INTERGOVERNMENTAL PANEL ON climate change

WMO UNEP

IPCC Workshop on the Use of Scenarios in the Sixth Assessment Report and Subsequent Assessments

Bangkok, Thailand
25-27 April 2023

Workshop Report

Edited by:

Valérie Masson-Delmotte, Hans-Otto Pörtner, Debra C. Roberts, P.R. Shukla, Jim Skea, Panmao Zhai, William Cheung, Jan Fuglestvedt, Amit Garg, Brian O'Neill, Joy Pereira, Joana Portugal Pereira, Keywan Riahi, Anna Sörensson, Claudia Tebaldi, Edmond Totin, Detlef van Vuuren, Zinta Zommers, Alaa Al Khourdajie, Sarah Connors, Roger Fradera, Chloé Ludden, David McCollum, Katja Mintenbeck, Minal Pathak, Anna Pirani, Elvira Poloczanska, Shreya Some, Melinda Tignor

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ISBN 978-92-9169-166-1

Published July 2023 by the IPCC Working Group III Technical Support Unit, Imperial College London, United Kingdom and Ahmedabad University, India. Electronic copies of this report are available from the IPCC website (www.ipcc.ch).

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IPCC Workshop on the Use of Scenarios in the Sixth Assessment Report and Subsequent Assessments

Bangkok, Thailand, 25 -27 April 2023

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This Workshop Report should be cited as:

IPCC, 2023: *Workshop Report of the Intergovernmental Panel on Climate Change Workshop on the Use of Scenarios in the Sixth Assessment Report and Subsequent Assessments* [Masson-Delmotte, V., H.-O. Pörtner, D.C. Roberts, P.R. Shukla, J. Skea, P. Zhai, W. Cheung, J. Fuglestvedt, A. Garg, B. O'Neill, J. Pereira, J. Portugal Pereira, K. Riahi, A. Sörensson, C. Tebaldi, E. Totin, D. van Vuuren, Z. Zommers, A. Al Khourdajie, S.L. Connors, R. Fradera, C. Ludden, D. McCollum, K. Mintenbeck, M. Pathak, A. Pirani, E.S. Poloczanska, S. Some and M. Tignor (eds.)]. Working Group III Technical Support Unit, Imperial College London, United Kingdom, 67 pp.

Preface

Scenarios provide plausible descriptions of how the future may develop. Based on a coherent and internally consistent set of assumptions about key driving forces (e.g., rate of technological change, prices) and relationships, they are neither predictions nor forecasts, but are used to provide a view of the implications of developments and actions. As a vital part of the scientific literature on climate change, they are an important consideration in the work of the Intergovernmental Panel on Climate Change (IPCC) and provided a key integrative mechanism for linking the assessments of Working Groups I, II and III during IPCC's Sixth Assessment cycle.

The IPCC, at its 54th(bis) Session in December 2021, considered a cross-Working Group proposal for an Expert Meeting on the Use of Scenarios in the Sixth Assessment Report and Subsequent Assessments to advance the scientific agenda associated with scenario development and use with attention to overall scenario architecture; to consider ways of further enhancing cross-Working Group collaboration; and to consider institutional aspects, including the relationship between IPCC and relevant IPCC bodies and resourcing issues. The Panel endorsed the proposal but elevated the status of the Expert Meeting to that of an IPCC Workshop with the consequence that participants were nominated by Governments and Observer Organisations.

The Workshop, held from 25 to 27 April 2023 in Bangkok, Thailand, brought together 94 experts from 47 countries. It provided an opportunity for modellers and scenarios builders, scientists from a range of disciplines, and scenarios users in governments and other stakeholder groups to jointly reflect on the contribution of scenarios to the AR6, identify gaps, consider innovations, reflect on how to further develop cross-Working Group collaboration on the use of scenarios, and consider how the diversity of contributors to the scenario-building process could be improved.

This report provides a summary of the preparation and planning for the Workshop, the discussions held over the course of the three-days, and the outcomes and recommendations arising from the meeting. Annexes provide further detail on the development of the workshop, the participant selection process, and includes copies of the agenda and participant list.

We would like to thank all participants for their constructive inputs and fruitful discussions. The continued dialogue between the scientific, policymaking and stakeholder communities is crucial for furthering the development and use of scenarios. The Workshop provided further clarity on a range of issues and yielded key recommendations for five audiences: the scientific communities involved in modelling, the scientific communities not involved in modelling, research funders, the IPCC, and those communicating scenarios.

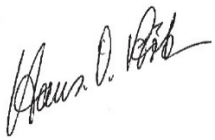
We very much appreciate the guidance of the members of the Scientific Steering Committee, which has supported the design, convening of and reporting on the Workshop. We thank them for their work in the preparation of the agenda and other meeting materials, for assisting the IPCC Working Group Bureaux with the selection of participants, and for their efforts in carrying out the Workshop.

We would further like to thank the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) and the Government of Thailand for their support and hospitality. The financial support of the IPCC Trust Fund and the logistical assistance of the IPCC Secretariat is also gratefully acknowledged. The excellent and efficient work of the Technical Support Units at all stages of the Workshop organisation and in the production of this report is very much appreciated.

This was an important meeting that has led to the identification of a number of knowledge gaps, challenges and opportunities to improve the development, use and communication of scenarios. We are convinced that the outcomes of this meeting will serve as a useful input to furthering the development and use of scenarios, informing subsequent assessments, and supporting the science-policy interface.

Valérie Masson-Delmotte
IPCC Working Group I Co-Chair

Panmao Zhai
IPCC Working Group I Co-Chair



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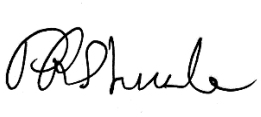

P. R. Shukla
IPCC Working Group III Co-Chair

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Summary and Recommendations

Overview of the workshop

The Intergovernmental Panel on Climate Change (IPCC) Workshop on the Use of Scenarios in the Sixth Assessment Report (AR6)[1] and Subsequent Assessments was agreed by the IPCC at its Fifty-Fourth (bis) Session, held from 14 to 16 December 2021. The purpose of the Workshop was to address ongoing challenges associated with scenarios both from a scientific perspective and with regard to the institutional processes linking the relevant scientific communities to the IPCC assessment. The Workshop had three main objectives: 1) to advance the scientific agenda associated with scenario development and use with attention to overall scenario architecture; 2) to consider ways of further enhancing cross-Working Group (WG) collaboration; and 3) to consider institutional aspects, including the relationship between IPCC and relevant IPCC bodies such as World Climate Research Program (WCRP) and Integrated Assessment Modelling Consortium (IAMC), and resourcing issues.

To facilitate the Workshop's objective, the following goals were:

- To take stock of the contribution of scenarios to the AR6 products, and the strengths and weaknesses of the approaches adopted;
- To identify gaps in the AR6 scenario approach, taking account of the needs and expectations of government and other users;
- To consider how best to build on the Representative Concentration Pathway (RCP)/Shared Socio-economic Pathway (SSP) framework adopted in AR6 and possible scenario architectures for AR7 and beyond;
- To consider innovations in the scenario approach which could be pursued in concert with the relative research communities, for instance related to biodiversity;
- To consider how to further develop cross-WG collaboration on the use of scenarios;
- To address any improvements in the institutional mechanisms for developing, applying and curating scenario data and the respective roles of IPCC and the modelling communities. The role of the IPCC Task Group on Data Support for Climate Change Assessments (TG-Data) is relevant in this respect; and
- To consider how the diversity of contributors to scenario-building processes could be improved.

The Panel agreed that the Workshop would engage modellers and scenario builders from the WG I, WG II and WG III domains, as well as scientists from a range of disciplines and scenario users in governments and other stakeholder groups. Relevant communities would include:

- Modellers and scenario builders with expertise in the physical science, natural and socio-economic aspects;
- Experts on the physical science of climate change;
- Domain experts in adaptation and mitigation;
- Experts in biodiversity and ecosystem services;
- Scientists with relevant cross-cutting socio-economic perspectives, for example, economists, and other social scientists;
- Representatives of IPCC member governments; and
- Stakeholders from the relevant United Nations Framework Convention on Climate Change (UNFCCC) constituencies, such as business and industry non-governmental organisations (NGOs), environmental NGOs, local government and municipal authorities.

[1] See Annex V for a list of all acronyms.

Participants for the Workshop were nominated by IPCC member Government Focal Points and Observer Organisations, with additional nominees from the three WG and Task Force Bureaux. A Scientific Steering Committee (SSC) was appointed to support the design, convening of, and reporting on the IPCC Workshop and advise the WG Bureaux on the selection of participants. Selection was based on the criteria defined by the IPCC: (i) representation of a wide range of scientific, technical and socio-economic views and expertise; (ii) geographical representation; (iii) gender balance; and (iv) a mixture of experts with and without previous experience in IPCC.

387 experts from 88 countries were nominated for participation (168 (43%) nominees from developing countries or economies in transition, 219 (57%) from developed countries; 113 (30%) female nominees, 260 (70%) male nominees); 124 participants were invited from 60 countries (62 (50%) participants from developing countries or economies in transition, 62 (50%) participants from developed countries; 42 (34%) female participants and 82 (66%) male participants); where participants declined to attend, further invitations that sought balance against the stated criteria were issued[2]; and the final attendance of the workshop was 94 participants from 47 countries (42 (45%) participants from developing countries or economies in transition, 52 (55%) participants from developed countries; 35 (37%) female participants and 59 (63%) male participants).

To prepare participants for the Workshop, the SSC (i) prepared a background document to provide an overview of key concepts and terms associated with scenarios and an overview of frameworks for their development, and (ii) convened online webinars summarising the use of scenarios across the AR6 with an opportunity for participants to ask clarificatory questions.

The Workshop was held in Bangkok, Thailand, from 25 to 27 April 2023. It followed a thematic structure, where exchanges from each day fed into the next:

- Day One: looked backwards on the use of scenarios in AR6 to derive lessons learned and best practices;
- Day Two: focused on challenges identified; and
- Day Three: moved towards identifying recommendations to address these challenges, along with the enabling conditions to achieve change.

The format for the workshop was based around plenary sessions, where all Workshop participants met together, and Breakout Groups (BOGs) on specific themes and topics. Sufficient flexibility was left in the agenda to allow topics to be addressed based on issues arising from discussions during the Workshop.

The Workshop resulted in a series of suggestions, recommendations and discussion topics directed at five audiences: (i) scientific communities involved in modelling, (ii) scientific communities not involved in modelling, (iii) research funders, (iv) the IPCC, and (v) the communication of scenarios.

Suggestions and discussion topics for the consideration by scientific communities involved in modelling

The BOG did not have sufficient time to arrive at a set of high-level recommendations. Various topics were discussed during this breakout group (BOG). Below is a list of key topics that arose from the discussion. The detailed topics under each theme are summarised in Section 4.1.

- *On updating and improving community scenario frameworks*
  Different views were expressed on the continued use, updating and improvement of scenario frameworks and the choice of policy-relevant scenarios and possible future climate outcomes (high warming, Paris

[2] 136 participants were invited in total, including first, second and third round invitations.

Agreement-compatible), intersections with climate, for example, biodiversity, SDGs. There was agreement on strengthening transparency and inclusivity in the scenario development and prioritisation process, and widening the scope of scenario narratives and drivers.

- *On strengthening research activities and model intercomparison projects (MIPs)*
  Broadening the range of scenarios in the mitigation community, which would be achieved through the use of the complete set of existing Shared Socio-economic Pathways (SSPs) or an extension of the existing set, and their use in MIPs, with inclusive processes to enhance policy-relevance, participation and buy-in, and addressing processes and feedbacks in Earth system models, integrated assessment models, including emulators alongside complex models.

- *On enhancing regional and temporal resolution*
  Improving regional and near-term temporal resolution, with more focus on regional and sub-regional, also city-scale studies, including ecosystem aspects, as well as undertaking multi-scale studies, supporting regional climate modelling and downscaling activities, including with stability in CMIP cycles.

- *On increasing participation and inclusivity of the scientific modelling communities*
  Increasing diversity in the research community and modelling centres, building capacity, increasing participation (including of the social sciences) and mobilising funds to implement these efforts.

- *On broadening the assessment of scenarios and modelling approaches*
  Going beyond climate to also include impacts and biodiversity, the assessment of scenarios beyond the use of standard statistical metrics to characterise scenarios falling within specific categories, and classification of scenarios that also includes non-climate outcomes such as energy demand.

- *On strengthening links to impacts, adaptation and vulnerability (IAV) communities*
  Integrating scenarios of vulnerability and exposure into impact pathways within existing scenarios frameworks, generation of impact/adaptation pathways, better treatment of irreversible impacts, ecosystem shocks, and tipping points into scenarios, and reflect biophysical constraints, exploring how policy actions may affect impacts and risks, and the implications of climate change impacts on different groups for equity and alleviation of poverty.

- *On exploring scenarios of exceedance and return (overshoot) of levels of global warming*
  Considering overshoot scenarios, particularly the detection and assessment of impacts, including post-2100 scenarios, the reversibility of climate and impacts, mitigation consequences, and a broader assessment of carbon dioxide removal (CDR) options.

- *On further development of a community scenarios database*
  Potential improvements to the Scenarios Database hosted by the International Institute for Applied Systems Analysis (IIASA), 'live' and continuously updated open access to both vetted and unvetted scenarios, widening the range of scenarios and variables.

Recommendations for scientific communities not involved in modelling

- Encourage plurality of scenario development approaches for mitigation and adaptation, including both modelled and non-modelled.
- Develop methods, information, and data for scenario assessment and classification of local-level (bottom-up and non-modelling) scenarios to gain complementary insights to quantified scenarios.

- Promote more diverse representation and inclusion in scenario, climate modelling and Impacts, Adaptation, and Vulnerability (IAV) development and use.
- Help scenario efforts with developing a richer and more diverse set of narratives and drivers.
- Data baselines production to complement literature gaps in sectors, regions and local level.

Recommendations for research funders

- *Participation/Representation:* Increase the richness and the diversity of expertise in models and scenarios by engaging a wider variety of researchers/stakeholders from around the world throughout the research cycle (conceptualisation, implementation, dissemination).
- *Capacity:* Direct funding to engage communities not currently/effectively represented in scenario processes.
- *Infrastructure:* Increasing funding for data curation, including establishing, maintaining, expanding, updating scenario-relevant databases and supporting tools.
- *Science of scenario assessment:* There is a need for targeted funding on the science and methodologies of assessing scenarios: for example, not simply treating scenario sets as statistical distributions, and combining qualitative and quantitative scenarios.

Recommendations for the IPCC

- *Provide and ensure early planning and guidance.* Planning should start early for coordination across WGs including processes for coordination and fostering the interaction of Integrated Assessment Models (IAMs) and sectoral modellers and other knowledge communities. Recommendations included the production of guidance documents on processes and lessons learned from AR6 such as methodological guidance on assessing and reviewing scenarios, providing ways of establishing a clear connection among scenarios and other lines of evidence, and linkages between sectors and practitioners and the inclusion of variables or elements such as equity and fairness in scenarios.
- *Formulate ways to institutionalise coordination*. Formalising bridging roles for Bureau members, with strong support from the Technical Support Unit (TSU), would facilitate the process. More formalised processes for, for example, Bridging Authors could be initiated to support coordination mechanisms.
- *Embed coordination in each step of the process*, starting early to ensure the inclusion of the necessary expertise regarding scenarios during scoping and in the author teams, for example, scenarios modellers, social sciences and humanities and practitioners (with humanitarian and business sector representations), and processes such as webinars with focal points and across WGs, internal reviews across WGs, and cross-WG papers. Broader engagement, for example, with multiple disciplines, in vetting processes for scenarios and collaboration between the WGs and TFI inventory work would advance coordination.

Recommendations for the communication of scenarios

- Conduct a targeted survey on perception and use of scenarios from the AR6 cycle.
- Develop and provide accessible IPCC explainers on scenarios.
- Develop a guidance note on inclusive, co-developed scenario elaboration.
- Build and cultivate a network of trusted intermediaries to communicate scenarios.
- Strengthen institutionalised science communication experts throughout the IPCC process.

1. Introduction

Background

Two Intergovernmental Panel on Climate Change (IPCC) Expert Meetings on scenarios were previously held at the end of the Fifth and beginning of the Sixth Assessment cycle: the cross-Working Group (WG) Expert Meeting on Scenarios[3], hosted by the International Institute for Applied Systems Analysis (IIASA) in Laxenburg, Austria in 2015, and the WG III IPCC Expert Meeting on Mitigation, Sustainability and Climate Stabilisation Scenarios[4], held in Addis Ababa, Ethiopia in 2017.

The 2015 recommendations for IPCC included: improving the integration of knowledge across the WGs in the Sixth Assessment Report (AR6); increasing participation of developing country representatives in scenario development as well as scenario-related capacity building activities; and pursuing synergies with other organisations and assessment bodies interested in scenario analysis. Recommendations for the research community included: fostering further bi-directional integration in scenario applications; improving the understanding of the propagation of uncertainties across the whole process chain in climate change research; and the development of a scenarios assessment report. Process-related recommendations for the research community included: identifying and communicating key research questions/gaps; developing a transparent timeline for further development and application of the scenario framework; ensuring continued flexibility and openness of the scenario process; the development of a best practices guidance note for users of scenarios; and developing a communication strategy.

The 2017 recommendations for IPCC included: strengthening cross-WG collaboration on scenarios; considering carefully how to use the Shared Socio-economic Pathways (SSPs); and establishing a clearer distinction between 'assessment' and 'research'. Recommendations for the research community included: establishing a scenario database that included relevant scenarios from a variety of sources; enhancing transparency by being more explicit about assumptions, trade-offs, and uncertainties; and broadening the range of people (including social scientists, businesses and other stakeholders) involved in the design of storylines that feed into scenarios.

Purpose and preparation for the Workshop

The Workshop on the Use of Scenarios in the Sixth Assessment Report and Subsequent Assessments aimed to address ongoing challenges associated with scenarios both from a scientific perspective and with regard to the institutional processes linking the relevant scientific communities to the IPCC assessment. These challenges included:

- timeliness, given the time needed for scenarios development and publication by the scientific community, and their subsequent assessment by IPCC;
- innovation in the use of scenarios as part of the IPCC process, transparency and the boundary between research activities and the assessment process;
- ongoing scientific challenges associated with linking the approaches to quantify uncertainties when addressing physical aspects of the Earth system with different approaches needed to address uncertainties about socio-economic developments; and
- challenges in the IPCC timeline and process for implementing a coordinated and consistent assessment of possible futures across the WGs.

[3] https://www.ipcc.ch/site/assets/uploads/2018/05/EMR_Scenarios-1.pdf
[4] https://www.ipcc.ch/site/assets/uploads/2018/02/IPCC_2017_EMR_Scenarios.pdf

At the Fifty-Fourth (bis) Session of the IPCC (IPCC-54(bis))[5], held from 14 to 16 December 2021, the Panel considered a proposal from the Co-Chairs of WGs I, II and III for an Expert Meeting on the Use of Scenarios in AR6 and Subsequent Assessments. However, recognising the importance of the topic, the IPCC decided to elevate the activity to that of an IPCC Workshop. While Expert Meetings focus on a theme by bringing together a limited number of experts, IPCC Workshops consider cross-cutting and complex topics requiring input from a broad community of experts and include participant nominations from IPCC member Governments and Observer Organisations. To this end, the Workshop sought to bring together experts from diverse domains, including modellers, scenario builders, and users from WGs I, II, and III scientific domains, as well as disciplinary experts with cross-cutting expertise, and scenario users from governments and other stakeholder groups. Relevant communities would include:

- Modellers and scenario builders with expertise in the physical science, natural and socioeconomic aspects;
- Experts on the physical science of climate change;
- Domain experts in adaptation and mitigation;
- Experts in biodiversity and ecosystem services;
- Scientists with relevant cross-cutting socio-economic perspectives, for example, economists, social scientists;
- Representatives of IPCC member governments; and
- Stakeholders from the relevant United Nations Framework Convention on Climate Change (UNFCCC) constituencies, such as business and industry non-governmental organisations (NGOs), environmental NGOs, local government and municipal authorities.

Participants were nominated by IPCC member Government Focal Points and Observer Organisations. The three WG and Task Force Bureaux also nominated participants. A Scientific Steering Committee (SSC) was appointed to support the design, convening of, and reporting on the IPCC Workshop and advise the WG Bureaux on the selection of participants in the Workshop (Annex 1: Workshop Development Process, including SSC Membership).

The selection of the participants followed an iterative process, with participants selected against the criteria of: (i) representation of a wide range of scientific, technical and socio-economic views and expertise; (ii) geographical representation; (iii) gender balance; and (iv) a mixture of experts with and without previous experience in IPCC.

