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Scenarios in IPCC assessments: lessons from AR6 and opportunities for AR7

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Scenarios have been an important integrating element in the Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC) in the understanding of possible climate outcomes, impacts and risks, and mitigation futures. Integration supports a consistent, coherent assessment, new insights and the opportunity to address policy-relevant questions that would not be possible otherwise, for example, which impacts are unavoidable, which are reversible, what is a consistent remaining carbon budget to keep temperatures below a level and what would be a consistent route of action to achieve that goal. The AR6 builds on community frameworks that are developed to support a coherent use of scenarios across the assessment, yet their use in the assessment and the related timelines presented coordination challenges. From lessons within each Working Group (WG) assessment and the cross-WG experience, we present insights into the role of scenarios in future assessments, including the enhanced integration of impacts into scenarios, near-term information and community coordination efforts. Recommendations and opportunities are discussed for how scenarios can support strengthened consistency and policy relevance in the next IPCC assessment cycle.

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INTRODUCTION

The Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC) has been characterised by an unprecedented level of coordination and integration across the three Working Groups (WGs) in the preparation of three Special Reports (SRs), as well as the three WG assessment reports and the Synthesis Report. Scenarios have also received much attention, for example in terms of the scenario characteristics and underlying assumptions and of how assessment findings related to scenarios are communicated, at each IPCC plenary session for the approval of the summary for policymakers (SPM) of these reports.

The term "scenarios" is used to represent many aspects of climate change at a wide range of temporal and spatial scales across the literature and in public dialogue. For the purpose of this paper, we define scenarios as internally consistent socioeconomic, emissions, and climate projections, and then discuss the various parts, uncertainties within and among the various components and how they relate to each other, and opportunities for enhanced developments, connection and coordination going forward. What is intended by 'internally consistent' is that the drivers of a scenario or pathway are internally consistent, co-varying or related to each other in a plausible way. In the literature, the terms pathways and scenarios are often used interchangeably, with the former more frequently used in relation to climate goals. The two terms are often used interchangeably in the literature and in discussions. It would be helpful to distinguish the two terms consistently going forward to avoid confusion. In the IPCC reports, to aid communication to a broader audience, the distinction has been made that the term 'scenario' should be used to characterise an outcome that clearly identifies an objective: a '1.5 °C scenario', a '2 °C scenario', a 'non-overshoot scenario' etc., while the term 'pathway' has been mostly used to describe the different ways (e.g. different combinations of technologies, of trajectories etc" to reach a specific outcome, or 'scenario'. Working Group I (WGI) primarily used the term scenarios and Working Group III (WGIII) mostly used the terms modelled emission and mitigation pathways. The Synthesis Report primarily uses scenarios when referring to WGI and modelled emission and mitigation pathways when referring to WGIII.

Stronger collaboration and linkages across communities were developed thanks to the cross-cutting nature of the SRs, and this continued in the writing of the three WG reports. A cross-WG coordination team on scenarios was put in place at the start of the WG assessments, as recommended at the IPCC Expert Meeting on Mitigation, Sustainability and Climate Stabilisation Scenarios held in 2017[1] and building on the strong cross-WG interactions established during the preparation of the SRs. The team included authors, Bureau members and Technical Support Unit (TSU) representatives from across the WGs. The coordination team provided support with coordination and sharing information on the use of scenarios across the WGs and discussed and advised on topics such as labelling, and the selection of core scenarios, in the drafting process to be consistently used across chapters and reports to assist integration and synthesis.

A dedicated session on the use of scenarios in AR6 and recommendations for AR7 was held at the second Scenarios Forum (https://scenariosforum.org) in June 2022 (The recording of Session 63 on the use of scenarios in the IPCC AR6 is available

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here: https://www.youtube.com/watch?v=9gCt67X2vyE). The session addressed the role of scenarios for the development of key findings from the WG reports and discussed knowledge gaps and challenges in the context of new and emerging research. Topics included a debriefing on the assessment of emissions, modelling of climate responses, risks and development pathways, on both near-term and long-term time scales, regional climate changes and impacts and costs and benefits of mitigation and adaptation in the context of sustainable development. This paper draws on the discussions and outcomes of this session. A variety of other activities, involving the IPCC directly or the scenarios community more broadly, have been organised for a comprehensive debriefing process from the AR6 and to lay the groundwork for preparations for the AR7:

