Forum on Scenarios for Climate and Societal Futures

International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria
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Meeting Report

December 2022

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SCENARIOS FORUM 2022

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Table of Content

Background and meeting goals

Development and application of new integrated climate change scenarios began in the early 2010s. The process involved a community effort to produce alternative future climate change outcomes and societal development pathways, and then integrating them to develop scenarios useful for different research communities to investigate future risks as well as the effectiveness of mitigation and adaptation response options. In terms of future climate outcomes, climate models simulated a set of alternative futures as part of the fifth Coupled Model Intercomparison Project (CMIP5) activity, driven by a range of alternative projections for greenhouse gas concentrations, aerosols, and land use based on the Representative Concentration Pathways (RCPs). As part of CMIP6, these projections were based on both the Shared Socioeconomic Pathways (SSPs) and RCPs. The SSPs, a new set of societal futures, were developed over the past decade; integrated assessment models then produced global energy, land use, and emissions scenarios based on the SSPs. The integrated scenarios are increasingly being applied to different sectors and regions. For example, large-scale impact assessments of health, agriculture, water, and ecosystems used CMIP5 and CMIP6 climate projections with information about future societal capacities and vulnerabilities from the SSPs. In addition, SSPs were extended to the regional level to inform region-specific assessments. Use of the SSPs is expanding beyond the climate change community to facilitate work on sustainability.

The ambition of the SSPs to provide a broad coverage of societal futures (e.g. including for example future projections and narratives on economics, demographics, human behavior, governance, institutions, energy, technology, greenhouse gas mitigation, land use, biodiversity, vulnerability and resilience, inequality) combined with the wide variety of applications of the SSP-RCP framework (e.g. mitigation, risks, adaptation, sustainability) has led to a very broad and diverse set of communities involved in the development, application, and use of climate and societal futures. This includes a variety of scientific disciplines, along with developers and users with different backgrounds and needs, like scientists, businesses, policy- and decision-makers, and advocacy groups.

To facilitate the wide variety of activities taking place related to the scenario framework, the first Forum on Scenarios for Climate and Societal Futures was organized in Denver in 2019, bringing together researchers to discuss their experiences, progress, and plans. The first Scenarios Forum facilitated integration across the climate modeling, integrated assessment, and impacts, adaptation, and vulnerability communities, as well as with additional relevant research communities including future studies, development economics, and governance. The first Scenarios Forum summarized the state of the use of the Scenarios Framework for Climate and Societal Futures and identified several next steps for the scenario process, synthesized in a paper by O'Neill et al. (2020).

During the first Scenarios Forum, it was decided that regular bi-annual Forums on Scenarios for Climate and Societal Futures would be beneficial to building an interdisciplinary community of scenario developers and users and as a platform to make progress on the Scenarios Process itself. However, since the first Scenarios Forum, the COVID-19 crisis reduced options to organize a second Scenarios Forum in-person, which was considered important for community building. Therefore, the second Scenarios Forum took place in June 2022 in Laxenburg, Austria.

The goal of the second Scenarios Forum was to bring together the diverse set of communities using or developing scenarios in climate change and sustainability analysis to:

- exchange experiences, ideas, and lessons learned;
- identify opportunities for synergies and collaboration between communities;
- reflect on the use of scenarios; and
- identify knowledge gaps for future research.

By taking stock of recent progress, reflecting on the use of scenarios in environmental assessments and policy-making, and facilitating further scenario-related research, this meeting informed the use of scenarios in the preparation for the next cycle of IPCC Assessment Reports (AR7) and helped ensure a research base sufficient to inform future national and international assessments as well as policy initiatives, including the implementation of the Sustainable Development Goals (SDGs).

An important, but not exclusive, focus of the meeting was on the ongoing process of developing, updating, and using the so-called “Scenarios Framework” for fostering integrated climate change and sustainability research.

The Forum addressed the critical need for researchers from various disciplines to come together to share their experiences, progress, and plans. It provided a means of promoting integration across the climate modeling, integrated assessment, and impacts, adaptation, and vulnerability communities, as well as with additional research communities in the social, natural, sustainability, economic and cultural sciences. It also aimed to improve linkages among the research, assessment, practitioner and policy communities.

The main body of this report provides a description of the meeting and the main outcomes of the parallel and plenary sessions. More detailed information is contained in a series of appendices that include the participants and agenda, reporting from the parallel session organizers, and a summary of research gaps and needs. The agenda and video recordings of the Scenarios Forum sessions are available at www.scenariosforum.org.

Outline of the meeting

The Forum was organized primarily through a bottom-up approach, to best reflect current activity and interests in the diverse communities mentioned above.

The meeting was hosted by the International Committee on New Integrated Climate Change Assessment Scenarios (ICONICS), which put out a Call for Organizers early 2020, to request interest from potential organizers for the second Scenarios Forum. This call received one application, from IIASA, after which it was decided to organize the Scenarios Forum in Laxenburg, Austria. The organization was through a Scientific Steering Committee (SSC) formed for the purpose of organizing the second Scenarios Forum. The SSC was constituted in dialogue with the ICONICS Steering Committee once the broad outlines of the meeting and its location and date were settled. Periodic updates to, and feedback from, the ICONICS Steering Committee occurred during regular ICONICS conference calls and to the broader ICONICS research community during ICONICS webinars.

After postponing the original meeting from 2021 to 2022 due to the COVID pandemic, a Call for Sessions was advertised widely in October 2021. Out of 100 submitted session proposals, the Scientific Steering Committee selected 55 candidate sessions. That list was used to set up a Call for Abstracts in January 2022. This attracted 540 abstract submissions. A final set of sessions and abstracts were selected through an interactive process involving the SSC and session organizers (during which some sessions did not attract enough quality abstracts and had to be cancelled/merged, while others were allocated multiple 90-minute time slots). Plenary sessions were scheduled by the SSC to address key meeting-wide issues, including the role of scenarios in the IPCC and other global assessments and frontier research topics around scenarios.

Participation in the meeting was open to everyone who registered and included both online and on-site attendance, with live streaming of plenary and parallel research sessions, with the option to ask questions via the online platform, IIASA Connect (commenting area and session specific discussion documents). Workshop sessions were not live-streamed, only included some online participation of remote panelists, and are published on the Scenarios Forum website with the exception of the Finance Session (#10) that took place under Chatham House rules. For on-site participation, a waiting list process was set up to ensure that attendance would not exceed the capacity of the location. In total, there were more than 500 registered participants (309 in person, 197 online; Appendix I) from 33 (28 for in person participants) countries. Of those, 195 (40%) were females (118 on-site, 77 digital) and 296 (60%) males (186 on-site, 110 digital).

The digital meeting took place on the IIASA Connect platform and started two weeks before the on-site event. All presenters were asked to record their presentation and upload

it to the online conference platform, and poster presenters to post the virtual version of their posters. In the period 7-17 June, remote and on-site participants were able to use the conference platform for the following activities:

- Watch recordings of all presentations
- Read the posters
- Ask questions to the presenters
- Discuss the topics of the sessions with the presenters and organizers

The on-site meeting was held at the International Institute of Applied System Analysis (IIASA) and the Laxenburg Conference Center in Laxenburg, Austria over a 3-day period. The agenda (Appendix II) included an opening plenary session introducing the meeting and provided an overview of the current status of scenario frameworks and their use. It was followed by a second plenary on the role of community scenarios in IPCC and other global assessments. The remainder of the meeting included 43 parallel sessions on a wide range of topics. Two additional plenaries on days 2 and 3 featured talks on frontier topics in scenario-related research. A final plenary for synthesizing lessons learned and the status of scenario process closed the conference on day 3.

Several steps were taken during and following the meeting to collect input from participants to inform the meeting conclusions and assess the format of the meeting and whether its goals were met. Session organizers were asked to provide written summaries of key session outcomes (see Appendix V for the questionnaire and responses from each session). Both during the digital period and the on-site meeting, participants were requested to write questions and share thoughts on the discussion documents that were available for each session on IIASA Connect. The closing plenary consisted of two panels, both initiated by brief statements by panelists spanning a range of disciplines and communities. The first panel focused on insights from key-session topics during the Forum while the second panel consisted of representatives from active institutions in the Scenarios Process (i.e., the process to develop the Scenarios Framework). In October 2022, the Forum SSC hosted an ICONICS webinar to present the main conclusions in this meeting report and collect more participant feedback in online breakout sessions. These closing panels, the webinar, and the accompanying discussions with the participants offered different perspectives on key takeaways and possible next steps. The SSC drew on all these materials, in addition to their own experiences at the Forum, to produce this report.

Reflections on the meeting format

The hybrid meeting format was experimental, especially the posting of recorded presentations before the actual meeting. The main aim was to allow remote participation in a meaningful way with quality inputs into the discussions by those who were not on-site. Moreover, as the physical Forum had seven parallel sessions, even on-site participants

could participate in only part of the meeting, so the hybrid format allowed them to pre-watch presentations. While this format was found useful by 60% of the participants in the evaluation-survey (see below), it also required a large effort from the organizers to collect and organize the presentations on the online platform and from the speakers to pre-record their work. Written interactions on the online platform were rather limited during the two-week period before the Forum, but we don't have any information on the extent to which presentations were viewed. One session organized two preparatory online workshops from which the discussions in the actual physical session benefited greatly, according to the organizers.

The hybrid organization during the three days of the Scenarios Forum technically worked very well. Participants mentioned especially that the camera view on the audience during the Q&A sessions gave them a stronger connection with the room. However, the number of online questions was rather limited, potentially due to the limitation that online questions had to be asked in writing. In sessions with remote speakers, there was not much technical advantage of playing recordings of their videos over live presentations by the speakers. The latter was more interactive, but technologically more challenging and not possible in all rooms.

Regarding the physical meeting, the duration of three days worked well to schedule the many sessions. However, participation declined during the last afternoon and the large number of parallel sessions appeared to have increased the perception of the Scenarios Forum as "conference" where numerous participants popped in and out rather than a full meeting to be attended from beginning to end.

Meeting outcomes

Main outcomes of parallel sessions for Scenarios Framework

Reports from session organizers were received from nearly all the 43 total sessions. The common themes and main outcomes for the Scenarios Framework are summarized briefly below, organized into four topics (key highlights/advances, hindering features and practices, suggested improvements/extensions, follow up activities) based on the six questions to which session organizers responded. The questionnaire and full reports from sessions are included in Appendix IV and a structured collection of responses in Appendix III.

Notable advances and key-features of the Scenarios Framework

Session organizers generally concluded that the SSP-RCP Framework continues to be widely used throughout the climate and sustainability research communities. It is also beginning to be applied in communities not as frequently represented in the past. Examples are climate finance, the rich development of sub-global extensions to the SSPs, the use of scenarios in ocean research, and the emerging development of broad sustainable development scenarios.