The call for nominations was issued to IPCC member Governments Focal Points and Observer Organisations on 27 September 2022. A total of 387 experts from 88 countries were nominated for participation (168 (43%) nominees from developing countries or economies in transition, 219 (57%) from developed countries; 113 (30%) female nominees, 260 (70%) male nominees)[6]. The SSC met on 6 December 2022 and reviewed the nominations, seeking to ensure that those to be invited to the Workshop held relevant expertise, either as those involved in the creation of scenarios or as scenario end users. The SSC presented to the Working Group Bureaux a first selection of invitees and reserves that provided broad geographical representation, gender balance, and equal participation from developing and developed countries. The Working Group Bureaux reviewed the recommendations, made suggestions for amendments and additions, and requested that the WG III Technical Support Unit (TSU) issue invitations, which were sent on 10 January 2023. This comprised 124 participants invited from 60 countries (62 (50%) developing countries or economies in transition, 62 (50%) developed countries; 42 (34%) female and 82 (66%) male). The SSC and Working Group Bureaux sent second- and third-round invitations, based on those invited who declined to attend. The workshop consisted of 94 participants from 47 countries (42 (45%) developing

[5] https://www.ipcc.ch/site/assets/uploads/2022/03/FINAL-REPT-P-54Bis.pdf
[6] Fourteen nominees did not state their gender.

countries or economies in transition, 52 (55%) developed countries; 35 (37%) female and 59 (63%) male). Annex 3: Participant Selection provides additional detail on the nominations and selection of participants.

In parallel, the Scientific Steering Committee prepared background material, which was shared with participants one week prior to the meeting. Two webinars were also organised to set the scene and provide participants with a common knowledge base on scenarios. These webinars, identical in content, were held one week before the start of the Workshop on 18–19 April and scheduled to accommodate time zones across both hemispheres. Fifty participants joined the first session, seventy took part in the second session.

Structure and outputs of the Workshop

Over the months leading up to the Workshop, the SSC developed a programme for the Workshop. The three-day Workshop followed a thematic structure, with exchanges from each day feeding into the next:

- Day 1 looked backwards, reviewing the Sixth Assessment Report (AR6) to derive lessons learned and best practices.
- Day 2 focused on lasting challenges.
- Day 3 supported the identification of recommendations to address these challenges, alongside enabling conditions to implement change.

The structure of the Workshop (Figure 1) was based around plenary sessions, where all Workshop participants met together, and Breakout Groups (BOGs) on specific themes and topics. This approach was designed so as to allow participants to spend the maximum amount of time taking part in the focused, detailed discussions enabled by BOG discussions, with shorter plenaries dedicated to report-backs and group discussions. Participants were allocated to BOGs for the first BOG session, but thereafter participants self-selected which BOG they would attend. While the topics of the BOGs for Day 1 were selected upfront by the SSC, for Day 2, which focused on the theme of challenges, room was left for manoeuvre so that discussions on Day 1 could identify topics that should be addressed (Table 1). The SSC met at the end of each day to refine the agenda, discuss arising issues, and plan for the next day.

The SSC designed the agenda (Annex 2: Workshop Agenda) around five different BOG sessions, with each session including multiple breakout groups.

- On Day 1, session BOG.1 focused on what worked and what could have worked better in terms of the science during the AR6.
- Later that day, session BOG.2 addressed what worked and what could have worked better in terms of scenario design and process.
- On Day 2, session BOG.3 focused on key scenario challenges.
- Later that day, session BOG.4 comprised shorter breakout groups of one-hour duration, providing opportunity for deep-dive discussions on focused topics either identified by the SSC or proposed by Workshop participants.
- Finally, on Day 3, session BOG.5 focused exclusively on recommendations.

A final, longer plenary on Day 3 presented the initial BOG conclusions, recommendations, and topics for discussion with all Workshop participants.

In terms of outputs, the Workshop led to the identification of knowledge gaps, challenges and opportunities to improve the use and communication of Scenarios by the IPCC and its ecosystem. The provisional recommendations and conclusions of the Workshop were presented at an IPCC Side Event during the UNFCCC's Subsidiary Body for Scientific and Technological Advice (SBSTA) in June 2023. The Workshop report has been

made available for consideration prior to the 59th Session of the IPCC in July 2023, as well as for other relevant upcoming meetings, such as the Integrated Assessment Modelling Consortium (IAMC), the International Committee on New Integrated Climate Change Assessment Scenarios (ICONICS), and the Coupled Model Intercomparison Project Phase 7 (CMIP7).

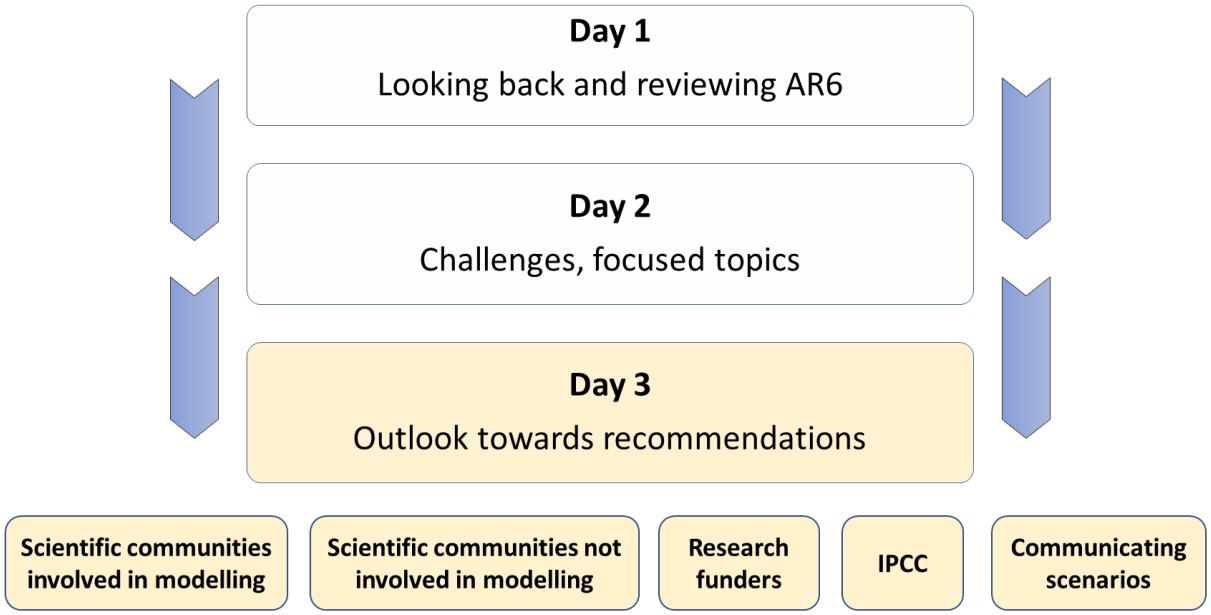


Figure 1: Structure of the Workshop

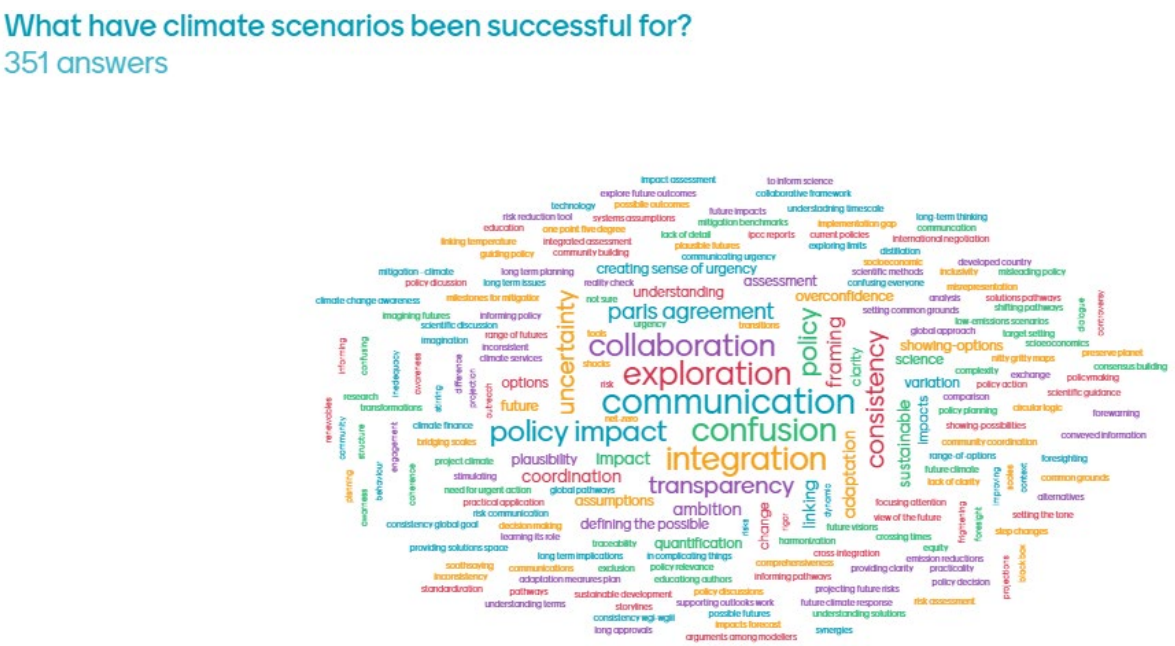
Table 1: List of Breakout Group topics held on Days 1 and 2. Day 3 Breakout Group topics were based on the five audiences shown in Figure 1.

Day 1: What worked and what could have worked better	Day 2: Challenges
1.1: Earth systems modelling, emulators and mitigation scenario categorisation **1.2:** Climate drivers, hazards, risks and risk reduction **1.3:** Socio-economic context. Mitigation/ adaptation pathways and climate action	**3.1:** Scenario architecture: designing scenario sets. **3.2:** Likelihood and other approaches to uncertainty **3.3:** Scale (time and space) **3.4:** Justice and equity in scenarios **3.5:** Communication of scenarios to users
2.1: Scenario data and curation **2.2:** Scenario architecture: the design of scenario sets **2.3:** Coordination and collaboration across scientific domains **2.4**: Integration of scenario use across and within IPCC working groups	**4.1:** Hard adaptation limits for species, ecosystems and human societies **4.2:** Multi-level scenarios (Including sub-national and cities) **4.3:** Overshoot **4.4:** Plausibility and feasibility **4.5:** Scaling up near-term actions **4.6:** Adaptation pathways

2. Summary of Plenary Discussions and Breakout Groups on Day 1: Review of AR6

This first day of the Workshop focused on a retrospective of the Sixth Assessment Cycle (AR6): what worked and what could have worked better in terms of scenario design, integration, and process. The initial plenary session in Day 1 comprised talks on how scenarios are used in policymaking, and the role of scenarios and other types of evidence in the IPCC, as well as an introduction to the workshop itself. Two word clouds were generated (Figure 2) from participant responses to the questions: "What have climate scenarios been successful for?" and "What are the key challenges associated with using climate scenarios to inform decision making?" Some topics appear as responses in both figures, for example, communication, indicating that although progress has been made, challenges still remain.

The backward-looking review of AR6 on Day 1 included seven Breakout Groups that spanned across Working Groups (WGs). The first three breakout groups on Day 1 focused on interactions across specific WGs: Earth systems modelling, emulators and mitigation scenario categorisation focused on interactions between WG I and WG III, Climate drivers, hazards, risks and risk reduction focused on interactions between WG I and WG II, and Socio-economic context. Mitigation/adaptation pathways and climate action focused on interactions between WG II and WG III. All sessions on Day 1 established the basis for the sessions discussing challenges and recommendations on Days 2 and 3, respectively.



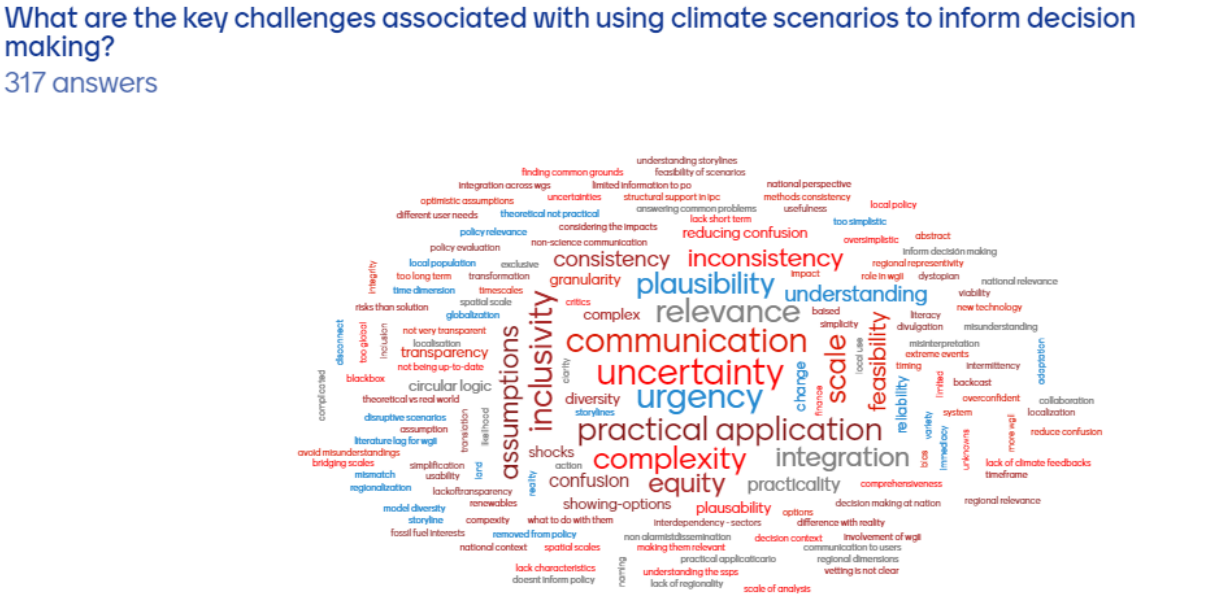


Figure 2: Word clouds generated from participants of the Day 1 plenary focused on reviewing scenarios used in the IPCC AR6 cycle.

2.1. Earth Systems Modelling, Emulators and Mitigation Scenario Categorisation

Breakout Group 1.1 Chairs: Ole-Kristian Kvissel and Anna Pirani
Breakout Group 1.1 Rapporteur: Sophie Szopa
TSU Science Support: Sarah Connors

This Breakout Group (BOG) focused on retrospectively looking at how well the scenarios in Earth System Models (ESMs) and emulators were used to understand climate change responses and to categorise mitigation scenarios, including reflecting likelihood and uncertainty. This BOG focused primarily on the connections between Working Group (WG) I and WG III.

The first half of the BOG focused on the role of emulators. The groups reflected that there was a strengthened use of emulators in AR6, notably in WG I, compared to previous assessments, for example, in constraining the assessment of global surface air temperature and sea level rise, and combining modelling and observational evidence. Use of regional emulators should have been strengthened more, in particular for the effect of land use change considerations. Future considerations for the IPCC included the need to strengthen timelines and to reinforce WG I-WG III cooperation, but the group cautioned that emulators should only be used to interpolate within the range of studied scenarios and not to extrapolate.

Future considerations for the research community included the need:

- For more diverse emulators, for example, that can incorporate pressure on ecosystems.
- To include responses on short-term and at regional scales.
- To keep working on ESMs to address process and feedback uncertainties and regional responses.
- To better convey uncertainties in the scenario design and ESM-emulator chain.
- To strengthen links between communities: ESMs <-> emulators <-> Integrated Assessment Models (IAMs).

- To provide more variables from ESM to the impact community based on the most realistic scenarios and on the near-term.
- To better disseminate information on scenarios (e.g., through an atlas allowing to navigate in the assumption), their use and limitations.

The second half of the BOG focused on the labelling, choice, and plausibility of scenarios in AR6. Positive reflections from WG I participants in the BOG included the focus on SSP3-7.0 (e.g., Chapter 4, WG I AR6) and not over focussing on SSP5-8.5, after communication received from the WG III community during the process on high-end emission scenarios, such as RCP8.5 and SSP5-8.5, becoming less likely with climate policy and technology change. WG I AR6 also included a wider range of air pollution control hypotheses. Caution was noted about the dismissal of high-end emissions scenarios since such concentration and warming levels may still be reached with the inclusion of strong carbon or climate feedbacks, and including these scenarios in the assessment can provide information on 'worlds avoided', and they inform on carbon cycle responses/feedbacks and other poorly constrained processes. Low-end emissions scenarios allow to document missed opportunities and/or ecosystems' recovery after peak and decline. Communication across the WG I/WG III assessments are needed to appropriately use these scenarios for a consistent assessment.

It was discussed that the SSP labelling of scenarios (SSPx-y) in the WG I AR6 can be confusing when focusing on the radiative outcome ('y' in the SSPx-y label, or RCP), but is necessary for characterising air pollution and land use change. Future considerations for the IPCC regarding scenario labelling for clearer communication should consider the use of labels that indicate clearly the purpose of the scenario, rather than confusing the use of the scenario with the plausibility of the socio-economic outcomes. Future scenario design and labelling would benefit from including end-users. Identifying policy-relevant questions (if done early enough in the process) could help with selecting some of the core scenarios of the Coupled Model Intercomparison Project (CMIP). Scenarios need to be better linked with some specific communities, for example, communities working on impact assessments of ecosystems, the side-effects of large deployment of different technologies, abrupt changes (e.g., volcanic events) and the representation of urbanisation. Overshoot was identified as a topic for further assessment including the consideration of different characteristics, including scale of the overshoot, and duration.

2.2. Climate Drivers, Hazards, Risks and Risk Reduction

Breakout Group 1.2 Chairs: Hans-Otto Pörtner and Elvira Poloczanska
Breakout Group 1.2 Rapporteur: Alexander Ruane
Flash Talk: Matthias Garschagen
TSU Science Support: Katja Mintenbeck, Shreya Some

This Breakout Group (BOG) focused on the challenges of using climate scenarios to systematically assess climate drivers, hazards and risks; the ways in which climate scenarios inform risk assessment including risk reduction and adaptation strategies; and the major barriers and successes in integrating cross-Working Groups (WGs) methodologies for risk and adaptation assessment across sectors. To inform and initiate the discussion, a flash talk was given by Matthias Garschagen on reflections from the IPCC Synthesis Report (SYR) and new developments.

Participants highlighted the need for a bottom-up development of scenarios. To improve understanding and usefulness for policymakers, transparent and inclusive approaches for scenario generation are needed based on process understanding; particularly as there is growing interest in regional and sectoral scenarios. Another overarching point was on the risk assessment and the importance (and current gap) to consider that risks are not differentiated only by regions but are particularly connected to distributional aspects within society (gender,

ethnicities, wealth/income, etc.) and across generations. The need for an increased focus on adaptation scenarios and smaller-scale scenarios (regional, local, city level, etc.) was also emphasised in the discussions.

In the more detailed discussion of major gaps and challenges in the IPCC Sixth Assessment Report (AR6), five key issues were identified in this BOG:

- Scenarios struggle with disequilibrium responses related to speed of change, low-likelihood, high-impact events/shocks and recovery, representation of stability and instability (e.g., consistency of agricultural production; patterns of flood/drought), and lag of some climatic impact drivers changes, particularly in the cryosphere and oceans. Concerns over use of averaged climate projections smoothing out some regional patterns and extreme events were raised.
- Scenarios do not represent changes in pathway trajectories well, such as future shifts from one pathway to another, tipping points (physical, biological systems, social systems), overshoot and irreversible scenario elements, shocks and recovery, and emissions vs greenhouse gases (GHGs) vs sea level rise vs adaptation, and so on. Concerns were raised over systems effects, i.e., abrupt turns in one perspective may make more sense when viewed from a larger perspective.
- The different WG timelines and lags in literature in uptake of scenarios was a challenge and resulted in different scenarios used in the assessments (e.g., WG II used more CMIP5/RCPs vs WG I CMIP6/SSP-RCP; CMIP: Coupled Model Intercomparison Project; RCP: Representative Concentration Pathway; SSP: Shared Socio-economic Pathway), which makes the integration of outcomes across Working Groups more difficult.
- Scenario element sensitivities were discussed. Sometimes it is difficult to disentangle complex scenarios. The Integrated Assessment Modelling Consortium (IAMC), Coupled Model Intercomparison Project (CMIP), Agricultural Model Intercomparison and Improvement Project (AgMIP) and others are doing scenario sensitivity analyses for fundamental understanding. Although there is no need for the IPCC to reproduce this, identifying clear policy-relevant questions and entry points for key findings are clearly needed.
- Challenges of synthesising areas without a clear framework were also highlighted. Each WG had its own portfolio of scenarios used. With changing climate and socio-economic/geopolitical drivers, vulnerability and exposure will also change, which needs to be considered in the WG II risk assessment. There are also different types and degrees of adaptation, usually referred to as 'high' vs 'low' adaptation (used as metrics), but these terms may not be used consistently. Some of the assessments were 'capped' - for example, the adaptation feasibility assessment was done for 1.5°C only. It was also a challenge to connect RCP scenarios with climate resilient development pathways (CRDPs) – as the first are quantitative while the second are qualitative; so CRDPs require more information than is currently provided. Improved process understanding is needed to connect climate, crop and biodiversity scenarios, to meet the requirement of addressing climate change and biodiversity loss together.

