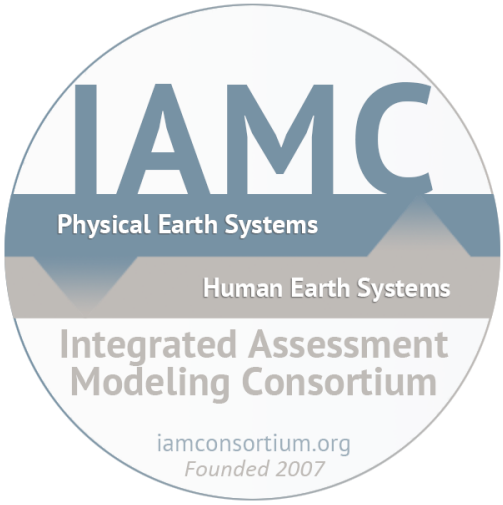

Report on the Fifth Annual Meeting of the Integrated Assessment Modeling Consortium

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Contents

1 Introduction

The Integrated Assessment Modeling Consortium (IAMC) is an organization of scientific research organizations that pursues scientific understanding of issues associated with integrated assessment modeling and analysis. The IAMC mission has three key elements:

1. The IAMC facilitates and fosters the development of integrated assessment models (IAMs), peer interaction and vetting of research associated with IAMs, and the conduct of research employing IAMs, including model diagnosis, intercomparison, and coordinated studies.

2. The IAMC promotes, facilitates and helps to coordinate interactions between IAMC members and members of other scientific research communities studying climate change, such as Climate Modeling (CM), Impact, Adaptation, and Vulnerability (IAV), and technology and engineering communities.

3. The IAMC provides a point of contact with other institutions and organizations that use scientific results from the IAM community, such as the IPCC.

The annual meetings organized by the IAMC form one of the means of accomplishing these mission elements. From November 12 to November 13, the IAMC organized its fifth meeting in Utrecht, the Netherlands. So far, the IAMC meetings have mainly been focused on community activities organized by the IAMC. At the fifth meeting, for the first time, it was decided to add scientific presentations ("mini workshops") around four priority themes of Integrated Assessment research. These themes are:

- Climate Modeling in IA models
- Energy, water and land interactions
- Evaluation, diagnostics and uncertainty in IA Modeling
- Impacts and adaptation in IA research

In the summer of 2012, IAM teams were invited to submit abstracts for presentations of each of these themes. The meetings program was based on a selection of these presentations (those selected by the organizing committee) and a number of invited speakers. The meetings agenda is included in this report, in Appendix A (Section 7.3).

The host of the meeting was PBL Netherlands Environmental Assessment Agency. The financial support of the Japanese Government through the National Institute of Environmental Studies enabled the organization of the meeting.

This report captures the most important discussions and conclusions of the meeting.

2 Opening Plenary Session, 12 November

2.1 Introduction of the meeting

The meeting started off with three presentations by Pieter Boot (Head of the PBL Department of Climate, Air and Energy), Detlef van Vuuren (Senior researcher IMAGE team, PBL) and John Weyant (Stanford University, Chairman of the Scientific Steering Committee of the IAMC), welcoming participants and indicating the purpose of the meeting.

Next, John Weyant presented the 2011 award for extraordinary contributions to the field of integrated assessment. It is the intention that this award will be given each year to someone in the community. The 2011 award was (as announced earlier) presented to Detlef van Vuuren for his contributions in developing the Representative Concentration Pathways (RCPs).

2.2 Plenary discussions on key topics of IAM modeling

2.2.1 SSP scenario development

Tom Kram (PBL) and Keywan Riahi (IIASA) subsequently presented current work on Shared Socio-economic Pathways (SSPs). Tom Kram first reviewed the overall process of SSP development, and the role of the joint IAMC-IAV committee in this work. Next, Keywan Riahi summarized the activities currently performed by various IAM teams in quantifying the SSPs. During their presentations, both speakers emphasized that the SSPs can be useful for IAMC activities in various ways:

- The SSPs create a common set of storylines and quantified drivers for various community activities. The sets cover a wide range of possible futures.
- As the SSPs have been jointly developed with various other communities they may also facilitate further cooperative activities with these communities.
- In terms of the timeline, important progress in further developing the SSPs has to be made in early 2013.

In the ensuing discussions, questions were raised concerning the feedback of changes of environmental parameters on the SSP drivers, and the role of governance processes within the SSP storylines. It was indicated that both issues, currently, are not fully covered, but that research teams are in fact clearly invited to work on these issues in order to further develop insights with respect to these pathways.

2.2.2 IAMC Scenario database and the IPCC AR5 report

Next, Volker Krey presented the further development of the scenario database hosted at IIASA and the ideas with respect to management of this database. To date, the database has been used in a wide range of model comparison projects. Also, IPCC's AR5 intends to use the database for its assessment work. This means that clear rules are required regarding the management of the database and its access. On the technical side, major improvements to the database have been made over the last year - and further improvements are currently being implemented (such as submission in the form of .csf files).

