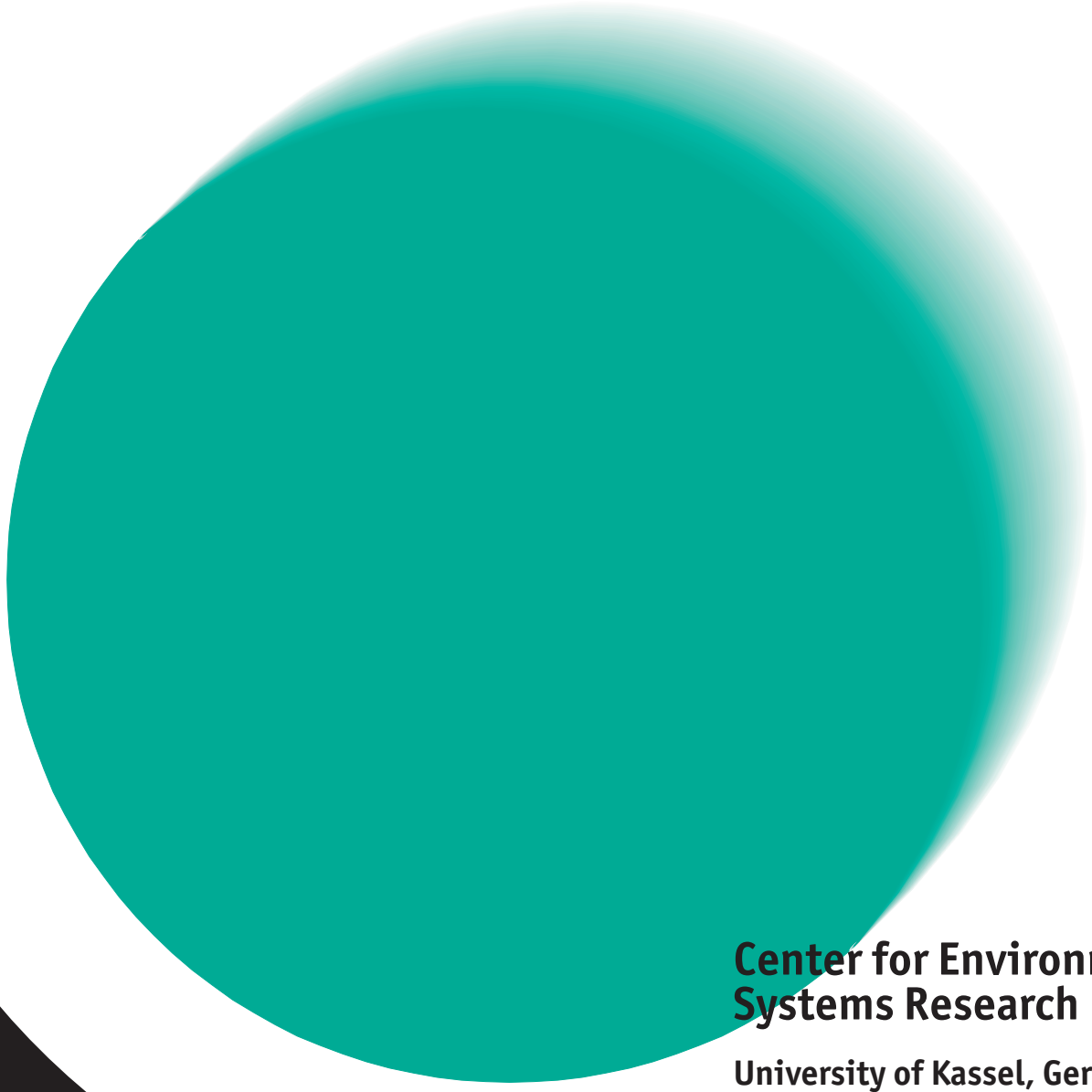
Workshop Report

Sixth International Workshop on Using Global Models to Support Climate Negotiations

Open Questions after Kyoto

Janina Onigkeit, Marcel Berk, and Joseph Alcamo



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Open Questions after Kyoto

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1. Introduction

The Sixth Workshop on ”Using Global Models to Support Climate Negotiations” was held in Kassel, Germany on 28-29 May 1998 with the aim to provide a continuation of the policy-science dialogue that was established in the so-called ”Delft Process” (Alcamo, *et al.* 1996, van Daalen et al. 1998).

The main objective of the earlier five workshops was to use the integrated assessment model IMAGE 2 in support of the climate negotiations leading up to the Kyoto Protocol. However, since the adoption of the Kyoto Protocol, the situation has somewhat changed. The subtitle of the sixth workshop, ”Open Questions after Kyoto”, reflects this change, and also gives its main objective: The identification of questions that are policy relevant in the post-Kyoto phase and can be addressed by global models like IMAGE. The purpose of this report is to summarise results of the Workshop, especially the key policy questions identified by participants. The Workshop Programme and a List of Participants can be found in Appendix 1 and 2, respectively.

The workshop consisted of three parts:

- The first part was a reflection on the Delft policy-science dialogue leading up to Kyoto and on the implications of the changed situation after the adoption of the climate protocol. A summary of discussions about this topic are given in Chapter 2 of this report.
- The second and main part was based on two presentations dealing with questions that arise from the Kyoto protocol. The identification and prioritisation of key policy questions was the main goal of this part. The resulting priority list of policy questions can be found in Chapter 3.
- The third part focused on new developments on the scientific side of the climate policy process, including activities of the Intergovernmental Panel on Climate Change (IPCC). Some modelling and IPCC results were presented that were thought to be possible starting points for further analyses in preparation for the fourth Conference of Parties (CoP4) in Buenos Aires in November, 1998 (see chapter 4).