The question on how to include the optimistic side of climate feedbacks, or benefits, was also raised in the discussion.

2.3. Socio-Economic Context. Mitigation/Adaptation Pathways and Climate Action

Breakout Group 1.3 Chairs: Malak Al-Nory and Diana Ürge-Vorsatz
Breakout Group 1.3 Rapporteur: Şiir Kilkiş
Flash Talk: Malte Meinshausen
TSU Science Support: Alaa Al Khourdajie, Chloé Ludden

This Breakout Group (BOG) focused on socio-economic context included and not included in scenarios. Discussions were orientated around the following prompts: what are the underlying reasons behind the focus on Shared Socio-economic Pathway 2 (SSP2) in recent literature; how representative are mitigation and adaptation pathways compared to current socio-economic contexts and developments; and what have been the key contributions and shortcomings of mitigation and adaptation pathways to guide climate action?

Participants questioned the focus on SSP2 in the scientific community, raised equity issues, and the absence of scenarios considering limited growth. The group agreed on the need to not limit future scenarios to predefined storylines and called for the consideration of more creative and transformational scenarios in the Seventh Assessment Cycle (AR7). Criticisms of scenarios included their inability to capture flexibility, renewable penetration, system costs, reliance on least cost calculations, and exclusion of path dependencies. Suggested ways forward included integrating practical information about future risks and policy options in scenarios, better reflecting the speed of action as a function of resources and institutions, expanding the set of variables to better inform policymakers, clearly distinguishing between models, scenarios, and the IPCC assessment process, encouraging research efforts in the science of categorising scenarios beyond the Shared SSPs and Representative Concentration Pathways (RCPs), designing scenarios that reflect international commitments, and finally diversifying the researcher base to increase the richness and diversity of world views underpinning scenarios.

Discussions touched on some lessons learned and possible recommendations that were contained in the report back to plenary including:

- Improve the representation of mitigation and adaptation pathways in current socio-economic contexts and developments.
- Consider the rapid implementation and economic effectiveness of renewable energy in scenarios.
- Explore metrics beyond gross domestic product (GDP) for assessing progress and encourage creativity in scenario development.
- Expand the breadth and depth of development pathways, including additional dimensions such as equity and justice.
- Include elements in scenarios that can guide investment and trade decisions.
- Increase the variety of scenarios beyond SSP2 to widen the possible representation of developments.
- Improve transparency in scenario assumptions, acknowledging the complexity involved.
- Develop scenarios that meet multiple challenges, including international conventions.
- Advance the science of scenarios categorisation to reflect distinct characteristics of interest to policymakers.

The following plenary discussion reflected on the need for transparency in scenarios, with a focus on the level of transparency that should be provided from the users' perspective. The separation between models and scenarios was discussed, with an emphasis on clearly understanding and communicating the range of outcomes that can be provided by existing models. There was a call for scenarios to bridge the gap and increase the match between the visions and narratives of the scenarios and the ambitions and expectations of stakeholders.

2.4. Scenario Data and Curation

Breakout Group 2.1 Co-chairs: Ben Sanderson and Alaa Al Khourdajie
Breakout Group 2.1 Rapporteur: Ben Sanderson
Flash Talks: Ed Byers, Ben Sanderson
TSU Science Support: Sarah Connors

This Breakout Group (BOG) focused on the success and challenges primarily of the Working Group (WG) III scenario database. Introductory talks were given on the curation process and what type of data were stored in the scenario database, and on the CMIP6 (CMIP: Coupled Model Intercomparison Project) scenario data distribution process that is used in WG I.

One success of the scenario database was that, in an effort to move towards Findable, Accessible, Interoperable, and Reusable (FAIR) data principles, for the first time, Integrated Assessment Model (IAM) scenarios and some national-level scenarios were made openly available after the publication of the AR6 Special Reports and WG III Report. Several challenges were identified with the structure and process of creating the scenario database including: vetting, categorisation, infilling and harmonisation was cumbersome and time consuming for all stakeholders involved; identifying biases and synthesis was too difficult due to lack of person power; the database scenarios were unable to provide relevant data for some WG III chapters (e.g., in Chapter 5) in part due to the barriers to submission; there is a disparity between IAM historical emissions accounting and national greenhouse gas (GHG) inventories under the United Nations Framework Convention on Climate Change (UNFCCC) process; and the database is not currently open during the process due to intellectual property fears. It was also noted that there was a lack of sufficient crediting for early career researchers contributing to the processes of setting up and pre-processing the database (including the climate-emulators workstream across with WG I), and post-processing the data to make it usable by relevant chapter. A lack of standardised experimental design and ad hoc contributions in the WG III database creates a mix of idealised and operational scenarios, and an uneven contribution from different models and centres. Vetting, harmonisation and infilling were considered to be in need of better uncertainty quantification and alternative methodologies.

Some topics were discussed to feed into the recommendations BOG on Day 3. These included: the need for a less manual process for inputting scenarios to the database; allowing for a greater diversity of scenarios (e.g., more national level scenarios) to be eligible for submission – need more discussions with the relevant science communities; funding to support infrastructure development; greater focus on uncertainties especially with respect to, and compatibility with, the UNFCCC emissions framework; and learning more from the CMIP process, which is more open-access and established, despite issues around CMIP6 being considered too large for the timeframe established.

2.5. Scenario Architecture: the Design of Scenario Sets

Breakout Group 2.2 Chairs: Zinta Zommers and Amjad Abdulla
Breakout Group 2.2 Rapporteur: Saritha Sudharmma Vishwanathan
Flash Talk: Brian O'Neill
TSU Science Support: Elvira Poloczanska

This Breakout Group (BOG) considered use of the Representative Concentration Pathways / Shared Socioeconomic Pathways (RCP/SSP) framework and was structured around three guiding questions: what were the challenges behind the systematic adoption of existing scenario architecture across all modelling communities; how does the current design of scenario sets address complexity and uncertainty; and how does existing practices

for scenario design ensure the robustness and relevance of scenarios sets across space, time and sectors? Participants reflected on lessons learnt from AR6 for the IPCC assessment and for the broader research community.

Participants noted that a common architecture, with similar assumptions, allowed comparability among results from different research communities, however not everything needs to fit into the framework. IPCC assesses published literature which in the Integrated Assessment Modelling (IAM) community is currently dominated by SSP2, so it is recommended that a broad range of scenarios be used. Scenario design and evaluation are two different processes, while smaller communities, for example, global IAM community may be involved in aspects of scenario design/modelling, vetting involves a much larger community. Scenarios are developed in response to proposals, for example, inclusion of policy-relevant questions, missing scenarios. Communication of the uncertainty and range of scenarios could be improved, assessing what the scenarios show and their assumptions. Models are complex; however, simplified outcomes are needed for decision-makers. Providing historical background about the development of scenarios and assumptions would help understanding of what the models are doing and their results, for example, what socioeconomic conditions do the uncertainty ranges correspond to? It was also suggested that IPCC build a series of webinars on process and history of scenarios for next generation researchers.

The need for the framework to become more dynamic was highlighted. This is because some scenarios may become outdated to some extent for AR6, new topics emerged during the course of IPCC Sixth Assessment Report (AR6) cycle (e.g., Net Zero) and some topics become relevant later on (e.g., overshoot is currently gaining importance). The challenge is to make the framework easier to update over time. The need for scenarios to address national policy-relevant questions was highlighted; however, the literature is currently deficient. Similarly, the focus in the past has been on least cost optimization and not burden sharing schemes (especially from equity perspective) due to limited literature. It was noted that research questions change over time; designing and building new scenarios requires resources (time, investment).

2.6. Coordination and Collaboration Across Scientific Domains

Breakout Group 2.3 Chairs: Jan Fuglestvedt and Gabriela Avila
Breakout Group 2.3 Rapporteur: Kate Calvin
Flash Talk: Elmar Kriegler
TSU Science Support: Anna Pirani, David McCollum

This Breakout Group focused on the successes and challenges of scenarios collaboration across different scientific communities; how applicable the scenario design and production processes were to the needs of the impact modelling community; and the barriers to further involve the social sciences in the design and production of scenarios. Elmar Kriegler presented a scene-setting talk on the linkages between the different communities that underpin the Working Group (WG) assessments.

Integrative chapters and report structures and authors from different communities participating in assessments together are a key element in successful collaboration in the use of scenarios across different communities. The quite radical change in structure of the Sixth Assessment Report (AR6) cycle Working Group I (WG I) report led to significantly improved integration in the assessment of multiple lines of evidence compared to the Fifth Assessment Report (AR5) cycle. The assessment of scenario-based information across WG I - Working Group III (WG III) was successful, with the capacity to transfer information across communities to produce results quickly. This was thanks to a staged and timed process, building on the experience gained through the WG I-WG III Special Report on

Global Warming of 1.5°C (SR1.5) Chapter 2, and was heavily dependent on the community-level establishment of infrastructure and coordination. The ability to produce harmonised regional messaging and use of global warming level pattern scaling in WG I and Working Group II (WG II) is another success, with the WG II burning ember based on the outcomes of WG I Chapter 11. This built on the experience of the WG I-WG II SR1.5 Chapter 3, and also the inclusion of WG I-type authors as part of the WG II regional chapter teams that had clear terms of references and maintained regular contact with authors from the WG I report. The inclusion of authors in common across IPCC reports as Contributing Authors, and as authors of the Global Environment Outlook (GEO) and Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) reports have also strengthened the links across these assessments.

Challenges were related to weak or missing links between some communities, for example, economic modelling and social sciences communities, or where more communication is needed to inform other communities of the availability of information (e.g., WG I and WG II were not aware that Network for Greening the Financial System modelling was included in the scenario database). There are disparities in spatial and temporal scales that make integration challenging, for example, for scenario-based information to be relevant for adaptation, information is needed at local scales. There are opportunities to strengthen linkages with WG I and WG II, for example, addressing the lag in impacts literature behind climate modelling literature, including ISIMIP (Inter-Sectoral Impact Model Intercomparison Project) in the scenario and modelling pipeline, leveraging CORDEX (Coordinated Regional Climate Downscaling Experiment) more as a handshake mechanism, and linking WG II representatives to WCRP (World Climate Research Programme) activities such as the My Climate Risk Lighthouse Activity. Links need to be strengthened between IPBES and WG III to incorporate mitigation responses with the biodiversity assessment, and also between WG II and WG III. The link between scenarios and sectoral assessments (top down, bottom up) also needs to be strengthened. Advanced planning is needed for coordinated timelines and infrastructure to support handshakes between communities. The SR1.5 was particularly important for integration. While the Seventh Assessment Report (AR7) cycle is due to start with the Special Report on Cities and Climate Change, participants thought that this might not be sufficient to cover all aspects of integration related to scenarios, and some participants thought that a Special Report more focused on scenarios would be more effective to build a more integrated assessment of scenario-based information.

The weaker use of the scenario framework in the WG II report resulted from a limited uptake, relevance and applicability of Shared Socioeconomic Pathways (SSP) framework for, for example, agricultural, fisheries, biodiversity sectors, from missing sufficient regional context, and the potential for double counting and overlapping effects (e.g., adaptation limit in a crop model compared to productivity trend in an Integrated Assessment Model (IAM)). Representatives of the SSP framework noted that the SSPs are intended as boundary conditions that can be used to explore sectoral information, linking to more regional/local contextual information. Stronger collaboration is needed to develop common narratives and diagnostics, and participation from WG II communities to develop extensions to tailor SSP narratives. Funding, capacity building and training needs to develop these extensions. A participant suggested that adaptation results could be communicated in terms of national priorities.

Participants discussed the barriers to involve the social sciences in the design and production of scenarios. There was general enthusiasm for the value and need of including social scientists in scenario-related research and assessments. Different non-quantifying disciplines were identified as being relevant: economics (different strands), philosophy, ethics, political science, political economics, law, behavioural science, anthropology, sociology, psychology, history. Barriers include not seeing the importance of non-quantifying disciplines, the relevant data for social scientists not being available, the social sciences being less coordinated/organised and with fewer funding opportunities. Comments were also made on how the quantifiable and non-quantifiable results of these disciplines could be communicated. There are also different epistemological approaches, for example, empirical work often implies future approaches will be similar to the past, while often we need to break away from past approaches.

Suggestions to increase collaboration included through qualitative foresight studies, the assessment of feasibility and plausibility, in the design of scenarios, for example, how to design an equitable outcome, and to examine the utility maximisation framing.

2.7. Integration of Scenario Use Across and Within IPCC Working Groups

Breakout Group 2.4 Chairs: Detlef van Vuuren and Hans-Otto Pörtner
Breakout Group 2.4 Rapporteur: Şiir Kilkiş
TSU Science Support: Shreya Some, Chloé Ludden

This Breakout Group discussion was stimulated based on reflections on the integration of scenario use across and within Working Groups (WGs) in the Sixth Assessment Report (AR6). Reflections covered climatic-impact drivers, the carbon budget, risk assessment, adaptation feasibility, consequences for climate resilience, overarching narratives on routes to mitigation, and investment requirements. The discussions focused on the needs and possible ways forward.

Integration *across* WGs would be improved by i) exploring different dimensions of integration (e.g., temperature levels) to bridge different methodologies, ii) formalising WG interactions, with more frequent meetings across WGs to solve issues early in the assessment, and iii) using narratives to combine WG findings. A formal coordination mechanism on emissions/scenarios and the creation of formal roles, such as coordination mandates within the IPCC Bureau and ambassadors for cross-WG collaboration designated from the beginning of the cycle were also suggested.

Integration *within* WGs would be advanced by i) ensuring ways of increasing the breadth of regional assessments connected with scenarios, ii) increasing multi-assessment cycle collaboration, iii) addressing sustainable development themes, and iv) emphasising mutual changes in human and natural systems.

Existing collaboration among the Integrated Assessment Modelling Community and scholarship trends would be enhanced by submitting proposals of what is not being captured in other realms of the literature, and pointing out knowledge gaps to the scientific community to facilitate the process. Considering socio-economic impacts from climate change, diversifying Shared Socio-economic Pathway (SSP) assumptions, and ex-ante/ex-post equity were noted.

Scenarios building would be facilitated by i) integrating discussions on the re-assessment of underlying assumptions, facilitating their co-creation between policymakers and the science community, ii) improving the understanding of adaptation-mitigation linkages, iii) looking into grey literature for regional/ local scenarios, and iv) establishing modelling group/capacity building programs to examine how equity and justice can be usefully implemented in scenarios, and v) integrating biodiversity scenarios would take care of the need to address climate change and biodiversity loss together. The need for funders was also raised.

Group discussion also addressed the scoping process. Conducting the scoping of the IPCC Synthesis Report (SYR) earlier to facilitate the integration of scenario use, the need to develop alternative narratives before the SYR scoping, and holding early expert meetings to build trust with policymakers were shared as possibilities. Ensuring upstream cross-talk, coordination during scoping meetings, and cross-WG work in the selection of chapter teams was also mentioned. The need for mitigation/adaptation linkages was deemed important for the coordination process that could start with reflections during WG Reports' scoping meetings. Participants noted the need not to overcrowd the next cycle with numerous reports, utilise the entry point of cities, and delve into issues in detail.

Additional points highlighted during the report back included:

- Shorter delay times in communicating cross-WG findings based on scenarios across the WGs are necessary to make the process more efficient and effective.
- Planning ahead for the integrated use of scenarios and narratives, the timing of interactive cross-WG collaborations, and modalities of working together.
- The importance of connecting the communication of equity and justice as well as ecosystem collapse (tipping points) and societal collapse to climate impacts and inaction.
- The need to find an appropriate balance between simplicity and complexity in the communication of scenarios to facilitate the science-policy interface, moving forward from the Interactive Atlas.
- The rapporteur also noted the need for cross-cutting contributions on ecosystems and biodiversity, considering how ecosystem services are currently accounted for in AR6, what would be needed to improve this representation going forward, and the human-centric nature of SSP narratives.

In plenary, discussions then touched upon the possibility for a wider ongoing database, which would need rebranding, as it would not be an 'approved' product. Although it is possible to update the scenario data, narratives, and frameworks used in the models, it remains important to separate climate signals from the socio-economic parameters. Experiences that have been gained during AR6 on data curation, the need for defining roles across the scientific community for cooperation and encouraging national scale models/scenarios were emphasised.

3. Summary of Breakout Groups on Day 2: Challenges

The second day of the workshop was aimed to identify challenges based on the discussions from Day One, which focused on reviewing the use of scenarios in the Sixth Assessment Report (AR6). Challenges were identified and discussed in two segments, one on key scenario challenges and one on focussed topics. This first segment on key scenario challenges included five different breakout groups to identify and discuss challenges around scenario architecture, likelihood and other approaches to uncertainty, scale, justice and equity in scenarios and communication of scenarios to users (Sections 3.1-3.5). This second segment of Workshop Day Two on challenges included six different Breakout Groups (BOGs) on relevant focussed topics (Section 3.6-3.11). Here, challenges related to hard adaptation limits, multi-level scenarios, overshoot, plausibility and feasibility, scaling up of near-term actions and adaptation pathways were identified and discussed.

3.1 Scenario Architecture: Designing Scenario Sets

Breakout Group 3.1 Chairs: Detlef van Vuuren and Svitlana Krakovska
Breakout Group 3.1 Rapporteur: Sonia Seneviratne
Flash Talk: Detlef van Vuuren
TSU Science Support: David McCollum, Alaa Al Khourdajie

This Breakout Group (BOG) revolved around the current scenario architecture and its potential gaps, focusing on the coverage for policy making and implications for long-term climate research, including beyond 2100. It was highlighted that a new architecture is needed to accommodate global, national, and subnational/city-level scenarios, while remaining flexible for evolving Shared Socio-economic Pathways (SSPs). The suitability of SSPs in transitioning between scenarios, particularly in overshoot scenarios, was questioned. The applicability of the existing SSP-RCP (Representative Concentration Pathway) framework to national scenarios was also raised, emphasising the need to explore equity dimensions within the existing scenarios. Ambiguity surrounding the choice of a 'baseline scenario' across different research communities was discussed, along with the underutilisation of the socio-economic dimension in the SSP-RCP matrix, which holds significant importance for land use and air pollution research. Suggestions were made to enhance SSP narratives to provide clearer guidance on non-climate dimensions such as food security and equity. The importance of developing more policy-relevant overshoot scenarios and the relevance of focusing on different warming levels for earth systems modelling were also deliberated. Overall, the discussions centred on whether the identified gaps in current scenarios should be covered by the SSP-RCP scenario architecture or through individual research projects beyond the limited set of SSP-RCP scenarios. The former option aims for stability in construction without significant changes over time, as different Working Groups (WGs) need to run them in parallel.

In the report back to plenary, the following points were also raised:

- Rename scenarios to include climate information first or only.
- Consider non-linearities that allow for shifts in strategies, actions, and outcomes over the coming decades.
- Establish links between subnational/national/regional scenarios and global scenarios.
- Balance between aspirational and plausible scenarios.
- Integrate demand-side scenarios.
- Incorporate Sustainable Development Goals (SDGs) and equity as additional dimensions, making it easier for policymakers to understand synergies.
- Enhance cross-WG integration, including regional climate and impact emulators.
- Ensure inclusivity in the development of scenarios.
- Consider multiple Paris Agreement-compliant scenarios.
- Regularly update scenarios.

In the plenary discussion, the conversation focused on understanding the proposals for additional scenarios, particularly those related to degrowth as a driver. There was a call for ensuring that these scenarios represent the entire globe and not just the Global North. The purpose of the emerging recommendations on community scenarios was questioned, with suggestions for a broader community working on these and stronger integration across WGs. The need for a Scenario Model Intercomparison Project-type of scenarios that can be used for several purposes was also discussed.

3.2 Likelihood and Other Approaches to Uncertainty

Breakout Group 3.2 Chairs: Anna Sörensson and Malte Meinshausen
Breakout Group 3.2 Rapporteur: Ben Sanderson
TSU Science Support: Anna Pirani

This Breakout Group (BOG) discussed how to better convey the likelihood or lack thereof, of different emission scenarios to policymakers and the wider public, how to improve the representation of deep uncertainty and low likelihood high impact (LLHI) in climate scenarios, and what promising approaches to addressing likelihood and uncertainty could be considered in future research. To initiate the discussion, Anna Sörensson and Malte Meinshausen gave a flash talk on the use of calibrated IPCC uncertainty language, as well as an introduction to what LLHI outcomes and deep uncertainty are, and what storylines are and how they are used to provide physically consistent narratives of possible outcomes.