2.2.3 Climate modeling and IAMs

The next two presentations by Bill Collins (LBNL) and Detlef van Vuuren (PBL) focused on the interaction between the climate modeling community and the IAM work. In his presentation, Bill Collins specifically focused on aerosols, given their importance for forcing levels and the large uncertainties surrounding their contribution. Bill Collins emphasized that, although insight into the role of aerosols in climate change is increasing, this does not mean that quantified uncertainty ranges have been narrowed. In fact, climate models use very different numerical representations to calculate aerosol forcing.

In the second presentation, Detlef van Vuuren discussed the issue of increased cooperation between IAM and ESM modelers. In his view, it is clear that further cooperation is needed to better understand important issues in relation to mitigation, impacts and adaptation. He showed that this cooperation can take different forms, ranging from a straightforward exchange of information to full model coupling. He provided criteria that might be used in order to determine which form of cooperation would be the most appropriate. For example, Detlef van Vuuren proposed that the most complicated form of cooperation (full coupling) might only add enough additional value relative to other, less complex methods if feedbacks are both strong and occur via processes that cannot be adequately represented by simple climate models.

In the discussion that followed, questions were raised on how to represent aerosols best in IAM models, as well as the possible implications for mitigation. Also, discussions were started on how to classify some existing research projects in terms of the cooperation forms that were presented. Moreover, it was indicated that the IAM and IAM perspective on cooperation might not necessary be the same.

2.2.4 Validation and diagnostics

John Weyant (Stanford University) and Elmar Kriegler (PIK) presented two important community projects in the United States (PIAMDDI) and Europe (AMPERE) on model evaluation and diagnostics. First, John Weyant presented the purpose and structure of the PIAMDDI project and the type of projects that are currently being run. Second, Elmar

Kriegler presented the type of experiments run in AMPERE, and also indicated how on the basis of these experiments diagnostic indicators can be derived that can successfully qualify models in terms of key model characteristics, such as the type of mitigation response (supply side versus efficiency improvement) and the depth of the response. Such diagnostic indicators might be very useful in interpreting model results across different models.

In the subsequent discussion, respondents expressed clear interest in the type of indicators that were developed (See also the specific session on this topic).

3 Parallel Session: Climate Modeling in IAMs

3.1 Report on individual presentations

In this session, several topics regarding climate modeling in IAMs were discussed. The first presentation, by Andries Hof (PBL), emphasizes the importance of the climate representation in the context of IAM applications. This was done by showing that the benefits of mitigation (i.e. the avoided damages compared to baseline) in cost-benefit type IAM models strongly depend on the climate representation. Differences, especially related to the climate sensitivity and the temperature-response time, may lead to differences in the benefits of mitigation by a factor of more than two. A relatively slow temperature response time - and therefore a slow effect of mitigation - automatically leads to a lower benefit of mitigation (and thus would also lead to a higher estimate for the optimal temperature).

In the second presentation, Detlef van Vuuren (PBL) discussed the pros and cons of using CO2 budgets (instead of climate targets) for both policy making and model comparison projects. Clear advantages of using CO2 budgets are that i) they allow to run models with and without full greenhouse gas representation for the same target, ii) running models under CO2 budgets reduces uncertainty and focuses the analysis on the area where most of the action would need to occur, and iii) the concept of CO2 budgets might be interesting for communication with policymakers, as they emphasize that substitution in time is possible while communicating at the same time the cumulative character of the relationship between emissions and temperature. In the AMPERE project (work lead by Michiel Schaeffer), new CO2 budgets have been estimated for achieving certain climate target; however, it was found that this relation is far more uncertain than suggested by earlier papers. One reason for this is that, at the time, researchers were drawing from a much more limited set of scenarios. This findings in AMPERE imply that CO2 budgets can still be useful, but that uncertainty needs to be communicated.

In the next presentation, by Bill Collins (LBNL), the integrated Earth System Model (iESM) project was introduced. The three major objectives of this project are i) to create a first generation integrated Earth System Model (iESM) closely coupling the human components of an IAM and those of a biogeophysical ESM; ii) to develop linkages within the

iESM and apply the model to improve our knowledge of coupled physical, ecological, and human system, and iii) to add hydrology and water demand, allocation, and availability to the coupled system. As such, the development of iESMs will enable fully consistent analysis of potential future climate change, emission mitigation options, and impacts and adaptation options. An iESM allows immediate testing of climate impacts for future scenarios and quantification of feedbacks and interactions that are cannot be treated by other cooperation method and yet could be significant on mitigation timescales.

The three following short presentations by Keywan Riahi (IIASA), Maarten van den Berg (PBL) and Daniel Johansson (Chalmers University) discussed the effect of using different greenhouse gas accounting methods on CO2-equivalent emissions. Currently, the UNFCCC uses Global Warming Potential (GWP) values for determining the CO2-equivalence of different greenhouse gasses. As the GWP was not constructed to facilitate the implementation of a cost-effective climate stabilization regime, the question is whether other accounting methods could achieve climate targets at lower costs. The presentation showed that changing between different GWP metrics published in subsequent IPCC reports has little impact on costs and abatement strategies. Using Global Temperature Potentials (GTP) has more impacts on total mitigation costs and would impact the profile of methane reductions. Using more complex accounting methods, such as cost-effective trade-off ratios (Global Cost Potential - GCP) instead of the GWP could enhance the cost-effectiveness of a stabilization regime, but at the expense of having to depend on complex optimizing IAMs. An alternative method (CETP) was suggested, which is simpler and closely approximates the GCP under a range of assumptions and models structures.