2. The Policy - Science Dialogue Before and After Kyoto

The following summary of the main outcomes and the structure of the five previous workshops on "Using Global Models to Support Climate Negotiations" is based on a presentation by Els van Daalen (Delft University). Between July 1995 and June 1997 five policy - science workshops were held at the Delft University of Technology, The Netherlands. As noted above, the main purpose of these workshops was to explore and enhance the use of the IMAGE 2 and other models to support international climate negotiations leading up to CoP 3 in Kyoto.

Structure of the Workshops

All workshops had the same iterative structure: In the first part the modelling team presented results of analyses they worked out using the IMAGE 2 and other models. The second part of each workshop consisted of an identification and discussion of a priority list of policy relevant questions that should be taken up by the modelling team for further analyses. The results of these analyses were further discussed in each of the following Delft workshops.

Participants

The workshops were attended by policy makers and policy advisors as well as members of non-governmental organisations and people from the global modelling community. They came from a great number of countries including industrialised and developing countries. Seventeen people from fourteen different countries participated in the third Delft Workshop for example.

Results of the Delft Workshops

The following are the main outcomes of the five Delft workshops:

- A dialogue process between policy makers and global modelers was established. Issues of direct relevance to the climate negotiations were identified and addressed at each of the following workshops. The working atmosphere and discussions can be described as open but nevertheless very result-oriented.
- A set of new policy oriented scientific concepts were developed, namely the Safe Landing and Safe Emission Corridor concepts (Alcamo et al. 1996, 1997; Swart et al., 1998).
- A user-friendly scientific program was developed for presenting simplified scenarios from the IMAGE model: The Interactive Scenario Scanner (Berk & Janssen, 1997).

- Policy relevant results from the workshops were presented at meetings of the Ad hoc Group of the Berlin Mandate (AGBM) and CoP3 in Kyoto (e.g. Alcamo et al., 1997)

Summary of Discussion Regarding Previous Workshops

The five previous workshops held in Delft were regarded as very useful especially in providing relevant information on the issue of the timing of policy actions and in supporting the AOSIS group in formulating their policy position. However, since the priority of climate policy issues is changing, the profile of Workshop participants should also change. In particular:

- More stakeholders from the industry/economy sector should be invited to take into account their arguments concerning climate negotiations.
- There should be more participants from developing countries.

However, it was also pointed out that broadening the representation at the workshops may reduce their effectiveness because the homogeneity of previous workshops probably contributed to their productivity.

3. Critical Questions After Kyoto

Dr. B. Metz (RIVM) and Dr. K. Ramakrishna (Woods Hole Research Institute) gave introductory presentations that kindled discussion and further formulation of critical questions.

3.1 Introduction

The adoption of the climate protocol of Kyoto in December 1997 for the first time established legally-binding emission reduction commitments since the United Nation Framework Convention on Climate Change (UNFCCC) was formulated in 1992.

The protocol covers a "basket" of gases, including the three main greenhouse gases (GHG) CO_2, CH_4, and N_2O plus HFC's (hydrofluorocarbons), PFC's (perfluorocarbons) and SF_6. The emission reduction targets of the Annex I parties range from a reduction of 8% to an increase of 10% (based on 1990 emissions) in the first commitment period (2008-2012). This equals to a 5.2% reduction for all Annex I countries together.

Although the protocol explicitly states how much Annex I parties will have to reduce their GHG emissions during the first commitment period, it also raises many questions about how

these targets can be achieved. Furthermore, the Protocol does not specify what, if any, emission reductions should be carried out after the first commitment period.

With regards to Post-Kyoto issues, K. Ramakrishna also pointed out that industrialised and developing countries sometimes have different priorities:

Industrialised Countries	**Developing Countries**
Emission Trading	Equity
Joint Implementation	Technology transfer
Sinks	Financial assistance
Compliance and verification	Special Circumstances
Participation of developing countries	Common but differentiated responsibility
Clean development mechanisms	Clean development mechanisms

The purpose of this workshop was not only to list issues arising from the Kyoto Protocol but also to prioritise and formulate these questions as a kind of priority list for analysis with global models in the time up to Buenos Aires and beyond. First, important policy questions were identified and classified. Next, the time frame for answering these questions was identified based on political urgency and the availability of models to answer them. Finally, the questions were prioritised. As a result of the two presentations and following discussions about forty questions were formulated and grouped into five main topics:

A) Next steps towards achieving the ultimative objective of the Framework Convention on Climate Change (FCCC). This involves all questions regarding the achievement of stabilisation of atmospheric GHG's after the first commitment period, including the participation of developing countries.

B) Flexibility instruments: Questions that deal with the design and implications of flexibility mechanisms (Emissions Trading, Joint Implementation, Clean Development Mechanism).

C) Land use changes, forestry and agriculture (LUCF&A): All questions that deal with human induced carbon sinks and land use change.

D) Impacts on developing countries: Questions on how to identify and minimise negative effects on developing countries of climate policies carried out in industrialised countries.