The IPCC uncertainty guidance requires having to go through formal steps to get to an assessment. Guidance on uncertainty language could be expanded to clarify the possibility to report high confidence of consequences of LLHI outcomes and to avoid that deep uncertainty is conflated with LLHI outcomes. The definition of the deep uncertainty concept needs to be carefully applied and communicated, since there may be different considerations related to different Working Groups (WGs). The assessment of scenario outcomes can be confused with scenario plausibility, assumptions etc. For example, plausibility or likelihood of physical climate outcomes are assessed under the related Shared Socio-economic Pathway (SSP) narrative, not the narrative itself. The likelihood of an individual scenario is impossible to define, but a bounded range can be estimated. This is relevant for climate scenarios and for socio-economic narratives. Upper and lower bounds are subject to different parameters, for example, the low-end scenarios depend on assumptions of possible maximum deployment of mitigation technology, and high-end scenarios being subject to both uncertainty in the representable uncertainty (e.g., technology costs) and unrepresentable conceptual simplifications of model relative to real world.

Participants discussed the likelihood of low- and high-end scenario outcomes and how high-end concentration scenarios can be constructed to explore more LLHI plausible outcomes, for example including a plausible upper end scenario with a high warming outcome based on high carbon loss. Care is needed in the use of high-end emissions scenarios that are defined by concentrations because while emissions may be assessed to be less plausible (SSP5-8.5), carbon feedbacks leading to similar concentrations might not be possible to be ruled out. For low end emissions scenarios, the concentration-driven framing may be confounding given that all relevant uncertainties are upstream of emission concentrations themselves, and different pathways therein have very different uncertainty profiles.

The discussion addressed the use of storylines as part of the assessment report to summarise information and findings, including unexpected surprises (e.g., a higher climate sensitivity than expected) for more effective communication with stakeholders. Using physical climate storylines allows for exploring the impact of different physically consistent climate outcomes on global and regional scales, without attaching likelihood to those outcomes.

On a global scale, there is a narrative to reduce the use of fossil fuels, but on a national scale, wider narratives may be policy relevant. Emission pathways that are not tied to SSP narratives may also be explored. For example, in India different combinations (8) of scenario combinations are developed, beyond the five core scenarios. This is appreciated by policymakers, including a broader range of global CO_2 concentration and climatic outcomes for a fossil fuel world.

Information on the assessed plausibility is relevant for policy makers, including the full range of available scenarios in relation to risk-aversion, for example, whether a 4°C world cannot be ruled out, or whether we are on track to reach 3°C is policy-relevant information in the context of policy choices and actions, and supports a discussion of risks. The participants also noted that the IPCC risk framing should be more prominent upfront in reports since the risk framing in relation to hazards, socio-economic aspects, make the assessment more policy-relevant. Linking information as much as possible to enable a context specific assessment (e.g., national assessments) is useful, as is providing information on how scenarios compare to current trends or different trajectories of national and long-term targets.

3.3 Scale (Time and Space)

Breakout Group 3.3 Chairs: Claudia Tebaldi and Toshihiro Hasegawa
Breakout Group 3.3 Rapporteur: Johanna Nalau
TSU Science Support: Sarah Connors

This Breakout Group (BOG) focused on the challenges of applying the current scenario framework across different spatial and temporal scales to address global, regional and local issues, and across sectors. The group acknowledged that the need for scenario data across specific temporal and spatial scales will differ depending on the end users of the data, for example, across regions and sectors. An overarching challenge of designing Shared Socio-economic Pathways (SSPs) is that they are informative for a wide end-user basis but also flexible enough for users to complement/extend the various scenario components with additional detail/specificity if needed. Users often need district or local level data as that is the scale decisions are often made on, yet the scenarios are at broader scales.

A large number of challenges with respect to modelling spatial scales were discussed by the group, including linking global and regional change (i.e., what does a net-zero world look like on the regional scale?) and how to model across regions and sectors to get more representative information (e.g., urban form that is cross-boundary). One of the recurring concerns was to create scenarios consistent with/relevant to their individual countries' NDCs (Nationally Determined Contributions). There were also questions as to what was meant by 'regional': does regional mean West Africa or, e.g., a region in Ghana?

The challenge of a world that is in perennial transition because of climate change was also mentioned: local climate now may not be the same in the future; how do we capture the local climate feedbacks into the decision-making? For example, land-use change decisions may be affected significantly by climate impacts. How should the scientific community make SSPs more dynamic and flexible to changing baselines? Additionally, models also need to be verified with accurate observations when modelling plausible scenarios. The group also discussed if a mechanism could be implemented to identify and share lessons learned from what has already been done in downscaling and providing tailored regional-local-sectoral scenarios. One suggestion was for regional workshops to be organised by the United Nations Framework Convention on Climate Change (UNFCCC) Least Developed Countries Expert Group to help create local scenarios without reinventing the wheel every time. The timescales also often differ between scenarios and the timescales used by decision-makers so how can these difference scales be more

aligned or supportive of each other? Questions were also asked whether scenarios should be comprehensive and address all the issues or whether each issue should have its own scenario.

Challenges with respect to temporal scales identified in the discussions focused on the short term (years to decades from present) and the long term (post-2100). Short term information was identified as being very valuable but challenges that need addressing include robustly modelling near-term climate variability and how to incorporate extreme events, associated losses and damages, as well as adaptation measures, into the scenarios. There was a difference of opinion as to whether scenario information should focus on the very long term. Some expressed concern that the long-term focus should not deflect attention away from the need for near-term action in this critical decade of transition. Others stated that long-term information can be used to understand the importance of near-term actions, for example, committed sea level rise even at 1.5°C global warming. Long-term scenarios can also improve scientific understanding on topics such as committed change, the climate response to temperature stabilisation/ the zero emissions commitment, and the long-term durability of carbon dioxide removal technologies. The point was made that the two horizons need not be/are not in a trade-off with one another.

Finally, the group also discussed the emerging role of deep learning/artificial intelligence to compute higher spatial and temporal resolution more quickly, but these techniques should be used to interpolate, not extrapolate within the greater modelled scenario range.

3.4 Justice and Equity in Scenarios

Breakout Group 3.4 Chairs: Minal Pathak and Franck Lecocq
Breakout Group 3.4 Rapporteur: Shreya Some
Flash Talk: Tejal Kanitkar
TSU Science Support: Shreya Some, Chloé Ludden

This Breakout Group (BOG) focused on how scenarios can better inform discussions on equity and justice in the IPCC Seventh Assessment Report (AR7) cycle, how models can be improved to address equity and justice issues (granularity, variables, processes), and what type of scenarios should be produced and what procedure for scenario management should be improved to inform equity and justice discussions in AR7? The rich discussion of major gaps and challenges relating to scenarios and models in the IPCC Sixth Assessment Report (AR6) is summarised below.

Overall, the group discussed that equity and justice dimensions are critical for mitigation and adaptation policies, both within and across countries. IPCC assessments should thus (i) make the ex-ante distributional assumptions that underlie the literature it analyses clear, (ii) make the ex-post distributional consequences of the different actions it assesses explicit; and (iii) literature permitting, base its assessment on a broad range of underlying visions about what is just and fair. This is also critical for the ability of the IPCC to speak to a broad range of audiences.

Scenarios are only one of the sources of relevant literature available when addressing equity and justice considerations in IPCC assessments. Numerical models, in particular, do not capture many dimensions of equity and justice (e.g., human rights issues, issues associated with governance, etc.). Multiple lines of evidence must be combined. Yet scenarios constitute an important line of evidence in IPCC assessments, and should thus meet objectives (i), (ii), and (iii) above. Yet quantitative global mitigation scenarios used in AR6 have been criticised for being based on a narrow set of distributional assumptions (thus failing to meet objective iii). More generally, there was a consensus that in AR7 scenarios could do better with regard to all three objectives.

The following topics were suggested as ways to improve models to facilitate equity assessments:

- Model limitations include lack of relevant data and indicators, hence, the improved generation and collection of data to assess multidimensional indicators of well-being (in addition to gross domestic product (GDP)) would present a valuable way forward.
- Models could be improved by designing indicators of equity beyond GDP, producing model data to assess multidimensional indicators of wellbeing, improving granularity (gender, subnational, households, etc).
- Participants reflected on the need for better incorporation of adaptation in scenarios, to reflect and include inequity in adaptation efforts- such as financial inequities, vulnerabilities, loss and damage, and governance issues.
- It was also suggested that the modelling paradigms (e.g., computable general equilibrium) as well as the choice of processes that models represent or not have (e.g., representing informal economy or not) has a bearing on the distributional outcome of the scenarios they produce, and that this should be explored.
- While much of the discussion was about global Integrated Assessment Models (IAMs), it was recognized that much of the recommendations also apply to models at national and regional scale.

The following points were discussed with relation to developing a broader range of scenarios to capture different visions of equity:

- Explicitly capturing and addressing equity and justice dimensions into scenarios relies on developing scenarios jointly, within the community, and across disciplines, including stakeholders. Research efforts dedicated to establishing a justice framework that could be applied to scenarios were called for, building on the robust literature available on justice, fairness and equity.
- Developing qualitative narratives and scenarios, on how transitions are managed and governance across the Shared Socio-economic Pathways (SSPs), was also suggested. Participants supported displaying a wider range of scenarios/outcomes, including outliers and scenario storylines. Participants reflected on the need to improve the representation of narratives for, for example, entrenched institutions keeping inequity, changing values, ideologies, and economic quality and power and political processes. This would allow for a more exhaustive assessment.
- Mitigation scenarios in AR6 were mainly based on SSP2. It was suggested to expand the set of questions addressed in research beyond current SSP2 in mitigation and expand the scenario horizon. Many extensions to SSPs are now possible. SSPs have been extended for, for example, sub-national extensions-translated on spatial income distribution between rural and urban areas. There have been extensions of adaptive capacity based on different dimensions, however, these latest developments remain insufficient.
- Scenarios should better reflect narratives from the Global South, regional/national scenarios; and focus not only on mitigation but include a broader vision of development objectives, the distribution of mitigation efforts between regions and burden sharing; transition costs; climate finance; loss and damage aspects; governance aspects; adaptive capacity. Scenario design should also consider inter and intra-regional equity and justice aspects; gender aspects; the informal economy; and avoided emissions potential.
- The research community should explore both qualitative and quantitative scenarios and include a broad range of equity assumptions, for example, reporting under several SSPs, having dedicated processes/exercises to look into equity issues and capturing governance constraints.
- There is a need to engage diverse communities including more local/regional communities to incorporate more equity issues in modelling.
- More research is needed to consolidate how global robust numbers can be distributed- consolidate what equity means for global consumption, equity in the context of avoided emissions for some countries.

Other suggestions were also brought up in the BOG discussions:

- It was suggested that modelling exercises focused on equity would be useful to inform the discussion (and AR7).

- While much of the discussion was about international equity, it was noted that it is critical to assess not only international inequities/ inequalities but also intra-countries inequality.
- It was noted that the modelling capacity remains highly concentrated in OECD (Organisation for Economic Co-operation and Development) countries. Building modelling capacity in other regions of the world, for instance via the IPCC scholarship fund, would help enhance diversity among modellers, institutions, and model inputs.

3.5 Communication of Scenarios to Users

Breakout Group 3.5 Chairs: Pierre Boileau and Fatima Driouech
Breakout Group 3.5 Rapporteur: Kate Calvin
Flash Talk: Alaa Al Khourdajie
TSU Science Support: Katja Mintenbeck, Chloé Ludden

The discussion among this Breakout Group (BOG) focussed on three key questions: How climate scenarios can be presented in a way that is both understandable and relevant to policy makers, businesses and the wider public; What are the major challenges in communicating underlying uncertainties and biases; and How to achieve a balance between communicating findings from long-term scenarios alongside other lines of evidence, such as bottom-up modelling. To stimulate discussion, this BOG started with a flash talk by Alaa Al Khourdajie on communication challenges.

When considering the first question, presenting climate scenarios to policy makers, businesses and the wider public, the following points were raised. The diversity of scenario users generates different needs in terms of communication. Climate scenarios are also associated with different terminologies, both in the scientific literature and throughout IPCC reports. For instance, the Cross-Section Box.2 on Scenarios, Global Warming Levels, and Risks in the IPCC Sixth Assessment Report (AR6) Synthesis Report (SYR) refers to scenarios when addressing results from Working Group (WG) I, and to pathways for WG III findings. Participants called for the identification of a homogenised terminology right from the start of the IPCC Seventh Assessment Report (AR7) cycle. The translation of terms from the English language, complexity of IPCC figures, and confrontation with other knowledge systems such as Indigenous Knowledge and local knowledge, present additional hurdles to the effective communication of scenarios to users. To alleviate these, participants suggested i) conducting a survey of users views on the strengths and weaknesses of different IPCC products, ii) focusing on insights gained from scenarios rather than methodology, iii) using storylines to complement graphs, tables, and to illustrate how a scenario evolves over time, iv) selecting authors equipped with strong communication skills. Finally, the co-production of scenarios was deemed important, following a process similar to that of the AR6 figures, to rely on professional communicators and third-party institutions, instead of solely on authors.

The group discussed the difficulties that arise when it comes to communicating uncertainties and biases to users. The very notion of 'bias' may be interpreted differently by scientists, compared to the public, and some BOG participants suggested avoiding the term entirely when communicating with the wider public. Scientific uncertainty is also distinct from scenario uncertainty. Indeed, a wide range of results is not always associated with uncertainty but could also reflect flexibility in outcomes. Moreover, the WG III full database statistics illustrates very wide ranges for some variables, leading to difficulties in interpretation and capturing / communicating the correlations between variables. These challenges can lead to misunderstanding and the selection of wrong numbers, supporting the spread of false statements and interpretations in the wider public. The group agreed on the need to clearly differentiate between policymakers and the wider public going forward.

Finally, participants welcomed the opportunity to better connect scenarios to other lines of evidence in AR7, starting with improving the diversity and open-mindedness of author teams during the selection phase. The need to strike an appropriate balance between the representation of long-term implications and short-term decisions, instrumental to achieve long-term goals, was identified. Different users and sectors rely on different tools, with some users relying on their own models, others on International Energy Agency, or IPCC sources. Comparing different model types can be challenging given the differing scenario structures, metrics and reporting. BOG participants were also wondering what the right balance of different approaches would be in a Summary for Policymakers (SPM). The group suggested developing a brief on how top-down and bottom-up models are developed to pave the way for bringing them closer together.

After the report-back in plenary one workshop participant raised some doubts on the usefulness of a survey to collect user views as suggested by BOG participants during the discussion of the first question on how to best present scenarios.

3.6 Hard Adaptation Limits for Species, Ecosystems and Human Societies

Breakout Group 4.1 Chairs: William Cheung and Winston Chow
Breakout Group 4.1 Rapporteur: Aidin Niamir
TSU Science Support: Katja Mintenbeck

This session on hard adaptation limits started with a short kick-off presentation by the Breakout Group (BOG) co-chairs which was then followed by a stimulating group discussion focussing on three guiding questions: (i) how scenarios have been used to inform the assessment of adaptation limits, (ii) what are the gaps/challenges in using existing scenarios for this assessment and (iii) what can be done to facilitate/support the consideration of adaptation limits.

How were scenarios being used to inform the assessment of adaptation limits for species, ecosystems, and human societies? Existing scenarios are not really suitable for the assessment of adaptation limits – Working Group (WG) II was doing this assessment primarily based on Global Warming Levels instead. Adaptation limits differ across species, systems, sectors, and such specific adaptation limits are not part of the Shared Socio-economic Pathways (SSPs). The participants discussed that it is not only warming level that matters, but also the rate of change – for the description of adaptation limits, more specificity on both level and rate of change would help and improve alignment with WG I. Also, the impacts of adaptation limits on the effectiveness of mitigation strategies (e.g., afforestation) need to be considered. Overall, the BOG participants emphasised the need for and importance of cross-Working Groups communication for including adaptation limits with respect to climate modelling and mitigation effectiveness, and these should be aligned where possible.

What are the gaps/challenges in using existing scenarios to assess these adaptation limits? A lot of the discussion was around how engineering approaches, new technologies and using more robust species (e.g., in agriculture) might support adaptation and even in some cases might make hard adaptation limits become soft limits. But the limits associated with new technologies (e.g., engineered crops) would first need identifying. Also, challenges related to compound and cascading risks, which may lead to hard limits being approached faster/earlier (e.g., extreme events, shocks), were discussed.

What can be done to facilitate/support the consideration of adaptation limits through existing/new scenarios? Participants discussed how adaptation limits characterise tipping points in socio-economic contexts (i.e., soft limits become hard ones) and that projection/hindcasting/backcasting experiments might be useful tools to identify

adaptation limits. The question whether scenarios set adaptation limits or adaptation limits scenarios was also raised – and the need to implement some feedback mechanisms/loop.

3.7 Multi-level Scenarios (Including Sub-national and Cities)

Breakout Group 4.2 Chairs: Debra Roberts and Şiir Kilkiş
Breakout Group 4.2 Rapporteur: Mathias Garschagen
TSU Science Support: Minal Pathak

This Breakout Group (BOG) discussion focused on two key questions: What are the challenges faced in providing scenarios that can inform the IPCC Special Report on Climate Change and Cities? and What are the challenges faced in achieving consistency between multi-level scenarios? The BOG opened by setting the scene for the importance of multi-level scenarios for the IPCC Seventh Assessment Report (AR7) cycle and a presentation giving an overview of recent advances while acknowledging continuing challenges. The advances involved quantitative urban emissions scenarios based on consumption-based emissions, qualitative assessments, including urban adaptation gaps to current climate risks, an evaluation of mitigation options by urban typologies, and a Cross-Working Group (WG) Box on Cities and Climate Change.

The participants first reflected on the challenges faced in providing scenarios that can inform the IPCC Special Report on Climate Change and Cities. Views were raised on downscaling and risk assessment, the representation of human influence based on additional drivers in urban areas (e.g., infrastructure, land use, and urban form, energy and emission profiles, hydrological cycle, aerosol release), and the possibility of clustering predominant issues that can be tackled jointly, such as the urban heat island effect, flooding and air quality. The group concurred on the presence of gaps in urban scenarios and the need for urban scenario development that recognizes different types of cities using urban typologies and archetypes. Scenarios that can inform ways of making small cities safer and reduce exposure to climatic hazards were voiced along with a need for development-driven scenarios, particularly for the Global South. The choice of the boundary of urban emissions at the local scale was indicated to require dedicated thinking. Urban consumption-based emissions were deemed important given the interconnected nature of emissions. Another challenge involved the need to consider aspects of multi-level governance given the interaction of urban mitigation options with broader policies.

Participants then questioned challenges faced in achieving consistency between multi-level scenarios, covering both city and subnational scales. Discussions underlined the need for scenarios to cover less researched and missed cities and regions, including small cities and informal settlements where there is an absence of literature. The dynamics of fast-growing cities, rapid suburban development, coastal cities, landlocked cities, and their differing socio-economic contexts were exemplified, endorsing the need for categorization. The need to increase scenarios that can inform cities on ways of heading to more positive futures in normative scenarios was raised, pointing out the concern on the current imbalance on negative outcomes. Data gaps for local scenario development were voiced together with the need to utilise and soft-link global models with sectoral models with relevant granularity, including building integrated renewable energy. The need to systematise the categorization and binning of the diversity of urban scenarios was indicated as a critical issue for the preparation of the IPCC Special Report on Climate Change and Cities. Ways of capturing urban poverty and vulnerabilities alongside urban metabolism with global consequences near and far were emphasised, reverberating the needs for equity and justice.

Diversity of cities such as informality, degree of informality, geophysical context and development priorities needs to be covered in a more coherent manner across the WGs. The group concluded by acknowledging the presence of persisting gaps in urban scenarios, particularly those that can embrace mitigation, adaptation and development

perspectives for desirable futures in the context of transformation. Given recent advances and major improvements, urban scenarios were viewed as an opportunity to bring WGs together in a high impact area for climate action while being mindful of the need to manage expectations on scenarios at the city and subnational scales. Given a meaningful gap yet to be addressed, priorities included better modelling of urban form, stronger collaborations in modelling and scenario development, and ensuring that informality is part of urban typologies and archetypes explicitly.