The Scenarios Framework has been successful at enabling the types of applications for which it was designed, although limitations to the design are becoming more apparent. The Framework supports both research and assessment and appears to facilitate both activities well. Research work is supported by key aspects of the framework, such as the matrix architecture, sufficiently generic global narratives and quantifications, and the availability of climate model output information. Despite their background as scenarios for climate-energy-land modelling, the large and consistent set of narratives as well as quantitative projections of population and demographics, education, and economic development enables the use of the SSPs for other purposes. This aspect is widely appreciated by the research community. Missing aspects in the original SSPs (such as digitalization, fisheries, agriculture, conflict) have led to the development of extensions, interpretations, and the development of new knowledge that can be included in the next generations of community scenarios. The use of the framework has successfully transitioned out of the integrated assessment modeling community and is finding traction in a broader, more diverse community of global change researchers and practitioners.

In addition to research, the framework is facilitating assessment by providing a literature base with common assumptions about future societal and climate conditions. It assisted in drawing conclusions in the IPCC 6th Assessment Report and was drawn on to support the early assessments of the Intergovernmental science-policy Platform on Biodiversity and Ecosystem Services (IPBES). However, there remains an emphasis on only the climate system in many assessments despite increasing evidence (supported by the SSP framework) that socioeconomic factors are often more important than warming levels in determining risks. In the case of WGII of AR6, it remains unclear exactly which aspects of the scenario framework may have hindered its broader use in the assessment, because several individual chapters incorporated SSPs explicitly. It is possible that an obstacle is that a substantial amount of risk literature uses other scenarios or does not draw on scenarios, despite available solutions such as mapping other scenarios to the SSP-RCP Framework. The concept of climate resilient development pathways provided a more useful approach to considering potential futures in the context of decision-making for some WGII chapters; this should be considered in further scenario development.

Hindering features and practices

Several features of the Scenarios Framework, or practices in its use, emerged among user communities that may hinder its use in several situations. Limiting features include the lack of centrally available sub-national details, or sectoral details (such as transport, fisheries, agriculture) in the SSPs, both in terms of narratives and quantifications. Feedback from the session organizers shows a tension between missing perspectives, such as post-growth, gender diversity, or more diverse worldviews, and limitations to the number of scenarios that can be included in studies. The current SSPs include both “not enough” as well as “too many” different perspectives at the same time.

A complex feature is the timeline of information exchange between research communities during the parallel process and (IPCC) assessments. There is always at least one aspect of the SSP-RCP Framework in-between update cycles during an assessment (e.g., outdated socioeconomic scenarios, outdated climate model outputs, or outdated extended scenarios), leading to the suboptimal use of scenario information and/or assessment of outdated scenarios.

The emphasis on plausible combinations of SSPs and RCPs is perceived as limiting in participatory regional/local analysis. Combinations that seem unlikely at the global level can still be useful and insightful for smaller scale (local) analyses. Nevertheless, many applications of the framework currently use implausible combinations of socioeconomics and climate outcomes at larger geographical levels (see presentation by Carole Green). Another sentiment voiced during discussions and in feedback is that the emissions scenarios in the SSP-RCP Framework are perceived as being biased towards higher emissions (RCP4.5, RCP6, RCP8.5), with fewer scenarios exploring the different strategies for limiting warming to 1.5 or 2 degrees C.

Other session organizers highlighted that while the SSP-RCP Framework includes a wealth of information for baseline-uncertainty and studies at different levels of climate change, it provides limited starting points to explore alternative solution strategies. Examples of scenario frameworks that explore the solution space more systematically include the IPBES Task Force on scenarios and models Nature Futures Framework (NFF)[1] or the SHAPE project Sustainable Development Pathways (SDPs)[2]. It was suggested by multiple participants and session organizers to enrich the Shared Policy Assumptions (SPA) dimension of the SSP-RCP Framework to explore multiple solution strategies. This suggestion raises some questions that are further discussed below, about existing examples that can be used to operationalize this effort and the tension between over-detailing the SSP-RCP Framework and keeping it relevant to a broad range of users.

[1] Pereira, L. M., Davies, K. K., den Belder, E., Ferrier, S., Karlsson-Vinkhuyzen, S., Kim, H., Kuiper, J. J., Okayasu, S., Palomo, M. G., Pereira, H. M., Peterson, G., Sathyapalan, J., Schoolenberg, M., Alkemade, R., Carvalho Ribeiro, S., Greenaway, A., Hauck, J., King, N., Lazarova, T., … Lundquist, C. J. (2020). Developing multiscale and integrative nature–people scenarios using the Nature Futures Framework. People and Nature, 2(4), 1172–1195. https://doi.org/10.1002/pan3.10146

[2] https://shape-project.org/

For applications beyond climate, it was mentioned that the storylines of the SSP-RCP Framework did not cover all relevant sectors and dimensions. For example, storylines on fisheries and aquaculture were originally missing, or on drivers of biological invasions) and spatial scales (e.g., regional to national to landscape scale). Extensions in some areas have been slow or limited.

A final complex (hindering) feature is related to integrated scenarios for mitigation, adaptation, and risks and other dynamic aspects of scenarios that feed back to the basic drivers. A basic tension emerges between the role of the SSP-RCP Framework in supporting researchers to develop their own integrated scenarios and the wish from assessments and scenarios users to identify community level integrated scenarios that are fully internally consistent. This was a concern for mitigation/adaptation dynamics, and for cross-sector/cross border interconnections and feedback loops.

Beyond features of the Scenarios Framework itself, session organizers also highlighted practices emerging in the research community that are hindering the optimal use of scenarios. For example, marker scenarios were mentioned to act as anchors in the scenario space, where exploration of the wider space may be desired. The quantification of some key variables was mentioned to lead to an over-focus on indicators that can be modeled or quantified and an inherent under-representation of social variables (organization/cohesion) less commonly quantified for future projections. The underdeveloped formal guidance for using the SSP-RCP Framework was seen as providing flexibility in applications as well as not being clear enough to help researchers avoid bad practices (such as using implausible combinations of socioeconomics and climate outcomes or using one single scenarios for decision making). In addition, session organizers mentioned that the sex-disaggregated information available for the SSPs is underused in scenario studies.

One emerging community practice deserves special attention. CMIP6 and IPCC WGI recently adopted an SSP-based description for forcing trajectories. For example, the pathway in which radiative forcing is limited to 4.5 W/m2 in 2100 is referred to as SSP2-4.5, because the CMIP6 emissions and concentration pathway was produced with an integrated assessment model in which SSP2 was assumed to be the unmitigated baseline. This incorrectly implies that CMIP climate model projections for the 4.5 W/m2 pathway can only be combined with SSP2 socioeconomic futures when doing integrated studies. All scenarios in CMIP6 were named in a similar fashion (SSPx-y), leading to the inaccurate impression that only the specific SSP/RCP combinations used in CMIP6 were considered fully consistent. This undermines a basic principle of the SSP scenario matrix, that forcing levels can be matched with multiple SSP narratives for use in IAV analysis.

Suggested improvements and extensions

We have structured the suggestion from Forum participants for improvements and extensions of the Scenarios Framework into eight elements: (i) further extensions to the Scenarios Framework, (ii) types of scenario-based research that need further improvement,

(iii) training and guidelines, (iv) additional information or detail within the existing SSP-RCP framework, (v) improved interactions among research communities and the policy community, (vi) additional types of societal pathways or integrated scenarios not represented in SSPs, (vii) improved communications, and (viii) scenario development approaches.

(i) For further extensions of the SSP-RCP Framework, session organizers proposed to increase the use of, and expand the definition of, the Shared Policy Assumption (SPA) dimension of the Scenarios Framework. Proposals are to include adaptation strategies and mitigation strategies, but also to widen this dimension beyond climate policies to better encompass the needs of other communities, e.g., biodiversity or broader sustainable development. This would allow the SPA dimension to be used as a starting point for developing more target-oriented scenarios. Another major suggestion is to relabel the axes of the framework from "challenges to adaptation/mitigation" to something that is less climate-centered, to facilitate mapping and linkage to other research communities. To make the SSP framework more relevant for near-term analyses, key indicators need to be updated more regularly to include the most relevant near-term uncertainties. Updates to the narratives are suggested especially on the domains of economics, nature, agriculture, gender, governance, democracy and the finance sector.

(ii) Types of scenario-based research suggested by session organizers for further improvement include the inclusion of mitigation of non-CO2 greenhouse gasses and integration of transport and digitalization deeper in scenario narratives. Paying more attention to institutions, governance, and public policies was stressed as important elements of future scenarios.

(iii) Many of the discussions during the Scenarios Forum and in the session organizer feedback mentioned a demand for greater training and guidelines. The lack of strict guidance for using the SSP-RCP Framework was both seen as helping and hindering. In the session feedback forms, there were requests for guidance for application of the main scenarios within the framework and to address emerging practices, as well as for stimulating the development and use of scenario variants beyond the main five SSP scenarios. While not mentioned explicitly, it should fall within ICONICS activities to develop such guidance.

(iv) Sessions noted that there is a large gap between the level of generalization within the existing global SSPs and the additional more detailed information required for sub-global policy relevant outcomes. It was suggested that information on political development needs to be included in future scenario narratives and that more projections for (political) institutions, governance, conflict and the finance sector are required. Furthermore, improving consistency in scaling scenario information is an important gap, and refining

scenario descriptions of international connectivity would help for risk analysis applications and for adaptation practice. Finally, more probabilistic information, especially for the short term, was suggested.

(v) A large number of suggestions from session organizers focused on improving the interactions among research communities and the policy- and practice communities. Beyond calls for more central data availability and the increased use of scenarios by the ocean, biodiversity and agriculture communities, most suggestions focused on the development of consistent, integrated scenarios that include mitigation, adaptation, and risks of climate change. The risk community can set up model comparison exercises to collect and organize information for use by the mitigation community. Also, emulators of the physical climate as well as risks can help support this interaction.

(vi) There were two main aspects to additional types of societal pathways or integrated scenarios not represented in SSPs. First, focusing more on the policy and solution space by expanding the use of the SPA dimension of the Scenarios Framework. Second, missing perspectives were explicitly identified. Most suggestions clustered around the demand for a more diverse, ecologically-minded scenario like the SRES B2, a more positive, bottom-up driven regional sustainability scenario, or post-growth scenarios that do not associate high human development and environmental sustainability with high economic growth. Another suggestion is for more diverse scenarios that pair high international connectivity in one aspect with low connectivity in another.

(vii) On communication, the compartmentalized approach of the SSP-RCP Framework proves to be challenging. Suggestions from session organizers are to decrease complexity and contextualize scenarios better by integrating multiple aspects. These include suggestions for integrated analyses (risks/adaptation/mitigations) as well as including more dynamics of (societal) change that incorporate dynamic responses to mitigation action, or to impact from climate change.

(vii) Finally on scenario development approaches, there was a clear call to include more diverse methods for scenario development and quantification. This could help to bring the scenarios closer to user-needs as well as capture developments in the scientific literature.

Summary of plenary sessions

The Forum included five plenary sessions: beyond the opening and closing plenaries, one session focused on the use of scenarios in IPCC Assessments (especially AR6) and in other communities. Two more plenary sessions contained a collection of presentations covering frontiers in scenarios research.