E) Impacts of climate change: Questions that deal with necessary improvements of global integrated assessment models.

In the next section we describe the groups of questions according to their priority status: high priority, undecided priority or low priority. Moreover, a time frame was assigned to each question, in which it should and could be answered:

- (S): short term question, for which results should be obtained before the end of 1998.
- (M): medium term question, for which results should be obtained in 1999 - 2002.
- (L): long term questions, where results cannot be expected or are not needed before 2002.

The resulting list of questions was informally reviewed by a group of policy makers at the 8th meeting of the Subsidiary Bodies of the FCCC, June 1998 in Bonn. The comments and additional questions from this meeting are included.

3.2 High Priority Questions

The following policy questions were given high priority by the workshop participants. These are questions that (1) can be analysed by global models and (2) should be given priority by global modelers because of their importance to Post-Kyoto discussions.

A) *Next steps towards the ultimate objective of FCCC*

Under this item questions arising from the Kyoto Protocol were related to the objective of article 2 of the Framework Convention on Climate Change (FCCC): ”...stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system...”.

Questions that were formulated:

1. What are the implications of stabilisation scenarios? (M)
   a) What are the costs and environmental effects of different stabilisation pathways/targets?
   b) What are methods for evaluating stabilisation pathways/targets under uncertainty?
   c) What is the maximum feasible greenhouse gas reduction rate given by social/economic/policy inertia?

d) What do long-term choices mean for the next commitment period?
e) What are the impacts of short-term solutions on long-term sustainability?

2. How do different burden sharing schemes affect stabilisation scenarios and what do different stabilisation scenarios mean for burden sharing? (M)
   a) What are the implications of the Brazilian proposal and variations thereof?
   b) What are the implications of various convergence and graduation mechanisms?

3. What are the trade-offs between the six gases in the Kyoto approach? (S)
   a) Base year data, projections, uncertainties
   b) Policy options and costs

B) *Flexibility instruments*

The flexibility instruments, namely emissions trading, joint implementation and clean development mechanism are included in the Kyoto Protocol. But because the protocol is quite vague in how to implement these instruments, clarification is urgently needed:

1. What cost reductions can be achieved as compared to reducing emissions domestically?
2. What is the potential "leakage" when using these instruments (e.g. hot air, baseline, replacement of activities)?
3. What would be the influence of the clean development mechanism, joint implementation and emissions trading on energy technology development, application and transfer?

C) *What is the role of land use change, forestry and agricultural policies in stabilisation of atmospheric GHG concentration?*

1. What are the long-term consequences of the carbon offset approach?
2. What are the policy implications of the biosphere shifting from a carbon sink to a carbon source?

D) *What are the impacts on developing countries? (S/M).*

1. What are the implications of instruments used in Annex I during the first commitment period and beyond on developing countries? (welfare, trade balance and oil prices).
2. What are costs and benefits of action or non-action?

E) *Impacts of climate change*

Under this item none of the questions was given high priority.

3.3 Low Priority Questions

These are questions that either (1) cannot be analysed by global models, or (2) cannot be analysed in the necessary time frame or (3) are less important to Post-Kyoto discussions.

A) *Next steps towards the ultimate objective of FCCC*

How can country specific baseline assumptions affect the evaluation and effectiveness of policy options to mitigate climate change? (M)

B) *Flexibility Instruments*

1. What are positive/negative effects (economic, environmental, social, and others) of different flexibility instruments? (S)
2. What are the kind of institutional arrangements and other policy actions available to stimulate a market for flexible instruments? (S)

C) *What is the role of land use change, forestry and agricultural policies in stabilisation?*

What are the links between land use changes, forestry and agriculture (LUCF&A) and other environmental issues (such as biodiversity)? (M)

D) *What Are the Impacts on Developing Countries?*

None of the questions stated under this item was considered to be of minor priority.

E) Impacts of climate change

What are appropriate performance standards for a national system to measure greenhouse gases?(S)

3.4 Questions of Undecided Priority

These were questions that were not assigned to either of the previous two categories.

A) *Next steps towards the ultimate objective of FCCC*

1. What role can technology transfer play? (M)
2. What incentives are available to encourage participation of developing countries? (S)

B) *Flexibility instruments*

1. What is the impact of ”caps” on flexible instruments? (S)
2. How should ”hot air” be dealt with? (S)
3. What is the influence of trading blocs? (S)
4. What is the interaction between flexible instruments and sink issues? (S)
5. What are the influences of flexible instruments on emissions? (S)

C) *How to deal with land-use changes, forestry and agriculture (LUCF&A)?*

1. What are the policy options for slowing deforestation? (M)
2. What are the precise definitions of “land use changes”, and other terms used for these policies? (S)
3. What are policy options for encouraging sinks? (M)
4. What methods should be used to measure and report on carbon stocks? (S)
5. What additional categories of direct human-induced LUCF&A activities should be included? (S)
6. Compare LUCF&A policies with biomass options. (M)
7. What are baseline projections of LUCF&A ? (S)
8. What carbon leakage will occur under different approaches of LUCF&A? (S/M)

D) *Impacts on developing countries*

1. Can a clean development mechanism help to avoid/minimise impacts or yield benefits? (S)
2. Can technology transfer avoid/minimise impacts? (M)

E) *Impacts of climate change*

1. What are the risks of non-linear changes in the climate system? (M/L)
2. What are the risks of changes in climate variability and what are the possible consequences of this change? (M/L)