Specific recommendations included bridging global modellers and urban researchers, initiating and upscaling the conversation on multi-level scenarios and consistency, increasing funding for the science of cities, including those for less researched cities, diffusing regional capacity for urban research and climate scenarios, and ensuring a scoping process for the upcoming IPCC Special Report on Climate Change and Cities with clear workstreams for urban scenarios that are able to connect researchers and policy-relevant needs. The rapporteur emphasised the rich and constructive discussions that took place, underlining the need to cover a diversity of cities through urban typologies and archetypes and calling for a systematic process for classifying, binning and synthesising urban scenarios that are also able to bring together both explorative forward-running and normative back-casting scenarios at local levels.

Additional points on lessons learned for future consideration included:

- Better integrate urban scenarios between WGs through archetypes
- Provide a clear workspace for scenarios in the scoping for the IPCC Special Report on Climate Change and Cities
- Include scenarios focusing on the local/regional level to support adaptation
- Address gaps in the availability and use of scenarios to guide urban adaptation
- Produce scenarios that are development-driven, particularly for the Global South
- Consider ways of expanding global models with more urban representation
- Ensure a systematic process for classifying, binning and synthesising urban scenarios

3.8 Overshoot

Breakout Group 4.3 Co-Chairs: Jan Fuglestvedt and Oliver Geden
Breakout Group 4.3 Rapporteur: Matt Gidden
Flash Talk: Jan Fuglestvedt and Oliver Geden
TSU Support: Anna Pirani

This Breakout Group (BOG) focused discussions on overshoot (exceeding a warming level and returning) around three questions: What are the unanswered questions and knowledge gaps in the IPCC Sixth Assessment Report (AR6); What overshoot scenarios would be useful (warming levels, magnitude and duration of exceedance, timeframes beyond 2100, etc.) for policymakers and for understanding climate system responses; and What is the role of the different communities in designing and using overshoot scenarios?

Questions that have not been comprehensively assessed in the AR6 includes the highly uncertain ability of the land sector to sustain net carbon removals approaching and achieving net-zero CO_2 emissions, the reversibility of a variety of physical responses and impacts, for example, ecosystem impacts, in the context of mitigation responses are an area of active research which needs to be accelerated to inform overshoot pathways across the Working Groups (WGs), and the role of disturbances (pests, fire, etc.) can significantly negatively impact the efficacy of land-based removals, and are generally not included in land-surface models that inform Integrated Assessment Models (IAMs). Also, the current set of emulators used to connect WG I-III are not trained to evaluate impacts of overshoot scenarios.

There was a discussion on whether 'overshoot' is even the right term to use since this confuses policy makers that are accustomed to considering levels above a warming limit. It may be more appropriate to refer to 'peak and decline' of global mean temperature. Communication regarding exceedance of a given level of global mean temperature remains an important issue, in the context of annual global surface temperature estimates and other statements on the state of climate. In addition to the concept of a 'remaining' carbon budget, participants wondered whether a 'return' carbon budget could be considered and thus assessed in the IPCC Seventh Assessment Report (AR7) cycle.

Aligning the assessment of overshoot scenarios across WGs presents fundamental challenges. Impact assessments, like the burning embers, are assessed against global warming levels which are assumed to be monotonically increasing. There is a need to move beyond an assessment of impacts that is extrapolated to the overshoot context and a need to differentiate between immediate and reversible impacts, immediate and irreversible impacts and delayed (committed) impacts that are reversible or irreversible.

The group discussed whether overshoot scenarios need to be defined more explicitly (e.g., level of global warming, magnitude and duration of exceedance, timeframes beyond 2100) and that answering overshoot questions will need emissions-driven Earth System Model (ESM) runs to understand uncertainties in the carbon cycle, land-use sector and climate system feedbacks with a more comprehensive basis in the literature to assess the role of land-based Carbon Dioxide Removal (CDR) after net-zero CO_2 as well as studies to explore the full range of possible constraints (biogeophysical, institutional, political, technical), and for a better understanding non-CO_2 contributions to overshoot scenarios.

Participants discussed what kinds of overshoot scenarios would be useful for understanding climate system responses and which would be policy-relevant. Overshoot scenarios will likely require running past 2100, potentially with different extensions to explore more widely the response post 2100. Mitigation scenario classification based on the availability of pathways by the time of the AR7 cycle will need to be reassessed. It will be useful to explore differences between high overshoot (C2) and limited overshoot (C1) across WGs, enhancing policy relevance. Scenarios that exceed warming levels above 1.5°C (e.g., 2°C, 2.5°C, 3°C may all be relevant). Participants noted that it would be valuable to explore scenarios that link WG II and WG III to explore the sustainability of levels of CDR, low-carbon climate resilient pathways, and adaptation and mitigation challenges to deliver CDR.

A key design question that was highlighted was to develop scenarios which implement a set of actions and measures, irrespective of how the climate will respond. This would be useful for understanding how mitigation, adaptation, etc., that target low-end Greenhouse Gas (GHG) emissions futures operate with increasing temperatures that exceed a level of global warming. It is important to explore implications, for example, of stranded assets, under different overshoot scenarios. A better understanding of hysteresis effects is important, for example, related to ecosystem responses to net negative emissions. As an anecdotal example, a participant remarked that 'a period of net negative emissions would be the worst time to be a plant'. Scenarios designed to explore overshoot could be designed in 'layers', with targeted scenario design for individual Model Intercomparison Projects (MIPs) based on (or starting from) a core set of scenarios, with a varying degree of overshoot or effectiveness of removals, etc. The importance and role of the different communities that cut across WGs (e.g., Earth system modelling; impact, adaptation and vulnerability; IAM studies of mitigation, international cooperation, feasibility assessments, etc.) was highlighted for the design and use of overshoot scenarios.

Participants discussed the question of whether the Shared Socio-economic Pathways (SSP) framework was fit for purpose to answer questions around overshoot. The SSP framework doesn't currently have narratives about CDR so it could be useful to develop these. Different options were presented with varying agreement (or disagreement)

amongst the participants including existing overshoot scenarios based on the SSPs; the development of 'Shared Overshoot Assumptions'; how to explore possible 'transitions' from one SSP to another; developing a new 'axis' dimension (not SSP) that describes a new dimension of uncertainty related to overshoot.

Timing is critical to deliver the next round of drivers for Earth system models considering the tight assessment cycle timelines. Participants noted the need to keep it simple for Scenario Model Intercomparison Project (ScenarioMIP), focusing on key challenges and research questions, for example, for land use. We may want to decouple the SSP-RCP (Representative Concentration Pathway) framework to explore overshoot scenarios. Given the time constraints for information and literature to be ready in time for the AR7, exploring SSP variations could be undertaken after an initial first step based on the existing scenario framework.

More broadly, participants highlighted the need to be very clear when communicating about overshoot that this consists of at least two aspects that can be communicated and assessed in separate ways: distinguishing (1) actions and consequences until peak warming vs. afterwards, and (2) what actions are needed and the consequences this decade on the way to reaching net-zero CO_2 emissions. Formulating scenario exercises that disentangle the transition to net-zero CO_2 emissions from net-negative CO_2 emissions will be critical. Incorporating disturbances in land-surface models will be important to inform possible outcomes of effectiveness of removals.

3.9 Plausibility and Feasibility

Breakout Group 4.4 Co-chairs: Kate Calvin and June-Yi Lee
Breakout Group 4.4 Rapporteur: Saritha Sudharmma Vishwanathan
TSU Science Support: Sarah Connors

This Breakout Group (BOG) focused on the challenges surrounding the plausibility and feasibility of climate scenarios; namely on how to reflect this, what new approaches have proved successful and could be built upon in the IPCC Seventh Assessment Report (AR7) cycle, and how to better incorporate these factors into future scenario development processes.

The group discussed the need for a definition for both feasibility and plausibility, as the definition differed based on the Working Group (see Glossary) use and understanding. Either the terms can be used to answer general questions (e.g., is limiting 1.5°C global warming possible) or a framework can be used to assess specific adaptation or mitigation response options' feasibility/plausibility. Feasibility was assumed to be a subset of plausibility.

The challenges around plausibility focused primarily on uncertainty: how to incorporate uncertainty into scenarios that aren't modelled already (e.g., impacts and climate feedbacks); and how to incorporate unknown unknowns (e.g., future shocks to the system, both socio-economic and geophysical, such as tipping points)? It was noted that implausible scenarios can still serve a purpose in the research community, for example, some climate sensitivity studies are implausible, but they increase our understanding of the earth's response to carbon dioxide. Feasibility also has a spatial and temporal dimension. Something that is not feasible now, could be in the future (and how much does the IPCC influence that?). The communication of these terms to policymakers/stakeholders/user community has been observed to be difficult to explain. Finally, the group noted that, within the solutions policy space, having the next IPCC Synthesis Report released before the Global Stocktake in 2028 would help international feasibility discussions.

3.10 Scaling Up Near-term Action

Breakout Group 4.5 Chairs: Franck Lecocq and Joy Pereira
Breakout Group 4.5 Rapporteur: Franck Lecocq
TSU Science Support: Elvira Poloczanska, Shreya Some

The IPCC Sixth Assessment Report (AR6) highlighted the need for rapid scaling-up of near-term action given the gaps in mitigation, adaptation, and financing. This Breakout Group (BOG) considered what is required from scenarios in the near-term with discussion structured around two themes: What is needed to scale up near-term action (e.g., what specific information is needed from scenarios, what does this imply for models and modelling communities that produce scenarios, what specific scenarios that should be explored?); and How does this link with longer-term scenarios.

On the topic of scenarios for the short-term, the discussion highlighted that Integrated Assessment Models (IAMs) are not necessarily the best tool for exploring scenarios for short-term action. IAMs capture trade-offs but are limited at national scales and are limited in mitigation options - more could be captured (e.g., blue carbon, grasslands and agroforestry). There are other communities that produce scenarios relevant for short-term action (e.g., sectoral transition roadmaps, NGFS (Network for Greening the Financial System), IPBES (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services)). They have granularity and a level of detail for specific sectors, economic and financial incentives, and regulatory frameworks. Comparing IAMs outputs with outputs from national and regional models will give insights for near-term actions. Suggestions were made to build national capacities for bottom-up modelling.

Discussion took place on how to explore avoided emissions, enabling and other conditions in models for near-term action. Participants suggested building narratives with storylines could be a way forward and models planning time to get permits for renewables, readiness of supply chains and regulatory time could be addressed in models. Creating a regional database alongside the global database was also suggested.

Discussion also focused on ways to include a broad view of development objectives, within scenarios and the complexity of adaptation and integration with mitigation. Participants suggested using short-term scenarios to inform climate resilient development. Participants discussed the need of including economics of disequilibrium (e.g., jobs, costs in short-term scenarios).

On the topic of scenarios for the long-term, links were identified in both directions: both long-term models picking up on trajectories from short-term models, and long-term scenarios informing shorter term, for example, what is gained in the longer term by short-term action, implications for equity and justice. Concerns were raised that IAM is longer term and its outputs are used to make statements in short-term. Participants suggested exploring new options not included in current scenarios (e.g., future scenarios). To facilitate both themes, processes are required.

3.11 Adaptation Pathways

Breakout Group 4.6 Co-Chairs: Marina Andrijevic and Alexandre Magnan
Breakout Group 4.6 Rapporteur: Anita Wreford
TSU Science Support: Chloé Ludden

The Breakout Group (BOG) discussion focused on the limitations, successes and fruitful avenues for the future representation of adaptation in scenario pathways, in terms of both the enabling conditions for adaptation and responses' sequencing over time. Existing conditions and evolutionary changes in social systems are not reflected

in current risk assessments synthesised by the IPCC, which for example, consider adaptation potential solely in terms of temperature (i.e., *high* and *very high* risk levels in burning embers). Impact models also conceptualise adaptation in a simplistic, binary, outcome-oriented fashion, where adaptation is either fully present and implemented, or absent. The group raised the need to integrate more nuance in terms of the process of adapting (both on the driver and response sides) and not only in terms of outcomes on risk reduction. Other challenges include the aggregation of biophysical elements with socio-economic contexts, over-reliance of global Integrated Assessment Models (IAMs) on historical trends (e.g., agricultural productivity), and the unrealistic character of current models, which exclude for instance demographic changes or urbanisation trends as well as more qualitative aspects (e.g., changes in risk perception and governance arrangements). In this context, the potential of adaptation pathways to envisage the underlying conditions for change, assess investment options, identify solution-oriented roadmaps, contribute to loss and damages international negotiations, and improve humanitarian and development contexts were underlined.

Participants extensively discussed the tension between temporal and spatial scales, questioning the very relevance of exploring horizons up to 2100 (disconnection with current policy processes vs trigger to anticipate transformational changes). The inclusion of response times (between the identification and actual implementation of adaptation options), lock-in times, and implications of delaying costs and action (to reflect risks associated with non-action), in both locally-specific and dynamic scenarios, was called upon. Secondly, participants pointed to a disconnect between generic adaptation pathways for regions and sectors (e.g., in the Working Group II Contribution to the IPCC Sixth Assessment Report, (WG II AR6)) and national to sub-national circumstances/specificities, and pressed modellers to reflect on how to ensure the relevance of their findings for regional and national policymakers. It was suggested that an improved scenario design could be facilitated by a co-production process, bringing together different policy makers and experts. This would not be an IPCC internal process, but one that could include downscaling and bringing models to the end users, to facilitate their ownership over the design process. Such a process was unanimously perceived as essential to translate global/regional dynamics as analysed in the IPCC context into local realities and reflect context-specificities.

The group called for the scenario design process to create space to explore alternative futures based on a mix of quantitative and qualitative scientific approaches and understand how adaptive capacity leads to actual adaptation. Starting at the national level, to then build a regional understanding and feed into global analysis was suggested in order to accurately reflect the capacities or potential of different communities to adapt. Looking ahead, participants expect a focus on transboundary risks in the IPCC Seventh Assessment Report (AR7) cycle, with an increasing need to understand how adaptation planning influences adaptation capacities in other areas. Finally, with adaptation pathways inherently concerned with good governance and the equitable distribution of capacity to adapt, the IPCC can be expected to be asked by governments to weigh in on the qualitative self-assessments prepared in the context of the United Nations Framework Convention on Climate Change (UNFCCC) Global Goal on Adaptation.

Additional points that were reflected in the report back to plenary included:

- Attempt to reflect the adoption rate of options in adaptation scenarios, building on other literature and not being constrained by the quantitative modelling approach.
- The importance of timing and understanding the implications of delaying costs and action, clearly identifying the benefits of action vs non action (and to whom), as well as long-term adaptation vs maladaptation.
- Represent different capacities or potential to adapt within different communities, not only adaptation needs.

- Use the co-development of adaptation pathways to create space for exploration and debate among WGs (e.g., quantitative and qualitative scientific approaches and communities) and at the science-policy interface.
- Focus on how to support not just the outcome, but also the process of bringing policymakers into discussions on the kind of future they would like to see, instead of trying to make them understand the complexities behind the models.
- In addition to models, the rapporteur called for more qualitative narrative approaches to adaptation scenarios.

4. Summary of Breakout Groups on Day 3: Recommendations

The last day of the workshop (Day 3) was dedicated to the compilation and elaboration of recommendations on how to address and overcome the problems and challenges identified during the two previous workshop days in the future. In five Breakout Groups (BOGs), potential recommendations for (i) scientific communities involved in modelling, (ii) scientific communities not involved in modelling, (iii) for research funders, (iv) for IPCC and (v) for communication of scenarios were discussed. The BOGs agreed on a set of clear recommendations, except for the first BOG (i) that had an ambitious agenda and did not have sufficient time to arrive at a set of high-level recommendations. Various themes were discussed during this BOG, with detailed topics therein.

4.1 Suggestions and Discussion Topics for Scientific Communities Involved in Modelling

Breakout Group 5.1 Chairs: Elisabeth Gilmore and Roberto Schaeffer
Breakout Group 5.1 Rapporteur: June-Yi-Lee
TSU Science Support: Anna Pirani, Alaa Al Khourdajie

The Breakout Group (BOG) addressed a set of topics that were drawn together from the previous two days' discussions covering updates and improvements to scenario frameworks, topics relevant for model intercomparison projects, the need for regional and temporal resolution, increasing inclusivity in scenario framework and modelling activities, how to strengthen the assessment of scenarios and modelling-based information, and how to increase links and appropriate integration with the impacts, adaptation and vulnerability, the treatment of overshoot, and considerations related to scenario databases and curation. Inclusivity and the need to increase diversity was highlighted as a key topic, both in terms of participation in, and co-creation of, scenario-based knowledge and information, and for the development of scenarios and modelling experiments.

4.1.1 Updating and Improving Community Scenario Frameworks

The discussion addressed how scenario frameworks, in particular the Representative Concentration Pathway (RCP)/Shared Socio-economic Pathways (SSP) framework, were being utilised as originally intended in the framework design or if modifications or further development were required to better suit the evolving needs of the community. Participants highlighted the importance of community scenarios and raised questions about the overarching issues that have emerged across all Working Groups (WGs) (e.g., BOG 3.1: Scenario Architecture: Designing Scenario Sets) and their implications for the scenario framework.

There were differences in views as to how proactive the IPCC should be in relation to the future scenario framework, including the selection of the core set of scenarios run by Earth system models, that is coordinated by the Scenario Model Intercomparison Project (ScenarioMIP), part of the World Climate Research Programme (WCRP) Coupled Model Intercomparison Project (CMIP). Participants were reminded that the choice of scenarios included in community scenario frameworks is of key relevance for the IPCC to carry out its mandate of a policy relevant but not policy prescriptive assessment. Most participants were of the view that the outcomes of this workshop should provide some general guidelines to ScenarioMIP in the context of the process in place to undertake community consultation to develop the final ScenarioMIP community proposal this coming year. Some participants, however, argued for more firm and specific recommendations. There was agreement that it is important to define which scenarios should be prioritised, the importance of considering different user and stakeholder needs and views in the development of the ScenarioMIP protocol, in order to underpin an IPCC assessment of a policy-relevant range of outcomes. The view was expressed that the communities involved in

modelling could consider the incorporation of multiple potential interpretations of Paris compatible scenarios in research activities.

The conversation delved into the need for scenarios that cover a comprehensive range of emissions and temperature outcomes. This includes scenarios with Greenhouse Gas (GHG) emissions trajectories of high warming outcomes, those that reflect current policies, and scenarios that are relevant to the implementation of the Paris Agreement. Participants discussed the need to reassess the plausibility of e very high and very low GHG emissions scenarios. The relevance of scenarios in the context of the Paris Agreement, the need to address current policies, and the consideration of overshoot scenarios were also discussed. To support the IPCC assessment, it is important that scenarios cover the full range of possible climate outcomes, including those that resemble emission trajectories of high warming outcomes and scenarios relevant to the Paris Agreement.

The scenarios and their policy-relevance were emphasised. To this end, participants raised the need for post-2100 simulations with the best possible spatial and temporal resolution from now until 2300, building on the Representative Concentration Pathways (RCP) framework, and linking to the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP) and Impacts, Adaptation, and Vulnerability (IAV) communities to develop impacts-relevant extensions, as well as vulnerability and adaptation. The need for scenarios that can support the cross-WG assessment of future risks was also highlighted, as well as how to address these via a broad range of policy actions. The importance of national and sub-national level scenarios, including cities, to inform policy development and implementation was noted.

The participants also emphasised the need for clearer labelling of scenarios, moving away from the current 'SSP/RCP' formulation to ensure a more consistent interpretation of risk assessment.

Points reported back in the plenary session *on updating and improving community scenario frameworks:*

- Scenarios that cover the full range of possible climate outcomes, including high warming outcomes and scenarios relevant to the implementation of the Paris Agreement. (Different views were represented on this formulation.)
- Scenarios relevant for addressing scientific and policy questions beyond climate-focused targets, such as biodiversity and Sustainable Development Goals (SDGs), and their intersections with climate.
- Enhancing transparency and inclusivity in the process for choosing scenarios for driving Earth System Model (ESM) simulations.
    - Survey users of scenarios and policymaker communities on what types of scenarios would be scientifically and policy relevant as input to develop scenario design and help guide prioritisation.
    - In addition to the peer review of scenario protocols, develop processes and encourage participation in open reviews of scenario protocols that are tailored for non-modelling constituents, including user communities and stakeholders to participate in.
    - Taking into account different technical understanding and access among interested communities during consultations and outreach.
- Improve clarity of labelling for scenarios than the current 'SSP-RCP' formulation to ensure a consistent interpretation of the SSPs-RCPs framework, as well as coherently supporting risk assessment.
- The development of a richer and more diverse set of scenario narratives and drivers.
    - Improve the reflection of policy-relevant developments such as extending post-2100, linking to the assessment of climate IAV and national, sub-national and city level scenarios.
    - Enhance the treatment of equity considerations.
    - Expand on the treatment of air pollution controls, health impacts.
    - Assessing the achievement of net zero CO2 and GHG emissions with ESMs, considering options such as Carbon Dioxide Removal (CDR) and Direct Air Capture with Carbon Storage (DACCS),

and the regional role of aerosols. Expanding scenarios to include novel elements, adaptation-mitigation linkages (e.g., adaptation pathways, limits to adaptation, dynamic feedback between adaptation and mitigation).