Opening plenary

The opening plenary included welcoming statements by IIASA, ICONICS, the IAMC and IPCC as well as the context and plans for the Scenarios Forum meeting itself. Introducing the context for the meeting, Carole Green from the University of Washington presented the freshly released update to the SSP literature database (Green et al., 2022), that contains 1133 papers that use the SSPs (part of a total of 1500 that is still being analyzed) published in the period 2020-2021. There has been a steep growth in SSP-publications over the past years, including growth of papers that use just a single SSP. The applications of SSP2 and SSP5 are most frequent, followed by SSP1, SSP3, and SSP4. Regionally, the applications focus mostly on global and the Asia region, and least on Small Island Developing States, Australia and New Zealand, and Latin America, regions with distinct vulnerabilities to climate change impacts. Beyond the climate community, applications focused on emissions reduction, agriculture and land use, water impacts, key human risks and SDGs. About 80% of the literature using SSPs focuses on risk studies, with fewer studies focusing on mitigation and adaptation. The recently published literature did not strongly address key recommendations from O'Neill et al., 2020 on reference scenarios, capturing relevant perspectives and uncertainties, and keeping the scenarios up to date. Some papers mentioned misconceptions about SSPs and the complexity of using them in the policy context. Discussion after this presentation focused on the need to submit more policy briefs to the ICONICS database, the plans to make this a continuous activity (threatened by the rapidly growing number of papers) and the use of "law", "regulation", and "decision making" in the search terminology.

Second, there was a recorded memorial presentation for Guillaume Rohat, an active young and upcoming member of the scenarios community who sadly passed away six months after the first Scenarios Forum. His PhD advisors, Hy Dao (UNIGE) and Johannes Flacke (Utwente), summarized the contributions from Guillaume to the scenario literature on exposure to extreme heat, using spatially explicit case studies that combined SSPs and RCPs at a variety of scales (subnational, regional and city-levels). His insights show the uneven spatial distribution of heat-related health impacts and the dominant role of socioeconomic vulnerability.

Third, Tim Carter from SYKE presented the history of community scenarios and IPCC scenarios. The use of global scenarios can be traced back to cold war strategy work and later their use for energy and global environmental issues. In 2022, it is 50 years after the Limits to Growth publication, and the 50th anniversary of UNEP, another key-player in the global scenarios landscape. The more than 30-year history of climate change scenarios started with the IPCC SA90 Scenario, replaced by the IS92 scenarios that covered a wider range of future emission scenarios. In 2000, an innovative set of scenarios was published (SRES), based on an open process that led to four scenarios aligning socioeconomic futures with emission futures. In 2006 the decision was taken by the IPCC to assess the scenario

literature and request and support the research community to develop and maintain long-term climate change scenarios. This led to the 'parallel process' that separated emission projections from socioeconomic projections. A small set of socioeconomic scenarios (SSPs) was developed separately from the emission scenarios (RCPs) that were derived from the existing literature. SSPs were kept limited in their specifications to allow their application across a range of regions, disciplines, and topics. The SSPs also allowed for regional extensions that can be used to combine regional socioeconomic projections and downscaled climate information.

Finally, Bas van Ruijven introduced the goals of the Scenarios Forum 2022, mainly to provide a platform for the diverse communities using and developing scenarios to meet, reflect, exchange experiences, and make progress. The structure of the second Scenarios Forum builds partly on the set of seven recommendations from the first Scenarios Forum (O'Neill et al., 2020)[3], all of which are covered in multiple sessions during the Forum and in plenary presentations as well. These recommendations include:

- Improve integration of societal and climate conditions
- Improve applicability to regional and local scales
- Improve relevance beyond the climate research community
- Produce a broader range of reference scenarios that include impacts and policy
- Capture relevant perspectives and uncertainties
- Keep scenarios up to date
- Improve relevance of applications for users

The role of community scenarios in IPCC and other global assessments

A session on scenarios in global assessments featured a panel with co-chairs from all three IPCC Working Groups. This meeting took place after the publication of the three WG reports and while work had started on the Synthesis Report.

Valérie Masson-Delmotte, co-chair of Working Group I stressed that scenarios were used in AR6 to support the integration across working groups. In the WGI report, the description of scenarios was a key topic during the approval session, where objections against the terms "core scenarios" and "SSPs" led to describing them in the Summary for Policy Makers as "illustrative scenarios that cover a range of possible future development of anthropogenic drivers of climate change found in the literature". The higher-end scenarios, like SSP5-8.5 and RCP8.5 were strongly represented in the assessment because many studies focus on a strong signal to analyze geophysical impacts of climate change. SSPs were used in the WG1 report in chapters on global projections, short-lived forcers and ocean and cryosphere, whereas the regional chapters build more on the older generation of RCPs prevalent in their

[3] O'Neill, B. C., Carter, T. R., Ebi, K., Harrison, P. A., Kemp-Benedict, E., Kok, K., Kriegler, E., Preston, B. L., Riahi, K., Sillmann, J., van Ruijven, B. J., van Vuuren, D., Carlisle, D., Conde, C., Fuglestvedt, J., Green, C., Hasegawa, T., Leininger, J., Monteith, S., & Pichs-Madruga, R. (2020). Achievements and needs for the climate change scenario framework. Nature Climate Change, 10(12), 1074–1084. https://doi.org/10.1038/s41558-020-00952-0

assessed literature, due to time lags in regional downscaling supporting regional studies. There was also confusion around the labeling of scenarios in cases where newer scenarios may have a corresponding label but a different forcing level as older scenarios. A major advancement of the WG1 efforts was the narrowing of climate sensitivity through multiple lines of evidence, which was used for constraining the temperature responses to the applied scenarios. Emulators were used for the connection with WGIII work. Physical storylines are an upcoming approach in the WG1 report but are not much used for integration with the other WGs. Several limitations were identified during the WG1 assessment, including the lack of scenarios with explicit or at least a wide variety of levels of overshoot, the lack of representation of hard limits in some natural resources from our changing climate in scenarios (for example, WGII flags hard limits on water availability after glaciers melt, but this is not integrated into scenarios) and the lack of consistency in the representation of carbon feedbacks (for example sinks of carbon becoming less efficient above 2C temperature change). With respect to non-CO2, there were advances to move beyond CO2-equivalent measures and improvements in the representation of methane, but there is still room for improvement. Reactivity and evaluation of plausibility of scenario – both aspects implying fast updates (e.g., from COVID, Ukraine) - are slow to penetrate through the literature and were not considered by WGI.

Hans Otto Pörtner, co-chair of Working Group II mentioned that scenarios were used in a non-systematic way in the WGII report. While Pörtner highlighted potential benefits of using scenarios, he argued that a systems view on using scenarios is still not comprehensive enough and potentially misleading. In the WGII work, the concepts of planetary health and human health led to the concept of climate resilient development pathways, but these have not been operationalized into specific scenarios. Scenarios also trickled into the WGII work through the concepts of risk analysis and the expansion of the burning ember figures with socioeconomic futures. Pörtner encouraged the community to work on more integrated scenarios for ecosystems and societal health, risks, adaptation, and hard adaptation limits.

Jim Skea, co-chair of Working Group III, explained the WGIII approach to global emission pathways, based on 3000 community scenarios. This was reduced to 1200 after vetting and quality selection. These were then used to analyze levels of climate change as well as provide a basis for five illustrative scenarios that highlighted key mitigation strategies. Lack of diversity was a major issue on two dimensions, regional (a small group of European models provided >70% of all scenarios) and socioeconomic (>90% of the studies in the AR6 scenario database are based on SSP2), This led to issues with government approval and drawing conclusions on the importance of socioeconomic development. Governments highlighted a lack of equity in scenarios, lack of 1.5C/2C scenarios that reach net-zero GHG, 5Gt CO2 difference between national inventories and global statistics, and likelihoods of extreme climate changes. Process-wise, the short time between the literature cut-off date

and final version of the assessment led to limited use of scenarios by other chapters. Two aims for the IPCC Scenarios Workshop before the end of AR6 cycle are: 1) to understand how to build better on the SSP-RCP Framework and 2) to consider innovations in scenario approaches.

Discussion focused on the timing of the IPCC Workshop (which cannot be planned for the beginning of the AR7 cycle). There was a deliberate choice in the SSP-RCP Framework not to include climate feedbacks in the scenarios themselves but to leave this up to the research community to build such integrated scenarios. An opportunity for improvement would be through a potential special report on cities to move forward the integration between mitigation, risks, and adaptation. IAMs could take more constraints into account. Another topic of discussion was the lack of economic costs of inaction and the divergence between the multiple approaches to determine these. Other discussion topics were improving the socioeconomic diversity for AR7 and representation of equity in scenarios and assessments by starting from more policy relevant questions and developing more diverse scenarios. The WGII practice to conduct experiments where present day societies (i.e., present-day locations of populations, infrastructure, etc.) are confronted with future climates was critiqued. Pörtner warned against overconfidence in knowing the capabilities of future societies for adaptation.

Paula Harrison presented on the use of scenarios in IPBES, the Intergovernmental science-policy Platform on Biodiversity and Ecosystem Services. IPBES produced ten assessments to date, including four regional assessments and one global assessment and a methodological report on scenarios and models. IPBES and IPCC also published a joint workshop report on biodiversity and climate change. The regional and global assessments used a scenario archetype approach to categorize and classify the diversity of existing scenarios and synthesize insights for a set of indicators of biodiversity and nature's contributions to people. This allowed for clear messages to be communicated to policy makers based on a diverse set of scenarios. For the global assessment, the BES-SIM exercise developed a multi-model study based on three combinations of SSPs and RCPs. The IPBES report on scenarios and models published in 2016 concluded that most existing scenarios are focused on climate change, and lack diversity, stakeholder participation and nature-positivity. IPBES initiated its own task force on scenarios and models, which has developed (with the scientific community) a new scenario framework focused on positive futures for nature and people: the Nature Futures Framework (NFF)[4]. The scenarios assume that nature is valued more in the future, for multiple reasons: intrinsic values (nature for nature), instrumental values (nature for society), and relational values (nature as culture/one

[4] Pereira, L. M., Davies, K. K., den Belder, E., Ferrier, S., Karlsson-Vinkhuyzen, S., Kim, H., Kuiper, J. J., Okayasu, S., Palomo, M. G., Pereira, H. M., Peterson, G., Sathyapalan, J., Schoolenberg, M., Alkemade, R., Carvalho Ribeiro, S., Greenaway, A., Hauck, J., King, N., Lazarova, T., … Lundquist, C. J. (2020). Developing multiscale and integrative nature–people scenarios using the Nature Futures Framework. People and Nature, 2(4), 1172–1195. https://doi.org/10.1002/pan3.10146

with nature). The IPBES Scenario and Models Task force is developing a toolbox to support the community to develop their own scenarios aligned with the NFF and to help with modelling these futures. Coupling of biodiversity and climate change scenarios is limited in the literature on integrated scenarios but is critical given the biodiversity and climate change crises. Potential future directions include mapping existing SSPs to the Nature Futures scenarios, developing extensions of the SSPs that cover desirable futures, or adding a biodiversity policy dimension to the Shared Policy Assumptions (SPAs). Immediate discussion focused on whether the NFF encompasses climate change, which will be important for the ongoing IPBES Nexus Assessment. It was clarified that climate change is included in the framework as low emissions will be crucial for nature-positive futures.