4. Scientific Analyses and Tools to Support Climate Policy Making

4.1 Introduction

For the participants of this workshop, the situation after the adoption of the Kyoto Protocol was comparable to the situation before the first workshop in this series. They were able to identify many questions arising from the Kyoto Protocol but also needed clarification about the actual relevance and priority of questions for policy makers and their advisors. This led to a discussion about new scientific results about policy-relevant topics, and the current scientific activities of the IPCC. The following topics were discussed:

- *The adequacy of the Kyoto emission reduction commitments*: What are the implications of these commitments on long-term climate change and stabilisation targets?
- *Convergence of world wide per capita emissions*: What implications do different equity regimes have on long term emission reduction obligations of Annex I and non Annex I parties?
- *Emissions trading regimes*: What consequences do different trading regimes have on cost-efficiency of reduction obligations fixed in Kyoto?

Background information was also given on:

- New IPCC scenarios
- An interactive modelling framework to support climate negotiations
- The role of non-CO_2 GHG emissions

4.2 The (In)Adequacy of Kyoto Commitments

The adoption of the Kyoto Protocol in December 1997 for the first time established legally-binding emission reduction commitments for industrialised countries. The IMAGE 2 model was used to evaluate possible long term consequences of the Protocol commitments on (1) global emissions, (2) atmospheric CO_2 concentration and (3) temperature change up to 2100.

The implications of the Kyoto commitments were compared to the consequences of two other emission scenarios. Three scenarios were analysed

1. A *Kyoto Scenario* which takes into account emission reductions called for by the Kyoto Protocol.

2. The IPCC medium scenario *IS92a* which previously was considered a typical "business-as-usual" scenario, and
3. The *Stabilisation 550* Scenario, a global emissions scenario which leads to long-term stabilisation of atmospheric CO_2 concentration at 550 ppm.

The "Kyoto" Scenario

We made the following main assumptions to evaluate the implications of the Kyoto commitments:

- Anthropogenic CO_2, CH_4 and N_2O emissions of Annex I parties were assumed to remain constant after the first commitment period. In other words, we did not assume that emission reductions would be extended beyond 2010. Total emission reductions in Annex I according to the Kyoto Protocol are expected to be 5.2 % compared to 1990 emissions. To further simplify the analysis, 2010 was used as the final year of the first commitment period.
- For the trend of CO_2, CH_4 and N_2O emissions of non-Annex I parties, we used the estimates of the IPCC IS92a scenario.

Based on these assumptions we computed the global atmospheric CO_2 concentration and the change in global average surface temperature up to 2100 (see Fig. 1).

The IS92a Scenario

As a business-as-usual case, the temperature change and global CO_2 concentration resulting from the IPCC IS92a emissions scenario were estimated (Fig. 2).

Stabilisation 550 Scenario

In order to evaluate the implications of the 550 ppm stabilisation target we had to specify a pathway to reach this target and had to make assumptions about non-CO_2 greenhouse gases. For this purpose we used the IPCC pathway reaching the 550 ppm concentration target in 2150 (Enting *et al.*, 1994). For non-CO_2 greenhouse gas emissions, namely N_2O and CH_4 Energy/Industry emissions, we assumed a reduction proportional to CO_2 emission reductions. Non-CO_2 land-use emissions were taken from the medium IMAGE baseline a. Computed global CO_2 emissions are presented in Figure 1, and computed atmospheric CO_2 and temperature change in Figure 2.

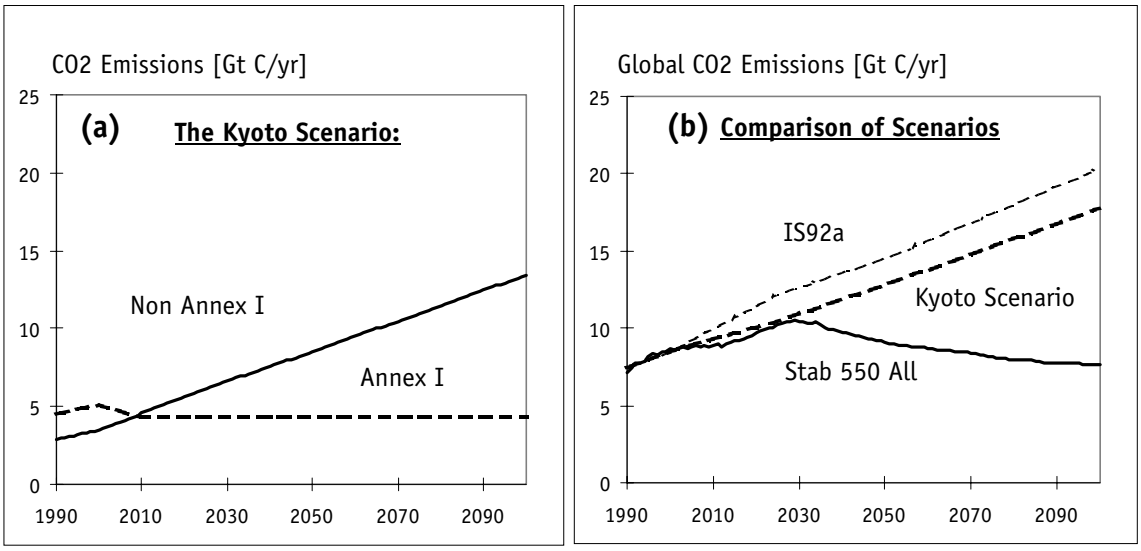

Figure 1: (a) Estimated trends in emissions for Annex I and Non-Annex I states, following from assumptions about the Kyoto Protocol. In this graph, the trends in Non-Annex I emissions follow the IPCC IS92a scenario. (b) Comparison of global emission estimates for three scenarios.

