working in both fields of IEA, have tried not to hide the mutual differences. Especially the strengths and weaknesses of each approach in assisting environmental policy-making are assessed. Section 3 introduces and explains integrated assessment modelling, while section 4 focuses on participatory integrated assessment. Section 5 takes a different angle in assessing the strengths and weaknesses of modelling and participatory approaches. It discusses three examples of what may go wrong if either one of the approaches stands alone. Section 6 presents conclusions as regards possibilities for combining modelling and participation in IEA.

2. What is integrated assessment?

Integrated environmental assessment is an active and rapidly developing field. It involves scientists and decision makers from a diversity of backgrounds and communities. Many approaches to this complicated but promising field co-exist.[1] A number of definitions of integrated assessment are around in the literature. Perhaps the broadest definition possible is the one used by the IPCC [123]:

> Assessment is integrated when it draws on a broader set of knowledge domains than are represented in the research product of a single discipline. Assessment is distinguished from disciplinary research by its purpose: To inform policy and decision making, rather than to advance knowledge for its intrinsic value.

Rotmans and Dowlatabadi [101] phrase it as follows:

> In general, integrated assessment can be defined as an interdisciplinary process of combining, interpreting and communicating knowledge from diverse scientific disciplines in such a way that the whole cause–effect chain of a problem can be evaluated from a synoptic perspective with two characteristics:
>
> (i) IAs should have added value compared to single disciplinary oriented assessment;
>
> (ii) IAs should provide useful information to decision-makers.

They also offer an alternative definition:

> Integrated assessment is policy motivated research to develop an understanding of the issue, not based on disciplinary boundaries, but based on boundaries defined by the problem:
>
> (i) to offer insights to the research community for prioritization of their efforts;

[1] Reviews and assessments of integrated (environmental) assessment can be found in [5,6,18,36,48,72,79,80,82,94,95,100,101,103,105,122,123].

(ii) to offer insights to the decision-making community on the design of their policies.

Parson [79] prefers to phrase it as:

> The two defining characteristics [of integrated assessment] are (a) that it seeks to provide information of use to some significant decision-maker rather than merely advancing understanding for its own sake; and (b) that it brings together a broader set of areas, methods, styles of study, or degrees of certainty, than would typically characterize a study of the same issue within the bounds of a single research discipline.

In any of these definitions, "integrated" conveys a message of multi- or interdisciplinarity, and "assessment" a message of policy relevance. They also imply that the whole of integrated assessment should be greater than the sum of the disciplinary parts and that the disciplines preferably participate at levels commensurate to "their contribution" to identifying and solving the problem. We use these notions as our guide.[2]

We take issue with the Rotmans and Dowlatabadi definitions, which presume that a clearly defined problem exists. Instead, we will argue that one of the goals of integrated assessment may be to structure the problem. One may be misled by the word "synoptic" in the first Rotmans and Dowlatabadi definition. This is not to imply a top–down view of policy making, but rather a broad and strategic look at the issue (cf. also [114]).

The definitions also imply that integrated assessment can contribute a great deal to the management of uncertainty in two ways: It may help to establish research agendas (see the second Rotmans and Dowlatabadi definition above) but also to enhancing political action based on incomplete but sufficient knowledge.[3]

In answering the question how integrated assessment may contribute most to environmental policy it is important to distinguish between specific goals and functions it may serve in the policy process. The Social Learning Group (forthcoming), as quoted in Toth and Hizsnyik [114], suggests the following three goals – or, as they put it, functions – of IEA:

1. Sorting out the character, underlying causes and implications of the issue ("risk assessment");
2. Identifying and evaluating management options ("response assessment"); and
3. Establishing objectives and strategies to achieve these ("goal and strategy formulation").

The Social Learning Group explicitly states that the role of IEA is limited in ex-ante and ex-post monitoring of the state of the environment, in implementing policies, and in evaluating policies' performances. This is because IEA takes a broad look at issues, whereas monitoring, implementation and evaluation require a more detailed view. It is argued below that multi-disciplinary tools are necessarily less detailed (per discipline) than their disciplinary counterparts.

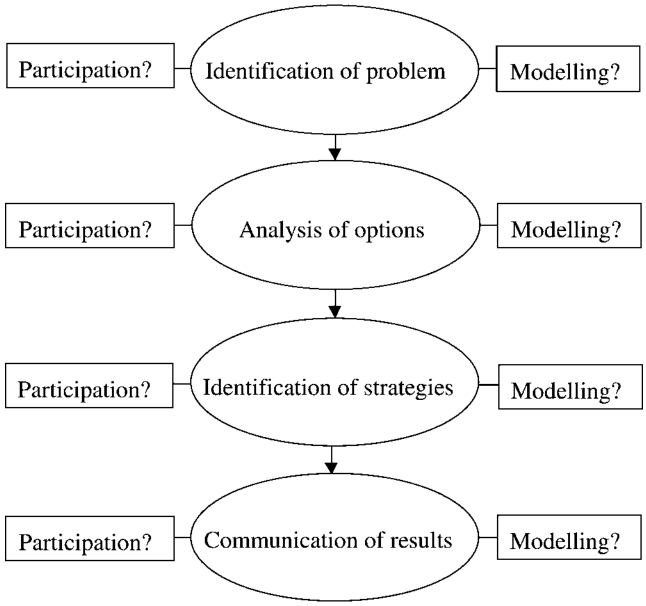

Figure 1. Schematic presentation of a typical integrated assessment.

Figure 1 puts the functions identified by The Social Learning Group in a somewhat different light, as it links them to the stages that are typical for an IEA: problem identification, analysis of options, identifying goals and strategies for action, and communication of results. The "risk assessment" function corresponds a great deal to the IEA's first stage, identification of problem. The "response assessment" function fits in quite nicely with the typical IEA's second stage, analysis of options, while "goal and strategy formulation" is quite identical with what we consider the IEA's third stage, but it also may overlap with its fourth, the communication of results to the relevant audiences.

Obviously, a real IEA may look different from a "typical" IEA. Depending on specific information needs on the side of the funding agency or the specific interest of the IEA project team, its scope and focus may vary from one of the goals as identified by The Social Learning Group to another. For instance, with regard to climate change, Dowlatabadi [20] focuses on defining the issue and its boundaries; Bruce et al. [12] identify and assess policy options; Wigley et al. [125] discuss policy strategies; and Schlumpf et al. [104] emphasize communication. Some IEAs focus on (regional) risk assessment of climate change, such as the Canadian Mackenzie Basin Impact Study [16] or the study of climate change impacts in the Alpine region [13]. Other studies focus on both risk assessment and the formulation of goals and strategies, such as the European ULYSSES (Urban LifestYles, SuStainability and integrated Environmental aSsessment) project. The Dutch COOL (Climate OptiOns for the Long term) project focuses on response assessment and the identification of strategies for

[2] Loosely defined as being policy-relevant, multi-disciplinary research into complex environmental issues, IEA is nothing new. Toth and Hisznyik [114] place IEA in its historical context.

[3] It is this kind of uncertainty that Ravetz [92,93] refers to as "usable ignorance", as opposed to "usable knowledge" [63].

Dutch long term climate policy. In the COOL study, the goal of long term climate policy, −80% GHG emissions by the year 2050, is taken as a starting point and the risks and impacts of climate change play a minor role in the assessment. Other examples of IEAs focusing on response assessments and strategies are the RAINS-project [47,48] and the so-called Delft process [7], which served in support of international negotiations on the Second Sulphur Protocol and the Kyoto-protocol, respectively. From the diverse range of IEA examples that are available, the IEA carried out by the Intergovernmental Panel on Climate Change comes closest to the four-stages IEA which is visualised in figure 1. The IPCC has working groups reporting on the actual progress in scientific knowledge on the climate system, climate change impacts and response options.

Apart from the differences with respect to goals and functions,[4] IEAs are very much different in the way they develop and use integrated assessment models and participatory approaches. Some IEAs are scientific modelling exercises, aimed at integrating scientific knowledge from different (disciplinary) sources into a model. Results are communicated to policy-makers and other potential user groups afterwards. On the other extreme, the integration of (scientific) knowledge from different sources is considered a mainly participatory activity. This kind of IEA is quite similar to what is known as Interactive Technology Assessment [45]. It is carried out as an iterative dialogue between stakeholders from the science and policy communities, but the scientific knowledge discussed is not at all presented in the form of integrated assessment models. Many IEAs, however, tend to balance the two extremes of pure discussion and pure modelling, with models (disciplinary, soft-linked, hard-linked or integrated) supporting expert panels and focus groups,[5] or expert panels and focus groups supporting models.[6] Interaction may take place by involving stakeholders but, equally important given the complexity of many environmental issues, by multidisciplinary panels of scientists, as, for instance, the Intergovernmental Panel on Climate Change.

The distinctions made in goals, functions or, as in figure 1, stages of IEA are meant to support the highly difficult, if not tricky undertaking of designing an integrated assessment. At the core of the design should be a clear understanding of what modellers and/or participating stakeholders can deliver, at what stage and how. If modelling and participatory approaches are to be mutually reinforcing, this issue should be addressed.

3. Integrated assessment modelling

Integrated environmental assessment is often done using models. Models combine scientific theory and data in a precise and rigorous way. Models allow for many, wide-ranging experiments with a virtual system, while we can only conduct one single experiment with the real system. A model's value is determined by its ability to realistically represent certain features of reality.