- An ICONICS webinar was held in October 2022 on the communication of scenarios. This included outcomes of a project that is being undertaken by the WGI TSU in collaboration with the Reuters Institute for the Study of Journalism.
- Two side events were held at COP27—one on the WGIII assessment of scenarios and one on the use and communication of scenarios by policymakers
- A discussion on the assessment of scenarios in the AR6 took place at the 2022 Integrated Assessment Modelling Consortium (IAMC) conference.
- The IPCC Workshop on Scenarios was held on 25–27 April 2023.

This paper first summarises some key advances in the IPCC assessment and use of scenarios in the AR6, and then discusses challenges for the coordinated assessment using global scenarios. Then, building on lessons learned from the AR6 cycle, some key areas that would support significant progress in enhancing integration and a consistent treatment of scenarios in the assessment are discussed: these include the improved incorporation of impacts into scenarios; obtaining near-term information; establishing a community-led "live" scenario database; and, more resources dedicated to the coordination and support of the use of common scenarios in the IPCC assessment process. We finish with some concluding remarks including some suggestions for what could lead to progress in how scenarios are assessed by the next IPCC cycle for even more consistent, comprehensive and policy-relevant outcomes.

ADVANCES IN THE ASSESSMENT OF SCENARIO FRAMEWORKS

Scenarios are used in the IPCC assessments as a way of synthesising climate change information, as are global warming levels relative to 1850–1900, and cumulative CO_2 emissions. From a scientific perspective, scenarios aid consistency and comparability across and within assessments, with internally consistent assumptions and narratives. They also aid communication of the assessment, helping the wider public understand different possible outcomes of human-induced climate change. The underlying international research communities develop socio-economic scenarios of the drivers of change, harmonise and prepare forcing datasets, run earth system model climate projections to simulate and understand climate consequences, and model impacts and future risks of different possible future socio-economic development scenarios. The interconnected workflows, their timing, and the availability of published literature unavoidably relate to the timing and sequencing of the IPCC WG reports. This interconnected scenario 'landscape' is illustrated in Fig. 1 (IPCC AR6 WGI Fig. 1.27[2]).