Detlef van Vuuren discussed the role of scenarios in other global assessments, such as IPBES, the UNEP Global Land Outlook, UNEP Global Environment Outlook, and the Network for Greening the Financial system (NGFS). A set of scenario archetypes can be identified that are common across these assessments (such as market optimism scenarios, reformed markets scenarios, sustainable development scenarios, and regional competition). The SSPs can be mapped against these archetypes, allowing for synthesis across the scenario literature. Many of the assessments focus on how to change the trend from a degrading baseline towards an envisioned, desirable future pathway. Many of these were based on SSP2 scenarios to describe the baseline business as usual future. In the IPCC assessment reports, the SSPs were used extensively in WGI and WGIII, but less than expected in WGII. Beyond the SSPs, the IPCC WGIII assessment identified a number of illustrative mitigation pathways that used different mitigation strategies. Detlef van Vuuren also discussed the current status of SSP/RCP updates. Some ad-hoc updates were recently made. Current projections are being remade by the OECD and IIASA-Population. When updating the SSP/RCP framework, the challenges to mitigation/adaptation framing could be replaced by a more generic proactive/reactive framing and develop an expansion of the SPA-dimension to cover different solution spaces.

Discussions focused on the geopolitical dimension of the storylines, where SSP3 covers a lot of the more negative scenarios; the role of the social sciences and humanities in scenario development, which IPBES specifically addressed in a NFF workshop; and the roles of adaptation/mitigation, by either bringing policies into the scenarios or developing and applying SPAs more extensively, for example by being less strict in using SPAs for only mitigation and bringing in other dimensions of solutions as well.

Frontiers in Scenarios

On the second and third day of the Scenarios Forum, two sessions on Frontiers in Scenario Research featured talks on sub-global SSP development using narratives (Kasper Kok), political institutions and forms of governance (Julia Leininger), Integrated Scenarios with Impacts, Mitigation and Adaptation (Franziska Piontek), Towards continuous evaluation of

plausible ranges for the RCPs (Bas van Ruijven), and Increasing policy relevance: connecting the SSPs and SPAs with the Paris Agreement (Elmar Kriegler).

Kasper Kok presented some examples of regional scenario development and a wishlist from the regional community. The regional scenarios start from the global SSP information, narratives, quantifications and information in the central databases. Kok pointed to three approaches emerging in the literature: 1) translating the global narratives to regional extensions which are then quantified, 2) downscaling the global information without developing regional narratives, 3) studies that take the SSP database numbers and develop narrative extensions after the quantification. Regional studies are almost always fully integrated on the mitigation and adaptation dimensions, a different nature than the global scenarios, so far. A literature assessment of sub-global SSP scenario studies revealed that sub-global scenarios cover a diversity of sectors, often cover at least four SSPs (with the SSPs 1-3 pair being always included and SSP4 being underrepresented). On improvements of the scenarios, Kok argued to expand the use of methods for scenario development, avoid the misunderstanding that ScenarioMIP selected a small set of "consistent" SSP-RCP combinations (i.e., back to SRES times) and the addition of new SSPs (including support for implausible combinations from the global perspectives) and integrated scenarios in the framework.

Julia Leininger expanded on "which world do we want to live in?", where most studies and scenarios focus on solving climate change and biodiversity issues but jump over the role of basic freedoms in reaching that desired future. Leininger introduced the argument that democratic institutions and principles such as political equality are important for sustainable development, where democracy also supports reaching the SDGs. Together with Staffan Lindberg, she presented that political science offers theories and indicators that can serve in narratives and input to models, focusing on the V-Dem database with long timeseries of a large variety of indicators relevant to archetypes of democracy (e.g., participatory, deliberative, liberal). This variety of indicators does justice to different forms of government and political regimes worldwide. Finally, the point was made that political institutions shape human behavior and are path dependent over time. Integrating political institutions in scenario quantifications is a necessity beyond what is currently part of the SSP narratives and can enrich the content and relevance of scenarios. This point was emphasized by showing the projections of democratic development along the SSPs, which are far too optimistic and do not match a realistic future development (published in Soergel et al., 2021).

Franziska Piontek provided examples of integrated scenarios for mitigation, impacts and adaptation. This class of scenario studies that is emerging is the final stage of "closing the loop" of the parallel process, to bring together the socioeconomic scenarios (SSPs) with climate model outputs (RCPs) for integrated studies. These studies have long been limited

by the available information on impacts, but recently this information has been expanded a lot and enabled integrated studies. Piontek classified studies into three levels of integration. The first level of "alignment" combines mitigation and impacts information for comparable scenarios to provide a full picture without dynamic feedbacks (i.e., NGFS scenarios). The second level of partial integration captures dynamic effects of impacts but does not adjust the mitigation pathway. Finally, full integration would feed back the climate impacts on the mitigation pathway (i.e., cost-benefit IAMs and COACH scenarios). Main challenges for making improvements on integrated scenarios are the inclusion of adaptation, uncertainty, partial coverage of impacts, and present-day impacts. To overcome these challenges, Piontek called on the community to make use of the already available information on impacts and adaptation, to advance methods to include adaptation, develop emulators of impacts, and to provide up-to-date SSP information to the impacts community.

Bas van Ruijven elaborated on how the recommendation from the last Scenarios Forum to move towards a process of continuous updates of the range of scenarios, could be implemented. He distinguished between four separate discussions on the range of scenarios. The short-term upper end is influenced by recent development of policies and technologies, whereas the long-term upper end is defined by the (changing) likelihood of high-coal and high-demand pathways in the absence of policy. The short-term lower end is the domain of feasibility discussions and the long-term lower end is dominated by the potential and realism of net-negative emissions. Van Ruijven called on the community to update scenarios more regularly to keep up with policy and technology development, discuss and support the development of high-end scenarios beyond no-policy counterfactuals (such as scenarios in which climate policies fail), alternative narratives for high-end emission scenarios and the inclusion of peak warming scenarios in the community frameworks. The public debate on scenarios makes clear that there is a need for more user guidance.

Elmar Kriegler focused on how climate policies can be better integrated into the Scenarios Framework. Policies enter the framework through the concept of Shared Policy Assumptions, that connect the socioeconomic SSPs with the climate-change-levels of the RCPs. The policy component is one of the fastest developing components of the Scenarios Framework. In practice, new SPA's have emerged in the literature, such as current policy scenarios, NDC scenarios and more recently, policy scenarios with country-level net-zero targets. The class of bridging-scenarios link these policy scenarios with target-seeking scenarios for 1.5 or 2C warming levels. In the IPCC AR6 an ex-post policy scenario categorization was developed, with reference scenarios, immediate policy scenarios and delayed policy scenarios. Kriegler called upon the community to expand the concept of SPAs beyond mitigation policy, including broader sustainable development, governance, poverty/inequality, or adaptation.

Finally, Keywan Riahi presented the process of scenario collection, harmonization, vetting and assessment during the IPCC AR6. This process currently only happens once every 5-7 years during each IPCC Assessment Report (and sometimes for Special Reports), leading to the continued use of outdated scenarios. Riahi proposed to strengthen the community efforts on standardizing and updating mitigation policy inputs to mitigation scenarios and to move towards a continuous "live" database for submission, and (bi-)annual vetting, assessment and publication of up-to-date scenarios. He also proposed that post-processing modules of information portals could be built upon such as up-to-date databases, to better serve multiple scenario-user groups.

Main research and collaboration needs (final plenary)

The final plenary consisted of two panel discussions. One focused on insights from the Scenarios Forum 2022, including organizers from sessions across the topics at the Forum, and a second panel on next steps for the scenarios process with more institutional members.

Panelists on the first panel were Bjoern Soergel (PIK), Elisabeth Gilmore (Carleton), Laura Pereira (U Witwatersrand), Claudia Tebaldi (JGCRI) and it was chaired by Henrik Carlsen (SEI). Tebaldi's report focused on the IPCC session, highlighting three categories of improvements that would facilitate the use of scenarios in future IPCC assessments: process-level improvements, e.g., related to the timing of products, or the formation of scenarios task-forces early in the IPCC report writing process; needs for top-down championing of scenarios as organizing principles, i.e. on the part of WG chairs; and progress at the grass-root level in terms of increased collaboration between the scenario communities, i.e., the physical climate, impacts, mitigation and adaptation research communities. Briefer reports from the Earth-system-related sessions highlighted dynamics and progress in the research and development of emulators/simple models, critically useful in facilitating the connection among those same communities; the recent increasing activity and focus on connecting models of the Earth and Human systems, and the value of physical climate storylines in providing alternative perspectives to scenario-based climate outcomes. Pereira spoke about the important links between biodiversity and other sectors, the need to create climate and biodiversity scenario information for IPBES and IPCC assessments, an emphasis on the values and normative component of scenarios, and the need for more diverse perspectives. Gilmore highlighted that there had been great growth in the discussions about governance, conflicts and political institutions compared to the 2019 Scenarios Forum. However, the social science community finds that it needs to learn about projecting qualitative and quantitative indicators, extend narratives and bring new perspectives to the scenario-discourse. As an outcome of the sessions at the Scenarios Forum, a workshop is planned to be organized to create a new social science scenario community. Finally, Soergel reflected on how inequality is becoming more

mainstream in (mitigation) scenario studies, how the coverage of the SDGs space has been increasing recently and how the number of post-growth or low-demand scenarios is increasing, but still missing from the SSPs space.

From the audience, it was noted that the community could do more to influence the grand historical narratives of how a society sees itself and what defines lived experience. A broader set of disciplines and approaches would be very useful. While gender was included as sessions during this Scenarios Forum for the first time, gender did not permeate to other presentations during the Forum. It was noted that population and migration discussions flourished during the Forum. Finally, there was a call for more critical discussion on assumptions in scenarios during future Forums.