The main carbon cycle results from the Earth System Model (ESM) comparison study CMIP5 were presented next by Peter Lawrence (NCAR) based on a presentation prepared by Pierre Friedlingstein (University of Exeter). Within the CMIP5 studies, an important set of experiments are those in which the carbon cycle behavior is back-calculated from the concentration provided by the RCPs. Although the ESMs showed fair agreement in their results for removal of carbon from the atmosphere by oceans, the model spread for the change in land carbon fluxes was larger than the spread among the scenarios. One reason for this is that some models severely under- or overestimated the soil carbon content and land sink. Another reason might be that some models have included a nitrogen cycle, which limits the ecosystem response to CO2 and might therefore lead to different behavior of the carbon cycle. Overall, the carbon budget calculations of the ESMs show broadly comparable pathways for anthropogenic carbon emissions as the original RCPs emission pathways from the IAM. Still, according to some ESMs achieving the RCP2.6 concentration path does not necessary require negative emissions. The results also suggest that the lower bound for CO2 concentrations as calculated by MAGICC (as part of the RCP exercise) seems to be lower than the ESMs outcomes. This is likely explained by the fact that MAGICC6 is calibrated to the full set of C4MIP models. This includes a suspicious model with very high ocean carbon uptakes that thus influences that MAGICC outcomes.

The final presentation in this section introduced the cooperation between the IMAGE IAM model and the EC-Earth ESM model (presented by Bart van den Hurk and prepared by Wilco Hazeleger, both KNMI). This project (called EC-IMAGE) looks into both land-use- and air-pollution-related issues. This EC-Earth ESM model is based on the weather prediction model ECMWF and can analyze seasonal, decadal and century timescales. The EC-Earth results for global temperature increase are comparable to those of CMIP5. In general, there are quite some challenges with respect to the outcomes of ESM models. This, for instance, involves the regional outcomes (with quite some differences across models). Another key issue is the systematic bias in ESM output, for instance for global mean temperature (which can differ across models over a range of more than 1oC). For model couplings, it is necessary that such biases are corrected.

3.2 Conclusions

On the basis of this session, it became clear that further cooperation between the climate modeling community and the IAM community would be useful.

- The climate representation in IAMs plays an important role in the results. IAMs may more systematically want to represent the uncertainty ranges in climate parameters (instead of just representing one position in the uncertainty range).
- On the issue of comparing multiple GHGs, the IAM models have some important insights to offer. However, to date analysis has mostly focused on the relationship between alternative metrics and global emissions mitigation costs. It would be useful to look further into the regional consequences of alternative GHG weighting systems and their implications for burden sharing.
- Interesting research is currently being done in bringing IAM and ESM teams closer together. It is useful to continue this pioneering work, also to start establishing best practices in terms of the various forms of cooperation.
- The current use of the RCPs by the climate modeling community reflects an important benchmark in cooperation between IAMs and the climate community. Initial ESM results appear largely consistent with the results of the IAM models. A more systematic exchange of information between ESM and IAM research teams to interpret the RCP results is a promising next step in the collaborative process.

4 Parallel Session: Interactions Between Energy, Land and Water

4.1 Report on individual presentations

In the first presentation, Adam Schlosser presented work with the IGSM-WRS framework on regional risks for managed water basins due to global climate change. The presentation indicated that this integrated complex system would be well-suited to address the issues at hand, given its ability to operate at a high resolution (both geographically and spatially). A critical question in assessing impacts of changing precipitation patterns is that of how to draw general conclusions if often even the signs of change are unclear, and differences in patterns between GCMs are larger than for different climate forcing levels explored with one GCM.

Next, Mohammed Hejazi presented work on modeling the interactions between energy, water, land, using the GCAM model, specifically focusing on the integration of water with other issues. The presentation first showed new projections of water demand driven by widely ranging assumptions on socio-economic development. The resulting water demands were downscaled and combined with assessments of water supply under changing climate conditions assess water shortage and water stress at the grid-scale level. The presentation concluded by indicating some key areas of research including competition, climate change impacts on water demand, and accounting for non-renewable water resources.

Keigo Akimoto, in his presentation, focused on scenarios that addressed both climate policy and sustainable development issues. An important issue addressed in the presentation was the importance of climate change compared to socio-economic factors. The latter were often found to be more important than climate change for sustainable development targets. The discussion regarding this presentation focused on the possible relationships with SSPs, but also on the relevance of extreme effects versus gradual climate change.

In his presentation, Mark Howells presented work at the Energy System Analysis division of KTH. He indicated that the interactions between climate, land, energy and water were important research areas. A key aspect to model these interactions is the integration across different scales. He illustrated the importance of accounting for interactions in two case studies in Africa. One of these looked at the net energy and CO2 gains from agriculture intensification in Burkina Faso. He emphasized the importance of finding ways to link the national level (relevant for many decision-making processes) to on the one hand the local level (where several key processes occur) and the more aggregated levels of global change processes.