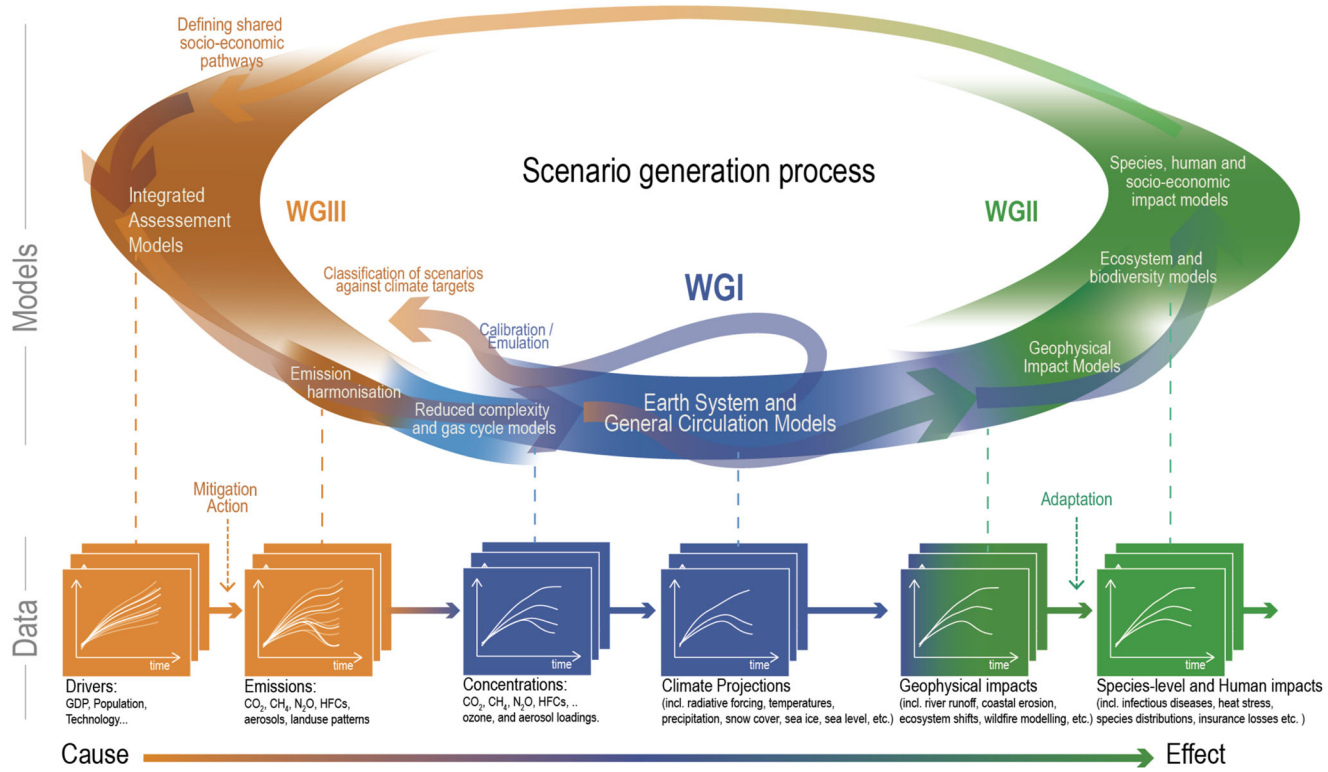

Fig. 1 A simplified illustration of the scenario generation process involving the scientific communities represented in the three IPCC Working Groups. The circular set of arrows at the top indicates the main set of models and workflows used in the scenario generation process, with the lower level indicating the datasets. (Fig. 1.27, in Chen, D., M. Rojas, B.H. Samset, et al., Framing, Context, and Methods. In Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Masson-Delmotte, V., P. Zhai, A. Pirani, et al. (Eds.). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 147–286. https://doi.org/10.1017/9781009157896.003 (2021).

WGI on the physical science basis of climate change considered a core set of scenarios based on the Shared Socio-economic Pathways (SSP) framework from climate models participating in the Coupled Model Intercomparison Project Phase 6 (CMIP6) of the World Climate Research Programme, according to the ScenarioMIP protocol[3]. The selection and prioritisation of scenarios for running Earth system and climate models made by ScenarioMIP is important for the IPCC assessments as these are necessarily based on the availability of scenario-based findings in the underlying literature. The report also considers regional climate modelling results forced by CMIP5 outcomes based on representative concentration pathways (RCPs). The core set of scenarios spans a broader range of greenhouse gas and air pollutant futures than in earlier WGI reports. Future climate change under a given scenario was assessed using multiple lines of evidence - process understanding and theory, paleoclimate records, observational products, emulators (i.e. simple climate models) and complex Earth system models (ESMs). The assessed ranges of future projections of global surface temperature, ocean heat content and sea level rise were narrowed compared to the underlying CMIP6 projections as a result of the assessment of climate sensitivity and observational constraints. Approaches to constrain the range of future projections of other variables or for regional changes remain to be further explored (see See Box 4.1 on ensemble evaluation and weighting[4]).

Early on, WGII on impacts, adaptation, vulnerability, and future risks evaluated by applying standardised climate and socio-economic scenarios, collecting chapter input and engaging with WGI and WGIII on touchpoints, developments, data, and integration opportunities. WGII identified a variety of issues and concerns, primarily with standardising socioeconomic projections, including fully and properly representing the very diverse impact literature, most of which is not based on scenarios, interpreting and implementing standardised scenarios, and standardised scenario shortcomings for representing local transitions and uncertainty relevant to exposure, vulnerability, adaptation, and risk. It is also important to note that, for the most part, due to the timing of the CMIP process and regional climate and impacts modelling efforts, the impacts literature available for AR6 is mainly based on CMIP5 and SRES-driven climate outcomes, temperature levels or hybrid CMIP5 RCP-SSP socioeconomic combinations, and not on CMIP6 nor the WGI AR6 assessed climate projections. Overall, WGII sectoral, regional and synthesis chapters assessed multiple lines of evidence, including that based on SSP and RCP scenarios of future socioeconomic and climate changes, sub-global to local scale analyses of future physical and economic impacts, and studies of current impacts or vulnerability. WGII also integrated, as far as possible, this assessment with a conceptual framing and evaluation of near-term transitions for climate-resilient development.