As integrated assessment combines disciplines, integrated assessment models (IAMs) consist of coupled "disciplinary" modules, or simplified forms thereof.[7] The respective disciplinary parts can stand alone and communicate with one another through exchanges of input and output data (soft-linked models), perhaps in a common shell (hard-linked models). The parts can also be integrated into a single computer code (integrated models). The latter is preferable from a theoretical point of view, but may meet insurmountable difficulties. Differences in spatial scales, temporal scales (incl. equilibrium versus real-time models), modelling concepts (optimisation versus simulation, local versus global optimisation), data availability and quality, and maturity of disciplinary modules often make coupling and integration difficult or even impossible. And then there are practical difficulties, related to differences in hardware, software, jargon, and so on.

There are many ways to design an integrated assessment model. Various classifications of existing IAMs are conceivable and have been proposed. A major distinction is the way in which "policy" is brought into the IAM. IAMs can be policy evaluation or policy optimisation tools [123].[8] Policy evaluation IAMs analyse the outcomes of proposed policy strategies.[9] Policy optimisation IAMs advice de-

[4] Another way of distinguishing different types of IEA is provided by the dichotomy vertical-horizontal. In a *vertical* integrated assessment, all aspects of one particular issue (such as, in the case of climate change; development, equity, energy sector and so on) need to be taken into account. In a *horizontal* integrated assessment, all aspects of a sector (e.g., energy), system (e.g., a river basin) or region (e.g., an island) become articulated Note that the definitions of horizontal and vertical integration are sometimes reversed. Note also that some prefer "horizontal integration" to mean integration between scientific disciplines, and "vertical integration" to mean integration between science and policy.

[5] See, for example, Van der Sluis and Jaeger [119] and ULYSSES [23,50, 54,55,94].

[6] See Hordijk [46] for a model review by an expert panel.

[7] A proper simplified form contains all the essentials, but not the details of the larger model. Simplified models are also referred to as reduced form models, meta-models or computationally efficient models.

[8] After the IPCC Second Assessment Report was written, a third type of IAMs emerged: equilibrium models [31]. Simulation models are recursive-dynamic models; these models calculate the future from a given initial state and rules about the evolution of the states. Optimization models are dynamic-control models; in addition to a recursive-dynamic component, some intertemporal objective function is optimized. Equilibrium models are intertemporal general equilibrium models; agents in each time period maximize their own welfare while exchanging goods with other agents in other time periods. Although unrealistic, equilibrium models are useful for thought experiments in which the interests of different generations are explicitly treated. In their approach to policy, equilibrium models are similar to simulation models, although aimed at more fundamental policy choices (e.g., about intergenerational distribution of resources).

[9] Examples of policy evaluation models for climate change are IMAGE1 [98], ESCAPE [102], IMAGE2 [2], AIM [73], GCAM [25] and SIAM [35]. An example of a policy evaluation model for acidification is RAINS [1,3,28].

cision makers by analysing how certain goals can best[10] be accomplished.[11] Optimisation models thereby not only evaluate policy strategies, but also select and judge them. Note that optimisation can only be accomplished at the expense of a detailed representation of the system.[12] Policy optimisation models tend to place more emphasis on economics; policy evaluation models tend to place more emphasis on the natural sciences. However, the division in modelling approaches does not follow sharp disciplinary boundaries.

Another distinction between the various current integrated assessment models is their treatment of uncertainty. Some modelling teams try to capture the underlying system as accurately as they can, resulting in very detailed models.[13] In this approach, it is attempted to avoid uncertainty by putting as much knowledge into the model as possible. The problem with this approach is that the resulting model is not necessarily as accurately as needed, particularly not for complex environmental issues on large spatial and temporal scales. Adding detail to a model implies an increase in computer time to run it, the same time increasing the number of judicious choices and parameters to be analysed in a sensitivity analysis. Other modelling teams place uncertainty in the core of their endeavour,[14] trying to capture the range of possible directions in which the underlying system may develop. All parameters are described by a probability density function rather than a single value, variants of the model are used to analyse uncertainty about functional relationships between variables, and alternative models are used to analyse uncertainty about model and problem structure. Note that uncertainty can only be properly analysed by sacrificing the details of the model.

It appears that in both "evaluation versus optimisation" and "best estimate versus uncertainty", the level of detail forms an important distinction. Because in modelling evaluation is a special case of optimisation, and best guess a special case of uncertainty, optimisation under uncertainty appears to be the proper approach to integrated assessment modelling (that is, if one accepts that optimality can be defined, and uncertainties meaningfully quantified). However, the amount of detail sacrificed is considerable, and may render the exercise futile to decision makers.

Since there is no single-best modelling approach, integrated assessment requires multiple modelling approaches – each with its strengths and weaknesses – to answer multiple questions and obtain multiple insights.

This diversity of modelling approaches is needed especially when there is no consensus on what the actual problem is, or many questions need to be answered. It does not suffice, however, to have diversity of model approaches. Within each approach, a diversity of models is desirable. This is to enhance creativity through competitiveness, to avoid institutionalised favours to the outcomes of particular models, and to allow for the robustness of results to be analysed. Yet, models should be comparable. A challenge for the integrated modelling community lies in understanding what drives the models' outcomes and, particularly, the similarities and differences in the outcomes for different assumptions, different models and different modelling approaches.

Strengths and weaknesses

Formalisation of integrated assessment in a mathematical model has a number of advantages, such as: (i) internal consistency; (ii) subject to formal sensitivity, robustness and uncertainty analyses; and (iii) transportability.[15] Disadvantages are that: (i) only well-defined problems can be analysed; (ii) it is hard to represent the "softer" parts of integrated assessment (e.g., social structure, politics); and (iii) continuous intuition checks (e.g., to prevent overextrapolation) are absent in a computer code.[16]

A particular difficulty with models is that, in most cases, the modellers, and not their clients, determine which variables are reported and how, and which objectives are optimised and how. Hence, it may happen that the modeller's answer does not match the decision maker's question. This implies that the decision maker does not necessarily get the full answer to the question. The decision maker may also fail to recognise the mismatch between question and answer, for instance, because the differences between the model's jargon and the real world have not been made explicit.

Current IAMs suffer from a number of more tractable problems too. We list five.

- Often, data are farther interpolated or extrapolated than one would like to. For example, detailed knowledge about a single tree species is used to model a mixed forest. Or, case studies of Egypt and Zimbabwe are used to model the whole of Africa.
- The "softer" parts of the model are treated in a rather *ad hoc* manner. For instance, models of the impact of climate change use "rules of thumb" to represent decisions

[10] Note that the definition of better and best is model-dependent. Note also that most models take a mainstream neo-classical economic stance.

[11] Examples of policy optimization models for climate change include DICE [74–76], RICE [77], MERGE [67,68], CETA [83–88], DIAM [33], FUND [109,111], and CSERGE [26,27,66]. An example of a policy optimization model for acidification is ASAM [4]; later versions of RAINS are able to minimize emission reduction costs given deposition targets [56].

[12] A first attempt to build more complicated optimization models is Janssen's [52] OMEGA model.

[13] The "kitchen sink" approach to uncertainty.

[14] Examples of such models for climate change are ICAM [21], PAGE [44, 90,91] and the model of Yohe and Wallace [127]. See also [29,62,108, 116].

[15] Some would argue that an additional advantage of mathematical formalization is transparency. However, transparency is a relative concept. A mathematical model is only transparent to one with a fair understanding of mathematics. Complex models are only transparent to the initiated in that particular brand of modelling. In addition, qualitative assessments can also be transparent, though not necessarily to a mathematician.

[16] Some would argue that mathematical formalisation does not ensure policy-relevance, a fourth disadvantage. However, policy-relevance is not precluded either. Furthermore, qualitative assessments are not necessarily more policy-relevant.

about adaptation, such as "all densely populated land will be protected from sea level rise" or "low income countries will not irrigate more of their agriculture".

- A number of IAMs draw on a single set of disciplinary studies, so that there is model proliferation but not diversity. For example, most integrated assessment models adopt Nordhaus' [74] impact estimates (see [112]). In fact, there are only a relatively small number of (independent) integrated models.
- Those independent models that are around are too diverse in modelling approach to be comparable.
- Many models are intransparent. A few models are secret, most are not fully documented, some are enormously large, some are badly programmed, some are written in an unfamiliar programming language, some are documented in an unfamiliar tongue.

Given the diversity of models available and the assessment of strengths and weaknesses of integrated assessment modelling, it is possible to draw some conclusions on the way modelling can be used in the various stages of IEA:

Problem identification

– Models provide policy-makers and policy stakeholders with information on how environmental conditions may develop, with or without certain interventions. They help to assess the impacts of a change in environmental conditions on human life, global or national economies *et cetera*. Models can also help identifying problems related to the distribution of costs and benefits.
– Since models are only capable of analysing well-structured problems, models are necessary but not sufficient tools to identify and define the problem to be evaluated in the IEA.
– Once the problem is identified and structured, existing models need to be adjusted or new ones developed.

Analysis of options

– Models, especially optimisation models, provide information on the effectiveness, efficiency, and equity of response options. Given the specific assumptions and variables that characterise a model, analysis of options benefit from the use of various models yielding different outcomes.

Identification of goals and strategies

– Since the identification of goals and strategies to a large extent implies a choice or ranking of values, the role of models in this respect is limited. Given a clear set of preferences, models are useful in assessing complex trade-offs between conflicting interests.
– Models can be used or designed in order to assist in identifying acceptable levels of risk as related to expected impacts. Models can also help to set timeframes for established goals. An example of this is provided by the so-called save landing analysis carried out in the Delft process [7].