Toshi Masui, in his presentation, focused on the development of new scenarios addressing impacts, adaptation and mitigation using the AIM model. This development required the inclusion of impacts within the AIM framework. A key focus area for research is water,

for which the H08 model has been introduced into the framework. The results show that climate change impacts such as water stress and food demand cannot be neglected in scenario development. The results also indicate, however, that socioeconomic drivers exert a large influence on welfare, not just climate change. In that context, the next step would be to couple the climate impacts (and consequences of adaptation) back to the drivers.

Niko Bauer (PIK) presented work on building an integrated model encompassing the economy, energy use, land use and climate. The system builds upon a set of PIK's existing model systems: ReMind, MagPIE and LPJmL. Some preliminary findings are that, especially for low stabilization targets, the interactions between land use and energy are very important. For instance, bio-energy with carbon capture and storage (BECCS) becomes a key technology. A consequence may be increased competition over land use. A particularly important result was that pricing carbon emissions from land can have a substantial effect on land use change emissions and therefore on the requirements for emissions in the energy sector.

Mikiko Kainuma presented work on the Low Carbon Society project for Asia. In this project, extensive analysis was done on specific emission reduction strategies. The project intends to build on consensus building by extensively discussing the project results with various stakeholder groups. Important conclusions from this work are that, in most Asian countries, reduction strategies are not consistent with the so-called 2 oC target. It is also not very clear whether the pledges by Asian countries will be achieved. Focusing more on co-benefits may play an important role in this context.

4.2 Conclusions

Several conclusions about future community activities were drawn from the session:

- Many IAM teams are currently working on the interactions between land, water and energy. This often implies that teams go beyond their original expertise. Modeling water scarcity, for instance, can only be done with reasonable accuracy in a meaningful way at a high resolution (e.g. grids, watersheds). This is raising new challenges in the IA modeling.

- The work on interactions between water, land and energy will therefore require model improvements. Key areas were progress needs to be made are those on spatial resolution (in particular on coupling different levels of scale), temporal resolution, representation of extremes, and finally, the representation of governance and institutional arrangements.

- The new work on interactions between land, energy and water could possibly be interesting for model intercomparison exercises (i.e. after the current exercises are finished). In that context, the following observations were made:

  - For land use, the models are ready for this sort of activity.
  - The groups that are working on global water scarcity could work together on a simple comparison. The modelers seem to be facing many of the same issues.
  - There may be some value in comparing regional and global models in order to understand the implications of scale in modeling.

- Extending their original expertise implies that teams will encounter several data issues. Data on water, for instance, often are more scarce and uncertain than data on energy use. This raises several important questions and issues.

  - Could we find ways to give other communities an incentive to produce these data?
  - Are the options for joint work on data development (a kind of GTAP for water)? Is there a role for the IAMC in this activity?
  - And finally, even if each team has to manipulate data for its model individually, there may be value in documenting and sharing information about different sources. Also here the IAMC may play a role.

5 Parallel Session: Impacts and Adaptation in IA Research

5.1 Report on individual presentations

This session presented results from impact and adaptation modeling in IAMs. The session kicked off with a presentation on the consequences in terms of climate impacts of shifting from the RCP8.5 to the RCP4.5 emission scenario, according to the GRACE model, as presented by Asbjon Aaheim. This CGE model contains 15 impact functions for 11 world regions, based on European studies. One of the main conclusions from this exercise was that the model assumptions regarding smallholding farmers may be wrong. According to the model, reductions in crop yields (due to climate change) do not necessarily lead to negative impacts for farmers and land owners, as inelastic agricultural demands can increase prices and generating increased revenue for the reduced supply. However, for small land holders with a large share of own consumption, increasing prices do not compensate reduced crop yields.

The results of integrating different impacts of climate change into one model (GEMINI-E3), as part of the Ermitage project, subsequently were presented by Santosh Joshy. The model includes 14 world regions and 24 sectors and takes into account interactions between impacts and indirect effects between sectors and regions. The main findings were that developing countries mainly seemed affected by climate change, and that positive effects

may occur in Eastern Europe (due to lower mortality) and China (due to less heating). An important caveat in this approach is that health effects only take into account the effect on labor, while mostly children and the elderly are affected by climate change. Moreover, impacts have been based on means only, while extreme events may be more important.

The following presentation focused on impacts in the agricultural sector, undertaken in the framework of the Global-IQ project. This work was presented by Franziska Piontek. In this work, the gap between biophysical models and IAMs was bridged by including an agro-economic model. The key challenge tackled is the aggregation of effects. Climate change results in a higher producer surplus, but a lower consumer surplus, which can be explained by the earlier finding of agricultural price increases. This makes the overall effect fairly small, which is a misrepresentation. Furthermore, the preliminary results showed mixed effects within regions, a challenge for aggregation from grid scale to regional level. Finally the CO2 fertilization effect makes represents a large source of uncertainty, with positive impacts up to 4C when it is included.