To facilitate a consistent assessment of impacts and its synthesis, WGII adopted common dimensions of integration, including linking to the WGI and WGIII assessments (see Cross-Chapter Box CLIMATE | Climate Reference Periods, Global Warming Levels and Common Climate Dimensions[5]). These included selected global warming levels (GWLs, e.g. 1.5, 2 °C), time periods, and regional climate variable ranges by GWL. WGII, with WGI input, also developed a translation resource to relate these to CMIP5 (RCP-based) and CMIP6 (SSP-based) scenario projections (and vice versa). This WGII approach is compatible with the WGI assessment of GWLs and the WGIII classification of global emissions scenarios relative to global average temperature levels. Chapters were encouraged to communicate impacts uncertainty for other dimensions, such as socioeconomic condition and adaptation potential, and SSP socioeconomic-based impacts literature was considered in WGII chapters together with non-SSP literature as available, relevant and appropriate.

While serving as an integrative dimension within WGII and across WGs, the assessment of impacts according to GWLs would need to include consideration of alternative potential local socioeconomic conditions and responses to assess vulnerability and risk. GWLs can provide information that can complement the insights from the specific pathways associated with global scenarios. In the Special Report on Global Warming of 1.5 °C, GWLs were successfully used across the report and were used in the categorisation of emissions scenarios by WGIII, to identify mitigation pathways consistent with, for example, 1.5 °C.

In AR6, Working Group III (WGIII) on mitigation of climate change assessed more than 2000 global scenarios. The emissions scenarios database that is assessed by AR6 WGIII is hosted by the International Institute for Applied Systems Analysis (IIASA, available here: https://data.ene.iiasa.ac.at/ar6/). For a more comprehensive WGIII assessment, the scenario database was extended to also include submissions from sectoral and national teams. Screening and curating data from scenario developers for inclusion was time-consuming and challenging but provided a more inclusive process and assessment. The completion of the WGIII assessment of scenarios was also under a number of time constraints due to interdependencies in the AR6 scenarios process, including the coordination with the WGI assessment via the use of climate emulators, the scenario vetting process, the use of the emissions scenario database in multiple places across the report, and the literature cut-off date for scenarios that could be assessed. Climate emulators (simple climate models) calibrated to the latest WGI assessment, were used to evaluate the climate outcomes of the scenarios which were subsequently categorised by GWLs, amongst other indicators. A cross-cutting assessment of avoided impacts and costs in relation to mitigation actions was also undertaken between WGII and WGIII.

COORDINATION CHALLENGES WITHIN THE IPCC ASSESSMENT

The coordination of scenarios during the assessment was faced with the proliferation of scenario concepts that were introduced during the AR6 cycle across the WGs. In addition to the SSP/RCPs, these include climate-resilient development pathways (CRDPs) in WGII, and in WGIII, shifting development pathways (SDPs), and illustrative mitigation pathways (IMPs), as well as the aggregation of findings from the bottom-up sectoral scenarios.

The timing of the CMIP process and regional climate and impacts modelling efforts have meant that the WGI assessment of possible climate outcomes from Earth system models was based on CMIP6 simulations, and thanks to the emulators use, so was the categorisation of the mitigation pathways according to GWL bins in WGIII. However, the literature available on regional climate change (WGI) and impacts and future risks (WGII) modelling was generally, almost exclusively in the case of the latter, based on CMIP5.