Communication of results

– Models provide a powerful tool to communicate research results. Especially their capacity to visualise potential future developments makes them appealing to a wider audience. This is what happened with environmental issues such as acid rain and ozone depletion.
– However, since models are often difficult to understand for non-modellers and intransparent, they may meet with scepticism or even suspicion. The evaluation and communication of modelling results may therefore require the involvement of stakeholder panels.

In conclusion, models play an important role in all stages of IEA. It appears, however, that they are unfit for the identification of complex environmental issues and policy goals and strategies, especially if they are the only assessment tool.

4. Participatory integrated assessment

Participatory Integrated Assessment (PIA) can be considered as a form of participatory policy analysis, which aims at supporting the policy process by designing and facilitating policy debate and argumentation [71]. A wide range of participatory methods and techniques has been developed within the realm of disciplines such as social psychology, policy sciences, decision analysis and anthropology.[17] Some of these are quite old, like brainstorming [78] or decision seminars [60], others are of more recent date, such as policy exercises [81,82], consensus conferences [53] and interactive technology assessment [32]. The introduction of participatory methods into the integrated environmental assessment community is of quite recent date, which has contributed to the misconception that participatory methodologies are less developed and matured than integrated assessment modelling.[18]

Like there are many different kinds of models, there is participation in many different forms. Mayer [71, p. 251; 70, p. 202] distinguish seven kinds of participation:

(1) *Information/education*. The primary function of stakeholder involvement is to make them aware of scientific findings and to explore the usability of the information offered.

(2) *Consultation*. Stakeholders are asked what they know about the problem and what should be done about it.

[17] See for an overview [70,124].

[18] One other explanation for this misconception may relate to the fact that many of those working in participatory environmental assessment have made the step into this field quite recently and sometimes lack a training in the social sciences.

(3) The *anticipation of future developments*, often used in IEA. Forecasting and backcasting are methodologies that fit in with this approach.

(4) *Mediation.* Here, the question is: What do participants know about mutual values? What level of consensus can they reach?

(5) *Co-ordination* addresses questions such as: What interdisciplinary knowledge should participants generate? What is the relation with other policy issues or sectors?

(6) *Co-production*, a concept introduced by Susskind and Elliot (1983) relates to joint problem solving. The main question is: What shared responsibility can participants achieve?

(7) *Learning.* This kind of participatory activity enhances a change in core knowledge and attitudes. Participants are asked to explore new styles and strategies for policy-making.

The above participatory activities are ranked on a scale, which ranges from a lower to a higher level of actual participation. In PIA, stakeholder involvement, debate and argumentation are matters of degree. The approach chosen in a specific situation, may depend on factors such as the focus of the project and its specific information needs. However, in order to better understand the way participatory projects are carried out in practice, it is worthwhile to briefly examine their underlying assumptions.

Two approaches to PIA[19]

The huge diversity of methods and techniques that are used in PIA basically reflect two main approaches to participation, which both focus on knowledge dissemination and use in support of policy development. For reasons explained below, these approaches are labelled the *cognitive approach* and the *argumentative approach*.

The *cognitive approach* departs from the observation that policy-makers, because of their daily concerns, are not always open for information on complex issues. Preoccupied with the short term, they tend to neglect the long term. Especially in situations of high risk and pressure, they tend to narrow down their scope to their immediate network. This may lead to miscalculations of the problem situation and wrong decisions. The goal of a PIA exercise is to widen policy-makers' scope, or, to put it in jargon: to change their "cognitive map". This is basically done by creating distance between the policy makers and the policy issue, which can be accomplished by means of a role game and/or by moving the decision-problem to another country or a future situation. Distance is assumed to contribute to an atmosphere, in which policy-makers become able to consider new information and creatively think about new options. Gaming and simulation exercises provide tools for policy support. In this view on participatory assessment, originally developed in the military and for the training and design of complex systems such as nuclear power plants and aircraft, distance between the participant and the subject matter is essential, as Parson explains:

> These methods involve displacing participants from their real and immediate tasks, roles, identities and decision contexts. They pose decision situations that are future, or counter factual, to move participants outside their normal habits and positions, and encourage creative thinking, new ideas, and insights [80, p. 12].

The cognitive approach can also be recognised as underlying methodologies for future research, such as Delphi in its original form [64,65] and backcasting [22]. It should be noticed that, in the most extreme but not unrealistic case, participants in a PIA exercise may not at all enter into a discussion with one another. Some kinds of participatory activities, especially communication and consultation, do not necessarily require any stakeholder interaction; they may just respond to the information presented to them. Many techniques used in other kinds of participatory activities, too, are designed to prevent or restrict debate and argumentation. The underlying justification is that debate and argumentation might prevent the discussants from taking distance from the here and now and, hence, constitute a barrier to open-mindedness and creativity. Of course, methodologies and techniques like Delphi and backcasting can also be applied differently, depending on the design of the project.

The *argumentative approach* starts with the observation that stakeholders from the policy and science communities are unlikely to improve their understanding of a complex problem situation, if they are provided with (new) factual knowledge. This is explained by the observation that ignorance does not primarily follow from a lack of information but from a lack of understanding of the conflicting assumptions underlying diverging viewpoints. Stakeholders may not only be unaware of each other's assumptions, they may be unaware of their own assumptions as well. PIA therefore aims at increasing an understanding of ones own and others' assumptions, some of which may look trivial at the beginning of the process but may turn out to be quite essential for a specific viewpoint in the end.

Stakeholder dialogue is a form of problem structuring, i.e., the identification, confrontation, and – where possible – integration of the most divergent views with respect to a given problem situation [37,39,40].[20] Problem structuring is meant to avoid that the "wrong" problem is being addressed by policy. Therefore, debate as regards the structure of the problem is as much about what the problem is or should be as about what it is not. A typical example is the question as to whether addressing traffic congestion will help to address climate change. This question can be partly addressed by

[19] This section is based on Berk et al. [8].

[20] A problem is normally defined as a gap between a standard, value or goal and an existing situation. Problems are socially and politically constructed. This is far from saying that they do not really exist, but refers to the notion that facts and values are not similar to all observing them.

providing stakeholders with information about technology that leads to zero emission cars. But this may not convince an audience which tends to put the climate change issue into a wider perspective of sustainability than just addressing issues of technology. Therefore, the core beliefs, which may relate to feelings and emotions rather than to straightforward facts, have to be addressed as well. Structuring an un- or ill-structured problem, global climate change being a typical example, is the kind of participatory activity which aims at *learning*.

Learning, as Thissen and Twaalfhoven phrase it, can be considered as "breaking through cognitive fixations" [107]. Learning by debate and argumentation implies that stakeholders must be addressed as the persons they really are, that is in the here and now. Creating distance would constitute a barrier for the surfacing or eliciting of their assumptions. Methods for problem structuring, like assumptional analysis [69] and the Devil's Advocate approach [106] have in common "that conflict, if properly introduced and managed, can improve the quality of decisions" [106, p. 153], quoted in [61].[21] Conflict may highlight the pros and cons of different options and the underlying argumentative structure.

To wrap up, there are many participatory approaches that underlie different visions about how participation may contribute to a successful integrated assessment. PIA as an approach to integrated assessment may not be confused with increasing democracy and is not exclusively rooted in the theory of participatory democracy.[22] The cognitive and argumentative approach, as they are labelled here, seem to most comprehensively reflect the different notions that underlie participatory activities. In practice, PIAs may to some extent balance between both views. Backcasting, for example, starts by putting the participants in a situation distant from the here and now but will end up with investigating the consequences of the long term assessment for present policy making. PIAs may especially differ as regards the following characteristics:

Participants

The identification and selection of stakeholders is a crucial and time-consuming activity. If the project aims at exploring the various aspects of a complex, unstructured, issue, then participants should constitute a heterogeneous group representing the whole range of (potentially) conflicting views.[23] If the project aims at communicating a scientific model to a group of potential users, heterogeneity will be not that important [7].

Process

The design of the process must be dependent on what the project is supposed to deliver. Processes can be more or less interactive and more or less consensus-oriented. Learning does not necessarily lead to consensus.[24] It is often more satisfying to work towards the structuring of a diversity of views than towards unanimity as related to goals and strategies.

Role of scientists

Participation has a two-way critical function, as the interactive identification and evaluation of policy options requires a critical evaluation of the available knowledge, and, *vice versa*, the identification of a policy relevant research agenda cannot avoid a critical examination of policy options and associated research needs.[25] PIA may thus include scientists or may even be restricted to scientists in the form of expert panels.[26] Experts can contribute by providing information, but the stakeholder dialogue may also operate as an "extended peer review", which critically analyses and evaluates the assumptions that underlie scientific findings and models [30]. Furthermore, stakeholders may bring their practical knowledge to the fore in order to balance the – in their eyes – unrealistic picture put forward by science. Scientists and laypersons may dismiss each others' opinions, as witnessed by the government review of the Second Assessment Report of Working Group III of the IPCC (cf. [110]).

Strength and weaknesses

The major strengths of PIA appear to be the following: First, PIA is able to highlight and analyse different views, especially with respect to a certain problem. For obvious reasons, models lack that ability. Secondly, PIA can initiate *learning*, resulting in new insights for policy that could not have been obtained otherwise. Thirdly, PIA may increase stakeholder involvement and commitment to joint problem solving.