The second panel was chaired by Bas van Ruijven (IIASA) and consisted of Kris Ebi (UW), Alaa Al Khourdajie (IPCC), Roberto Schaefer (IAMC), Paula Harrison (IPBES), and Alex Roehrl (UN DESA). Kris Ebi spoke as co-chair of ICONICS and co-chair of the assembly of Future Earth, and she highlighted how the connection with Future Earth can be strengthened. Alaa Al Khourdajie explained the planned IPCC Scenarios Workshop, to be organized in the first quarter of 2023. This workshop aims to take stock of scenario use in AR6, identify gaps in scenario approaches, evaluate the SSP/RCP/SPA framework towards AR7, and innovation of the scenarios approach. It will also reflect on the process across IPCC WGs and the diversity of model contributions. Roberto Schaefer spoke about how the IAMC can contribute more strongly to future IPCC Assessments: by updating the SSPs, by developing a process for regular updates to scenarios parallel to the IPCC timeline, and by expanding the recently established IAMC scientific working group on national models. Paula Harrison stressed the need for climate and biodiversity scenario frameworks to be more connected and that the policy/solution space should be explored more to connect the two frameworks. On the process side, the IPBES task force on Scenarios and Models and IPCC community should collaborate closer, and Harrison called upon the community to develop more biodiversity and integrated scenarios for the next assessments. Alex Roehrl voiced the potential for scenarios in the UN process, calling on the community to develop scenarios beyond the SGDs and their timeline, more national level scenarios, and improve the institutional interface for a partnership between the scenario's community, the UN system and policy makers at the national level.

Summary of participant survey

A survey sent to all participants after the Scenarios Forum received 56 responses, with about two-thirds from on-site participants. Over 76% of respondents were first-time participants. The Forum was highly rated on a 5-point scale, with 48% rating the Forum as high and 39% as very high. Nearly 52% felt the Forum significantly increased their knowledge and 48% somewhat increased their knowledge. There was high satisfaction with the organization of the Forum, including registration, technology, etc. Nearly 60% found the hybrid format, where all speakers

uploaded recordings of their presentations in advance, useful. The plenaries were considered very to generally useful, with appropriate content and format. Nearly 70% would prefer a longer meeting with fewer parallel sessions for next editions of the Forum. Overall, 96% would like to attend the next Scenarios Forum.

Two-thirds of respondents identified as male. Total work experience was varied, with about 20% each of respondents having 0-5 years, 5-10 years, and 20-30 years of experience. About 30% of respondents had 10-20 years of experience and 9% had over 30 years. Over 87% of respondents were researchers or academics, with a few participants from the finance sector, government, and international organizations. Of those who were academics, over one-third were integrated assessment modelers. Other common areas of study were political economy (18%) and economics (14%). Over half of respondents identified as being in the domain of the IPCC WGIII, 35% in IPCC WGII, and 10% IPCC WGI. Responses were split on whether the Scenarios Forum was similar to or different from the meetings of the Integrated Assessment Modeling Consortium, indicating the need to work with session organizers to distinguish future editions of the Forum.

A wide variety of concepts were identified as deserving more attention in community scenarios (see figure for most common concepts), including a long list of other topics receiving single votes.

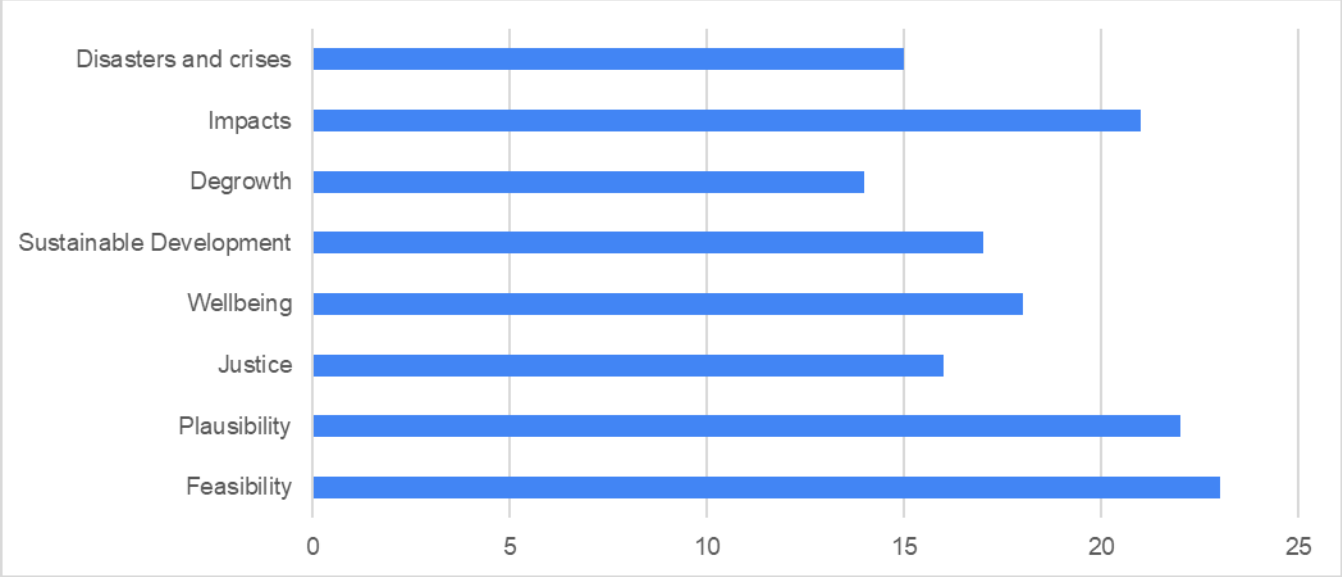

Figure 1: Counts of suggested topic deserving more attention in community scenarios

Table 1: Additional suggestions deserving more attention in community scenarios

Ethical Aspects of Scenario Choice
Biodiversity
Diversity
Realism. I don't see that the internal coherence of scenarios (assumptions/developments in one area being compatible with those in other areas) and the coherence with the external world (linked to feasibility) is

ensured. Some unrealistic scenarios (if clearly flagged) can be useful, but most of them just generate noise at best and confusion at worst.
Gender, Socio-political influences
Human-Earth connection and the cost-benefit aspects
Agency of actors other than national policymakers (especially corporates and the financial sector); non-linear technological change; optimistic scenarios that focus on opportunity and possibility
Overshoot, CDR, and SRM
Plausibility, Democracy/Governance
Societal-led innovation to speed up mitigation
Risk, vulnerability
Disasters and crises, Framing and local meaning
Usability among practitioners
Probability - quantify distributions of driver factor assumptions
Need to work on communication with policymakers/decisions makers?
A Moral Change. Ethics and Morality are contextual; now our context has dramatically changed and we should change our moral foundations too.
Low energy and materials
Population
Wild cards (adverse or beneficial)

A detailed account of the participant survey is provided in Appendix V.

Conclusions and next steps

The discussions during the Scenarios Forum 2022 identified several ways in which the Scenarios Framework and scenario work in general could be improved. The first was the need for expansion of the solution space to facilitate a wider diversity of response strategies. The SSP/RCP matrix, consisting of columns of SSPs and rows of RCPs, contains cells describing the individual combinations of SSPs and RCPs. The practice during the first rounds of applications was that there is only one strategy to move down each column that is consistent with each SSP, for example globally harmonized climate policies in SSP1 or fragmented national policies in SSP3. However, within each of these columns of the Scenario Matrix, a variety of response strategies can be explored against a background of the uncertainty of socioeconomic developments. For example, a nationally diverse set of demand-side strategies for emission reductions can be explored under multiple SSPs and yield different results. Structuring this solution space and facilitating the use of diverse response strategies is a future need for the Scenarios Framework.

Other key discussions included broadening the labeling of scenarios space from “challenges to adaptation and challenges to mitigation” towards “proactive and reactive” axes that would facilitate connection to applications beyond climate to biodiversity and other aspects of sustainability.

The modeling community, especially Integrated Assessment researchers, also recognized the increased need for continuous updates and release of scenario products and discussed plans and options for future regular (annual) releases and assessments of scenarios. As part of the updates to the Scenarios Framework, a discussion about high-end community scenarios is needed, to establish a shared understanding of the limitations and applications of high-end emission scenarios.

Finally, across the many discussions during the Scenarios Forum, the tension in the Scenarios Framework between providing building-blocks for scientists to carry out their own scenario-studies and developing and identifying consistent integrated community-level scenarios became clear. Here, the discussions will need to continue to develop a shared understanding of what should be harmonized at the community-level and which aspects of scenarios can be developed by individual studies and projects (for more details see Session #12 below).

Planned follow up activities

Session participants noted several planned or desirable next steps in the scenarios process. Several products from the meeting itself are in preparation. The Forum Scientific Steering Committee is producing a meeting report and synthesis paper of broad meeting conclusions and proposed next steps. A series of ICONICS webinars will be held to continue discussions from the Scenarios Forum. Several discussions will require the development or assessment of specific scientific literature.

Several sessions identified follow up meetings, such as a planned IPCC workshop on scenarios in 2023, a workshop on improving institutions and political sciences in scenarios by IDOS (formerly DIE), SEI, PRIO and V-Dem, and continued discussions at IAMC, AGU, and ISIE-SEM meetings. Several individual sessions plan on writing papers, reviews that take stock of the current literature are underway, as well as a special issue on Stakeholder-Engaged Integrated Assessment Modelling for Global Scenarios in a Changing World. A number of projects or activities already underway were advanced by Forum sessions and are working on key-topics discussed during the Forum, including the EU-sponsored projects IMAGINE on national scenarios, PROVIDE on climate impact information, SHAPE on sustainable development pathways, ENGAGE and MANIFEST on feasibility, CASCADES on interlinked dynamics and WorldTrans on linking human and earth systems.

The Scenarios Forum is planned to be a continued recurring event, about every 2-3 years and ICONICS will work with parties interested in hosting the next event.

SCENARIOS FORUM 2022

Appendices

Appendix I: List of participants

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SCENARIOS FORUM 2022

Appendix II: Forum agenda

The full program, with all talks, speakers, and abstracts by session, is provided on the meeting website at https://www.scenariosforum2019.com/program. We provide a program by session name here.