Thus, there are some fundamental issues in the timing of the development of the literature associated with each WG, with for instance WGI being able to evaluate climate projections that the impacts literature assessed by WGII has yet to adopt. Choices in the CMIP6 ScenarioMIP design were intended to provide continuity and comparability, to some degree, between CMIP5 and CMIP6 simulations (three CMIP6 SSP-based scenarios have the same end-of-century radiative forcing as CMIP5 RCP scenarios), however, incompatibility is challenging because of different generation climate models are used, with higher climate sensitivity in CMIP6-generation models, and the scenarios have differing effective radiative forcing and combinations of GHG and aerosol forcings[6]. The issue remains, however, that although much of the recent scenario-based impacts literature uses SSPs[7], some studies use older scenarios, e.g. SRES[8] and there have also been attempts to align the SRES-based scenario literature with the SSP/RCP-based literature[9], and, for various reasons, a significant portion of the impacts, as well as mitigation, literature is not based on global socioeconomic scenarios. Impact results,

particularly in large-scale quantitative impact studies, are also not consistently available for all scenarios. Similarly in WGIII, the majority of scenarios were based on SSP2. At the IPCC workshop on scenarios, considering equity and different growth paradigms, there was a recommendation to increase the variety of scenarios used beyond SSP2 to widen the representation of development objectives.

As noted above, socioeconomic projections coordination is also a challenge. With the diversity of WGII literature–scopes and types of information, it is difficult to fully, properly, and meaningfully represent that literature with standardised global socioeconomic conditions. Local transitions and uncertainty relevant to exposure, vulnerability, risk, and risk management strategies are particularly challenging. The challenges and limitations found by WGII will still exist for AR7, including for climate resilient development and local mitigation planning and strategy development. On the one hand, this highlights the need for developing alternative and complementary approaches to standardised global socioeconomic projections, especially to inform national and local planning. On the other hand, wider adoption of standardised scenario frameworks for impact modelling can aid global synthesis and characterisation of the diverse underlying literature.

The ongoing WGI-WGIII handshake during the AR6 meant that WGIII had access to initially one but ultimately three WGI emulators during the WGIII assessment. This was a process that brought many benefits and was widely acknowledged as an overall positive improvement in cross-WG collaboration. However, changes to various parts of the WGI assessment (e.g. assessment of the magnitude of radiative forcing and historical warming) resulted in the final hand-over and choice of the WGI emulators for their use in WGIII occurring not long before the WGIII report submission. Without the delays to the WGIII schedule that occurred due to the COVID-19 pandemic, the timing would have been even more challenging, if not infeasible.

With regards to the categorisation of the WGIII scenario ensemble and choice of the Illustrative Pathways as an outcome of the assessment, the timing was such that it meant (1) uptake of these scenarios in other chapters was lower than hoped for, and (2) changing data meant that figures and text based on the scenarios, including alignment with the WGI assessment, meant that re-calculation was needed several times between Second and Final Government Drafts.

PROGRESS IN SCENARIO FRAMEWORKS THAT WOULD SUPPORT FUTURE ASSESSMENTS

The enhanced integration of scenarios into impact studies

The assessment of impacts and possible future outcomes, including risks, has been strengthened and has become more comprehensive in the WGII report, based on a broad range of literature and different lines of evidence, of which scenarios are but one. There are opportunities to explore how to further integrate and bring together findings from the disparate impacts literature. These opportunities include a more comprehensive and consistent use of scenarios as well as other dimensions of integration, notably different levels of global warming. While an assessment that uses approaches other than scenarios has advantages, it has led to a weaker connection to the development of global narratives and the assessment of global scenarios in the other WGs.

An integrated approach to assess future impacts and risks needs to bridge across scales; there is a tension between undertaking a global assessment, where scenarios are a key tool, and impacts, risks, and adaptation responses that occur mostly at a local level. There is a need to integrate the “systemic approach” that is applied in the scenarios with granular information which comes from the bottom-up impacts and mitigation analyses that could be connected through narratives (e.g., sectoral or national SSPs). There is an opportunity for the research community to develop approaches to translate information across these scales, for example by mapping the impacts literature based on climate projections to common climate dimensions. There has been limited progress on this translation across scales. One limitation is that local, bottom-up studies are often based on understanding current exposure and vulnerability, and then inferring that risk will be higher in the future because climate hazards will increase. This approach doesn’t account for possible future changes in vulnerability but has the advantage of being grounded in observed experience. It is hard to synthesise this kind of work with scenarios since scenarios or assumptions about the future of society are not used.