During the report back in the plenary session, the participants reflected on the need for more inclusive discussions and processes to integrate and represent diverse perspectives in scenario design, including modellers, scenario designers, scenario users and communication experts. The participants also discussed the policy implications of certain scenarios, such as those exploring adaptation limits and losses and damages. The discussion also highlighted the need for cross-disciplinary discussions, including social sciences perspectives, on what can and cannot be done with scenarios to address these issues. Participants also discussed the prevalence of the use of scenarios up to 2100, a timeline not specifically defined in the Paris Agreement, and the need to go beyond the end of this century, including to 2300.

The process by which decisions are taken to prioritise which scenarios for climate model simulations was discussed, with an emphasis on the need for an open and inclusive process, and information on the steps and schedule by when these decisions would be made available.

4.1.2 Strengthening Research Activities and Model Intercomparison Projects

The discussion revolved around the development and application of SSPs and MIPs. The participants emphasised the importance of broadening the range of scenarios in the mitigation community, which would be achieved through the use of the complete set of existing SSPs or an extension of the existing set.

The discussion highlighted the need for MIPs to elicit feedback and input from research communities and country representatives to improve buy-in. This would increase participation and inclusivity and may be facilitated, for example, by encouraging peer-review processes and open reviews of scenario protocols.

The participants also discussed several topics relevant for MIPs, including ESM carbon cycle feedbacks, land-surface and vegetation models, and Integrated Assessment Models (IAMs) including aspects such as aerosols, land use patterns, ecosystem services, biodiversity and energy demand-side issues. The use of emulators alongside complex climate models was also discussed, emphasising the importance of maintaining rigorous validation and open infrastructures.

and the need for policy-neutral and policy-relevant assessment were also discussed. The discussion concluded with the need for different types of socio-economic development models, not just IAMs, to be considered in the future.

4.1.3 Enhancing Regional and Temporal Resolution

The BOG discussion highlighted the importance of improving the representation of regional aspects over ocean and land in IAMs.

The need for stability in scenarios over cycles was emphasised to support consistency in downscaling at regional scales. The discussion underscored the need to support regional climate modelling activities, such as CORDEX (Coordinated Regional Climate Downscaling Experiment), which are also a means to connect better with user communities and stakeholders, to cover regional modelling with higher resolutions and accelerate the timing of global modelling output for regional modelling efforts. The discussion also emphasised the significance of multi-scale studies that connect short-term and long-term scenarios, and resolutions across spatial scales. The participants also discussed the need for regional and sub-regional studies, including ecosystem aspects. The discussion also noted upon the importance of city-scale scenarios and information, including dynamical and systematic statistical downscaling, and high-resolution global modelling.

Points reported back in the plenary session *on enhancing regional and temporal resolution:*

- Improving regional and near-term temporal resolution in IAMs.
- Stability in scenarios over CMIP cycles to support consistency in downscaling at regional scales.
- Support regional climate modelling activities (e.g., CORDEX) to facilitate regional modelling at higher resolution.
- Encouraging multi-scale studies connecting short-term and long-term scenarios, and resolutions across spatial scales.
- More focus on regional and sub-regional, also city-scale studies, including ecosystem aspects.
- Streamlining open-access data baselines across communities to complement literature gaps in sectors, regions and local level.

The plenary discussion touched upon the need for policy-relevant scenarios and the importance of multi-scale studies. The participants also discussed the need for high-resolution MIPs and the importance of considering future tipping points and projected losses and damages. The discussion concluded with the suggestion for the scientific community to consider multiple potential Paris Agreement relevant scenarios and the need for such scenarios to drive climate science impact models and ESM.

4.1.4 Increasing Participation and Inclusivity

The BOG discussion emphasised the importance of inclusivity in scenario development, involving a more diverse range of researchers from around the world, including those from social sciences to enrich the perspectives and views included in scenarios-based activities. The participants underscored the value of engaging with regional modelling communities and enhancing the spatial and temporal resolution of models to increase diversity. They also stressed the need to include social sciences in scenario development and knowledge co-creation. The discussion touched upon the necessity of considering different levels of technical understanding and access among interested communities during consultations and outreach. The discussion also highlighted the need for resources to create opportunities for capacity building and the need for funding for modelling centres worldwide to be able to effectively support a wider participation.

Points reported back in the plenary session *on increasing participation and inclusivity*:

- Increasing diversity in the research community and modelling centres, building capacity, and mobilising funds to implement these efforts.
- Engaging with regional modelling communities.
- Including social sciences in scenario development and knowledge co-creation.

During the report back participants emphasised the importance of inclusivity, funding, developing an open consultation and review process, and capacity building in the development of ScenarioMIP.

4.1.5 Broadening the Assessment of Scenarios and Modelling Approaches

The BOG discussion focused on the assessment of scenarios, both by the IPCC and through secondary research conducted by the community, emphasising that this should extend beyond climate to also include impacts and biodiversity, thereby the need to facilitate these linkages. The participants suggested that the assessment of scenarios should go beyond the use of standard statistical metrics to characterise scenarios falling within specific categories, and that the classification of scenarios should also include non-climate outcomes such as energy demand. They also discussed the importance of exploring a range of potential options and solution spaces to reach Paris Agreement goals. The discussion touched upon the need for models and modelling to continue running scenarios that are not only 'global least costs' but also other options. The need to assess regional, sectoral and local scenarios and modelling activities, alongside global scenarios and modelling, was noted. The participants also highlighted the importance of diversifying modelling communities through well-funded capacity development activities.

Points reported back in the plenary session *on broadening the assessment of scenarios and modelling approaches:*

- Enhancing scenario assessments by going beyond statistical analyses.
- Assessing scenarios that have not passed vetting tests designed to screen for compatibility with historic trends, or suitability for a full assessment of climate outcomes, in order to extract otherwise valuable insights.
- Considering non-climate outcomes and conditional plausibility in scenario outcomes.
- Continuing to explore scenarios that are not only 'global least costs' but also many other options.
- Exploring a range of potential options and solution spaces to reach Paris Agreement goals.
- Assessment of regional, national, and local scenarios, including in grey literature.
- Increasing interactions between global models and sectoral assessments.
- Encouraging the development of national scale models (feeding into Nationally Determined Contributions (NDCs)).
- Diversifying modelling communities through well-funded capacity development activities.

4.1.6 Strengthening Links to Impacts, Adaptation and Vulnerability Communities

The BOG discussed the importance of integrating scenarios of vulnerability and exposure into impact pathways within existing scenarios frameworks. The discussion emphasised the barriers to integrating the SSPs into the WG II Contribution to the IPCC Sixth Assessment Report (AR6) and to incorporate SSPs into impact/adaptation projections, as well as reasons why SSPs are inappropriate for synthesising knowledge and assessment. The discussion also highlighted the necessity to generate impact/adaptation pathways, better include irreversible impacts, ecosystem shocks, and tipping points into scenarios, and reflect biophysical constraints. The BOG also suggested exploring how policy actions might affect impacts and risks, and the implications of climate change impacts on different groups for equity and alleviation of poverty.

Points reported back in the plenary session *on strengthening links to IAV communities:*

- Promoting a dialogue and mutual consideration, the integration of SSPs into the WG II Contribution to the IPCC Seventh Assessment Report (AR7) cycle where appropriate, and the development of impact/adaptation projections is recommended.
- Developing impact/adaptation pathways, incorporating future scenarios of exposure and vulnerability.
- Including irreversible impacts, ecosystem shocks, and tipping points in scenarios, reflecting biophysical constraints.
- Exploring the effects of policy actions on impacts and future risks.
- Investigating the implications of climate change impacts on different groups for equity and poverty.
- Encourage plurality of scenario development approaches for mitigation and adaptation, including both modelled and non-modelled.

The plenary discussion after the report back highlighted several key points, including the potential policy implications of including topics like adaptation limits and losses and damages in scenarios, with a recommendation for cross-disciplinary discussions on these issues.

4.1.7 Exploring Scenarios of Exceedance and Return (Overshoot) of Levels of Global Warming

The BOG participants discussed the relevance of considering overshoot scenarios, particularly the detection and assessment of impacts and the importance of these scenarios for communities working on tipping points and thresholds. They emphasised the need to include post-2100 scenarios and simulations to address delayed impacts and irreversibility. They discussed the reversibility of climate and impacts, mitigation consequences, and the need to keep ScenarioMIP and other relevant efforts simple and timely. The BOG participants suggested exploring a wider range of overshoot scenarios and defining them more explicitly by magnitude and duration. They also highlighted the need for a broader assessment of CDR options, and the use of emissions-driven ESM runs to understand uncertainties in the land-use sector and climate system feedbacks.

Points reported back in the plenary session *on exploring scenarios of exceedance and return (overshoot) of levels of global warming:*

- Exploring a comprehensive range of overshoot scenarios and their characteristics, including magnitude, duration.
- Connecting with communities working on tipping points and thresholds and include delayed impacts as well as irreversibility.
- Exploring the role of land-based CDR after net-zero CO_2, trajectory to net zero, and degree of overshoot or effectiveness of removals.
- Building on progress in land-surface and vegetation models to inform possible outcomes of effectiveness of removals.
- Conducting emissions-driven ESM runs to understand uncertainties in the land-use sector and climate system feedbacks.

4.1.8 Further Developing a Community Scenarios Database

The BOG participants discussed the potential improvements to the Scenarios Database hosted by International Institute for Applied Systems Analysis (IIASA), suggesting that it should be 'live' and continuously updated with open access to both vetted and unvetted scenarios. They emphasised the need to include a wider range of scenarios and variables, such as UNFCCC national emissions data. The BOG also highlighted the importance of

improving the infrastructure and flexibility of the process to bring in a wider range of scenarios into the database. They suggested that the database should continue to provide scenarios for global use as well as sectoral and national scenarios. The BOG also discussed the need for funding and community ownership to support implementation, decision making, and management of the database, and the inclusion of Indigenous Knowledge and local knowledge.

Points reported back in the plenary session *on further development of a community scenarios database:*

- Broadening the types of information and diversity of views, including Indigenous Knowledge and local knowledge.
- Making the Scenario Database a 'live' and continuous activity with open access to all scenarios (e.g., those that are 'vetted' for specific assessments versus all available scenarios).
- Including a wider range of scenarios and variables, including UNFCCC national emissions data.
- Improving the infrastructure and flexibility of the process to bring in a wider range of scenarios into the database.
- Continuing to provide scenarios for global, sectoral, and national use.
- Ensuring community ownership and funding support for the database

4.2 Recommendations for Scientific Communities Not Involved in Modelling

Breakout Group 5.2 Chairs: Diana Ürge-Vorsatz and Carlos Nicolás Zambrano Sánchez
Breakout Group 5.2 Rapporteur: Maria Virginia Vilariño
Flash Talks: Elmar Kriegler, Bas van Ruijven
TSU Science Support: Minal Pathak, David McCollum

The Breakout Group (BOG) focused on recommendations for communities not involved in modelling. The discussion focused on several aspects including the importance of the qualitative component in the scenarios building process and the connection between narratives, drivers and indicators that can contribute to the modelling process. Existing challenges include representation of traditional knowledge especially for adaptation, community-based finance, addressing limitations in the application of models at local level, linking global scenarios with national scenarios and integrating regional and sectoral information. There is a need to build on low demand scenarios focusing on lifestyles, efficiency and reduced energy consumption. Participants acknowledged uncertainties in the process which poses challenges for producing harmonised scenarios. There is a need for better engagement between the modelling community and non-modelling communities.

Recommendations were categorised into five themes.

Encourage plurality of scenario development approaches for mitigation and adaptation, including both modelled and non-modelled.

- Better mapping of research questions that cannot be answered well with current quantitative scenario modelling practices.
- Develop methods to support non-modelling scenarios.
- Encourage funders and publishers to recognize more inclusive allocation of funding.

Develop methods, information and data for scenario assessment and classification of local-level (bottom-up and non-modelling) scenarios to gain complementary insights to quantified scenarios.

- Need mechanism to identify and share lessons learned from what has already been done in downscaling and providing tailored regional/ local / sectoral scenarios.

- Detection and attribution studies to assess economic shocks from losses and damages.

Promote more diverse representation and inclusion in scenario, climate modelling and impacts, adaptation, and vulnerability (IAV) development and use.

- Ensure inclusive representation among diverse communities, including, inter alia, Indigenous, local and traditional knowledge, as well as government, business and industry.
- Assessment of adaptation limits in the IPCC Seventh Assessment Report (AR7) cycle (e.g., further research to define transition from biological limits and differentiated measures how to improve resilience with response measures (technologies, etc))
- Ensure adequate funding to make diverse representation and inclusion possible.
- Engage in iterative dialogue across sectors and scales (global to local)

Help scenario efforts with developing a richer and more diverse set of narratives and drivers.

- Narratives to include, inter alia, normative and goal-oriented narratives of (socio-economic and political) equity and justice, adaptation, feedbacks, sustainability, biodiversity, post-growth, lifestyles.
- Drivers to include, inter alia, education, public awareness, well-being, gross domestic product (GDP) alternatives, lifestyles, production and consumption patterns.

Data baselines production to complement literature gaps in sectors, regions and local level.

- Need better, inter alia, observations, paleo proxies, socio-economic data at all scales, etc.

4.3 Recommendations for research funders

Breakout Group 5.3 Chairs: Leon Clarke and Joyce Kimutai
Breakout Group 5.3 Rapporteur: Matt Gidden
TSU Science Support: Sarah Connors, Shreya Some

The small but focused Breakout Group (BOG) covered recommendations for funding agencies, particularly focused on how to support the development and assessment of scenarios rather than the topics the scenarios should cover as this was covered in parallel BOGs 5.1 and 5.2 (see Sections 4.1 and 4.2). The group acknowledged that different research funding agencies exist who would sometimes focus on particular recommendations. These include but are not limited to government (national and international), private sector and philanthropy. Discussions focused on support for engaging a wider variety of researchers from around the world including collaboration between developing and developed countries in order to increase the richness and the diversity of views in these scenarios and support for research on the science of scenario assessment and classification based on multiple relevant factors. Recommendations were categorised into four broad themes.

Participation / representation

Increase the richness and the diversity of expertise in models and scenarios by engaging a wider variety of researchers/stakeholders from around the world throughout the research cycle (conceptualisation, implementation, dissemination).

- There is a particular need to ensure participation and representation across regions and disciplines when funders are developing research calls.
- Ensure a wide range of funding mechanisms for participation, for example, through fellowships or early career scholarship funds, in scenarios and model development.
- Ensure support for incorporating scenario research into IPCC assessments, for example, for submitting scenarios to the IPCC Scenario Database.

Capacity

Direct funding to engage communities not currently/effectively represented in scenario processes.

- There is a particularly critical gap in scenario, impact, and climate modelling capacity in the global south. Both in-country and international funding have a role to play in filling this gap.
- Capacity development for disseminating national scenarios including from government agencies, for example, by submitting them into the IPCC Scenario Database.
- Support for documentation, communication, and outreach for using or working with scenarios for non-involved scientific communities, policymakers, private sector.

Infrastructure

Increasing funding for data curation, including establishing, maintaining, expanding, updating scenario relevant databases and supporting tools.

- Scenario relevant databases and supporting tools across all three Working Group (WG) domains are global public goods and need targeted and sustained funding.
- Such funding should promote the lowering of barriers to submission and database maintenance requirements. In particular, supporting open-source tools to facilitate scenario submission, processing, vetting, analysis and access are important for enhancing transparency.
- Interactive tools like the WG I Interactive Atlas are valuable means of disseminating information to users and similar tools could be developed across all WG domains.

Science of scenario assessments

There is a need for targeted funding on the science and methodologies of assessing scenarios, for example, not simply treating scenario sets as statistical distributions, and combining qualitative and quantitative scenarios.

4.4. Recommendations for the IPCC

Breakout Group 5.4 Co-chairs: Valérie Masson-Delmotte and Itchell Guiney
Breakout Group 5.4 Rapporteur: Şiir Kılkış
Flash Talk: Elvira Poloczanska
TSU Science Support: Elvira Poloczanska, Mxolisi Shongwe

The Breakout Group (BOG) commenced by considering how the relevant recommendations gathered over the course of the previous two days of the workshop apply at different stages of the IPCC cycle from process design to post-approval. Modes for bringing together all Working Groups (WGs) early in the process, ways to increase interfaces and joint initiatives, and sharpening evidence were emphasised. The subsequent discussion was centred around three key messages that formed the main recommendations.

Provide and ensure early planning and guidance

Planning should start early for coordination across WGs to better pursue integration between scenarios and related topics, such as climate-resilient development as well as mitigation and avoided risks. Processes for coordination also include the glossary for integrating concepts during the assessment and fostering the interaction of Integrated Assessment Models (IAMs) and sectoral modellers and other knowledge communities. The prospect for an IPCC Special Report or Expert Meeting on scenarios early in the IPCC Seventh Assessment Report (AR7) cycle was proposed, bringing together streams of expertise, for example, global climate modellers (Coupled Model Intercomparison Project (CMIP), social scientists and business, to provide guidance and set up the handshakes among Working Groups.

Additional suggestions included scoping the IPCC Synthesis Report early in the cycle but after an IPCC Expert Meeting on scenarios to set the cross-WG coordination and considering the IPCC Special Report on Climate Change and Cities in AR7 as an opportunity for cross-WG coordination on scenarios. Governments could be surveyed on how scenarios are embedded in decision-making to ensure policy-relevance and delivery of coherent messages. Also proposed was coordination with the World Climate Research Programme (WCRP) and CMIP ahead of AR7 on how to support AR7 in the use of emulators, including evaluation of climate emulators, comparison across models (existing and next generation). Recommendations included the production of guidance documents on processes and lessons learned from the IPCC Sixth Assessment Report (AR6) cycle such as methodological guidance on assessing and reviewing scenarios (including multi-dimensional feasibility and plausibility and regional representation), providing ways of establishing a clear connection among scenarios and other lines of evidence, and linkages between sectors and practitioners. Also, the inclusion of variables or elements such as equity and fairness in scenarios in a technically and scientifically feasible manner, and how this can be done. There were also discussions on whether the IPCC should continue to source scenarios from the scientific community or develop scenarios in-house, however, there were serious concerns that developing scenarios in-house might impact on the objectivity, independence and policy-relevance of the IPCC.

Formulate ways to institutionalise coordination

The IPCC Bureau could play (and have played in AR6) a leading role in coordination across Working Groups. Formalising bridging roles for IPCC Bureau Members, including in their Terms of Reference (e.g., mandating responsibilities to look after cross-cutting topics with strong support from the TSU), would facilitate the process. More formalised processes for 'bridging authors' could be initiated to support coordination mechanisms as well as consideration of focused cross-WG author meetings. Scoping documents for IPCC Special Reports and WG Assessment Reports could provide more detail regarding integration and be explicit regarding the assessment of scenarios. It was suggested that each WG could have a 'Global Assessment' chapter for coherency.

Embed coordination in each step of the process

Embedding coordination should also start with the early steps of the assessment including processes to ensure the inclusion of the necessary expertise regarding scenarios during scoping and in the author selection process with a view on having a balance of authors across chapters and WGs and across disciplines, for example, scenarios modellers, social sciences and humanities and practitioners (with humanitarian and business sector representations). Holding webinars with IPCC Focal Points on scenarios (e.g., on the outcomes of an IPCC Expert Meeting early in the process) could inform the nomination process and ensure relevant expertise is reached. Increased training for authors on conducting assessments bridging multiple lines of evidence (feasibility, limits, pathways, tipping points, maladaptation) can facilitate the process and sensitise authors to scenarios as a framework of synthesis. Consistency in the use and treatment of scenarios across WGs could be strengthened through increasing participation in internal review processes, encouraging experts in other WGs to review the draft assessments and providing cross-WG webinars on scenarios. Further coordination across WGs is needed to better pursue connections such as those of ecological and social systems, and the need to better communicate interdependencies in mitigation among sectors was suggested.

AR7 could consider producing cross-WG Papers, for example, similar to cross-WG Boxes throughout AR6 as well as the Cross-Chapter Papers in the WG II AR6. Participants discussed the vetting process for scenarios and that plausibility checks should include experts from social sciences, humanities, consider biogeophysical constraints in a warmer world (e.g., hard limits related to water or biomass availability, afforestation, yields, habitability) as a cross-WG effort. In integrating across WGs, consideration should be given to fostering collaboration between the WGrs and the Task Force on National Greenhouse Gas Inventories (TFI) inventory work, (e.g., links with TFI on land-based emission inventories) and consistency with models and scenarios and strengthening interactions with the IPCC Task Group on Data (TG-Data).