PIA's major weakness seems to be that participatory activities meet with a lot of difficulties and are time consuming. There are always difficulties caused by external factors that cannot be influenced by the project team. But difficulties also relate to the design and execution of the project itself. A critical weakness is that PIA tends to produce incidental results. A replication of a PIA with other stakeholders may

[21] Apart from methods to be used in stakeholder dialogue there are many methods that policy analysts can use for reconstructing policy argument. We refer to Hoogerwerf [43], Van de Graaf and Hoppe [117], Dunn [24] and Leeuw [61] for overviews of different methods.

[22] Berk et al. [8] argue that the cognitive approach to PIA has its roots in democratic theories that argue against public participation in public policy.

[23] Note that the verb "represent" is a problematic one. The more participants act as representatives of an organisation or group, the more difficult it may be to enhance creativity and learning. The more stakeholders engage in learning, the more difficult it may be to commit their organisations to results afterwards.

[24] It seems as if stakeholder groups show a "natural" tendency to reach consensus at the expense of clarity and understanding. If consensus turns out to be artificial, the PIA project may have failed.

[25] See, for example, [7,9,10,41,57,121].

[26] Examples of this approach include the MINK [96], and [115] studies, on the impacts of climate change on one region.

yield completely different outcomes. It is also far from certain whether participants are committed to the views, ideas and options generated in the assessment. In short, participatory approaches often lack the reliability that is necessary in order to be useful for policy-making [42]. So far, it is uncertain whether this is an inherent shortcoming of PIA, or a shortcoming of most of its applications to date.[27]

A possible weakness, from the perspective of scientific experts, is conservatism: Suppose that the King of Spain in 1490 had established a focus group in order to find out whether to subsidise the expedition of Columbus. This proposal may well have been evaluated as silly and rejected, because the lay population at that time believed the earth is flat. Stakeholders may formulate their own criteria for evaluating the usability of science, one cannot know whether they may hinder what experts consider as progress, or stimulate what scientists think unnecessary.

Given the diversity of participatory approaches and the assessment of their strengths and weaknesses, it is now possible to draw some conclusions on the way participation can be used in the various stages of IEA:

Problem identification

- PIA is particularly suitable for problem structuring, especially those PIA approaches that aim at debate and argumentation.
- PIA may evaluate scientific analyses with respect to the problem.

Analysis of options

- There are many participatory techniques for the identification and evaluation of policy options. However, whereas models will focus on the evaluation of effectiveness of options and their costs, participation is more suited for evaluating implementation trajectories.

Identification of goals and strategies

- Participatory activities are indispensable for identifying goals and strategies in an IEA.

Communication of results

- PIA can be used to communicate science to policy stakeholders and to evaluate elements of scientific quality, especially the conditions under which specific science findings are valid.

[27] Policy analysts think differently about the question as to whether participatory methods can be evaluated according to standards applied to other social science methods, including validity and reliability. On the one hand, Thissen and Twaalfhoven [107] state that, since social problems are constructed, participatory assessments cannot be evaluated with respect to content. The underlying assumption here is that there may be an infinite number of stakeholder views that can never be fully taken into account in an assessment. On the other hand, Dunn [24] argues that the range of stakeholder views can be determined within reasonable limits.

5. The need for a combined approach

This section presents three case examples, each of which illustrates from a different angle the need for a combined approach in integrated assessment. The first example highlights the need for stakeholder involvement in order to structure and restructure the problem to assist ongoing research for policy on acidification and eutrophication. The second example illustrates the need for a combined approach in response assessment: Scientific analysis of the potential for emission reduction options in the case of climate may turn into a fairy tale, if it is not accompanied by a participatory assessment of the potential for implementation. The third example, the outcomes of the big Dutch National Debate on future air transport, highlights some of the basic requirements for a combined modelling and participatory approach.

5.1. Acidification and eutrophication

Acidification and eutrophication are problems resulting from a significant human intervention in the nitrogen cycle. Additional nitrogen is introduced in the environment as a byproduct of burning fossil fuels and as a waste product of food production and consumption by a growing population of animals and people.

The effects of the emissions of NO_x and NH_3 into the atmosphere and nitrogen into the water system are: degradation of trees and plants through air and soils (acidification), and overfeeding of water systems (eutrophication).

The overall result of the human intervention in the nitrogen cycle is more food and energy than would otherwise be available on the one hand and a degradation of the quality of water, air, soils and nature on the other hand. The latter results into a reduction of societal benefits such as the availability of drinking water, agricultural production, recreation, human health and cultural heritage.

The Netherlands government initiated environmental policies to reduce the negative impact of acidification and eutrophication in the course of the eighties. These policies were based on scenario analysis of (future) input of nitrogen and other emissions such as sulphur and phosphates into the environment and modelling analyses of the environmental effects to be expected. The scenario analysis and the effects modelling was carried out by governmental labs and governmental research institutes such as RIVM and RIZA. The results of the studies were translated directly into long term targets for acceptable emission levels (for the years 2000 and 2010) and shorter term targets in combination with short term implementation policies and measures. The public and the parliament, triggered by the catastrophic futures projected by the governmental institutes was eager to support far reaching measures.

In retrospect one may conclude that this rather direct and reactive way of policy making (trying to avoid a catastrophe) has been partially successful. The emissions of NO_x from stationary sources such as power plants and refineries have drastically reduced. Emission reduction by the transport sector was only partially successful, as the emission reduction per vehicle was compensated by the increasing number of vehicles. Emission reduction of NH_3 and nitrogen from the agricultural sector was unsuccessful as end of pipe measures were hardly available and a volume approach was politically not accepted by the sector.

The quality of air and water has improved over the last 15 years, be it less than desirable. The Netherlands inland and coastal waters continue to be degraded by eutrophication, the problem is in fact increasing for a large number of lakes. The input of nitrogen in the water system is still 5 times as high as it would be under pre-industrial conditions. Also atmospheric deposition of nitrogen is still high: in the order of 50 kg per hectare per year. This amount of the same order of magnitude as the fertiliser put on the agricultural land by farmers in the 1950's.

Improvement of environmental quality will require a further reduction of NO_x emissions from the transport sector and a significant reduction of NH_3 and nitrogen input into the environment by the agricultural sector. Already earlier far reaching emission targets have been established and some policy measures have been introduced. The success of the policy measures however has been limited. Mainly because of the short comings in the analyses of the problem (diffuse sources are more difficult to control than stationary sources and require different policy instruments) and related policy failures. Another problem is the international dimensions of the problem. A major part of the nitrogen effecting the environment and ecosystems in the Netherlands is emitted in neighbouring countries. The NH_3 and livestock related problem however is mainly a national problem.

A typical feature of the reactive environmental policies developed in the eighties is the predominance of natural sciences analyses and end of pipe solutions. This approach was successful when stationary sources were predominant. However in the early nineties it became very clear that the traditional approach would not be adequate for the diffuse sources.

It became also clear that economic policies were having the opposite effect of what environmental policies were trying to achieve. Agricultural subsidies and other incentives continue to enhance production and export of agricultural products. Simultaneously governmental economic policies are boosting transport through promoting the role of the Netherlands as international distributor and through investments in the mainports Rotterdam Harbour and Amsterdam Airport.

Another reason why eutrophication and acidification policies stagnated in the course of the nineties is the decrease of public support for these policies. The public noticed that the catastrophic predictions did not materialise. The forests and the water systems did not collapse. Moreover the public and the press demonstrated some kind of backlash after the heavy period of environmental debates and policy making in the late eighties, early nineties.

The question we want to ask is the following. Why does it take so long for environmental analysis and environmental policy making to adjust to a changing situation? We believe that the system of environmental analysis and environmental policy making that was successful in the late eighties has been carried on in the nineties, without adjusting to changes in the nature of the problem and it's potential solutions. Economic analysis should have been used much earlier, to increase the understanding of the cost and environmental and societal benefits of emission control. A painful example is the lack of cost benefit analysis in the development of nitrogen policies for the river basins around the North Sea. A 50% reduction of nitrogen entering the North Sea was internationally agreed, without an analysis of cost and societal implications at the level of farmers, sectors and national economies. Even more troublesome is the lack of knowledge about the improvement of the environment resulting from such an emission reduction.

Governmental experts and the governmental research institutes that were so successful in developing environmental policies in the late eighties, were well aware of the shortcomings in eutrophication and acidification policies at the start of the nineties. Still they did not act accordingly. Even in the late nineties economic analysis is weak and policy approaches to deal with diffuse sources are scarce. One may conclude that in times of deregulation, liberalisation and participatory policy development the system of environmental policy making needs to be adjusted. Environmental analysis solely by governmental labs and governmental research institutes feeding directly into the governmental policy making process may not be adequate. A more open process with outside peer review, including the early involvement of stake holders and relevant disciplines would have helped to restructure the problem and to mobilize the relevant knowledge basis.

5.2. Estimating the costs of greenhouse gas emission reduction

Having "committed" itself to the Kyoto Protocol,[28] the Government of the Netherlands, particularly its Ministry of Public Housing, Spatial Planning, and Environment (VROM), sought advice how to achieve the target emission reduction[29] and what it may cost, as input to the white paper Implementation of Climate Policy.[30] We discuss the difficulties the ministry's research and advisory bodies had to deliver meaningful information.

The process was rather straightforward. ECN and RIVM, both governmental research institutes with a strong expertise in the field, were to prepare a technical background report, the so-called *options document*. The VROM-Raad, a council

[28] The text of the "administration agreement" – the deal between the three coalition partners in the government – conditions this commitment, *inter alia*, on ratification by the USA and an EU-wide carbon tax.

[29] The greenhouse gas emissions in the years 2008–2012 should be at 94% of their 1990 levels.