Main findings:

1. Global emissions of the Kyoto Scenario are below the emissions of the IS92a scenario, but far above the emissions trend that achieves the stabilisation of CO_2 in the atmosphere at 550 ppm (Figure 1b).
2. The atmospheric CO_2 concentration of the Kyoto Scenario is also slightly below the IS92a scenario, but far above the pathway to 550 ppm (Figure 2a). We note that stabilisation at 550 ppm is under discussion in the European Union as a target for climate policy. Moreover, the CO_2 concentration under the Kyoto scenario is still sharply increasing in 2100, as compared to its slower increase under the Stabilisation 550 scenario.
3. The global temperature increase of the Kyoto scenario (2.3°C) lies between the IS92a scenario (2.6 °C) and the Stabilisation 550 scenario (1.7°C) (Figure 2b). However, under the Kyoto scenario, temperature in 2100 is still sharply increasing as compared to the Stabilisation 550 scenario. (As an aside, the climate sensitivity of the IMAGE 2 model is 2.37 °C which is within the often-cited range for climate models of 1.5 to 4.5 °C.)

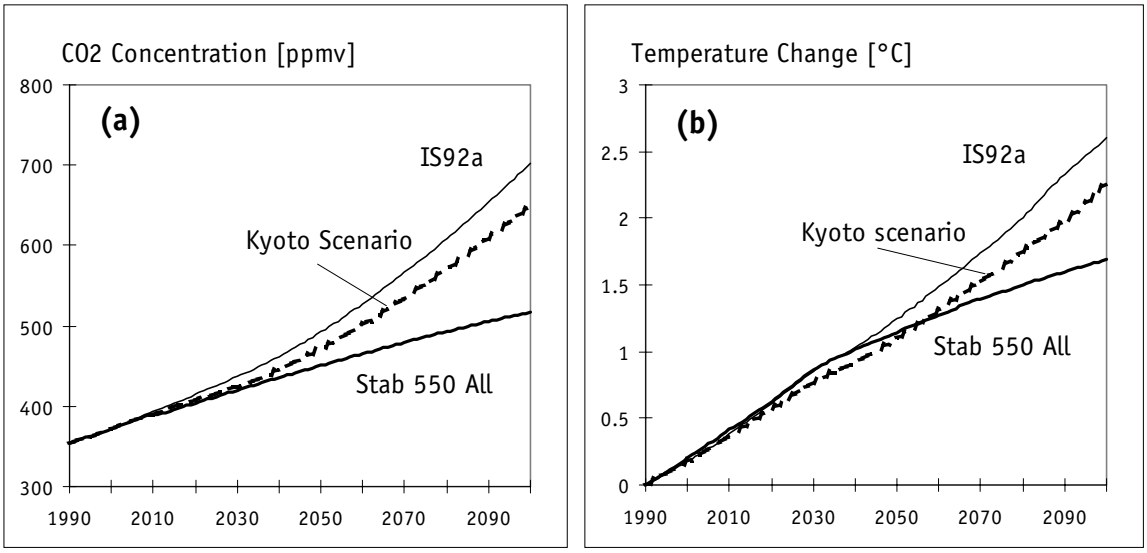

Figure 2: (a) Comparison of computed global atmospheric CO_2 concentration for three scenarios. (b) Comparison of computed increase in global average surface temperature for three scenarios.

4.3 New Global Emission Targets: Convergence of Per Capita Emissions

The reduction commitments for Annex I parties, stated in the Kyoto Protocol, are a step in the direction of controlling the growth of global greenhouse gas emissions. But what are various options for the next step or steps? Here we evaluate the consequences of some emission reduction regimes on long term reduction obligations of Annex I and non-Annex I parties. In this analysis we use the concept of *convergence of per capita CO_2 emissions* of Annex I and non Annex I parties to illustrate one way to equitably share the burden of controlling emissions. We go further, and combine this burden-sharing concept with the concept of climate protection. Our question is, what emission regimes both share the burden of emission reductions and at the same time help protect the global climate system? To help answer this question we perform the following analysis:

1. As an illustration of a goal that aims to protect climate, we use the goal of stabilising the concentration of atmospheric CO_2 at 550 ppm. This is the same as the "Stabilisation 550" scenario used above. The estimated global emissions that would comply with this goal were already shown in Figure 1b, and are shown again in Figure 3b.
2. We next specify a beginning year and an action of non-Annex I countries: Two possible years were analysed: 2010 or 2020. Until that time non-Annex I emissions are allowed to grow according to the IPCC IS92a scenario. After 2010 or 2020, the following actions are specified for non-Annex I states: (a) per capita emissions of non-Annex countries are frozen until they equal Annex I per capita emissions. (b) When per capita emissions of non-Annex I countries converge with those of Annex I countries, then both non-Annex I and

Annex I per capita emissions follow the same path. For these calculations, the population scenario of the IPCC IS92a scenario is used.