Report Back of Recommendations

The main recommendations were presented in the Stocktake Plenary. The need for better balancing workloads from collaborative tasks and activities was given as a comment from the floor. It was noted that formulating ways to institutionalise coordination should also serve to address workload aspects. Holding a physical IPCC Expert Meeting on scenarios early in AR7, including webinars, was emphasised.

4.5 Recommendations for communication of scenarios

Breakout Group 5.5 Chairs: Debra Roberts and Alexander Ruane
Breakout Group 5.5 Rapporteur: Kevin Hennessy
TSU Science Support: Katja Mintenbeck, Chloé Ludden

The discussions in this Breakout Group (BOG) were informed by challenges and needs identified in previous BOGs held during Day 1 and Day 2 of the workshop, in particular BOG 3.5 (see Section 3.5) on the communication of scenarios to users on Day 2. After lively and fruitful discussions on what is needed to improve the understanding and communication of scenarios, by whom, and considering potential enabling conditions for more effective scenario communications, the BOG participants came up with five key recommendations:

Conduct a targeted survey on the perception and use of scenarios in the IPCC Sixth Assessment Report (AR6) cycle

It is strongly recommended to the IPCC and the scientific community to conduct a targeted survey with scenario users to obtain deeper insights into user types, to determine their knowledge about and use of scenarios, and to better understand and respond to scenario needs from the users' (demand-side) perspective (who, why, how, what?). Such a survey will allow us to collect views on scenarios' strengths, weaknesses, gaps, future needs and questions, will help us understand what awareness-raising efforts were effective, and will inform differentiated scenario communication processes and production. Finally, this survey could collect feedback on the reception and distribution of scenario types, the perception of high, low and intermediate emission scenarios, needs to fill in gaps between explicit scenarios, and the presentation of scenarios in text and figures. IPCC and UNFCCC (United Nations Framework Convention on Climate Change) Focal Points will need to be engaged. Additional funding might be required to develop and conduct such a survey, and to analyse and distribute the results.

Develop and provide accessible IPCC explainers on scenarios.

These are urgently required to improve the understanding and transparency of scenarios and provide guidance on how to use scenarios in risk assessments. To make the explainers more relevant and accessible, the IPCC could customise the explainers for multiple audiences (e.g., Focal Points, policymakers, private sector, public, author teams, scientists). These documents could also describe proven approaches to create scenarios through co-design and co-production, conscientious of ethical considerations. These scenario explainers could build on already existing explainers, such as those provided by Carbon Brief. Participants agreed on the importance of ensuring that these explainers are co-developed by stakeholders, scenario experts and IPCC Working Group (WG) communication experts. Additional dedicated funding would be required for the development of such accessible IPCC explainers on scenarios suitable for a broad audience.

Develop a guidance note on inclusive, co-developed scenario elaboration

Elaborated scenarios at the global, regional, and sectoral level are going to be increasingly required for the IPCC assessments to be credible. Guidance notes can convey how decisions are being made about what is included or left out of scenarios, how to determine scenarios elements that are necessary for a planned analysis, how

scenarios can cohesively/coherently nest, and what information allows elaborated scenarios to connect cohesively for aggregate analysis. For the effective communication of scenarios, an inclusive process based on co-development between scientists and stakeholders is required. Co-development practices will also address the urgent need to build trust and ownership over scenarios, thereby increasing their utility to end-users. It will also encourage a two-way flow of information. The development of a guidance note on inclusive, co-developed scenario elaborations is strongly recommended to guide this process, clearly articulate the questions that scenarios could and should address and contribute to building internal consistency with global scale scenarios. This guidance material should be developed by an IPCC expert team in close collaboration with relevant global, regional and sectoral stakeholders and scientific partners. The development of such useful guidance material would require dedicated funding as well as government and institutional support.

Build and cultivate a network of trusted intermediaries to communicate scenarios

Building a wide, global network of trusted intermediaries or knowledge brokers familiar with IPCC scenario approaches will improve the 2-way flow of information and knowledge and help increase trust in scenarios, as well as their utility. This network would involve, for example, foundations, non-governmental organisations (NGOs), business associations, extension experts, peak bodies and reputable climate communication groups. As a first step towards such a network, the identification of (i) trusted knowledge brokers already working in this field and (ii) existing communication gaps that need to be addressed will be required. To enable and facilitate increased intermediaries' capacity, pre-existing sectoral and local networks could be leveraged to build expert approaches via the convening power of the IPCC. Engaging with social media and cultural influencers was also recommended. However, sustained funding and legacy will be required to build and, in particular, to cultivate such a wide global network for the communication of scenarios.

Strengthen institutionalised science communication experts throughout the IPCC process

The important role of science communication experts in making the work of the IPCC, the outcomes of the assessments and underlying science accessible to a broad audience, in different languages, has repeatedly been emphasised across several BOGs during the workshop. Strengthening and more deeply institutionalising science communication experts will improve IPCC products and increase the capacity for co-development of communication products, including key messages and, for example, accessible IPCC explainers on scenarios (see above). This will require devoted funding from reliable and committed governments. Responsibility for implementation will remain with the IPCC Seventh Assessment Report (AR7) team and Technical Support Unit (TSU) funding (and other) governments.

When the recommendations from this BOG were presented in plenary, the importance of using simple storylines, where possible supported by clear and easy to understand graphics, to effectively communicate scenarios about a range of possible futures was again emphasised by workshop participants. In addition, the importance of co-producing scenarios with stakeholders and communication experts was highlighted again, as well as the need for close cross-WG collaboration to ensure consistent use and terminology (including on the communication of uncertainty). Finally, the need for guidance notes/materials to address current gaps, for example, issues of equity and justice was discussed, and, since action usually occurs locally, guidance material should include a focus on sub-regional/local aspects.

Annex 1: Workshop Development Process, including Scientific Steering Committee Membership

At the Fifty-Fourth (bis) Session of the IPCC (IPCC-54(bis)), held from 14 to 16 December 2021, the Panel considered a proposal from the Co-Chairs of Working Groups (WGs) I, II and III for an IPCC Expert Meeting on the Use of Scenarios in the IPCC Sixth Assessment Report (AR6) and Subsequent Assessments. Recognising the importance of the topic, the IPCC decided to elevate the activity to that of an IPCC Workshop. An IPCC Workshop considers cross-cutting or complex topics requiring input from a broad community of experts. It requires nominations by IPCC member Government Focal Points and, as appropriate, Observer Organisations. The relevant WG/Task Force Bureaux, or the IPCC Chair, may also nominate experts and select the participants to the Workshop.

The IPCC Trust Fund Programme and Budget submitted to IPCC-54(bis) included a request for the addition of a budget line to the proposed budget for 2022 for the Workshop, with a requested provision of a budget of CHF 187,200, comprising travel support for participants from developing countries and economies in transition of CHF 240,000 (60 journeys) and Other expenditure pertaining to venue and other costs of CHF 40,800. Due to delays in the overall schedule for the AR6, the Workshop was held in 2023, with the IPCC annual budget adjusted accordingly.

The Co-Chairs of the WGs formed a Scientific Steering Committee (SSC) consisting of experts in the field of scenarios. Its members were:

Co-chairs:
Valérie Masson-Delmotte, France (Working Group I)
Panmao Zhai, China (Working Group I)
Hans-Otto Pörtner, Germany (Working Group II)
Debra Roberts, South Africa (Working Group II)
PR Shukla, India (Working Group III)
Jim Skea, United Kingdom (Working Group III)

Members:
William Cheung, Canada
Jan Fuglestvedt, Norway
Amit Garg, India
Brian O'Neill, the United States of America
Joana Portugal Pereira, Brazil
Joy Pereira, Malaysia
Keywan Riahi, Austria
Anna Sörensson, Argentina
Claudia Tebaldi, the United States of America
Edmond Totin, Benin
Detlef Van Vuuren, the Netherlands
Zinta Zommers, Latvia/the United States of America

The role of the SSC was to support the design, convening of, and reporting on the IPCC Workshop in accordance with Section 7.1 of Appendix A to the Principles Governing IPCC Work, Procedures for the Preparation, Review, Acceptance, Adoption, Approval and Publication of IPCC Reports. It will also assist the WG Bureaux with the selection of participants from nominations received. IPCC Technical Support Unit (TSU) members could attend SSC meetings as appropriate.

The specific mandate of the SSC was as follows:

a. To prepare the agenda for the Workshop.
b. To prepare the necessary documentation to inform the Workshop.
c. To recommend to the Bureaux of WGs I, II and III a list of participants in the Workshop.
d. To prepare a document describing the outcomes of the Workshop to be transmitted to the IPCC Secretariat for transmission to the Panel and for publication.

The work of the SSC ceased when the report of the Workshop was submitted to the IPCC Secretariat.

The SSC met four times virtually (22 September 2022, 06 December 2022, 08 February 2023, 31 March 2023) and in-person the day preceding, and each day of, the Workshop itself.

The Workshop was held from Tuesday 25 April to Thursday 27 April 2023 in Bangkok, Thailand.

A total of 94 participants attended the meeting. A full break-down of the participant selection is provided in Annex 3: Participant List.

This Workshop Report was developed by the SSC, supported by the WG TSUs, liaising with Breakout Group (BOG) Co-Chairs and Rapporteurs to confirm BOG recommendations and outcomes as required. A draft of this report was provided to workshop participants for their consideration and feedback prior to publication.

Annex 2: Agenda

DAY 1: 25 April 2023

Time	Length	Title
	DAY 1	**REVIEWING AR6**
09:00-11:00	**Plenary Session 1**	**Setting The Scene Chair: Youba Sokona**
09:00	30 minutes	Opening Ceremony
09:30	10 minutes	Rationale and context for the workshop
09:40	5 minutes	Structure of the workshop/resource material
09:45	5 minutes	Q&A
09:50	10 minutes	Word Cloud
10:00-10:25	25 minutes	Scenarios and policymaking
10:25-11:00	35 minutes	The Role of Scenarios and other type of evidence
11:00- 11:45	***Break & icebreaker activity:*** **Connecting Without Climate Talk**	
11:45-13:00	**Breakout Group (BOG) Session 1**	**What worked and what could have worked better: the science**
		BOG 1.1: Earth systems modelling, emulators and mitigation scenario categorisation *Co-chairs: Ole-Kristian Kvissel / Anna Pirani* **BOG 1.2:** Climate drivers, hazards, risks and risk reduction *Co-chairs: Hans-Otto Pörtner / Elvira Poloczanska*

Time	Length	Title
		BOG 1.3: Socio-economic context. Mitigation/adaptation pathways and climate action *Co-chairs: Malak Al-Nory / Diana Ürge-Vorsatz*
13:00-14:00	***Lunch***	
14:00 – 15:30	**BOG Session 2**	**What worked and what could have worked better: scenario design and process**
		BOG 2.1: Scenario data and curation *Co-chairs: Alaa Al Khourdajie / Ben Sanderson* **BOG 2.2:** Scenario architecture: the design of scenario sets *Co-chairs: Zinta Zommers / Amjad Abdulla* **BOG 2.3:** Coordination and collaboration across scientific domains *Co-chairs: Jan Fuglestvedt / Gabriela Avila* **BOG 2.4:** Integration of scenario use across and within IPCC working groups *Co-Chairs: Hans-Otto Pörtner / Detlef van Vuuren*
15:30-16:00		***Break***
16:00-17:30	**Plenary Session 2**	**Day 1 Stocktake Chair: Greg Flato**
16:00	15 minutes	Report back BOGs 1
16:15	25 minutes	Discussion
16:40	15 minutes	Report back BOGs 2
16:55	25 minutes	Discussion
17:20		Day 2 Plan

Time	Length	Title
17:30		Close
17:30-17:40	**Group photograph**	
18:00-19:30	**Reception hosted by the Government of Thailand**	
19:00-20:00	**Scientific Steering Committee Meeting**	

DAY 2: 26 April 2023

Time	Length	Title	
	DAY 2	**CHALLENGES**	
09:30-10:15	**Plenary Session 3**	**Setting The Scene**	**Chair: Keywan Riahi**
	10 minutes	SSC report back	Anna Sörensson
	15 minutes	Overview of challenges and introducing the BOGS	Brian O'Neill
	20 minutes	Discussion	
10:15-13:00	**BOG Session 3**	**Key scenario challenges**	
Iteration including coffee break at 11:30		**BOG 3.1:** Scenario architecture: designing scenario sets *Co-chairs: Detlef van Vuuren / Svitlana Krakovska* **BOG 3.2:** Likelihood and other approaches to uncertainty *Co-chairs: Malte Meinshausen / Anna* Sörensson **BOG 3.3:** Scale (time and space) *Co-chairs: Toshi Hasegawa / Claudia Tebaldi* **BOG 3.4:** Justice and equity in scenarios *Co-chairs: Minal Pathak / Franck Lecocq* **BOG 3.5:** Communication of scenarios to users *Co-chairs: Fatima Driouech / Pierre Boileau*	
13:00-14:00		***Lunch***	
14:00-15:00	**BOG Session 4**	**Focused topics**	
		BOG 4.1: Hard adaptation limits for species, ecosystems and human societies *Co-chairs: William Cheung / Winston Chow* **BOG 4.2:** Multi-level scenarios (Including sub-national and cities) *Co-chairs: Debra Roberts / Siir Kilkis*	

Time	Length	Title
		BOG 4.3: Overshoot *Co-chairs: Jan Fuglestvedt / Oliver Geden* **BOG 4.4:** Plausibility and feasibility *Co-chairs: Kate Calvin / June-Yi Lee* **BOG 4.5:** Scaling up near term action *Co-chairs: Franck Lecocq / Joy Pereira* **BOG 4.6:** Adaptation pathways *Co-chairs: Alexandre Magnan / Marina Andrijevic*
15:00-15:30		***Break***
15:30-17:00	**Plenary Session 4**	**Report back and discussion Chair: Joy Pereira**
	75 minutes	Report back from BOGs
	15 minutes	Day 3 Plan
		Close
17:30-18:30	**Scientific Steering Committee Meeting**	

Day 3: 27 April 2023

Time	Length	Title
	DAY 3	**RECOMMENDATIONS**
09:30-09:45	**Plenary Session 5**	**Introduction to Day 3** **Chair Jim Skea** Recap on the workshop
09:45-13:00	**BOG Session 5**	**Recommendations**
Iteration including coffee break at 11:15		**BOG 5.1:** Recommendations for scientific communities involved in modelling *Co-chairs: Roberto Schaeffer / Elisabeth Gilmore* **BOG 5.2:** For scientific communities not involved in modelling *Co-chairs: Diana Ürge-Vorsatz / Carlos Zambrano* **BOG 5.3:** For research funders *Co-chairs: Leon Clarke / Joyce Kimutai* **BOG 5.4** For IPCC *Co-chairs: Valérie Masson-Delmotte / Itchell Guiney* **BOG 5.5** For communication of scenarios *Co-chairs: Debra Roberts / Alexander Ruane*
13:00-14:00		***Lunch***
14:00-16:00	**Plenary Session 6**	**Socialising the recommendations** **Chairs Debra Roberts and Jim Skea**
	110 mins	Report back from BOGs • Discuss points of contention Final Discussion
	10 mins	Close meeting Hans-Otto Pörtner
16:30-17:30	**Scientific Steering Committee Meeting**	

Annex 3: Participant Selection

Participants to the Workshop were selected following a process in accordance with IPCC policies and procedures, specifically Section 7.1 of Appendix A to the Principles Governing IPCC Work, Procedures for the Preparation, Review, Acceptance, Adoption, Approval and Publication of IPCC Reports. Criteria for selection were: (i) representation of a wide range of scientific, technical and socio-economic views and expertise; (ii) geographical representation; (iii) gender balance; and (iv) a mixture of experts with and without previous experience in IPCC.

The expert selection process occurred in five stages:

Stage 1 – Identification of experts

On 27 September 2022, IPCC member Government Focal Points and Observer Organisations were invited to submit nominations for experts to participate in the workshop. In line with the original proposal submitted to the Panel at the Fifty-Fourth (bis) Session of the IPCC (IPCC-54(bis)) to support the approval of the associated costs to the IPCC Trust Fund, experts were sought which spanned modelers and scenario builders from the Working Group (WG) I, II and III domains as well as scientists from a range of disciplines and scenario users in governments and other stakeholders. Relevant communities cited were:

- Modelers and scenario builders with expertise in the physical science, natural and socio-economic aspects;
- Experts on the physical science of climate change;
- Domain experts in adaptation and mitigation;
- Experts in biodiversity and ecosystem services;
- Scientists with relevant cross-cutting socio-economic perspectives, (e.g., economists, social scientists);
- Representatives of IPCC member Governments; and
- Stakeholders from the relevant United Nations Framework Convention on Climate Change (UNFCCC) constituencies.

A total of 387 experts from 88 countries were nominated for participation (168 (43%) nominees from developing countries or economies in transition), 219 (57%) from developed countries; 113 (30%) female nominees, 260 (70%) male nominees, 14 nominees did not state their gender).

Stage 2 – Evaluation of candidate's expertise

Scientific Steering Committee (SSC) members identified priority participants to the meeting. Their priority selections were consolidated by the WG Technical Support Units (TSUs).

Stage 3 – Identifying and filling major gaps

The SSC identified key gaps in expertise, geographic representation, gender balance and previous IPCC experience. Suitable nominated candidates to fill these gaps were proposed by the SSC with support from the WG TSUs. This list of potential participants was submitted to the WG Bureaux for their consideration. Reserve candidates for participation were also identified through this process.

Stage 4 - WG Bureaux advises on and agrees the first-round invitations

The WG Bureaux considered the proposed list and identified additions and substitutions, taking into account the criteria for selection, and reached consensus on the first-round of participants selected from the nominations,

The WG III TSUs then extended invitations on behalf of the WG Co-Chairs to selected participants on 10 January 2023.

A comparison of experts nominated by IPCC member Government Focal Points and Observer Organisations and experts included in the first-round invitation to participate in the Workshop is provided (Table 2).

Table 2: Comparison of experts nominated by IPCC member Government Focal Points and Observer Organisations and experts included in the first-round invitation to participate in the Workshop, including development status and gender

	Experts nominated by Governments and Observer Organisations		Experts included in first round invitation to participate in Workshop					
	Nominees		Invited nominees		Invited SSC and Bureau		Total invitees	
Developing and EIT	168	43%	39	46%	23	59%	62	50%
Developed	219	57%	46	54%	16	41%	62	50%
Female	113	30%	32	38%	10	26%	42	34%
Male	260	70%	53	62%	29	74%	82	66%
Total	**387**	**100%**	**85**	**100%**	**39**	**100%**	**124**	**100%**

A more detailed overview of the first round invitations by selection criteria is provided (Table 3 and Table 4).

Table 3: First Round Workshop Invitations by the World Meteorological Organisation (WMO) Region and Developed and Developing / Economies in Transition status

WMO Region	Developing / Economies in Transition	Developed	Total
Africa	23	-	23
Asia	19	5	24
Europe	1	35	36
North America, Central America and the Caribbean	3	13	16
South America	11	2	13
South-West Pacific	5	7	12
Total	**62**	**62**	**124**

Table 4: First Round Workshop Invitations by WMO Region and Gender

WMO Region	Female	Male	Total
Africa	8	15	23
Asia	6	18	24
Europe	11	25	36
North America, Central America and the Caribbean	5	11	16
South America	6	7	13
South-West Pacific	6	6	12
Total	**42**	**82**	**124**

Please note, citizenship is used for purposes of analysing participation by WMO region and development status.

Stage 5 – Iterative process for second- and third-round invitations

The places for those declining invitations or not responding were then filled by reserve candidates that met the same criteria for selection (i.e., scientific expertise, geographic representation, gender balance, mix of previous experience of IPCC). The WG Bureaux agreed to the invitation of each reserve candidate.

In order to ensure balanced representation from developed countries versus developing countries or economies in transition, at the point when there was no longer sufficient time for the processing of travel support from the IPCC Trust Fund for participants from developing countries and economies in transition, no further participant invitations were issued.

Including first-, second- and third-round invitations, a total of 136 individuals were invited to attend the workshop. 33 participants declined to attend and 9 accepted their invitations but subsequently were not able to attend. Of these 42, 29 were from developing countries or economies in transition and 13 were from developed countries; 12 were female and 30 were male.