The ongoing work on impact analyses by GCAM were presented next by Kate Calvin. The goal is to have seven impact sectors included in the model, which currently has only three: buildings, water, and agriculture. An interesting finding for the A2 scenario is the model projection that, by 2100, people in Florida will no longer use heating. The GCAM model was also extended to look into water availability. By combining the results for water supply and water demand, a water scarcity index can be constructed.

The following presentation introduced the multi-model comparison projects ISIMIP and AgMIP (Franziska Piontek and Dominique van der Mensbrugghe). The focus in these projects is on community activities rather than model results. The AgMIP comparison includes both general (6) and partial (4) equilibrium models. Two baseline no climate change scenarios (SSP2 and SSP3) suggest a modest increase (10%) in world agricultural prices for 2050. Future climate impacts on crops was assessed using a combination of two ESMs and two crop models for a total of four RCP 8.5 scenarios. The impacts on crop prices were relatively small under all variations. The ISIMIP project focuses on the difference in impacts on agriculture, water, biomes, and malaria between situations of 2, 3 and 4C global temperature increases. For the first time, a model comparison study looked into several different impacts. The results will be presented in a special issue of PNAS, together with a public database.

The session continued with a description of the TM5-FASST model (by Frank Dentener), a global source-receptor model for air pollutants, radiative forcing and deposition, which includes 56 regions. The strengths of this model are its global coverage and consistency in calculating impacts, the speed of calculation (ideal for assessments requiring many scenario evaluations), and the internal consistency between various impact categories (health, vegetation, deposition, climate). The model also has some weaknesses, for example, in its description of non-linear processes, in inter-annual variability, and the effect of ozone on crop yields.

Following this presentation, Juan-Carlos Ciscar presented the main results of the PE-

SETA II project, aimed at modeling climate impacts in Europe. The results were based on projected physical impacts and on the CGE GEM-E3 model. Some of the main conclusions were that the largest impacts were projected for coastal areas, especially in northern Europe. For southern Europe, negative impacts were projected for agriculture. Adaptation was found to be very effective against sea level rise: it could reduce damages from 42 to 1.5 billion euros. Uncertainty in precipitation led to a wide uncertainty range in damages from river floods. An important caveat is that tipping points were not yet considered, and that it was difficult to achieve consistency across disciplines.

The following, final presentation also dealt with the modeling of climate impacts, but this time for the United States. This presentation, held by Jim McFarland, focused on ongoing work, based on the EPA project of Climate Change Impacts and Risk Analysis (CIRA) in collaboration with PNNL and MIT. The model analysis included a wide range of climate sensitivities, emission pathways and impact categories. The findings included that coral cover in Hawaii vanishes in the reference case, and decreases to 15% of current cover under the RCP3.7 scenario. Coral cover in Florida was projected to vanish under all scenarios. Possible future work would include taking into account any impacts on biodiversity as well as extreme events, and linking those impacts using a CGE model.

5.2 Conclusions

Several conclusions could be drawn on the basis of the discussions following these presentations.

- Several improvements could be made in the research on climate impacts. These include more focus on extreme events and on smaller scale geographic levels (in order for these events to be capture well); establishing a better link between climate damages and risks and those of air pollution; and to better capture adaptation (with the question of how to distinguish between normal and adaptation-related investments).
- There is a need for more multi-model comparisons of impact functions. In that context, it may be also important to improve the exchange of information on how to monetize damages.
- In research, impacts models should focus more on using ensemble data from climate models to best estimate uncertainty.
- Studies should communicate better about the winners and losers of climate change instead of only on the net effect.
- It would be useful to agree on standard methods for taking adaptation into account (e.g. no adaptation, optimal adaptation?).

- There is a clear need for new information on aggregated damage functions. Impact analyses have become more specific and current damage functions are based on old data.
- In the analysis it is important to include a better representation of agents (impacts differ between households and producers).

6 Parallel Session: Evaluation, Diagnostics and Uncertainty in IA Modeling

6.1 Report on individual presentations

The opening presentation, by Mort Webster, discussed work on sequential decision-making under uncertainty with IAM Models using approximate dynamic programming. Instead of looping over all possible states, actions and exogenous assumptions as in classic Dynamic Programming routines, the Approximate Dynamic Programming combines Monte Carlo and Adaptive Sampling to cut down on the number of evaluations. The ENTICE-BR model was used in this analysis, which was supplied with a second independent backstop technology with a higher initial price, to study when (if ever) R&D into the higher-cost backstop would occur and how a stochastic decision (and its variance and skewness) would differ from a deterministic decision. The results showed that while it is clearly relevant to invest in the high priced technologies, when and how much is determined by the price differential and risk properties.

The presentation by Patrick Reed investigated how the exogenous parameters in the DICE model control the uncertainties associated with climate abatement and damage costs. The results suggested that there is a strong non-linear amplification of costs. Interestingly, the driving uncertainties differ dramatically under a mitigation strategy (aggressive abatement vs inaction) making the problem non-separable. Parameter interactions are significant and change over time, both in number and degree. In DICE, the controlling uncertainties are technology efficiency and population growth dynamics, climate sensitivity, the formulation of climate damage and participation in abatement.