[30] Of course, instruments and costs were discussed before entering the international and EU negotiations.

of the Ministry of Environment, would, based on the options document, advice the government what to do.[31]

Although simple, this process is strange. Given the high stakes, one would expect a wider participation, including the ministries of Finance, Economic Affairs, Transport, Nature and Agriculture, and Foreign Affairs, and their research and advisory bodies. After all, these ministries have the instruments at hand to reduce greenhouse gas emissions. The VROM-Raad was indeed requested to seek input. Judging the presented material as inadequate, the Algemene Energieraad (the Energy Council) refused this, instead advising the Ministry of Economic Affairs directly.[32] The Raad voor Verkeer en Waterstaat (Council for Transport and Water Management) and the Raad voor het Landelijk Gebied (Council for the Countryside) did advice, but were only prepared to talk about the long run, after 2012.

The options document was dutifully prepared by ECN and RIVM. It contains long lists of technical measures (including some changes in behaviour) to save energy, switch to less carbon-intensive energy-carriers, or otherwise reduce emissions of the greenhouse gases covered by the Kyoto Protocol. The options document also indicates the costs per measure, and touches upon policy instruments and barriers to implementation.

The reaction of the VROM-Raad to this document was vehement. The following is a summary to their reaction, in our words. The options document reflects the viewpoint of a naïve engineer. The calculated costs are inadequate, reflecting private costs only partially, and lacking social costs altogether. The options document suggests a detailed system of command-and-control measures to regulate the relevant sectors. The discussion of potential barriers is rather thin.

In its advice to the government, the VROM-Raad decided to correct the shortcomings of the options document. In our opinion, it overreacted a bit. The advice of the VROM-Raad reflects the viewpoint of a naïve economist. It describes how one should implement a greenhouse gas emission reduction policy in the wonderful world of theoretical economics. It unfortunately overlooks the realities of international negotiations, EU-policies, and national politics. An example is the plea of the VROM-Raad for tradable emission permits, instead of the command-and-control measures suggested by the options document. The VROM-Raad backtracks its plea, by stating that tradable emission permits are only desirable if the permits can be traded internationally. However, many of the VROM-Raad members believe that an international market for greenhouse gas emission permits is unlikely to emerge in the near future.

The government was thus saddled with two reports, both of which are technically/scientifically sound, but which fall short to the problem at hand, namely the implementation of greenhouse gas emission reduction policy so as to meet the Kyoto target. How could this have been avoided?

It is clear that both the options document and the advice of the VROM-Raad lack the necessary reality check and a focus on daily policy making. The first problem was the lack of balance in both teams of experts. This should be avoided in future assessments. The assessment would improve by a wider consultation and review process. The latter solution may appear unnecessarily elaborate. However, in a consensus-driven society such as The Netherlands, it is important that stakeholders "own" the information that is put into the policy making/bargaining process. And, it is of utmost importance that a pervasive and long-term issue such as climate change is carried from the bottom up. The entire exercise illustrates the lack of reality checks regarding implementation. A stake holder (participatory) approach would have generated more useful advice to the government.

5.3. The future of air traffic

The ongoing political conflict related to the future position of Amsterdam International Airport Schiphol provides an example of an attempt to involve stakeholders from environmental and other interest groups as well as a wider public in the development of political decision-making on an intractable issue. The Dutch Government found itself in an uneasy position. The conflicting viewpoints were reflected in the cabinet. Still, the cabinet wanted to make a strategic decision related to the future of the Schiphol airport. It followed the advice of the WRR (Scientific Council for Government Policy), which had recommended involving society at large in an earlier stage of decision-making on big infrastructure projects. According to the WRR, an early involvement is likely to contribute to the acceptance of decisions that would facilitate implementation in a later stage. Therefore, in 1997, the Inter-ministerial project TNLI (Future Dutch Air Infrastructure) organised a four months debate with about 100 participants and a huge number of other activities including research in order to assist government decision making on long term air traffic policy. This debate had all characteristics of a participatory integrated environmental assessment.

The question was broadly formulated: How much space does The Netherlands want to make available for the future development of air traffic? The background of this question was whether it is useful and necessary for The Netherlands to facilitate a future growth of this economic sector?[33] It is claimed Schiphol should gain and maintain the position of a mainport, aiming to be one to the largest airports in Northwestern Europe. According to economic studies, such a mainport will increase the number of jobs in the Amsterdam area considerably, as it is expected to attract companies to settle in the area. Air traffic should be allowed to grow and environmental standards should not inhibit its competitiveness. If environmental conditions would restrict the po-

[31] Usually, the VROM-Raad is asked to react to government standpoints. In this case, it got involved in policy preparation.

[32] In this advice, the Algemene Energieraad shared the reservations of the VROM-Raad about the options document, see below.

[33] See "Hoeveel ruimte geeft Nederland aan de Luchtvaart? Integrale beleidsvisie over de toekomst van de luchtvaart in Nederland" en "De Dialoog. Verslag van de Nut en Noodzaak discussie", Den Haag, Ministry for Transport and Water Management (1997).

tential of Schiphol at its present site, a new site should be considered, either in the Flevoland polder or on an island to be created in the North Sea.

Opponents to this view put forward arguments which mainly relate to environmental impacts of air traffic: Air traffic causes air pollution, contributes to climate change and produces nuisance for surrounding areas, especially noise, stress, traffic congestion and, according to many opponents, risks for safety and health. The alternative is to shift, where possible, to other modes of transport such as rail and shipping. According to the opponents, travelling within Europe should be enabled by a network of high speed trains. The economic prospects of a growing airport are questioned as the environmental costs are not (yet) taken into account (e.g., the lack of taxes on aircraft fuels).

The project succeeded in making an inventory of many viewpoints. The dialogue came up with recommendations for government, but also research questions to be addressed in the near future. The main conclusion that can be drawn from the project is that the outcomes were not really surprising. Despite a good atmosphere among the dialogue partners, the project had not been able to produce new and creative insights.[34] The debate did not by any means change the shape and structure of the present conflict, it rather reflects the current positions as they are.[35] Furthermore, in spite of quite some initiatives, the attentive public showed little interest in participation.

This is not the place to make a detailed analysis of this process.[36] However, from the perspective of participatory analysis, it is possible to make some observations on why this happened.

1. Four months to discuss such a huge issue including the many research reports that were on the table is a ridiculous schedule. It takes Dutch governments four years or longer to address the issues related to air traffic. The fact that more than one year of preparation preceded the discussion does not mitigate this criticism.

2. The limitation of the debate to the future situation creates a serious obstacle for persons to participate, except for those who pretend to know what the future will bring. Present experiences by people living in the wider Schiphol area – either in favour or opposed to future expansion – could not systematically be taken into account. Instead, technological and economic optimism about future developments set the margins for the discussion. This may explain why members of the general public did not participate. People like to discuss issues they can relate to, they tend to leave other issues to experts.

3. There has been no systematic interaction between the discussants and the researchers, especially on the critical assumptions, which underlie the rosy economic scenarios. There has been a discussion on economic impacts, indeed. But this discussion took on the form of a *mediation* resulting in a fuzzy compromise between the opposing views. This compromise is reported as follows: "The parties agree that an important international airport can contribute significantly to the economic development of our country. At the same time, they reject the self evidence of doom scenarios if the economic growth will be no longer facilitated."[37] Next to the huge amount of taken for granted extrapolations by RAND and others, there were some critical economic studies.[38] But there was no assessment of either of these studies by the policy stakeholders, nor was there a parallel scientific panel.

In conclusion, we like to stress three major conditions to make a combined IEA a success: Firstly, we recommend a combined modelling and participatory Integrated Assessment approach in which there is sufficient time for project design, preparations and execution. Secondly, if policy stakeholders or members of the general public are supposed to participate, the subject matter for discussion should be phrased in a way these people can relate to. Thirdly, scientific uncertainty should be explicitly dealt with in the models and in the dialogue and should be processed in such a way that participants can grapple the horns of the issue. This supposes that also scientists with conflicting views get engaged.

6. Integrating the assessment

It can be argued that proper integrated assessment combines a modelling approach with a participatory, so as to have the advantages of both. This is easier said than done – indeed, in the worst case, we end up with the disadvantages of both.

This paper has explored modelling and participatory approaches to IEA, thereby focusing on the question where (in what stage, or with respect to what function or goal of the IEA) and how modelling and participation can deliver a meaningful contribution. Figure 2 below summarises our main findings with respect to this question.

Figure 2 highlights both the apparent strengths and weaknesses of both modelling and participation. It turns out that modelling is necessary, but limited in its applications, which supports the thesis that integrated assessment modelling may often benefit from participatory approaches. However, modelling exercises are likely to yield their anticipated results that are probably more specific than those anticipated in participatory assessments. Participation can always add value to an IEA, but can never form the whole assessment. However, there is still a need for improving participatory approaches and their practical application.

[34] See the conclusions of the project supervisory committee (Begeleidingscommissie) in "Integrale beleidsvisie", p. 68.

[35] See also Peterse and Hoppe [89]: In the Schiphol debate two coalitions are dominant, a hierarchist-individualist one and one based on egalitarian principles. A coalition which unifies egalitarian and individualist elements lacks.

[36] But see [120].

[37] Translation from "Integrale beleidsvisie", p. 49.

[38] By Rietveld, Van Ewijk and Verbruggen, Jansen and Rietveld.