Monday, June 20

Opening Plenary: Status of Scenario Process

9:00-9:15	**Opening and welcome**	Albert van Jaarsveld, Keywan Riahi (IIASA), Kris Ebi (ICONICS), Jim Skea (IPCC)
9:15-9:35	**Applications of the SSPs: insights from the ICONICS literature database**	Carole Green (UW)
9:35-9:45	**Memorial for Guillaume Rohat**	Hy Dao (UNIGE), Johannes Flacke (UTwente)
9:45-10:00	**History of the scenarios process**	Tim Carter (SYKE)
10:00-10:10	**Insights from the Scenarios Forum 2019**	Brian O'Neill (JGCRI)
10:10-10:20	**Goals of the Scenarios Forum 2022**	Bas van Ruijven (IIASA)
10:20-10:30	**Q&A**	

Plenary 1: The role of community scenarios in IPCC and other global assessments

11:00-11:45	The role of scenarios in the IPCC 6th Assessment Report	Valérie Masson-Delmotte (WG1), Hans Pörtner (WG2), Jim Skea (WG3)
11:45-12:05	**The global community scenario landscape – SSPs & IPBES scenarios**	Paula Harrison (UKCEH)
12:05-12:30	**Community scenario projects and updates to SSP drivers**	Detlef van Vuuren (PBL)

Parallel 1

14:30-16:00	**Adaptation ID #15 (R)**	Quantitative scenarios for adaptation and adaptive capacity
	Communication ID #201 (W)	Synthesis and communication of climate change risks in scientific assessments
	Regional socio-economic – 1 ID #26 (R)	Applying global socio-economic scenarios for regional climate change impact and adaptation analysis
	Transport ID #24 (W)	Scenario development and modeling that bridges scales and communities: the rich diversity of global transport futures
	Modeling SDGs ID #47 (R)	Modelling integrated scenarios for reaching climate and sustainable development goals
	Cros-border ID #69 (R)	Exploring and expanding the cross-border dimensions of the SSPs
	Agriculture ID #83 (W)	Representative Agricultural Pathways – Cross-scale and trans-disciplinary storylines for agricultural development and decision-making

Parallel 2

16:30-18:00	**Biodiversity ID #50 (R)**	New and on-going work on scenarios for biodiversity & nature contributions to people
	AR7 Recommendations ID #63 (W)	Scenarios in IPCC assessments: lessons from AR6 and recommendations for AR7
	Regional socio-economic – 2 ID #26 (R)	Applying global socio-economic scenarios for regional climate change impact and adaptation analysis

	Gender equality ID #94 / Climate change gender ID #93 (W)	Addressing the gender dimension in socioeconomic scenarios: policy and climate change impacts on gender equality & gender equality as a driver of change
	Global South ID #56 (R)	Assessing the impacts of the Global Energy Transition in the global south
	Physical Storylines ID #51 (R)	Physical climate storylines: applications and perspectives
	SSP Uncertainties ID #30	Interpreting and debiasing uncertainties in SSP-based model ensembles

Parallel 2 Extension

18:00-18:30	**Biodiversity ID #50 (R)**	New and on-going work on scenarios for biodiversity & nature contributions to people
	Gender equality ID #94 / Climate change gender ID #93 (W)	Addressing the gender dimension in socioeconomic scenarios: policy and climate change impacts on gender equality & gender equality as a driver of change
	Beyond illustrative ID #32 (W)	Beyond illustrative scenarios - novel approaches to assess future climate risks

Reception

18:00-19:30	**Poster session**

Tuesday, June 21

Parallel 3

11:00-12:30	**Demographic projections ID #85 (R)**	Multiscale and multidimensional demographic projections for the extended global scenario frameworks
	Distributional impacts ID #25 (R)	Poverty, inequality, distributional impacts of climate change mitigation and impacts
	Integrated Scenarios ID #22 (R)	Integrated scenarios of impacts, mitigation and adaptation
	Reflexivity ID #12 (W)	Reflexivity for sustainable and equitable futures: broadening scenario inputs for linkages across methods, scales, and levels
	Mitig/Adapt Capacity ID #82 (R)	Qualitative and quantitative approaches to represent regional capacity for mitigation and adaptation in the Shared Socioeconomic Pathways (SSPs)
	CDR ID #20 (W)	Improving the representations of Carbon Dioxide Removal (CDR) options in the SSPs
	Oceans ID #203 (W)	Blue scenarios: ocean and fisheries in Earth System

Parallel 4

14:30-16:00	**Feasibility -1 ID #48 (R)**	Feasibility of scenarios
	Pop and economic projections ID #17 (W)	Updating the population and economic projections in the SSPs
	Human-Earth ID # 42 (R)	Advances in human-Earth System interactions in scenario development

	Development process ID #202 (W)	Improving the scenario development process
	Materials ID #43 (R)	Scenarios of material stocks, flows, services, and practices: exploring nexus approaches to address climate change, air pollution and sustainability
	Non-CO2 emissions ID #6 (R)	The role of non-CO2 greenhouse gas emissions in mitigation scenarios and climate change
	Finance -1 ID #10 (R)	Building better climate scenarios for supervisors, private sector financial institutions, and development institutions
Parallel 5		
16:30-18:00	**Feasibility -2 ID #48 (R)**	Feasibility of scenarios
	CMIP6/7 ID #16 (W)	Scenarios in CMIP6 and CMIP7: lessons learned and new design considerations
	National Scale ID #8 (R)	Challenges and opportunities in constructing national scale scenarios from the SSPs/RCPs
	Non-state actors Workshop ID #21 (W)	What do non-state actors (e.g., corporations, NGOs, financial institutions, etc.) need from climate change scenarios?
	Digitalization ID #66 (R) / Lifestyle ID #64 (R)	Digitalization scenarios and implications for climate change / Future lifestyle changes at different geographical scales and in response to societal shocks (e.g., Covid-19)
	Stakeholder participation ID #29 (W)	Learnings from stakeholder participation for the development and implementation of scenarios and long-term pathways towards sustainable systems

	Finance -2 ID #10 (W)	Building better climate scenarios for supervisors, private sector financial institutions, and development institutions

Plenary 2: Frontiers in Scenarios 1

18:15-19:15	**Examples of translating global narratives to local stories**	Kasper Kok (WUR)
	In what world do we want to live in?: From policies to political institutions	Julia Leininger (DIE)
	Towards continuous evaluation of plausible ranges for the RCPs	Bas van Ruijven (IIASA)

Wednesday, June 22

Parallel 6

9:00-10:30	**Emulators -1 ID #46 (R)**	Emulators: new methods and role in integrating research across climate research communities
	Beyond GDP ID #38 (W)	Beyond GDP: economic dimensions of integrated assessment scenarios
	National Decarbonization -1 ID #7 (R)	National deep decarbonization scenarios: policy analysis and global narratives
	Target-seeking ID #52 (R)	Interacting with integrated assessment models for target-seeking under uncertainty
	Migration -1 ID #31 (R)	Scenario-based approaches to modeling migration futures
	Socio-political ID #23 (W)	Improving the representation and usability of socio-political factors in the Shared Socioeconomic Pathways (SSPs)

Parallel 7

11:00-12:30	**Emulators -2 ID #46 (R)**	Emulators: new methods and role in integrating research across climate research communities
	Climate and Biodiversity ID #59 (W)	Catalyzing climate and biodiversity coupled scenarios for assessments and policy
	National Decarbonization -2 ID #7 (R)	National deep decarbonization scenarios: policy analysis and global narratives
	Post-growth ID #37 (R)	Economic pluralism and post-growth scenarios
	Subnational decarbonization ID #104 (R)	Regional and subnational scenarios of decarbonization and sustainable development
	Migration -2 ID #32 (R)	Scenario-based approaches to modeling migration futures
	Low Energy Demand ID #70 (W)	Narratives for scenarios and pathways to provide decent levels of energy services at low demand of energy and resources

Plenary 3: Frontiers in Scenarios 2

14:00-14:30	**Increasing policy relevance: connecting the SSPs and SPAs with the Paris Agreement**	Elmar Kriegler (PIK)
14:30-15:00	**Integrated Scenarios with impacts, mitigation and adaptation**	Franziska Piontek (PIK)
15:00-15:30		Bas van Ruijven (IIASA)

Closing Plenary: Status of Scenario Process

16:00-16:20	**Improving Scenario Services**	Keywan Riahi (IIASA)

16:20-16:55	**Integrated Scenarios with impacts, mitigation and adaptation**	Bjoern Soergel (PIK), Elisabeth Gilmore (Carleton), Laura Pereira (U Witwatersrand), Claudia Tebaldi (LBL) (more selected during the Forum)
16:55-17:30	**Panel on next steps for the scenarios process**	Jim Skea/Alaa Al Khourdajie (IPCC), Roberto Schaefer (IAMC), Paula Harrison (IPBES), Alex Roehrl (UN DESA)

Forum adjourned

Appendix III: Framework Features, Research gaps, and needs

This section provides a structured collection of the Session Organized Feedback forms, which is the basis for the synthesis text in the main report. The detailed responses from Sessino organizers can be found in the individual feedback forms.

Features of the SSP-RCP Framework that helped research and assessment

- Matrix architecture
- Narratives, qualitative elements, quantifications. The different parts of the SSP-RCP Framework can be used as needed.
- SSP-RCP scenarios and their application are a “community activity” with broad definition of ‘community’ (e.g., Scenarios Forum attendees)
- Community “standards” help with interoperability of quantifications. *However, this feature also acts as a hindrance, as described below.*
- Lack of guidance. With no formal guidance, SSP-RCP users experiment
- The use of a number of SSP-RCP trajectories in Tier 1 and Tier 2 of ScenarioMIP supported the work of the WG1-type community, and will do so for a long time, given the 12PBs of data produced.
- The application of the SSP-RCP Framework in impact modeling and research allows the consistent use of impacts in IAMs.
- Overall, the framework is useful for regional scenario development. The SSP-RCP Framework has been sufficiently generic and flexible to allow for a broad range of regional applications,
- The SSP-RCP Framework provides a flexible space within which some of these emulators can work, exploring ranges, characterizing scenarios in terms of their GWL attainments.
- SSP-RCP provides a common framework for scenario analysis.
- Despite their background as scenarios for climate-energy-land modelling, the SSPs also provide a largely consistent set of narratives, population and demographics, education, economic development, etc., so several additional SDG dimensions are covered.
- The dominating scenario frameworks support assessment of feasibility by an increasingly accurate and detailed description of the levels of implementation of climate mitigation solutions compatible with various temperature or other social goals.

- The absence of an explicit treatment of digitalization in SSP frameworks provides a tabula rasa on which to interpret the existing SSP narratives in terms of their implications for digitalization. What is not clear is whether the potentially large opportunities and risks (for mitigation) from digitalization should be treated as being within existing narratives or additional to existing narratives. The first approach implies digitalization simply adds interpretive detail to otherwise unchanged scenario narratives and derived modelling. The second approach implies digitalization modifies the scenario narratives and so requires a new wave of derived modelling.

- The SSP narratives and quantitative database provide information from which it is possible to derive insights on the extent and nature of connectivity; this provides essential context information for the study of cross-border climate impacts and the cross-border effects of adaptation.

- The SSP-RCP Framework allows for a consistent comparison across modeling studies of different scopes and thereby helps to understand the relevance of cross-border impacts in an (inter-)national context.

- Especially GDP, education and other socio-economic indicators are extremely helpful for projections of other key variables of interest.

- WGII of AR6 used a “scenario-neutral” approach in the RFC burning embers and other means of synthesizing risks. It is unclear exactly what aspects of the scenario framework may have hindered its broader use, since several individual chapters incorporated SSPs in burning embers explicitly. It is possible that the fact that a substantial amount of impacts literature uses other scenarios or does not draw on scenarios at all was perceived as an obstacle, despite solutions being available such as mapping other scenarios to the SSP-RCP framework.

- Limited uptake in other assessments such as those conducted by the EEA. This may have been hindered by a lack of SSP-based literature at the time of those assessments, whereas the EU Climate Risk Assessment currently in progress is exploring how to draw more substantially on the scenario literature. A key factor will be the availability of SSPs at the European scale.

- Despite increasing evidence (supported by the SSP framework) that socioeconomic factors are at least as important as warming levels in determining risks, there remains an emphasis on the climate system.

- Projection of ocean biophysical variables

- The quantified dimensions of the SSPs (education, population, GDP, governance, gender inequality and others) were useful for the development of quantitative scenarios for adaptation and adaptive capacity.