Max Tavoni presented work with the WITCH model, investigating the impact of uncertainty in technology futures on RD&D investments. Using stochastic programming techniques, he presented how different assumptions on the likelihood of RD&D investments into Solar Radiation Management technologies have an impact on the calculated emission pathways. Also, a Monte Carlo analysis was done based on expert-solicitation-based probability-density functions for technology costs to further explore the impact of uncertainty in technology assumptions on future carbon prices

Joeri Rogelj presented soon to be published work by himself and several others. They

used cost-risk distributions for staying below a given temperature limit in an attempt to rank the importance of geophysical, technological and social uncertainties. More specifically, they considered the uncertainty in the carbon cycle and climate system, uncertainty around the technological future, such as carbon capture and storage or advanced transportation technologies, and future energy demand. By coupling a probabilistic version of MAGICC and the MESSAGE Integrated Assessment Model, they studied the impacts of delayed policy action with respect to mitigation and compared these to the above mentioned uncertainty ranges. When considering the probability of limiting global warming to below 2 C, they showed that delayed action (versus the optimal pathway) could have a considerable impact. This impact would be larger than that of uncertainty in biophysical and socio-economic parameters. The expectation about alternative technology futures has, on its turn, even a smaller impact.

Shunsuke Mori presented min-max regret and the max expected utility strategies as tools to explore climate policy under uncertainties by the expansion of Integrated Assessment Model MARIA. The analysis showed that when considering long-tailed distributions, decision-making based on expected utility would underestimate the extreme case, while an exaggerated risk aversion strategy would derive policy depending on the extreme assumptions regardless of plausibility. The minimum regret policy tends to prefer lower carbon emission pathways. The approach described in this study could be useful in irreversible, unrepeatable and asymmetric uncertainty cases.

Jana Schwanitz presented her ongoing research on the role that the use of stylized facts may have in evaluating IAMs. By confronting models with typical patterns observed in history, one can attempt to judge IAMs model behaviour. For instance, when looking at the trends in global income distribution, it became clear that model projections from REMIND deviated from historical patterns, probably driven by strong GDP convergence assumptions. In contrast, the projected future trends for primary energy intensity were much more in line with historical patterns. The examples show that the comparison with historically observed stylized facts can be a relevant method of analyzing IAMs. In that light, developing a list of stylized facts as a standard for evaluation and transparency of model seems a useful thing to do.

The GCAM team, represented by Leon Clarke, presented the results from their efforts in a hind casting exercise. The GCAM team calibrated two versions of GCAM - (1) to 1990 data and (2) to 2005 data. The analysis showed that, in the long term, impact on the residential sector is limited. The production of crops used for food is represented rather well as well, although the historical oscillations in production are obviously not represented. The growth in production of crops for biofuels are not represented well as the model did not anticipate biofuels policies. The exercise showed that certain things still remain to be learned about our models. Predicting elements that are closer to input assumptions is easier than others that are more conditional, while these are the ones that we are most interested in. Validation is very data intensive.

The closing presentation of this session was given by Rich Rosen. He gave a critical review of the main goals of IAMs and where he feels there is room for improvement. He specifically pleaded for increased transparency of the models contents, flexibility in model structure and detail to adapt to changing policy questions, and pointed to the differences in relevant applications of optimization, simulation and back-casting-based modeling frameworks. Rosen also pleaded for a larger diversity in scenarios to reflect system uncertainty and, when presenting results, to more explicitly state under which assumptions key conclusions do and do not hold.

6.2 Conclusions

- There was general agreement that it is important to pay more attention to the issues of model uncertainty, evaluation and diagnostics. Potentially, decisions involving large sums of money may be based (at least partly) on the results of IAM models. More and more policymakers are raising the issues of transparency and model validation.
- The work presented in the session, in that context, was very interesting and inspiring and may help responses to current calls. In the same context, also considered important were more and better documentation of IAMs and transparency. One suggestion was to use wiki-style documentation.
- Development of a list of stylized facts that could be tested for IAMs was found to be useful, including setting a standard for evaluation. In this area it could be useful to learn from other communities.
- Model validation does imply considerable data needs. Perhaps the repository database could be of help here.
- It was suggested to consider establishing a scientific working group in the IAMC on this topic. This working group could focus on both evaluation and uncertainty and could coordinate diagnostics and probabilistic analyses in IAMs exercises.

7 Closing Plenary Session, 13 November

7.1 Update on Integrated Activities

Several presenters gave a brief overview of the main characteristics of ongoing community exercises by IAM modeling teams. This presentation included very brief presentations on AgMIP, LIMITS, EMF 26, EMF24, EMF27, AMPERE, RoSE, ADVANCE, EMF 28, Low Carbon Societies, TEAM, MUG, and LAM.

7.2 IAMC Priorities

Subsequently, Jae Edmonds presented ideas for research priorities for the IAMC. He began with a discussion of priorities from previous meetings. He then presented concepts for how these priorities may have evolved over the past year and how the issues presented and raised at the meeting might play into the new IAMC priorities.