	MODELS	PARTICIPATION
Problem identification	LIMITED STRUCTURED PROBLEMS ONLY • Environmental conditions • Impacts • Effects of interventions • Costs, benefits and their distribution	ALWAYS ALL KINDS OF PROBLEMS • Problem structuring by debate and argumentation • Evaluation of scientific knowledge • Evaluating models
Analysis of options	LIMITED • Effectiveness • Efficiency • Equity	LIMITED • Implementation trajectories
Goals or strategies	LIMITED: • analysing trade-offs • identifying levels of risk • specifying time frames	ALWAYS IN ALL RESPECTS, HOWEVER DEPENDING ON SCIENTIFIC SUPPORT
Communication of results	LIMITED AFTER PARTICIPATORY EVALUATION • visualise developments	ALWAYS • science to policy stakeholders • conditions for validity scientific findings • raising commitment

Figure 2. Possible contributions of modelling and participatory approaches to IEA.

The examples discussed in section 5 support these general conclusions. As the acidification example shows, problem structuring by stakeholders representing conflicting interests and views turns out to be of utmost importance. Not only at the beginning of a science for policy process, but also when this process is already underway. A frequent feedback from society to science may prevent scientific efforts from "solving the wrong problem". The climate options example shows that a desk research approach toward analysing the potential and effectiveness of policy options may fail, if it is not accompanied by participatory approaches aimed at evaluating feasible implementation trajectories. So, both examples highlight the need for an integrated approach of modelling and participation. The air traffic example, however, shows that the design and management of participatory assessments is quite difficult (given only the number of actors involved). Among the many conditions for making a PIA successful, there are probably three that are both critical and at the same time hard to realise: Firstly, there should be sufficient time for participatory projects. Secondly, the subject matter of the dialogue and the participants should match, i.e., people can only meaningfully participate if they can relate to the issue to be explored. Thirdly, scientific uncertainty or disagreement should be explicitly dealt with.

These conclusions warrant a plea in support of strengthening the development of IEA, especially on the side of the participatory approaches. The current situation, however, shows that there is still more emphasis on modelling. This is illustrated by the Joint Program on the Science and Policy of Global Change of the Massachusetts Institute for Technology (MIT).[39] The bulk of the research program is about integrated assessment *modelling*. The team's researchers have built an impressive suite of models, which combined can be applied to a range of policy questions. The program has also a (minor) component of *participatory* integrated assessment. Except for its bias toward modelling, the MIT approach is fairly commendable. The policy–science interface is of apparent value to the researchers and the stakeholders, as both sides continue investing resources. The organisation of the program and its support structure ensure the academic freedom of the research done.

We close our argument by suggesting some directions for adjusting current practices. Firstly, IEA may give more attention to the heterogeneity of views in the policy as well as the science communities. The idea of transparent assessments beyond single research institutes and extended peer reviews implies that the plurality of perspectives within the scientific community is accounted for. Secondly, more intellectually competitive approaches to environmental analysis will be needed. This requires the participation of more than

[39] This is a large, multidisciplinary research program. It investigates the science, economics, and politics of climate change. The program is financially supported by a consortium of research funds, including government, foundation, corporate and MIT core funds. Corporate funding is the largest contributor (some 70%), with oil companies putting up most of that money.

one group and more than one institute. Relatively open assessment procedures involving different models and various expert panels could be the way ahead. Thirdly, a more integrated approach to economic analysis and environmental analysis is a prerequisite for understanding the interaction between economic and environmental processes. Such an integrated approach could set the stage for more consistency between governmental economic policies and governmental environmental policies. Further developing IEA into these directions is required in order to address the increasingly diffuse environmental problems of today and tomorrow.

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References

[1] J. Alcamo, R. Shaw and L. Hordijk, *The RAINS Model of Acidification: Science and Strategies in Europe* (Kluwer, Dordrecht, 1990).

[2] J. Alcamo, *IMAGE 2.0 – Integrated Modeling of Global Climate Change* (Kluwer Academic, Dordrecht, 1994).

[3] M. Amann, M. Baldi, C. Heyes, Z. Klimont and W. Schoepp, Integrated assessment of emission control scenarios, including the impact of tropospheric ozone, Water, Air and Soil Pollution 85 (1995) 2595–2600.

[4] H.M. ApSimon and R.F. Warren, Transboundary air pollution in Europe, Energy Policy 24(7) (1996) 631–640.

[5] P.D. Bailey, IEA: A new methodology for environmental policy?, Environmental Impact Assessment Review 17 (1997) 221–226.

[6] P.D. Bailey, C.A. Gough, M.J. Chadwick and G. McGranahan, *Methods for Integrated Environmental Assessment: Research Directions for the European Union* (Stockholm Environment Institute, Stockholm, 1996).

[7] M.M. Berk, E. van Dalen and M. Hisschemöller, Participative Integrated Assessment and the utilisation of scientific knowledge, Milieu, Special Issue on Global Climate Change 13(5) (1998) 275–285.

[8] M.M. Berk, M. Hisschemöller, L. Hordijk, M. Kok, D. Lieferink, B. Metz and W. Tuinstra, Climate options for the long term, Interim phase report, Bilthoven, Nationaal Onderzoekprogramma Mondiale Luchtverontreiniging en Klimaatverandering (1999).

[9] C. Bernabo, M. Hisschemöller and J. Klabbers, Enhancing the effectiveness of research to assist international climate change policy development. Phase I and II final report, Report No 410 100090, Dutch National Research Programme on Global Air Pollution and Climate Change (NOP), Bilthoven (1995).

[10] C. Bernabo, M. Hisschemöller and J. Klabbers, Enhancing the effectiveness of research to assist international climate change policy development. Phase III final report, Report No 410 200007, Dutch National Research Programme on Global Air Pollution and Climate Change (NOP), Bilthoven (1996).

[11] R. Braddock, J. Filar, R. Zapert, J. Rotmans and M. Den Elzen, The IMAGE greenhouse model as a mathematical system, Applied Mathematical Modelling 18 (1994) 234–254.

[12] J.P. Bruce, H. Lee and E.F. Haites, eds., *Climate Change 1995: Economic and Social Dimensions of Climate Change – Contribution of Working Group III to the Second Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge University Press, Cambridge, 1996).

[13] P. Cebon, U. Dahinden, D. Imboden and C. Jaeger, eds., *A View from the Alps: Regional Perspectives on Climate Change* (MIT Press, Boston, 2000).

[14] S.J. Cohen, ed., Mackenzie basin impact study – Interim report #1, Canadian Climate Centre, Downsview (1993).

[15] S.J. Cohen, Mackenzie basin impact study: Broadening the climate change debate, Ecodecision (1995) 34–37.

[16] S.J. Cohen, Mackenzie basin impact study final report, Environment Canada, Vancouver (1997).

[17] S.J. Cohen, Scientist-stakeholder collaboration in integrated assessment of climate change: Lessons from a case study of Northwest Canada, Environmental Modeling and Assessment 2 (1997) 281–293.

[18] H. Dowlatabadi, Integrated assessment models of climate change: An incomplete overview, Energy Policy 23(4) (1995) 1–8.

[19] H. Dowlatabadi, Adaptive management of climate change mitigation: A strategy for coping with uncertainty (draft) (1997).

[20] H. Dowlatabadi, Sensitivity of climate change mitigation estimates to assumptions about technical change, Energy Economics 20 (1998) 473–493.

[21] H. Dowlatabadi and G. Morgan, A model framework for integrated studies of the climate problem, Energy Policy (1993) 209–221.

[22] K.H. Dreborg, Essence of backcasting, Futures 28(8) (1996) 813–828.

[23] G. Duerrenberger, J. Behringer, U. Dahinden, A. Gerger, B. Kasemir, C. Querol, R. Schuele, D. Tabara, F.L. Toth, M.B.A. van Asselt, D. Vassilarou, N. Willi and C.C. Jaeger, Focus groups in integrated assessment: A manual for a participatory tool, ULYSSES Working Paper WP-97-2, Center for Interdisciplinary Studies in Technology, Darmstadt University of Technology (1997).

[24] W.N. Dunn, *Public Policy Analysis: An Introduction*, 2nd ed. (Prentice-Hall, Englewood Cliffs, NJ, 1994).

[25] J. Edmonds, M. Wise and C. MacCracken, Advanced energy technologies and climate change: An analysis using the Global Change Assessment Model (GCAM), in: *Global Climate Change – Science, Policy, and Mitigation Strategies*, eds. C.V. Mathai and G. Stensland (Air & Waste Management Association, Boston, 1994).

[26] S. Fankhauser, Valuing climate change – the economics of the greenhouse, EarthScan, London (1995).

[27] S. Fankhauser and S. Kverndokk, The global warming game – simulations of a CO_2-reduction agreement, Resource and Energy Economics 18 (1996) 83–102.

[28] W. Foell, C. Green, M. Amann, S. Bhattacharya, G. Carmicheal, M.J. Chadwick, S. Cinderby, T. Haugland, J.-P. Hettelingh, L. Hordijk, J.C.I. Kuylenstierna, J. Shah, R. Shrestha, D. Streets and D. Zhao, Energy use, emissions, and air pollution reduction strategies in Asia, Water, Air and Soil Pollution 85 (1995) 2277–2282.

[29] S.O. Funtowicz and J.R. Ravetz, Three types of risk assessment and the emergence of post-normal science, in: *Social Theories of Risk*, eds. S. Krimsky and D. Golding (Westport, Greenwood, 1992).

[30] S.O. Funtowicz and J.R. Ravetz, Uncertainty, complexity and post-normal science, Environmental Toxicology and Chemistry 13(12) (1994) 1881–1885.