- Generally, the SSP-RCP scenario framework helped insofar as it provided common inputs to otherwise disparate modeling methods.

- The main help of the SSP-RCP Framework is that it obviously presented an enormous basis of information as input for biodiversity assessments (land use, economic activity, climate change, pollution).

Features of the SSP-RCP Framework that hindered research and assessment

- Marker scenarios act as anchors in the scenario space, where exploration of the wider space is what is desired.
- Community "standards" introduce requirements for scenarios or scenario elements to be shared, which may discourage reflexivity.
- Lack of guidance. With no formal guidance, SSP-RCP users may employ/develop bad habits
- The timeline of development of trajectories of forcings is problematic, and the process itself can use improvements in automatization, updates, concerted testing and refinement of the hand-off of the trajectories from the IAM community to the ESM community. Some voiced the point that the more policy relevant issues appeared to be suboptimally addressed by the chosen scenarios, with less focus on the lower end than needed (SSP1-1.9 in Tier 2) and the need of more overshoots.
- The panel members also identified weaknesses in the existing scenarios. Currently, many modelers rely on the quantified core scenarios, namely GDP, to represent development and other institutional factors. GDP per capita is the mostly used proxy for vulnerability in the SSP framework as an indicator of economic level of development.
- Lack of subnational detail hinders the use of SSP-RCPs in many transport models. But this also provides an opportunity for future work in this area.
- Plausibility of scenarios: This is an issue that arises often in participatory regional analysis. Issues include: SSPs requiring modification to retain credibility at local scale, space needed within narratives to allow different views of key terms such as "sustainability", difficulties to include scenarios that depart from national policies and plans in centrally-planned and other non-western societal models; the end-point of local scenarios may not adhere to an SSP mapping; and the long time horizon of 2100 which is often regarded as being too long.
- Ill-advised SSP-based labelling of climate projections in CMIP6: The recent adoption by IPCC WG I of an SSP-based description for the forcing trajectories used in CMIP6 implies that the only combinations of climate and socioeconomic futures allowable are those selected for the specification of radiative forcing. This undermines a basic principle of the SSP framework, that forcing levels can be matched with any SSP narrative for use in IAV analysis. Can some other labelling scheme be amended?
- Number of SSPs: There are limitations in many local studies on the number of scenarios that can be usefully deployed with stakeholders (typically 2-4; rarely 5)

- RCP-SSP matrix excludes regionally useful combinations: At regional and certainly at local level, none of the combinations in the RCP-SSP matrix need to be excluded, as other developments can be assumed for the rest of the world. Combinations such as RCP8.5 x SSP1 are very useful to explore regionally.

- Discussions in this session have been more on the near-term until mid-century and related to rather 'incremental' mitigation benefits. The current SSP-RCP Framework contains is 'top-heavy' on unrealistically high emission scenarios and is thus not best equipped to answer questions like: What are the avoided impacts of 5 Gt CO2eq less emissions in 2030, or a 5 year earlier global net-zero date, or else.

- The absence of a (positive) scenario that without strong increases in economic output. All exogenous economic model projections of a sustainable future see strong economic growth - but in the past decade a large degrowth/postgrowth literature has emerged that strongly questions the plausibility of such scenarios. The most important single factor here may have been the interpretation of SSP1 as a 'green growth' scenario by the marker implementation of IMAGE, as highlighted by presenter Eric Kemp-Benedict (see figure below).

- The current process of operation (i.e., first IAM community developed the scenarios and then passes them to the climate model community) may have room for improvement

- For example, the fact that some variables are provided exogenously (population, education, urbanization, GDP) in the SSPs does potentially limit the exploration of the scenario space in our area which considers Earth System feedbacks on human societies. Taking a very simple example, a 3% per year sustained GDP growth over the course of the 21st century in SSP5-8.5 despite 4 to 5°C of warming seems rather implausible when we know that climate change is likely to bring devastation to whole regions under this level of warming by the end of the century, for example from large reductions in crop availability and climate damages from extreme weather. The economic feedback effects of high warming scenarios were studied by Woodard et al. (2019) in a simplified IAM, and shown to be significant. Models like FeliX (Eker) would have the ability for aspects of the system to interact with some of these components that are endogenously specified

- In terms of training emulators for policy relevant scenarios like overshoots that relative scarcity of this type of scenarios in the current main products (like the scenarios that could be run by ESMs in ScenarioMIP) hinders the emulation of a larger number of OS trajectories.

- Only one of the SSPs, SSP1, is to some extent aligned with the SDGs. Together with the GDP quantifications - which interpret SSP1 as a green growth scenario - this arguably provides a too narrow perspective on pursuing sustainable development, not reflecting different societal perspectives (presentation BS).

- At the same time, the existing scenarios framework hinder assessment of feasibility by:

- a lack of probabilistic assessments of the future: while scenarios provide increasingly detailed and numerous descriptions of futures under different assumptions, the probability of these assumptions is rarely rigorously assessed.

- the side-effect of increasing sophistication of models including through incorporation of 'barriers' and 'enablers' is a bias towards the factors which can be modelled and quantified rather than on those that have most effects on real-life feasibility

- passing the task of feasibility assessment to policy makers and other social actors involved in implementing climate solutions and thus ascribing the potential of implementation to political will, choice, and skill of implementors rather than to the feasibility of the solution.

- From the perspective of sustainability scenarios, the SSP-RCP scenarios do not represent or integrate alternative options for conserving and living in harmony with nature. This leaves nature and people as passive recipients of economic growth-driven socio-economic pathways. It is worth asking if these are the future we want for nature and people. The NFF aims to generate sustainable and transformative future scenarios with nature and people's relationship with nature at the center, reflecting diverse worldviews on multiple roles and benefits of nature. The NFF helps identify place-specific initiatives and interventions, small and large, that can be amplified in moving towards nature and people positive futures.

- Timing of the CMIP process and regional climate and impacts modeling efforts has meant that while the assessment of possible climate futures (WGI) and mitigation pathways (WGIII) was based on CMIP6, the literature available on regional climate (WGI) and impacts and future risks (WGII) modeling is generally based on CMIP5, particularly with RCP8.5. However, this was not a major hindrance since the scenario framework was designed to allow for using both CMIP5 and CMIP6 simulations (for example climate simulations based on RCP4.5 and SSP2-4.5 can be considered interchangeable for the purpose of assessing impacts associated with the 4.5 W/m^2 forcing pathway). Note that much of the impacts literature is not based on SSPs, e.g. using SRES. This can be addressed by binning SSP and SRES scenarios into common categories. Impact results are not equally available for all scenarios, so sometimes there can be gaps in the impacts literature, especially of large-scale quantitative impact studies. Finally, higher resolution and scenarios tailored to analyses questions and scope, and scenarios exploring uncertainties beyond the SSP-RCP framework, will continue to be essential.

- In addition, Global Warming Levels (GWLs) were found to be very useful for WGII AR6 integration and communications as Common Climate Dimensions (CCD), as well as for integration with the other WGs and connecting to and complementing scenarios. Among other things, GWLs provide an opportunity to explore hazard uncertainty via earth system variable ranges by GWL, as well as an opportunity to explore impacts exposure, vulnerability, and adaptation uncertainty and risk.

- The ongoing WGI-WGIII handshake meant that WGIII Ch3 had access to one WGI emulator in time for the WGIII FOD, however changes to various parts of the WGI assessment (e.g. historical warming, radiative forcing, climate sensitivity), meant that

final hand-over and choice of the WGI emulators for their use in Ch3 WGIII, occurred not long before the WGIII FGD submission – without delays to the WGIII schedule (e.g. COVID), the timing would have been even more challenging.

- We discussed the currently limited availability of quantified dimensions within the SSPs (e.g., awareness) that would allow a broader understanding of adaptive capacity. Further, the limited spatial scale of those variables was discussed. We also spoke about the limited SSP scenarios and that there should be more scenarios closer to SSP1 in terms of their socioeconomic storyline.

- First, the storylines of the SSP-RCP Framework were not covering all relevant sectors / dimensions (e.g., need for new storylines on fisheries and aquaculture, on drivers of biological invasions) and spatial scales (e.g., regional to national to landscape scale).

- Second, the current quantifications of the SSP-RCP Framework focus on climate. Therefore, the outcomes are often incompatible with the 2050 vision adopted by the Convention on Biological Diversity, and do not map on to the outcome space targeted by the new scenario framework developed by IPBES (Nature Future framework). The Nature Future Framework has the advantage of being directly focused on biodiversity - but the possible downside is that it is not clear how it aligns with the SSP/RCP framework, risking that independent quantifications are necessary for the drivers.

- Third, the SSP-RCP scenario framework does not explore in sufficient detail the processes enabling transformative change, required to reach the 2050 CBD vision and on which the Nature Futures scenario framework focuses.

- The lack of guidance for the IAV community on interpreting and using the scenario framework.

- Some forms of international connectivity, for example finance, supply chains or relevance to specific sectors and explicit region-to-region connections, are not described in the SSP narratives, which hinders the study of cross-border dimensions.

- In particular, modeling of cross-border dynamics is hindered by the absence of quantitative data on inter-regional connectivity in the SSPs. The lack of finance and climate risks in SSPs hindered their research and policy relevance.

- It is inherently difficult to quantify variables like social cohesion, let alone to project them into the future. This is an obstacle to studying security challenges within the SSP framework.

- The SSP-RCP Framework has limited information about agricultural systems, which makes them insufficient for agricultural applications. Further information is needed about food demand, land use, bioenergy, agricultural technologies, and policies that subsidize or hinder certain practices. The RAPs approach could therefore serve as a

framework for sectoral elaboration, although care is needed to ensure that assumptions made in one sector do not contradict those made in other sectors.

- We saw many empirical applications of sex-aggregated data or related to gender inequality. It is a challenge that many IAMs do not in fact use the sex-aggregated information available for the SSPs.

- No consideration of ocean and fishery scenarios

Further extensions of the SSP/RCP framework

- The impact community often lacks necessary quantified input data in the SSP framework, e.g. high resolution GDP and population data or other inputs consistent with the mitigation scenarios. Adaptation needs to be conceptualized in the framework, e.g. through SPAs, to channel developing efforts to include adaptation in the models in a harmonized way.

- SSPs are designed to map possibilities independent of climate and of policy. Shared climate policy assumptions (SPAs) bring in policy, but are somewhat neglected, especially for adaptation, though they have recently begun to find their way into the literature. Several ideas were explored for decoupling climate policy at local scale with that at global scale, which offers promising opportunities for extending the Scenarios Framework.