In the ensuing discussion, the audience indicated that it would be good to have the list of research priorities published in some form (either a journal paper, or for instance some form of document on the IAMC website). It would be a valuable document to refer to in research applications. It was suggested that the Scientific Steering Committee, and the SWG on research priorities in specific, would construct a condensed list of priorities for this document.

7.3 Open discussion

- After the presentation, a general discussion was started. Several important conclusions were drawn:

- There is an increasingly broader focus of the IAM teams that take part in the IAMC, from mainly focusing on energy and climate change to including more and more land-use elements, water and other topics. Some of these topics relate to other research challenges. It would be very useful for the Scientific Steering Committee of the IAMC to clarify what constitutes IA within the context of the IAMC.

- There is a lack of data in several research areas, particularly in areas such as water. However, data are also lacking in many of the traditional bread-and-butter elements of IA modeling, such as global data on energy services. It would be useful to consider how community activities could be organized to jointly collect, develop and manage data sources.

- The issue of an IAMC journal was discussed. The conclusion was drawn that, at this moment in time, the establishment of a new journal would be too much work in comparison to the possible benefits. Another idea that was raised was the establishment of Working Paper Series. For example, model documentation, which generally does not have a standard peer-reviewed journal outlet, could be published in such a Working Paper Series. The Scientific Steering Committee was encouraged to establish a working group to start such a Working Paper Series.

- The IAMC would be interested in a more regular contact with other communities. For the climate community, such regular contact has already been established in the form of climate modelers attending IAMC meetings, a number of collaborations with the climate modeling community (e.g., the iESM project, which is a collaboration between

the GCAM team and the CESM modeling group), and participation of a number of IA modelers in a number of key scientific working groups and forums in the climate modeling community (e.g., Detlef van Vuuren serving in the Working Group of Coupled Models within the WCRP, participation in the CESM Societal Dimensions Working Group). There are fewer formal interactions in the IAV community. However, some opportunities do exist. Examples include the following:

- The IAM-IAV joint committee for the SSPs provides a point of contact.
- The ISI-MIP project may act as a starting point for community organization for part of the IAV community.
- The ISI-MIP project is co-organizing a major conference on impacts and would welcome IAM participation.
- The new format of this IAMC Annual Meeting was seen as having been very successful and will be continued for the next annual meeting.

Appendix A. Meeting Agenda

The Fifth Annual IAMC Meeting was held at the Foundation of Renswoulde, Agnietenstraat 1-30, Utrecht, the Netherlands

Day 1: Monday, 12 November 2012

Opening Plenary Session, Chair: Leon Clarke

08:30 - 08:40 Welcome *by* Pieter Boot

08:40 - 09:00 Introduction *by* Detlef van Vuuren and John Weyant

09:00 - 10:00 Report of the Scientific Working Group on Shared Socioeconomic Pathways, Tom Kram and Keywan Riahi

10:00 - 10:30 Break

10:30 - 11:00 Report of the Scientific Working Group on Data Protocols and Management: Discussion of IPCC Data Request *by* Volker Krey

11:00 - 11:50 Plenary Topic: Linking IAMs to Earth System Models *by* Bill Collins and Detlef van Vuuren

11:50 - 12:40 Plenary Topic: Challenges in Evaluation and Diagnostics *by* John Weyant and Elmar Kriegler

12:40 - 13:40 Lunch

Parallel Session: Climate Modeling in Integrated Assessment

13:40 - 13:45 Introduction *by* Detlef van Vuuren, Brian O'Neil and Jae Edmonds

13:45 - 14:15 The benefits of climate change mitigation in integrated assessment models: The role of the carbon cycle and climate component *by* Andries Hof et al.

14:15 - 14:45 Estimating carbon budgets for model comparison and policy-making *by* Detlef van Vuuren

14:45 - 15:15 Results of carbon cycle CMIP5 / results climate outcomes CMIP5 *by* Pierre Friedlingstein and Peter Lawrence

15:15 - 15:45 Break

15:45 - 16:30 Influence Greenhouse Gas Accounting Methods *by* Daniel Johansson, Keywan Riahi and Maarten van den Berg

16:30 - 16:55 The integrated Earth System Model (iESM) project *by* Bill Collins and Jae Edmonds

16:55 - 17:10 Coupling of IMAGE with EC-Earthby Wilco Hazeleger and Bart van den Hurk

17:10 - 17:45 Open Discussion: Research Priorities *by* Chairs

Parallel Session: Energy-Water-Land Interactions

13:40 - 13:50 Introduction *by* Leon Clarke, Tom Kram and Steven Rose

13:50 - 14:20 Water modeling in the MIT iGSM framework *by* Adan Schlosser et al.

14:20 - 14:50 Modeling water, land, and energy interactions in GCAM - a water focus by Mohamad Hejazi et al.

14:50 - 15:15 Consistent Analysis of Different Scenarios of Climate Stabilization and Sustainable Development *by* Keigo Akimoto et al.

15:15 - 15:45 Break

15:45 - 16:10 A modeling framework for assessing Climate, Land Use, Energy and Water (CLEWs) Interactions *by* Mark Howells et al.

16:10 - 16:35 Application of AIM (Asia-Pacific Integrated Model) towards new socio-economic scenario development, integrating climate change mitigation, impact and adaptation *by* Toshihiko Masui et al.