3. Based on the actions in Step 2, non-Annex I emissions are calculated. These emissions are then subtracted from the allowable global emissions for achieving 550 ppm CO_2 in the atmosphere (Figure 3b) , and the remainder are the allowable Annex I emissions. That is to say that Annex I emissions are only allowed to fill the gap between non-Annex I total emissions and allowable global emissions.

The results for the case in which non-Annex I states begin take action in year 2020 are depicted in Figures 3a and 3b. The results for total and cumulative emissions of Annex I countries are presented in Table 1.

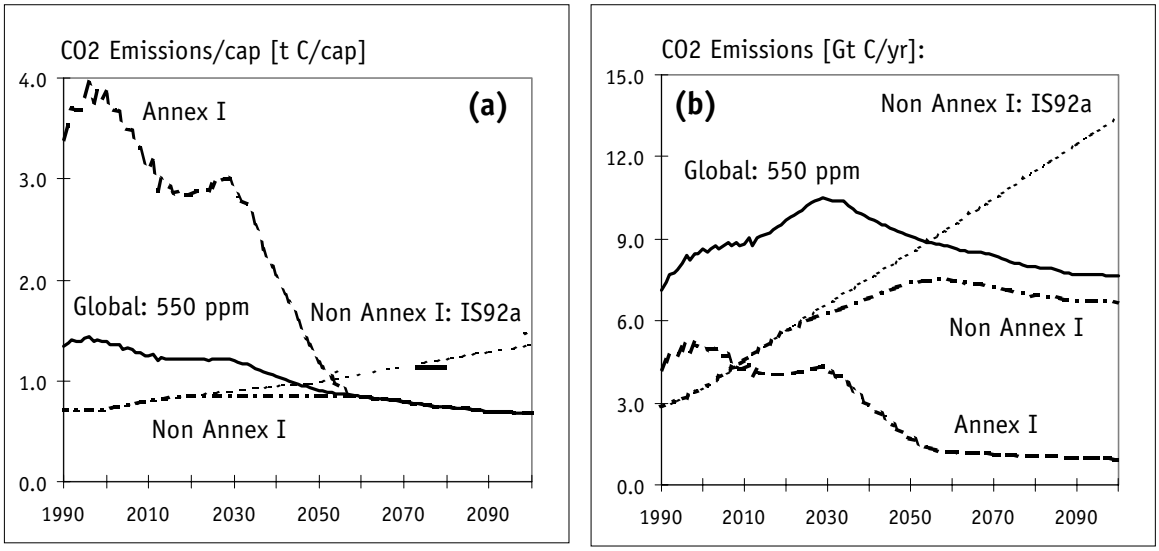

Figure 3: Emissions of CO_2 (including land-use emissions) assuming that per capita emissions of non Annex I are frozen in year 2020. Emissions of Annex I were reduced until per capita emissions reached the same level as non Annex I per capita emissions. (a) Global, non Annex I and Annex I per capita emissions and (b) the same for total emissions. Global CO_2 emissions result from the IPCC 550 ppm stabilisation path as calculated by the IMAGE 2 model.

Main findings:

1. If non-Annex I countries freeze their per capita emissions in 2010, then their per capita emissions converge with the level of Annex I in 2058 (Fig. 3a). Until that time, total emissions from non-Annex I countries may grow (Fig. 3b). Afterwards, non-Annex I per capita emissions must decrease at the same rate as Annex I (Fig. 3a) Per capita emissions in Annex I countries must sharply decrease until the convergence point in 2058 (Fig. 3a).

2. If non-Annex I countries freeze earlier, in 2010, then per capita emissions converge more than 10 years later, in year 2070 (not shown). In this case, non-Annex I countries must begin to decrease per capita emissions in 2070 rather than in 2058. This means that *freezing* per capita emissions in 2010 rather than 2020 allows non-Annex I states to *delay* the *reductions* of their per capita emissions by more than 10 years. Hence, acting earlier to freeze emissions, yields more time to prepare for reducing emissions.
3. Delaying action from year 2010 to 2020 will also lead to about 10% lower allowable cumulative emissions for Annex I (see Table 1).

Table 1: Cumulative and annual CO_2 emissions from Annex I countries as computed by assuming that per capita emissions are frozen in non-Annex I countries in 2010 and 2020.

	Annex I	
	Cumulative emissions in Gt C (between 2010 & 2100)	Annual Emissions in Gt C (in 2010, in 2100)
Non-Annex I per capita emissions freeze in 2010	224	4.3, 1.0*
Non-Annex I per capita emissions freeze in 2020	201	4.3, 1.0*
Kyoto Scenario	390	4.3 const

* Different emissions pathway between 2010 and 2100

Discussion

Participants of the workshop commented that not only equity considerations, but also efficiency of emission reductions should play a role in this kind of analysis. Moreover it would be helpful to further disaggregate the grouping of Annex I and non-Annex I into their constituent countries, and then experiment with burden sharing rules between countries.

4.4 Emission Trading Regimes - Results from the WorldScan Model

The Kyoto Protocol cites three instruments for achieving the reduction commitments of the Annex I parties of UNFCCC: (1) Emission Trading between Annex I parties, (2) Joint Implementation also between Annex I countries, and (3) the Clean Development Mechanism, enabling Annex I countries to meet their reduction targets by investing in projects in non-Annex I countries.