[31] R. Gerlagh, *The Efficient and Sustainable Use of Environmental Resource Systems* (Thela Thesis, Amsterdam, 1999).

[32] J. Grin, H. van de Graaf and R. Hoppe, Interactieve technology assessment. Een eerste gids voor wie het wagen wil, SDU (werkdocument Rathenau Instituut), Den Haag (1997).

[33] M. Grubb, M. Ha Duong and T. Chapuis, The economics of changing course, Energy Policy 23(4/5) (1995) 417–432.

[34] N. Haigh, Science-policy interactions from a policy perspective, Environmental Modeling and Assessment (1998).

[35] K. Hasselmann, S. Hasselmann, R. Giering, V. Ocana and H. Von Storch, Sensitivity study of optimal CO_2 emission paths using a simplified Structural Integrated Assessment Model (SIAM), Climatic Change 37 (1997) 345–386.

[36] A. Henderson-Sellers, Can we integrate climatic modelling and assessment?, Environmental Modeling & Assessment 1(1,2) (1996) 59–70.

[37] M. Hisschemöller, De democratie van problemen. De relatie tussen de inhoud van beleidsproblemen en methoden van politieke besluitvorming, VU uitgeverij, Amsterdam (1993).

[38] M. Hisschemöller, P. Groenewegen, R. Hoppe and C.J.H. Midden, Policy networking or problem structuring: Knowledge use and political choice in Dutch environmental policy, in: *Knowledge, Power and Participation in Environmental Policy. Policy Studies Review Annual*, eds. M. Hisschemöller, R. Hoppe, W.N. Dunn and J. Ravetz (1999).

[39] M. Hisschemöller and R. Hoppe, Coping with intractable controversies: The case for problem structuring in policy design and analysis, Knowledge and Policy – The International Journal of Knowledge Transfer and Utilization 8(4) (1995) 40–60.

[40] M. Hisschemöller and R. Hoppe, Weerbarstige beleidscontroverses: een pleidooi voor probleemstructurering in beleidsontwerp en analyse, in: *Bouwstenen voor Argumentatieve Beleidsanalyse*, eds. R. Hoppe and A. Peterse (Elsevier, Den Haag, 1998).

[41] M. Hisschemöller, J. Klabbers, M. Berk, R. Swart, A. van Ulden and P. Vellinga, Opties voor klimaatbeleid en hun implicaties voor beleidsgericht wetenschappelijk onderzoek, R-95/11, Instituut voor Milieuvraagstukken, Amsterdam (1995).

[42] M. Hisschemöller and C.J.H. Midden, Improving the usability of research on the public perception of science and technology for policy-making, The Public Understanding of Science 8(1) (1999).

[43] A. Hoogerwerf, Beleid berust op veronderstellingen: De beleidstheorie, Acta Politica 19 (1984) 493–531.

[44] C.W. Hope, J. Anderson and P. Wenman, Policy analysis of the greenhouse effect: An application of the PAGE model, Energy Policy 15 (1993) 328–338.

[45] R. Hoppe and J. Grin, eds., Interactive strategies in technology assessment, Industrial and Environmental Crisis Quarterly 9(1) (1995) (special issue).

[46] L. Hordijk, Review of the IMAGE model, 410100080, RIVM, Bilthoven (1993).

[47] L. Hordijk, Integrated assessment models as a basis for air pollution negotiations, Water, Air and Soil Pollution 85 (1995) 249–260.

[48] L. Hordijk and C. Kroeze, Integrated assessment models for acid rain, European Journal of Operational Research 102 (1997) 405–417.

[49] J.C. Hourcade, R.G. Richels, J. Robinson, W. Chandler, O. Davidson, D. Finon, M.J. Grubb, K. Halsneas, K. Hogan, M. Jaccard, F. Krause, E. La Rovere, W.D. Montgomery, P. Nastari, A. Pegov, K. Richards, L. Schrattenholzer, D. Siniscalco, P.R. Shukla, Y. Sokona, P. Sturm and A. Tudini, Estimating the costs of mitigating greenhouse gases, in: *Climate Change 1995: Economic and Social Dimensions – Contribution of Working Group III to the Second Assessment Report of the Intergovernmental Panel on Climate Change*, eds. J.P. Bruce, H. Lee and E.F. Haites (Cambridge University Press, Cambridge, 1996).

[50] C.C. Jaeger, S. Shackley, E. Darier and C. Waterton, Towards a polylogue on climate change and global modelling, ULYSSES Working Paper WP-97-3, Center for Interdisciplinary Studies in Technology, Darmstadt University of Technology (1997).

[51] J. Jaeger, Current thinking on using scientific findings in environmental policy-making, Environmental Modeling and Assessment (1998).

[52] M. Janssen, *Meeting Targets – Tools to Support Integrated Assessment Modelling of Global Change* (University of Maastricht, Maastricht, 1996).

[53] S. Joss and J. Durant, eds., *Public Participation in Science. The Role of Consensus Conferences in Europe* (British Science Museum, London, 1995).

[54] B. Kasemir, J. Behringer, B. De March, C. Deuker, G. Duerrenberger, S. Funtowicz, A. Gerger, M. Giaoutzi, Y. Haffner, M. Nilsson, C. Querol, R. Schuele, D. Tabara, M.B.A. van Asselt, D. Vassilarou, N. Will and C.C. Jaeger, Focus groups in integrated assessment: The ULYSSES pilot experience, ULYSSES Working Paper WP-97-4, Center for Interdisciplinary Studies in Technology, Darmstadt University of Technology (1997).

[55] B. Kasemir, M.B.A. van Asselt, G. Duerrenberger and C.C. Jaeger, Integrated assessment: Multiple perspectives in interaction, International Journal of Environment and Pollution (1998) (forthcoming).

[56] G.A.J. Klaassen, *Trading Sulphur Emission Reduction Commitments in Europe: A Theoretical and Empirical Analysis* (International Institute for Applied Systems Analysis, Luxemburg, 1995).

[57] J.H.G. Klabbers, R.J. Swart, R. Janssen, P. Vellinga and A.P. Van Ulden, Climate science and climate policy: Improving the science/policy interface, Mitigation and Adaptation Strategies for Global Change 1 (1996) 73–93.

[58] C.D. Kolstad, George Bush versus Al Gore: Irreversibilities in greenhouse gas accumulation and emission control investment, Energy Policy 22(9) (1994) 772–778.

[59] C.D. Kolstad, Learning and stock effects in environmental regulations: The case of greenhouse gas emissions, Journal of Environmental Economics and Management 31 (1996) 1–18.

[60] H.D. Lasswell, Technique of decision-seminars, Midwest Journal of Political Science 4 (1960) 213–232.

[61] F.L. Leeuw, On methods for reconstructing and evaluating program logics, *Paper presented at Third Conference of the European Evaluation Society*, Rome, 29–31 October (1998).

[62] M. Leimbach, Development of a fuzzy optimization model, supporting global warming decision-making, Environmental and Resource Economics 7 (1996) 163–192.

[63] C.E. Lindblom and D.K. Cohen, *Usable Knowledge: Social Sience and Social Problem Solving* (Yale University Press, New Haven, 1979).

[64] H.A. Linstone and M. Turoff, eds., *The Delphi Method, Techniques and Applications* (Addison-Wesley, Reading, 1975).

[65] H.A. Linstone, *Multiple Perspectives for Decision-Making. Bridging the Gap Between Analysis and Action* (North-Holland, New York, 1984).

[66] D. Maddison, A cost-benefit analysis of slowing climate change, Energy Policy 23(4/5) (1995) 337–346.

[67] A.S. Manne, R. Mendelsohn and R.G. Richels, MERGE: A Model for Evaluating Regional and Global Effects of GHG reduction policies, Energy Policy 23(1) (1995) 17–34.

[68] A.S. Manne and R.G. Richels, The greenhouse debate: Economic efficiency, burden sharing and hedging strategies, Energy Journal 16(4) (1995) 1–37.

[69] R.O. Mason and I.I. Mitroff, *Challenging Strategic Planning Assumptions* (Wiley, New York, 1981).

[70] I. Mayer and J. Geurts, De instrumentele mogelijkheden van de argumentatieve beleidsanalyse: participatieve methoden, in: *Bouwstenen voor Argumentatieve Beleidsanalyse*, eds. R. Hoppe and A. Peterse (Elsevier, Den Haag, 1998).

[71] I. Mayer, *Debating Technologies. A Methodological Contribution to the Design and Evaluation of Participatory Policy Analysis* (Tilburg University Press, Tilburg, 1997).

[72] M.G. Morgan and H. Dowlatabadi, Learning from integrated assessment of climate change, Climatic Change 34 (1996) 337–368.

[73] T. Morita, M. Kainuma, H. Harasawa, K. Kai, L. Dong-Kun and Y. Matsuoka, Asian–pacific integrated model for evaluating policy options to reduce greenhouse gas emissions and global warming impacts, AIM Interim Paper National Institute for Environmental Studies, Tsukuba (1994).

[74] W.D. Nordhaus, An optimal transition path for controlling greenhouse gases, Science 258 (1992) 1315–1319.

[75] W.D. Nordhaus, Rolling the 'DICE': An optimal transition path for controlling greenhouse gases, Resource and Energy Economics 15 (1993) 27–50.

[76] W.D. Nordhaus, *Managing the Global Commons: The Economics of Climate Change* (The MIT Press, Cambridge, 1994).

[77] W.D. Nordhaus and Z. Yang, RICE: A regional dynamic general equilibrium model of optimal climate-change policy, American Economic Review 86(4) (1996) 741–765.