16:35 - 17:00 Assessing long-term climate change stabilization using an integrated model of energy, economy, land use and climate *by* Nico Bauer et al.

17:00 - 17:15 AIM model approach towards Low Carbon Societies in Asia *by* Mikiko Kainuma et al.

17:15 - 17:45 Open Discussion: Research Priorities *by* Chairs

Day 2: Tuesday, 13 November 2012

Parallel Session: Impacts and Adaptation in IA Research

08:30 - 08:40 Introduction *by* Juan-Carlos Ciscar, Toshihiko Masui and Keywan Riahi

08:40 - 09:05 Consequences of shifting pathway from RCP8.5 to RCP4.5 by Asbjrn Aaheim et al.

09:05 - 09:30 Economic consequences of climate change *by* Santosh Joshiy et al.

09:30 - 09:50 Economic effects of climate change in the agricultural sector - towards a closed loop assessment *by* Franziska Piontek et al.

09:50 - 10:15 Impacts analysis in GCAM *by* Kate Calvin

10:15 - 10:45 Multi-model comparison projects: ISI-MIP and AgMIP *by* Dominique van der Menschbrugge and Franziska Piontek

10:45 - 11:15 Break

11:15 - 11:40 Multiple impacts of global air pollution: Tools, Methods and Applications *by* Dentener et al.

11:40 - 12:05 Modeling climate impacts in Europe (the JRC PESETA II project) *by* Juan-Carlos Ciscar

12:05 - 12:30 The Benefits of Mitigation Policies for the United States: EPA's Climate Change Impacts and Risk Analysis (CIRA) Project *by* Jim McFarland

12:30 - 13:00 Open Discussion: Research Priorities *by* Chairs

Parallel Session: Evaluation, Diagnostics and Uncertainty in Integrated Assessment Modeling

08:30 - 08:40 Introduction *by* Elmar Kriegler, Massimo Tavoni and John Weyant

08:40 - 09:05 Latest advancements in uncertainty analysis in IAMs, Mort Webster

09:05 - 09:30 Sobol method applied to DICE *by* Pat Reed

09:30 - 09:55 Technology uncertainty and optimal R&D portfolios (Overview of the TEaM Project) *by* Massimo Tavoni

09:55 - 10:20 Probabilistic cost estimates for climate change mitigation *by* Joeri Rogelj et al.

10:20 - 10:45 The Min-max Regret and the Max Expected Utility Strategies for the Climate Policy Evaluations under Uncertainties *by* the expansion of Integrated Assessment Model MARIA *by* Shunsuki Mori

10:45 - 11:15 Break

11:15 - 11:40 Evaluating integrated assessment models with stylized facts - an exercise with ReMIND *by* Jana Schwanitz et al.

11:40 - 12:05 A hindcasting experiment in GCAM *by* Leon Clarke and Jae Edmonds

12:05 - 12:25 A conceptual approach to the evaluation and diagnosis of integrated assessment models *by* Rich Rosen

12:25 - 13:00 Open Discussion: Research Priorities *by* Chairs

13:00 - 14:00 Lunch. During the lunch, Allison Thomson and Bill Collins presented the iESM modeling approach and indicated how different IAM models could possibly be coupled to the NCAR ESM model.

Closing Plenary Session, Chair: Leon Clarke

14:00 - 14:30 Update on Integrated Activities *by* Study Leaders

14:30 - 15:30 Parallel Session Reports (15 minutes each) *by* Rapporteurs

15:30 - 16:00 Break

16:00 - 16:30 IAMC Priorities *by* Jae Edmonds

16:30 - 17:45 Open Discussion: IAMC Priorities, Chair: Detlef van Vuuren

Appendix B. Meeting Participant List

Asbjrn Aaheim
Keigo Akimoto
Nico Bauer
Patrick Bogaart
Pieter Boot
Katherine Calvin
Juan Carlos Ciscar
Leon Clarke
William Collins
Gauthier de Maere
Olivier Dessens
Laurant Drouet
Jae Edmonds
Tommi Ekholm
Jiyong Eom
Frank Dentener
Mohamad Hejazi
Andries Hof
Mark Howells
Bo Hu
Daniel Johansson
Nils Johnson
Mikiko Kainuma
Jiang Kejun
Barbara Koelbl
Tom Kram
Volker Krey
Elmar Kriegler
Atsushi Kurosawa
Maryse Labriet
Peter Lawrence
Armin Leopold
Paul Lucas
Toshihiko Masui
David McCollum
James McFarland
Angelica Mendoza Beltrn
Shunsuke Mori

Franziska Piontek
Patrick Reed
Keywan Riahi
Joeri Rogelj
Richard Rosen
Peter Russ
Adam Schlosser
Jana Schwanitz
Rao Shilpa
Kaoru Tachiiri
Max Tavoni
Allison Thomson
Maarten van den Berg
Bart Van der Hurk
Dominique van der Mensbrugghe
Bas van Ruijven
Jasper van Vliet
Detlef van Vuuren
Marc Vielle
Kenichi Wada
Mort Webster
John Weyant