With regards to emission trading, the Protocol states that this approach should only *supplement*, and not replace, national measures. An interesting question then arises –Will limitations on emissions trading limit the amount of emission reductions that can be achieved abroad? To provide insight into this question, J. Bollen and colleagues analysed two different regimes for limiting emission trading:

(1) limitations on the fraction ("cap") of reduction commitments that may be fulfilled by emission trading , and

(2) limitations resulting from “club-formation” within the group of Annex-1 parties.

These limitations were expressed in the form of four different cases for achieving the Kyoto commitments using the macro economic model WorldScan (for more detailed information see Bollen et al., 1998):

1. *No trade*: Kyoto targets to be reached within Annex I by each model region separately.
2. *Full trade:* Kyoto targets to be reached within Annex I with full (unlimited) emission trading based on the Kyoto quotas.
3. *Clubs:* Kyoto targets to be reached within Annex I with two trading clubs (EU/EE and the rest of Annex I), with transfers within clubs but not between clubs.
4. *Restricted trade:* Kyoto targets to be reached within Annex I with trade up to 50% of the targeted reduction (compared with baseline emissions in 2010) in all Annex I regions.

Main Findings

The distribution of reductions between regions was computed in a way that all reductions in a year and in a region were most efficient. In other words, least-cost measures were carried out in every region. The resulting emission reductions achieved abroad, and the underlying carbon reduction prices are presented in Tables 2 and 3. The main conclusions are:

- The most cost efficient way for the USA to reach their reduction target would be for them to participate in restricted trading (rt50 case), or being in a „trading club“ with the Former Soviet Union.
- For the European Union, it would be uneconomic to limit trading.
- For Japan and the Rest of OECD the most cost efficient way to fulfill their commitments would be full trading or being in the „right“ trading club, that is in a club with the FSU and USA.

- Since Eastern Europe and the FSU would be sellers of permits, the trading regimes with the highest carbon prices would be most attractive to them. For Eastern Europe this would be being in a club with the EU, and for the FSU it would be the case of greatest competition for permits, that is, the full trading regime.

Table 2: Carbon prices in 1992 US$ per ton C by 2010

	No trading	Full trading	Clubs	rt85	rt80	rt75	rt50
USA	47	28	22	41	39	33	21
EU	103	28	55	90	84	72	46
Japan	99	28	22	87	82	71	47
ROECD	117	28	22	101	94	79	49
E Europe	12	28	55	10	11	14	25
FSU	6	28	22	10	11	14	25

Table 3: Percentage of emission reductions achieved abroad by 2010

	No trading	Full trading	Clubs	rt85	rt80	rt75	rt50
USA	0	35	51	15	20	25	50
EU	0	73	43	15	20	25	50
Japan	0	76	86	15	20	25	50
ROECD	0	75	83	15	20	25	50
E Europe	0	-118	-212	7	-6	-21	-97
FSU	0	-223	-184	-72	-90	-109	-199

4.5 New IPCC Scenarios

The IPCC is preparing a new set of GHG emission scenarios which can serve as baselines for climate change modelers. The “Special Report on Emissions Scenarios“ (SRES) consists of four “scenario families“ with four possible storylines of how the future world may be structured and the consequences of this structure on greenhouse gas emissions. The development of the four scenario families is driven by two main questions:

- Can adequate governance - institutions and agreements - be put in place to manage global problems?
- Will society's values focus more on enhancing material wealth or be more broadly balanced, incorporating environmental health and social well-being?

The four scenario families are described in Table 4. Within each of these scenario families one or more scenarios explore developments in the world´s population, economy and technology.

Table 4: Basic structures of the world behind the four scenario storylines

	"Open" world with high degree of global governance	"Closed" world with cultural, technical and economic pluralism
Limited, free-market orientation on environmental and social issues	**Golden Economic Age: A1**	**Divided World: A2**
Strong and explicit orientation on sustainibility and equity issues	**Sustainable Development: B1**	**Regional Stewardship: B2**

The story lines do not include explicit climate change policy measures but there are examples of indirect mitigation measures in some of the scenarios. Assumptions about growth of population and economy are given in Table 5.

Table 5: Basic assumptions of new IPCC scenarios

	A1 Golden Economic Age	**B1 Sustainable Development**	**A2 Divided World**	**B2 Regional Stewardship**
Population	2050: 9 bln 2100: 7 bln	2050: 8.7 bn 2100: 7.1 bn	2100: 15 bn	2100: 11.65 bn
GWP in 2100 (in 10^{12} 1990 US $)	550	350	250	244
Resource Base	Including unconventional oil, hydrates etc.	Identified reserves (> 5% probability)	Including unconventional oil, hydrates etc.	Identified reserves (> 5% probability)

4.6 Non-CO_2 Greenhouse Gas Emissions

Most analyses of obligations to reduce greenhouse gas emissions deal with CO_2 as the most important greenhouse gas. However, there is some evidence that land use emissions as well as SO_2 emissions will contribute to future climate change to an extent that shouldn't be ignored. Therefore results from IPCC land use and SO_2 emission scenarios were also presented to the Workshop.

4.7 The Interactive Scenario Scanner and Other Scientific Tools

The Interactive Scenario Scanner (ISS) was developed in response to requests and comments from policy makers participating in the previous Delft workshops. The ISS is a model that assists in the interactive construction and evaluation of long term emission scenarios. It was presented to illustrate the possible contribution of new interactive tools to support climate policy analysis.