Developing aggregated indicators of impacts, future risks, and adaptation measures for their assessment against different mitigation and adaptation implementation futures, as well as against the implementation of SDGs, would inform policy development integrating mitigation and adaptation to inform national and local planning and risk management. The assessment of aggregate benefits from avoided impacts expressed in terms of avoided economic damages in the context of mitigation pathways is another area where greater integration across WGII and WGIII would be important, also including well-being, welfare and other non-monetary aspects.

Impacts model intercomparison projects face methodological difficulties since results are often difficult to compare for estimating economic impacts or avoided impacts for benefit-cost analysis[10]. Progress is urgently needed to develop community standards for impact definitions and reporting to facilitate more systematic comparisons and also better connect, or integrate, impacts with socio-economic scenarios assessed by WGIII. Consistency is also needed in terms of the use of common baselines and how uncertainties are characterised to be able to integrate socio-economic factors into impacts and risk modelling and have a consistent and policy-relevant assessment that cuts across WGs II and III.

The integration of impacts with socio-economic scenarios and the assessment of policy options would be a novel, policy-relevant area to explore. Including impacts as part of the SSP narratives would be an important step forward in integration though this is limited to a large degree by the time delay that results from the current practice of first downscaling climate outcomes before estimating impacts. However, weaving impacts right into the global-model workflow should be explored, as some modelling centres are starting to do. Machine learning and modern workflow developments are opening doors here, as are the high-resolution global simulations that would be needed and that are becoming available.

Opportunities for better integration include:

- to include impacts directly in the development of the SSP framework narratives, including outcomes from coordinated impacts modelling exercises (e.g. ISIMIP - The Inter-Sectoral Impact Model Intercomparison Project - or similar) as components in the development of drivers for climate model simulations,
- to undertake coordinated model intercomparisons with the inclusion of different impact scenarios, as done with CMIP for climate scenarios;
- detailed impacts and risk analyses could be complemented by exploring a far broader range of possible outcomes and the related uncertainties at regional and smaller scales by using impact emulators, or simplified modelling or analytical approaches to estimate impact functions and aggregate impact-driver relations that would be relevant to assess climate policy options and possible climate outcomes;
- Integrated assessment models (IAMs) could be run with and without impacts for a broader assessment of sectoral impact

modules and new analyses of scenarios in terms of impact outcomes.

Near term information

The SSP–RCP scenario framework has generally focused on addressing scientific questions in the context of long-term climate goals and forcing covering the 21st century, as well as some highly idealised and simple extensions beyond that in particular to address committed, multi-millennial changes in the climate system. However, the rapidly increasing focus of policy on reaching net zero emissions and near-term action means that there is an urgent need for near-term (up to 2040) information that includes the treatment of uncertainties in socio-economic projections, potential risks and climate. This will be important for understanding potential risks and opportunities for adaptation and mitigation actions in the near term, but also on longer time horizons, as well as exploring recent socio-economic information, for example covering changes in emissions during the COVID-19 pandemic. Very few studies combine climate projections with socio-economic uncertainties and the assessment of near-term policies. To fully characterise climate outcomes in the near term, more information is needed on uncertainties from internal climate variability and in forcings from natural and anthropogenic aerosols, in addition to socio-economic uncertainties in emissions and vulnerability. The combined uncertainty information may also have implications for monitoring progress and the global stocktake.

A community-led "live" emissions scenario database

A core recommendation that has emerged given the AR6 experience is to establish a community-led 'live' database, distinguishing the scenario database development from the assessment of the scenario-based literature. With a continuous community-based process preparatory part of the work can be completed in advance of the assessment timeline, and earlier within it. A live database would have the advantage that high-quality and the most up-to-date information would be available more immediately and could be permanently public for use by communities at all times, as opposed to waiting for periodic data releases. Subsequently, only incremental updates would be needed on a regular basis in preparation for the AR7, reducing the level of activity that needs to take place in parallel with the assessment. Such a community-driven database would need a framework and formalised process to enable community participation and enhance its legitimacy, in addition to its current infrastructure which would also require additional development. Vetting and peer review of the submissions could be undertaken continuously during the assessment process by peers in the community, as well as co-development of automated checks and processes for quality control that already exist but could be expanded.