[78] A.F. Osborn, *Your Creative Mind* (New York, 1948).

[79] E.A. Parson, Integrated assessment and environmental policy making, Energy Policy 23(4/5) (1995) 463–475.

[80] E.A. Parson, Three dilemmas in the integrated assessment of climate change – An editorial comment, Climatic Change 34 (1996) 315–326.

[81] E.A. Parson, How should we study global environmental problemens? A plea for unconventional methods of assessment and synthesis, IIASA Working Paper WP-6-157, Luxemburg (1996).

[82] E.A. Parson, Informing global environmental policy-making: A plea for new methods of assessment and synthesis, Environmental Modeling and Assessment 2 (1997) 267–279.

[83] S.C. Peck and T.J. Teisberg, CETA: A model for Carbon Emissions Trajectory Assessment, The Energy Journal 13(1) (1991) 55–77.

[84] S.C. Peck and T.J. Teisberg, Global warming uncertainties and the value of information: An analysis using CETA, Resource and Energy Economics 15 (1993) 71–97.

[85] S.C. Peck and T.J. Teisberg, CO_2 emissions control: Comparing policy instruments, Energy Policy (1993) 222–230.

[86] S.C. Peck and T.J. Teisberg, Optimal carbon emissions trajectories when damages depend on the rate or level of global warming, Climatic Change 28 (1994) 289–314.

[87] S.C. Peck and T.J. Teisberg, Optimal CO_2 control policy with stochastic losses from temperature rise, Climatic Change 31 (1995) 19–34.

[88] S.C. Peck and T.J. Teisberg, International CO_2 emissions targets and timetables: An analysis of the AOSIS proposal, Environmental Modeling and Assessment 1(4) (1996) 219–227.

[89] Petersen and Hoppe (1998).

[90] E.L. Plambeck and C.W. Hope, PAGE95 – An updated valuation of the impacts of global warming, Energy Policy 24(9) (1996) 783–793.

[91] E.L. Plambeck, C.W. Hope and J. Anderson, The Page95 model: Integrating the science and economics of global warming, Energy Economics 19 (1997) 77–101.

[92] J.R. Ravetz, Usable knowledge, usable ignorance: Incomplete science with policy implications, in: *Sustainable Development of the Biosphere*, eds. P. Clark and C. Munn (Cambridge University Press, Cambridge, 1985).

[93] J.R. Ravetz, *The Merger of Knowledge with Power. Essays in Critical Science* (Mansell Publishing Limited, London, 1990).

[94] J.R. Ravetz, Integrated environmental assessment forum: Developing guidelines for "Good Practice", ULYSSES Working Paper WP-97-1, Center for Interdisciplinary Studies in Technology, Darmstadt University of Technology (1997).

[95] J. Risbey, M. Kandlikar and A. Patwardhan, Assessing integrated assessments, Climatic Change 34 (1996) 369–395.

[96] N.J. Rosenberg and P.R. Crosson, MINK: An overview, US Environment Protection Agency, Washington, DC (1991).

[97] N.J. Rosenberg, Towards and integrated impact assessment of climate change: The MINK study, Climatic Change 24(1,2) (1993).

[98] J. Rotmans, *IMAGE: An Integrated Model to Assess the Greenhouse Effect* (Kluwer, Dordrecht, 1990).

[99] J. Rotmans, ed., *TARGETS in Transition* (RIVM, Bilthoven, 1995).

[100] J. Rotmans, Methods for IA – Challenges and opportunities ahead, Environmental Modeling and Assessment (1998).

[101] J. Rotmans and H. Dowlatabadi, Integrated assessment of climate change: Evaluation of methods and strategies, in: *Human Choices and Climate Change: A State of the Art Report* (Batelle Pacific Northwest Laboratories, Washington, DC, 1997).

[102] J. Rotmans, M. Hulme and T.E. Downing, Climate change implications for Europe: An application of the ESCAPE model, Global Environmental Change 4(2) (1994) 97–124.

[103] J. Rotmans and M. van Asselt, Integrated assessment: A growing child on its way to maturity – an editorial essay, Climatic Change 34 (1996) 327–336.

[104] C. Schlumpf, J. Behringer, G. Duerrenberger and C. Pahl-Wostl, The personal CO_2-calculator: A modeling tool for participatory integrated assessment methods, Environmental Modeling and Assessment (1998).

[105] S.H. Schneider, Integrated assessment modeling of global climate change: Transparent rational tool for policy making or opaque screen hiding value-laden assumptions?, Environmental Modeling and Assessment 2 (1997) 229–249.

[106] C. Schwenk, Devil's advocate in managerial decision-making, Journal of Management Studies 21 (1984) 153–168.

[107] W.A.H. Thissen and P.G.J. Twaalfhoven, Towards a conceptual structure for evaluating policy analytic activities, European Journal for Operations Research (2000).

[108] M. Thompson, Cultural theory and integrated assessment, Environmental Modeling and Assessment 2 (1997) 139–150.

[109] R.S.J. Tol, On the optimal control of carbon dioxide emissions: An application of FUND, Environmental Modeling and Assessment 2 (1997) 151–163.

[110] R.S.J. Tol, The social cost controversy: A personal appraisal, in: *Proceedings of the International Symposium Prospects of Integrated Environmental Assessment: Lessons Learnt from the Case of Climate Change*, eds. A. Sors, A. Liberatore, S. Funtowicz, J.C. Hourcade and J.L. Fellous (European Commission DG12, Brussels, 1997) pp. 35–42.

[111] R.S.J. Tol, T. Van der Burg, H.M.A. Jansen and H. Verbruggen, The Climate fund – Some notions on the socio-economic impacts of greenhouse gas emissions and emission reduction in an international context, R95/03, Institute for Environmental Studies, Vrije Universiteit, Amsterdam (1995).

[112] R.S.J. Tol and S. Fankhauser, On the representation of impact in integrated assessment models of climate change, Environmental Modelling and Assessment 3 (1998) 63–74.

[113] R.S.J. Tol and P. Vellinga, The European Forum on Integrated Environmental Assessment, Environmental Modeling & Assessment 3(3), Special Issue on Challenges and Opportunities for Integrated

Environmental Assessment, eds. J. Rotmans and P. Vellinga (1998) 181–191.

[114] F.L. Toth and E. Hizsnyik, Integrated environmental assessment methodologies: A survey, Environmental Modeling and Assessment (1998).

[115] UKCCIRG – United Kingdom Climate Change Impacts Review Group, *Review of the Potential Effects of Climate Change in the United Kingdom* (HMSO, London, 1996).

[116] M.B.A. Van Asselt, A.H.W. Beusen and H.B.M. Hilderink, Uncertainty in integrated assessment: A social scientific perspective, Environmental Modeling & Assessment 1(1,2) (1996) 71–90.

[117] H. Van de Graaf and R. Hoppe, *Beleid en Politiek. Een Inleiding tot de Beleidswetenschap en de Beleidskunde* (Coutinho, Muiderberg, 1989).

[118] J.P. Van der Sluis, *Anchoring amid Uncertainty – On the Management of Uncertainties of Risk Assessment of Anthropogenic Climate Change* (Utrecht University, Utrecht, 1997).

[119] J.P. Van der Sluis, Towards a typology of computer tools for participatory integrated assessment, in: *Policy Studies Annual Review – Knowledge Power and Participation in Environmental Policy* (1999) (forthcoming).

[120] M. Van Eeten, *Dialogues of the Deaf. Defining New Agendas for Environmental Deadlocks* (Eburon, Delft, 1999).

[121] P. Vellinga, M. Hisschemöller, J.H.G. Klabbers, M.M. Berk, R.J. Swart and A.P. Van Ulden, Climate change, policy options and research implications, in: *Climate Change Research: Evaluation and Policy Implications*, eds. S. Zwerver, R.S.A.R. van Rompaei, M.T.J. Kok and M.M. Berk (Elsevier, Amsterdam); Studies in Environmental Sciences 65 A (1995) 119–134.

[122] J.P. Weyant, Insights from integrated assessment, in: *Critical Issues in the Economics of Climate Change*, eds. B.P. Flannery, K.R. Kohlhase and D.G. LeVine (IPIECA, London, 1997) pp. 245–278.

[123] J. Weyant, O. Davidson, H. Dowlatabadi, J. Edmonds, M. Grubb, E.A. Parson, R. Richels, J. Rotmans, P.R. Shukla, R.S.J. Tol, W.R. Cline and S. Fankhauser, Integrated assessment of climate change: An overview and comparison of approaches and results, in: *Climate Change 1995: Economic and Social Dimensions – Contribution of Working Group III to the Second Assessment Report of the Intergovernmental Panel on Climate Change*, eds. J.P. Bruce, H. Lee and E.F. Haites (Cambridge University Press, Cambridge, 1996).

[124] W.F. Whyte, ed., *Participatory Action Research* (Sage, Newbury Park, 1991).

[125] T.M.L. Wigley, R.G. Richels and J.A. Edmonds, Economic and environmental choices in the stabilization of atmospheric CO_2 concentrations, Nature 379 (1996) 240–243.

[126] B. Wynne, Risk and social learning: Reification to engagement, in: *Social Theory of Risk*, eds. S. Krimsky and D. Golding (Westport, Greenwood, 1992).

[127] G.W. Yohe and R. Wallace, Near term mitigation policy for global change under uncertainty: Minimizing the expected cost of meeting unknown concentration thresholds, Environmental Modeling and Assessment 1(1,2) (1996) 47–58.