Current Set Up of the ISS software

In the following section a brief description of the actual capabilities of the ISS program is given. A more detailed description of the software can be found in Berk & Janssen (1997).

- Scenarios of CO_2 emissions are computed by specifying the four components of the Kaya Identity:

$$CO_2 = Population \cdot \frac{GDP}{capita} \cdot \frac{Energy}{GDP} \cdot \frac{CO_2}{Energy}$$

- Scenarios of land use emissions of CO_2 are taken from the IMAGE 2 model.
- Scenarios of non-CO_2 emissions are assumed to have a fixed ratio to CO_2 emissions.
- All scenarios parameters can be changed individually for the Annex I and non-Annex I regions.

To evaluate the impact of an emissions scenario on global climate change and the global environment, we use the climate indicators of the Safe Landing Approach. These indicators are:

- Global temperature change
- Rate of temperature change
- Sea level rise

- Atmospheric CO_2 concentration

The ISS also explicitly depicts certain uncertainties involved in global modeling, for example, the uncertainty of a climate model´s "climate sensitivity", and the uncertainty of future pathways of sulfur emissions.

Planned improvements and extensions of the ISS

The following improvements and extensions of the ISS software are planned or under discussion:

- Update base year emissions from 1990 to 1995.
- Inclusion of HFC's and CFC's
- Interactive link to the IMAGE User Support System/library of additional (qualitative) information
- Inclusion of more regions as for example the six regions of OECD, Eastern Europe/Former Soviet Union, China, India and Rest of World.
- Extension of time horizon beyond 2100

Options for the development of new interactive tools

It is planned to develop a new interactive modelling framework for the evaluation of options for the evolution of commitments and burden sharing under the FCCC. This framework will cover:

- Schemes for convergence of per capita emissions
- Schemes for "graduation" of commitments
- Equal per capita approach (including historical emissions)

This new Framework for Analysis of International Regimes for burden sharing (FAIR) will be linked to other tools like the ISS and WorldScan/IMAGE (see Figure 4).

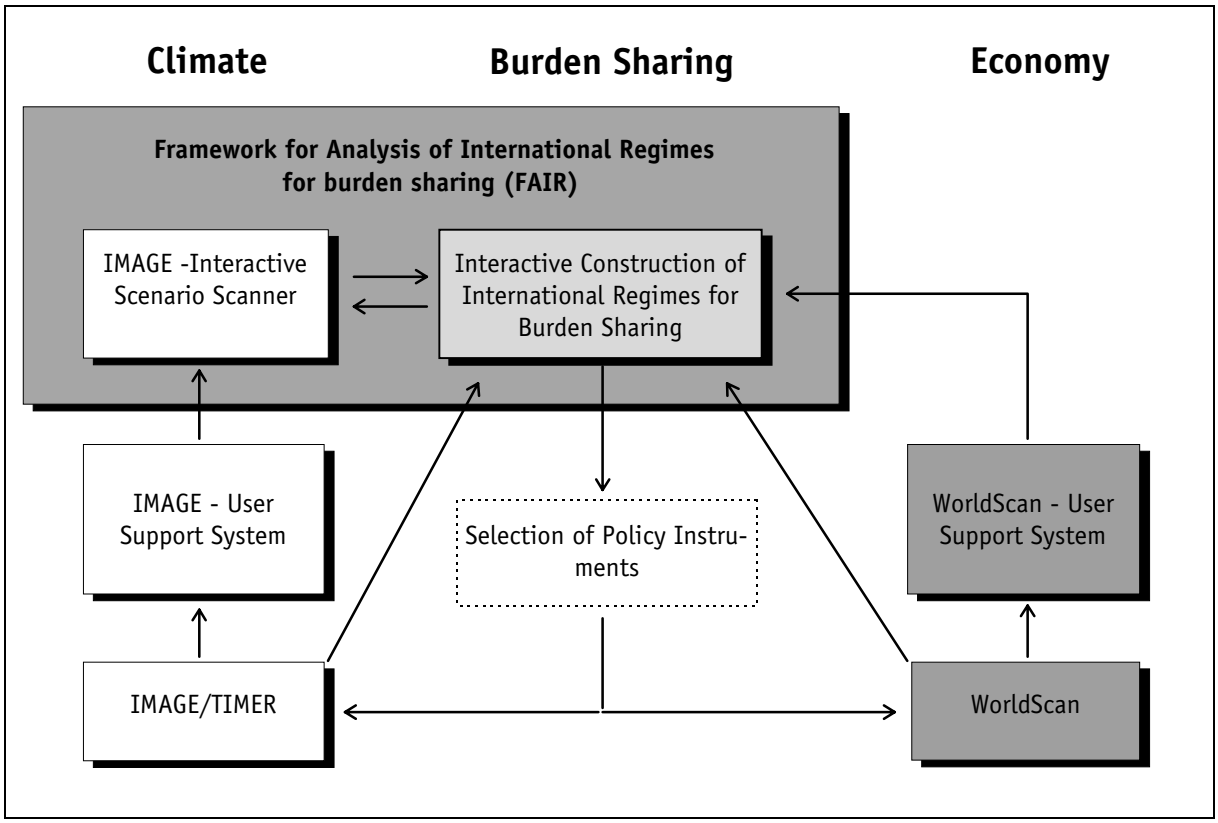

Figure 4: A new analytical framework of analytical tools for the assessment of policy options

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