There have also been suggestions to extend the database to include climate emulators and potentially impact emulators with regional resolution, to facilitate integration in the assessment and community studies more broadly. Other areas would include how new information on disruptive technology changes are addressed and taken into account with submissions on a more rolling basis. Monitoring to keep track of what integrated assessment modelling groups are working on would be helpful, for example in the context of the AR7 Special Report on cities and climate change, to know whether urban emissions scenarios would be vetted and included in time for supporting that assessment.

A CONSISTENT ASSESSMENT OF EMISSIONS, CLIMATE AND IMPACT SCENARIOS

A key goal of the scenarios framework is to facilitate the assessment of scientific research, and IPCC is the primary assessment body in the climate area. The scenario activities in AR6 give experiences that can form a basis for improvements in AR7, stimulate new research and broaden the communities that are contributing to the developments and knowledge base assessed by the IPCC. Recommendations for improved coordination and integration are aimed at supporting the identification of knowledge gaps and supporting progress for a policy-relevant assessment.

The use of future narratives that are shared across WGs and their underlying communities is a starting point for the integration of climate information to address systemic changes and the human dimension of climate change and to capture the full breadth of uncertainties that are relevant to assess future risk together with adaptation and mitigation options. The use of a coordinated set of narratives and scenarios across the WGs would strengthen the consistency of the assessment and support a more integrated assessment of collective progress in emissions reduction, for example including more scenario outcomes close to current implemented policies or those estimated from Nationally Determined Contributions (NDCs) and would also strengthen the synthesis of the AR7 assessment.

Overshoot, or exceedance and return, of a level of global warming, has been addressed in each WG in the AR6 though with slightly different perspectives, despite a commonly agreed glossary definition. An integrated assessment is needed going forward of scenarios that address different levels of exceedance and then return to a level of global warming, particularly for 1.5 °C global warming, including consideration of likelihood of exceeding, and feasibility, as well as possible non-linearities in the response. Another policy-relevant question is the relationship between low greenhouse gas emission pathways, and the more integrative climate resilient development pathways, assessed in WGIII and WGII respectively, and how these relate to climate outcomes based on the SSP scenarios framework, assessed in WGI.

Consideration of alternative and complementary approaches to global socioeconomic projections is also encouraged, as done so particularly by WGII, addressing some of the limitations of standardised scenario frameworks in relation to assessing context-specific aspects such as vulnerability, exposure, and the needs of local planners for climate resilient development and local adaptation and mitigation planning and strategy. For instance, opportunities of using GWLs or other dimensions of integration, or local transition analyses that account for local uncertainties, constraints, conditions and opportunities.

Debriefing activities from the AR6 have highlighted critical issues of timing and sequencing of IPCC reports, application of different scenario-related concepts, how work undertaken to produce the IPCC assessment is linked to and has implications for the underlying research communities, as well as the holistic approaches that are sought to deliver policy-relevant scenarios-based information. In general, more coordination is needed, earlier and more formalised within the IPCC, and also within and across communities independently of the IPCC. It is imperative not to lose the institutional memory of those authors, which includes Bureau members and TSU staff who were deeply involved in scenario coordination during the AR6, alongside the importance of bringing in perspectives from experts who haven't participated in IPCC before. There is a chance to make a step change for the next and future IPCC assessments in achieving an integrated and consistent assessment of scenario-based knowledge about climate change.

LOOKING FORWARD TO THE AR7

In addition to some of the more integrative scientific issues described so far, together with ways to enhance and structure activities in the underlying community, reflections on the AR6 have highlighted how important the IPCC assessment process and

management itself are in supporting the assessment of scenarios across WGs. First and foremost, more formalised coordination together with supportive leadership is needed to explore and guide the adoption of a scenario framework in the assessment from the very start. Planning for the assessment of scenarios should be formally built into the AR7 from the start and integrated into the assessment timeline. The start of the assessment would benefit from coordination meetings such as an IPCC Workshop or Expert Meeting with the associated documentation and reporting. A process to provide regular updates from the community could also be envisaged, at the beginning of the AR7, feeding into future IPCC assessments more effectively.