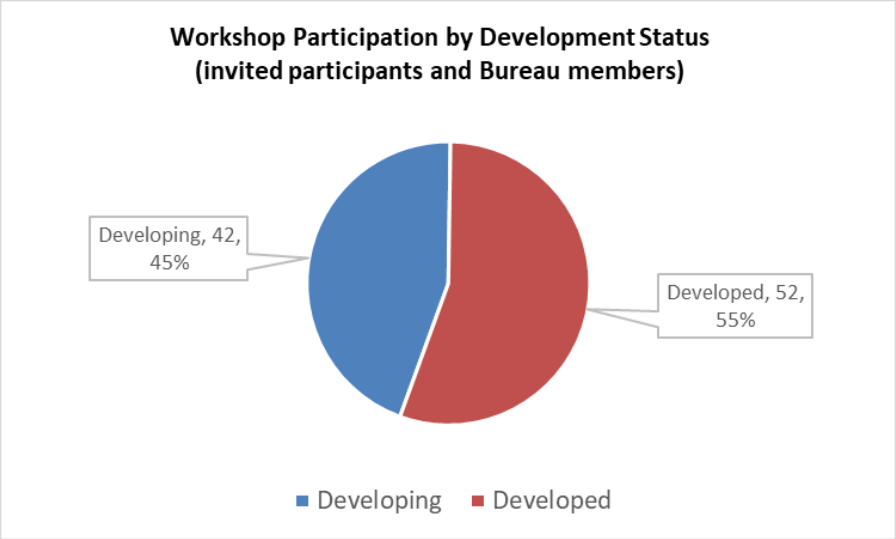
Table 5: Overview of invitees to Workshop who had accepted their invitation but subsequently could not attend

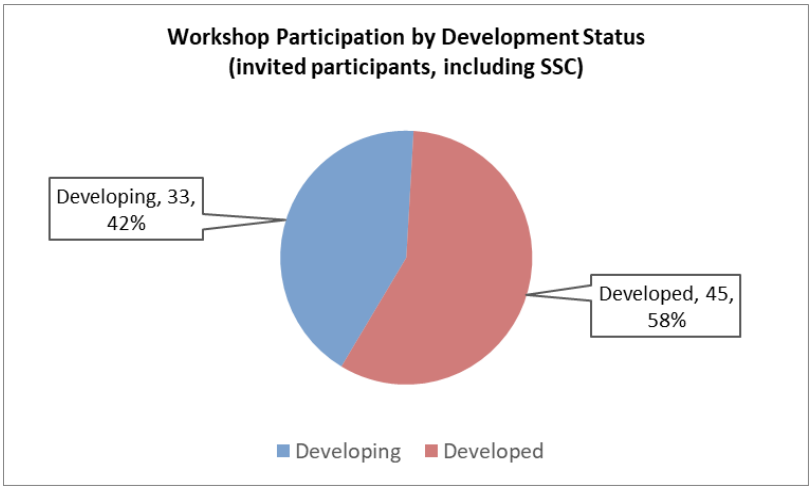
WMO Region	Invitees who declined invitation or accepted but subsequently could not attend	Of which Developing Countries or Economies in Transition	Of which Developed Countries
Africa	13	13	-
Asia	5	5	-
Europe	7	-	7
North America, Central America and the Caribbean	6	2	4
South America	8	8	-
South-West Pacific	3	1	2
Grand Total	**42**	**29**	**13**

A total of 94 experts from 47 countries attended the Workshop, including 78 invited experts (10 of which were members of the SSC) and 16 members of the IPCC Bureau. Of the total 94 participants, 42 (45%) were from developing countries or economies in transition, and 52 (55%) were from developed countries. 59 (63%) of the participants were male and 35 (37%) were female.

The break-down of participants across a number of criteria is shown in Figures 2 through 4. Tables 2 and 3 provide a break-down of participants by WMO region and (i) expertise assigned to an IPCC WG domain, and (ii) expertise broken down across a range of disciplines, areas of experience, or scenario user groups.

The full list of participants who attended the meeting is provided in Annex 4.





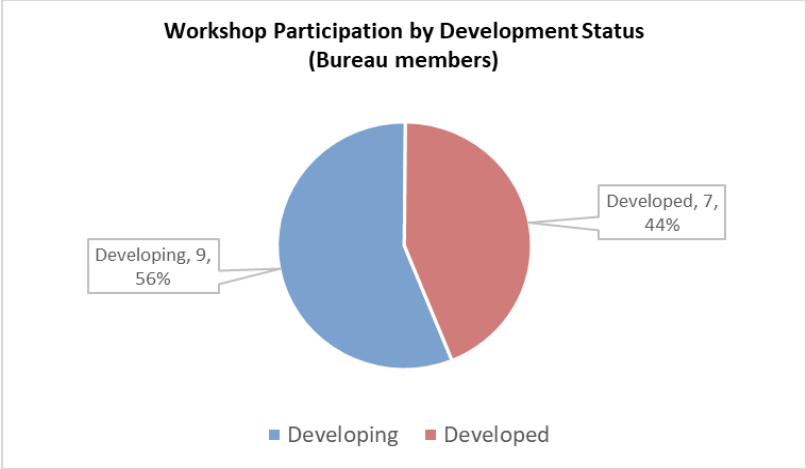


Figure 2 : Percentage of participants from developed and developing countries (including economies in transition)

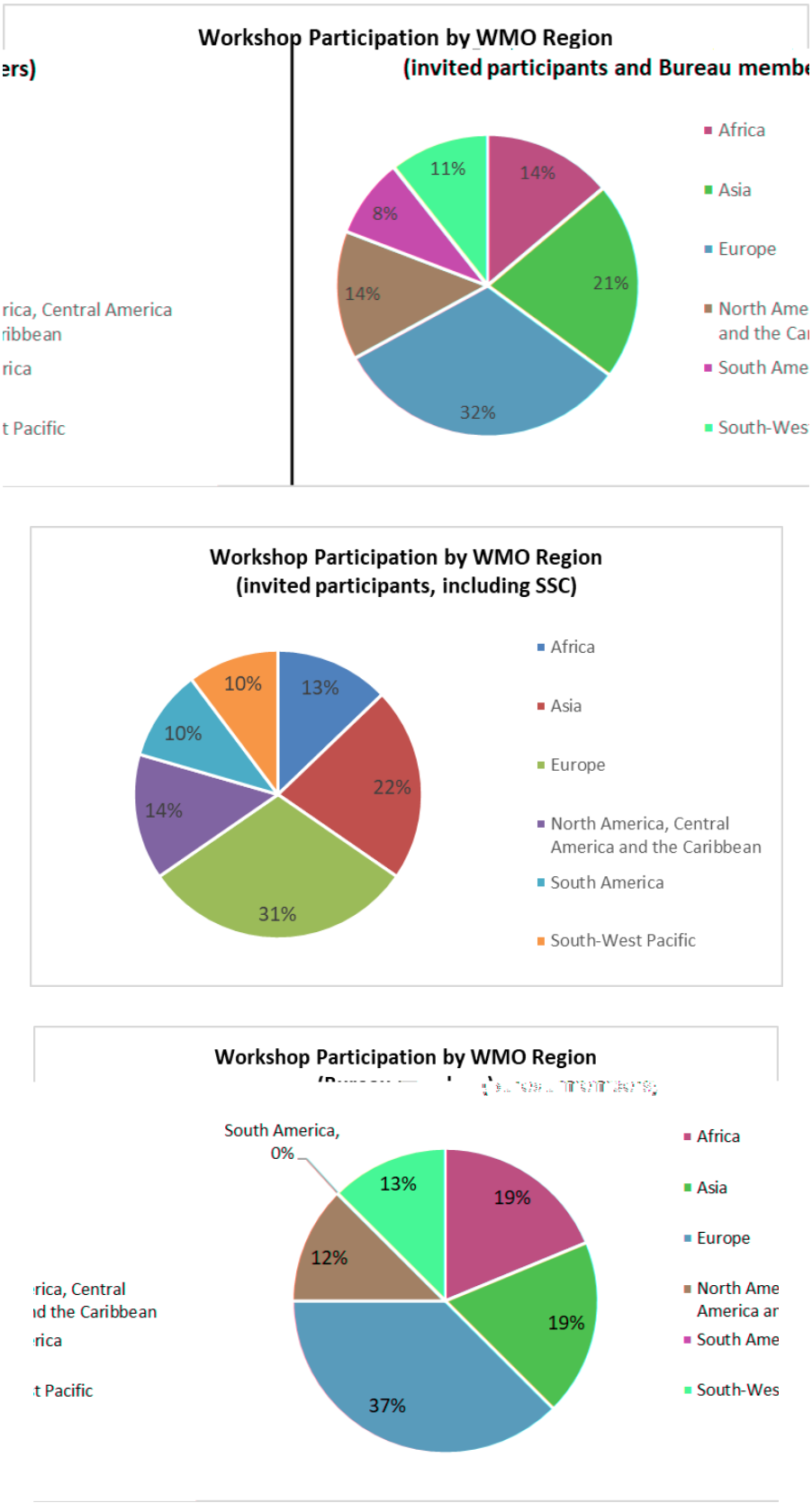
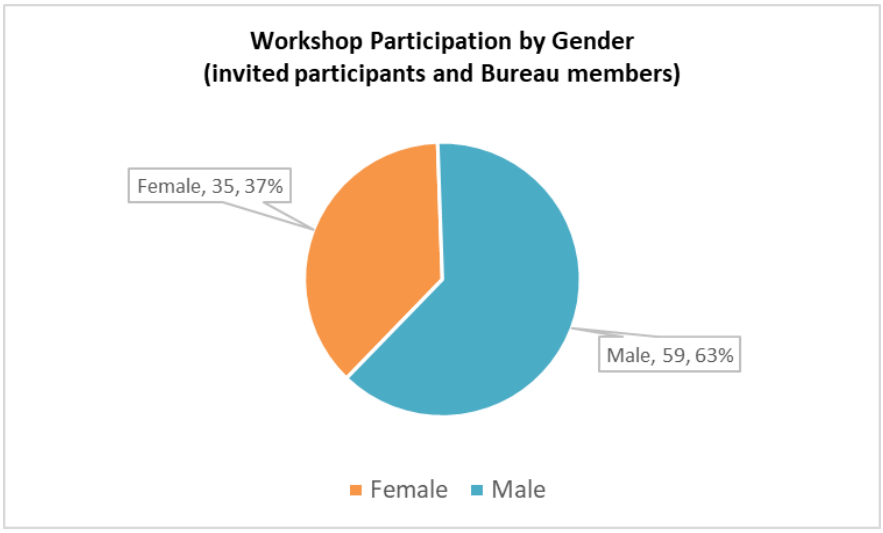
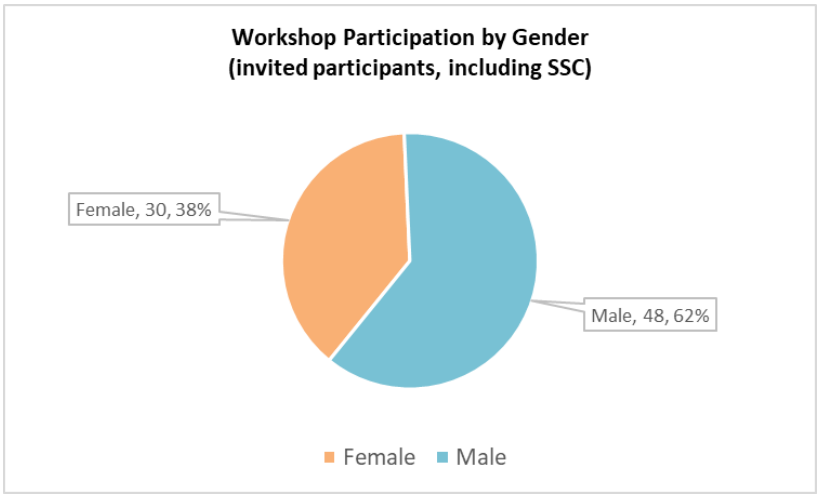


Figure 3: Distribution of participants across WMO regions





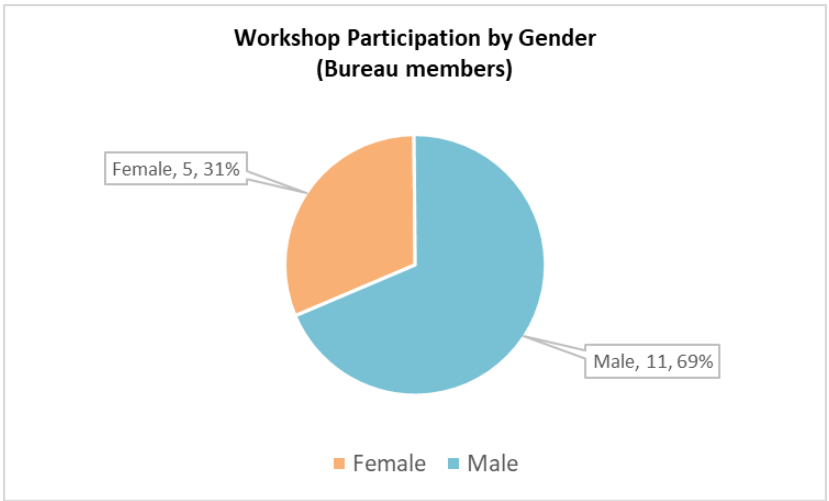


Figure 4: Gender balance of participants

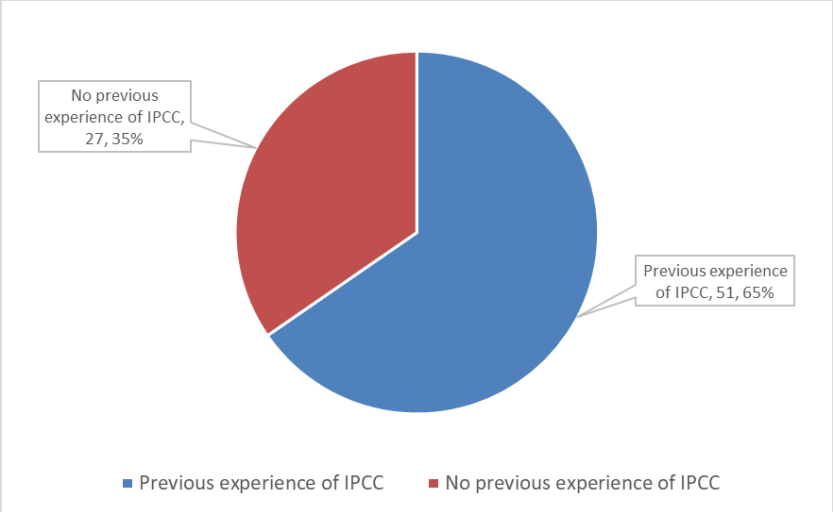


Figure 5: Workshop participation by previous experience of IPCC (includes invited experts and SSC, excludes current Bureau members)
Previous experience of IPCC includes as Coordinating Lead Authors, Lead Authors, Review Editors, or member Government Focal Points during the current or any previous IPCC assessment cycle, and Bureau members of previous assessment cycles.

Table 6: Workshop participation by WMO region and expertise as allocated to most appropriate IPCC WG domain (invited participants and IPCC Bureau members)

WMO Region	Expertise as allocated to most appropriate IPCC Working Group (WG) domain		
	WG I	WG II	WG III
Africa	3	5	5
Asia	5	5	10
Europe	11	8	11
North America, Central America and the Caribbean	3	5	5
South America	1	3	4
South-West Pacific	1	6	3
Grand Total	**24**	**32**	**38**

Table 7: Distribution of participants by WMO region and expertise

Expertise	Africa	Asia	Europe	North America, Central America & the Caribbean	South America	South-West Pacific	Grand Total
Non-modelling scientific expertise							
Biodiversity and ecosystem services	2	2	2	0	1	2	**9**
Climate change impacts, adaptation and vulnerability	6	6	8	5	4	3	**32**
Climate change mitigation	6	7	11	4	3	2	**33**
Cross-cutting socio-economic perspectives	1	4	8	2	1	4	**20**
Physical science of climate change	4	5	10	2	2	1	**24**
Sectoral expertise							
Energy	2	5	3	3	2	1	**16**
Human settlements and infrastructure	2	1	2	-	-	4	**9**
Land use	1	3	3	2	1	1	**11**
Materials and natural resources	3	2	-	-	-	-	**5**
Modelling expertise							
Modelling and scenario building (impacts, adaptation and vulnerability)	2	2	9	6	1	3	**23**
Modelling and scenario building (mitigation)	4	5	11	4	2	2	**28**
Modelling and scenario building (physical science of climate change)	2	4	7	1	1	1	**16**
Expertise as scenario end users							
Government representative	2	-	1	1	1	-	**5**
Non-governmental stakeholder	-	1	-	1	-	-	**2**

Annex 4: Participant List

Last Name	First Name	Country of citizenship / residence	Affiliation
Abdulla	Amjad	Maldives / United Arab Emirates	IPCC Bureau
Akimoto	Keigo	Japan	Research Institute of Innovative Technology for the Earth
Al-Hussein	Zeid	Jordan	University of Pennsylvania
Aldrian	Edvin	Indonesia	IPCC Bureau
Al Khourdajie	Alaa	United Kingdom / Syria	IPCC Working Group III Technical Support Unit
Alnory	Malak	Saudi Arabia	Ministry of Energy
Andrijevic	Marina	Croatia / Austria	International Institute for Applied Systems Analysis
Avila	Gabriela	Panama	Ministry of Environment
Bofana	José do Rosário	Mozambique	Catholic University of Mozambique
Boileau	Pierre	Canada / Kenya	United Nations Environment Programme
Bowen	Kathryn	Australia	University of Melbourne
Buhaug	Halvard	Norway	Peace Research Institute Oslo
Byers	Edward	Brazil / Austria	International Institute for Applied Systems Analysis
Calvin	Katherine	United States of America	National Aeronautics and Space Administration
Chacha	Nyangi	United Republic of Tanzania	Ardhi University
Cheung	William	Canada	Scientific Steering Committee-Workshop on the Use of Scenarios
Chow	Winston	Singapore	Singapore Management University
Clarke	Leon	United States of America	Bezos Earth Fund and University of Maryland
Connors	Sarah	United Kingdom / France	IPCC Working Group I Technical Support Unit
Denton	Fatima	Gambia / Ghana	United Nations University
Driouech	Fatima	Morocco	IPCC Bureau
Duić	Neven	Croatia	University of Zagreb
Ebi	Kristie	United States of America	University of Washington
Enoki	Takeshi	Japan	IPCC Task Force on Inventories Technical Support Unit
Federici	Sandro	Italy	IPCC Task Force on Inventories Technical Support Unit
Fischlin	Andreas	Switzerland	IPCC Bureau
Flato	Gregory	Canada	IPCC Bureau
Fradera	Roger	United Kingdom	IPCC Working Group III Technical Support Unit
Fuglestvedt	Jan	Norway	IPCC Bureau

Fujimori	Shinichiro	Japan	Kyoto University
Garg	Amit	India	Scientific Steering Committee-Workshop on the Use of Scenarios
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Annex 5: Acronyms

AgMIP: Agricultural Model Intercomparison and Improvement Project

AR5: Fifth Assessment Report

AR6: Sixth Assessment Report

AR7: Seventh Assessment Report

BOG: Break Out Group

CDR: Carbon Dioxide Removal

CMIP: Coupled Model Intercomparison Project

CORDEX: Coordinated Regional Climate Downscaling Experiment

CRDP: Climate Resilient Development Pathway

DACCS: Direct Air Capture with Carbon Storage

ESM: Earth System Model

GDP: Gross Domestic Product

GHG: Greenhouse Gas

GWL: Global Warming Level

IAM: Integrated Assessment Model

IAMC: Integrated Assessment Modelling Consortium

ICONICS: International Committee On New Integrated Climate change assessment Scenarios

IAV: Impacts, Adaptation, and Vulnerability

IPBES: Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services

IIASA: International Institute for Applied Systems Analysis

IPCC: Intergovernmental Panel on Climate Change

ISIMIP: Inter-Sectoral Impact Model Intercomparison Project

MIP: Model Intercomparison Project

NDC: Nationally Determined Contribution

NGFS: Network for Greening the Financial System

NGO: Non-Governmental Organisation

OECD: Organisation for Economic Co-operation and Development

RCP: Representative Concentration Pathway

SBSTA: UNFCCC's Subsidiary Body for Scientific and Technological Advice

SDGs: Sustainable Development Goals

ScenarioMIP: Scenario Model Intercomparison Project

SPM: Summary for Policymakers

SR1.5: Special Report on Global Warming of 1.5°C

SSP: Shared Socio-economic Pathways

SYR: Synthesis Report

TFI: Task Force on National Greenhouse Gas Inventories

TSU: Technical Support Unit

TG-Data: Task Group on Data

UNFCCC: United Nations Framework Convention on Climate Change

WCRP: World Climate Research Programme

WG I: Working Group I

WG II: Working Group II

WG III: Working Group III

WMO: World Meteorological Organisation