The IPCC is encouraged to consider adjusting the WG assessment schedules to facilitate integration and consistent treatment of scenarios across WGs and acknowledging cross-WG interdependencies. The schedules of the WG reports in AR6 were too close and constrained in terms of coordination, for example, the capacity for WGII to build directly on the WGI Atlas and for WGII and WGIII to integrate mitigation, adaptation, and development perspectives to assess climate-resilient development. The WGI Atlas is an interactive tool that is part of the WGI report to explore and analyse assessed datasets, including regional synthesis for climatic impact drivers (See: https://interactive-atlas.ipcc.ch/). Greater integration of the climate-resilient development pathway (WGII) and SDPs (WGIII) concepts would be highly policy-relevant, particularly if they could be translated or applied as policy development support tools and indicators to track and synthesise current and pledged implementation. Coordination across WGs is needed to consistently address key policy questions that have to some extent been addressed in WGIII but could not be systematically explored using scenarios in WGI/II. These include for example the impacts of overshoot, the consequences of delayed action, differential impacts between different increments of (peak) warming, different land use futures, etc. The assessment of scenario-based information is inevitably a parallel process with calls to the community to submit scenarios to the database and handshakes between the assessment in one WG with that in another, as experienced when WGIII had to update the scenario classifications used by its various chapters, each time WGI emulators were updated.

This article is primarily about the process of scenario development and integration across WGs, as discussed at the Scenarios Forum session in 2022, rather than about the substance of what should be in the future range of scenarios. The latter has been discussed at the subsequent IPCC workshop on scenarios and is an ongoing discussion in the community and amongst stakeholders and we expect that this will be addressed as a part of the scoping. Building on the discussions at the Scenarios Forum 2022 session summarised in this paper, recommendations for the AR7 and future assessments are as follows:

1. The establishment of a *'live' community-led scenarios database*, ideally an extension of the current database, coordinated by a network of institutions. The database would include submissions beyond current scenarios and also seek to include emulators of climate model outcomes and impacts. This would require an expanded coordination effort with both scientific and technical oversight, including overseeing the implementation of a community vetting process and maintaining a link to the relevant underlying scientific communities, as well as the IPCC. Leveraging existing structures, both in terms of infrastructure and coordination mechanisms, would make the most sense; examples include building on the emissions scenarios database hosted at IIASA and leveraging the ICONICS (International Committee on New Integrated Climate Change Assessment Scenarios) and IAMC (Integrated Assessment Modelling Consortium) communities.
2. Fostering advances in scenario frameworks and science, including the stronger *integration with impacts studies and understanding future risks*, as well as attention to near-term information through international meetings, such as the IAMC annual conference and the biannual Scenarios Forum, and community coordinated activities.
3. Stronger *coordination of schedules* between research community initiatives and the development of the IPCC assessment schedules, both in terms of literature cut-off dates and also the timing of key milestones in the assessment to allow for sufficient time for information to be taken up in the assessment and transferring the latest outcomes of the assessment across the WGs. This not only includes scenario development, but also, for example, coordinated modelling activities like CMIP, and the development of observational products. For scenarios, following Fig. 1, the optimal 'flow' from one WG assessment to the other is not straightforward, given the multiple inter-connections, loops, iterations, and different steps in the workflow to develop, run and assess scenarios.
4. *Formalised coordination* and oversight of the assessment of scenario-based information in the IPCC could be an effective mechanism for providing more support for both authors and the Bureau in the implementation of a consistent assessment process, as well as formal recognition for the substantial efforts that scenario processes require.

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A.P. and J.S.F. developed the manuscript and wrote the first draft. All authors wrote, read and approved the final paper.

COMPETING INTERESTS

The authors declare no competing interests.

ADDITIONAL INFORMATION

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