- Alternative futures for nature, diverse values and benefits of nature, visions for living in harmony with nature, and nature-based solutions for climate mitigation and adaptation were identified as gaps in the SSPs-RCPs. These gaps could be addressed by the biodiversity and climate research communities, co-developing scenarios that prevent biodiversity loss and mitigate climate change to secure livelihoods and the wellbeing of the planet. This will require modifying, improving and integrating existing scenario and modelling frameworks in filling these critical gaps. Specifically, the SSP-RCP Framework could be made more relevant to other scientific communities by (i) relabeling the axes from “challenges to adaptation/mitigation” to something that is less climate-centred; (ii) adding new positive or desirable SSPs or variants of SSP1; (iii) extending SSP1-RCP1.9/2.6 with multiple pathways (possibly based on the NFF) by incorporating biodiversity policies into the Shared Policy Assumption (SPA); and (iv) defining alternative pathways that bring the five SSPs towards sustainable and desirable futures. The less desirable SSPs could also be linked to the NFF if used as disruptive scenarios that stress or provide obstacles for pathways to nature-positive and sustainable futures. Coupling the SSPs with the NFF would help to align the role of scenarios across the IPCC and IPBES assessments, as well as better enabling interlinkages and feedbacks between climate and biodiversity to be represented in scenarios and models.

- Near-term information: SSP-RCP Framework focuses on climate goals and forcing in 2100, however carbon neutrality and short term action has become bigger focus. Need for considering socioeconomic uncertainty in near term is critical - very few studies that combine SSPs with socioeconomic uncertainty with short term policy assessment. Need for better information on uncertainties from internal variability and in forcings from natural and anthropogenic aerosols in addition to socioeconomic uncertainty. The combined uncertainty information may have an implication for global stocktake. Need to update the socio-economic projections, e.g. covering COVID and other trends, in the medium terms also completely new projections. Important for understanding of potential risks and opportunities for adapting and mitigating.

- Explicitly mentioning of gender in SSP narratives, model development to account for sex-aggregated data, an effort to present a broader framework for how gender inclusion can be a component of future scenarios work. This all directly relates to conversations about the future of governance and democracy as well, or the political institutional components of future SSP work in particular.

- Narrowed SSP-RCP Framework does not include policy relevant to poverty and inequality which could happen simultaneously with climate policy and thus we may want to consider such additional intervention.

- Probably the scenarios could use more explicit treatment of economic inequalities within countries. In addition, as discussed by Helene Benveniste in her presentation, there is a need for the SSPs to better account for the impact of migration in economic and demographic projections.

- The discussion revealed that there is a significant group of researchers that feel there should be a degrowth/post-growth variant of SSP1. Further discussions on how to reconcile this type of scenario with mainstream economic modelling seem an interesting avenue for research.

- a) large extensions in sectoral / spatial details, b) A more sustainable scenario and c) deep dive into processes enabling transformative change. It would also be interesting to explore further how the NFF and SSP-RCP Framework may or may not allign.

- Need development of additional reference scenarios that include impacts and/or policy, and this included adaptation as well as mitigation.

Types of scenario-based research that need further improvement

- The importance of going beyond technical mitigation measures to overcome barriers to non-CO2 mitigation, i.e., addressing also institutional and governance barriers. Currently this is not widely considered in the non-CO2 modeling community.

- Need to improve representation of F-gas emissions and mitigation in scenarios
- Integrated narratives and modeling of both passenger and freight transport would be a novel new area of exploration.
- Digitalization is an economy-wide and society-wide transformative force (or 'general purpose technology') with major risks and opportunities for mitigation. Adding it in to the SSP framework would enable further narrative and modelling analysis of these risks and opportunities and would help emphasize the importance of public policies for harnessing digitalization as a force for good.
- Need to foster use in understudied regions and topic areas

Training and guidelines

- Develop guidance for utilization of the SSP-RCP Framework that is also explicit about the need for reflexivity. Suggestions for what should be included in such guidance:
- Description of intended use of SSP-RCP framework. Such "normal science" is important to continue. The purpose of this description would be to address/correct confusion or 'bad habits' that might be emerging in the scientific community. Target audiences would be scientists in WGs I-III, scientific assessors (e.g. IPCC, authors of national assessments of climate change)
- Explicit recognition of need for reflexivity: Explicitly call for variants beyond marker scenarios and scenario innovations. This creates a recognized avenue for "post-normal science", which is also needed. Target audiences: Modelers in WGs I-III, researchers/creatives 'outside' scenarios community
- Clearer communication of SSP framework and elements, which would improve usage for example of extensions and at other scales
- Need guidance for IAV researchers on the use of the Scenarios Framework; the concept of limits to adaptation may be useful in facilitating this guidance. One problem is how users frame results of their work, for example characterizing SSP2-4.5 as a low emissions scenarios, or how to characterize results based on RCP8.5. It may be worthwhile to frame this as a scenario that is beyond some limits to adaptation. It may be useful in the future to have a high scenario that is an "artificial experiment" for climate models, not as part of a scenario set for application to IAV.

Additional information or detail within existing SSP-RCP framework

- The scenario framework ought better to consider the climate impact of regional aerosols, as shown by Laura Wilcox

- Global Narratives, SSP not equipped to inform policy in a detailed manner. Country scenarios explore how to get to a certain target. SSPs is to check what climate we're getting under certain assumptions

- SSPs don't dive into dynamics. Very high-level. They don't detail a roadmap.

- More lower end/overshoots, better exploration of alternative mixes of carbon capture (BECCS/DAC), better modeling of the possible feedbacks from the C-cycle; better exploration of the role of SLCFs.

- The existing SSPs can be augmented to integrate political development as well as an extended set of scenarios (including sub-regional) that examine a wider range of sociopolitical futures could be developed.

- Political development factors can be estimated as a function of existing SSP projections. This approach has been employed to develop estimates of future armed conflict risks along the SSPs that are consistent with the empirical relationships between armed conflict and features of development in the SSPs (e.g., GDP, population and education). Similarly approaches have also been employed to develop consistent futures for SDG indicators and other institutional factors.

- Political (and socio-economic) development can also be described as endogenous processes that interact with the core quantified features of the GDP. These formulations are more consistent with the theoretical understanding of the interdependence between economic and political developments. This approach enables feedback effects between economic and political developments (e.g., educational attainment). This, however, will also require more sophisticated modeling approaches, including simulation and coupling with other models and modelers.

- Finally, the narratives currently embedded in the SSPs can be expanded to better capture political futures. Not all information can be captured quantitatively - for example, where changes that are outside of the empirical record or other specific contextual information is desired. Social sciences can be especially informative in these cases to identify relevant historical analogies, identify and minimize biases that may hinder the development of narratives as well as identify best practices for engaging with all relevant voices.

- Scalability of SSPs: There are challenges in scaling up or down SSP quantitative information at intermediate time horizons and at different spatial scales.

- Interest in probabilistic projections: Socioeconomic projections can be expressed probabilistically in some situations (e.g., population). Relative uncertainty can be important to communicate in some situations

- Future versions of the scenario framework should also target a better representation of social science, societal dynamics, the role of institutions etc. in scenarios and models. One example is that many IAMs do not cover institutional quality at all - despite its key enabling role for transformative change. Similarly, education and gender equality are rarely covered explicitly in modelling exercises. Also, with respect to societal dynamics (e.g. concerning the adoption of healthy and sustainable diets), most models do not resolve the underlying policies or mechanism.

- Representing the finance sector by developing explicit elements e.g., of international finance markets for the SSP narratives, including a description of the role of finance, either as enabler or barrier, in the realization of the RCP-SSPs narrative.

- Improving and refining scenario descriptions of international connectivity (e.g., What free trade zones are in place? What are the regional zones for free movement of labor? Are there regional geopolitical blocks in place?) with explicit regional and sectoral extensions. Ideally, these extensions come with some quantifications.

- More differentiation between countries/world regions would be helpful to make projections in specific contexts.

- An explicit attention to the quantification of variables such as governance and conflict under different SSPs and more updated data with possible feedbacks along key variables would be extremely useful.

- The key development area is enhancing probabilistic elements in scenarios, particularly through incorporating the 'outside view' based on empirical evidence outside of the scenario framework. The dominant paradigm in scenario analysis is to shy away from probabilistic analysis and analysis of likelihood and to outsource feasibility assessment to the policymakers. For example, a final plenary keynote contained a suggestion to "throw ideas over the fence" and allow policy-makers assess what is feasible, which was in contrast to the approach on science-policy interaction in the area of feasibility used in most Session #48 contributions.

- The session highlighted that a number of assumptions made in IAMs, for instance regarding international trade in energy, are not always clearly linked to the assumptions on trade in the economic models, including those used for projecting GDP in the SSPs. While there is some information on these aspects in the scenario narratives, more can be done to ensure consistency across models used for constructing integrated scenarios.

Improved interactions among research communities and the policy community

- Need for improved local-level socioeconomic data: Several presentations and discussion points alluded to the need for quantitative data for defining vulnerability and exposure at municipal-scale. These data are often available, but in siloed, sectoral contexts that are difficult to locate and to integrate.

- The scenarios should allow (ideally, require) feedbacks from the climate system on to the energy-economic-human system. This is not an issue of the scenarios as they exist per se, but the tools used to evaluate them (IAMs and ESMs) currently don't talk to each other in the mainstream. WG1 and 2 communities should have interest in understanding how scenarios are developed, and in contributing to scenario development.

- Moving beyond demand to interaction supply-demand scenarios

- Better integration of waste and wastewater sectors - to be able to assess circularity scenarios, including nutrient recovery.

- Better integration of social sciences to develop scenario narratives

- Agent-based models to simulate the behavior of individual agents like humans, business, institutions, etc.

- The session clarified the need of thinking holistically about the choice/development of scenarios and the use of emulators, now that the latter seem to have stepped up to the plate more reliably. Therefore, as we look at further scenario development, especially the kind of products that support ESM experiments, the capabilities of emulators and their training needs should be considered.

- Enhanced integration of impacts

- Explore integration opportunities for bringing together the disparate impacts literature, including opportunities for using scenarios, GWLs and other common climate dimensions (CCD), climate projections, and climate projection-CCD mapping resources.

- Consistency in terms of potential baselines and characterizations of uncertainty to facilitate integration of socio-economic factors needed in impact and risk modeling and assessment.

- Directly include impacts into SSPs/ref scenarios/prep for CMIP i.e., make ISIMIP/ or equivalent an explicit part of the scenario process, along with narratives, drivers, IAM runs. Include impact model runs, coordinated model comparison runs for different types of impacts provided with the scenarios; like we do with climate models in the CMIP process, provided with scenarios

- 'Impacts MIPs' - face methodological difficulties since results are often difficult to intercompare e.g., for damages and cost-benefit space of avoided impacts. More work is thus needed to develop community standards for impact definitions and reporting (similar to the work that has been done in IAM model comparisons). This would facilitate

more systematic impact comparisons and permit to connect/integrate impacts better with the socioeconomic SSP projections and scenarios from WGIII.

- Bridging scales - tension for wanting to tell global stories but recognizing that impacts, risks, responses are mostly at local level. Scenarios are great with *global* stories, but at *local* level, you have to get into things that global scenarios can't necessarily provide.

- Explore impact emulators – discussions would be valuable with the impacts community, jointly with IAMs, and should also include WGII to evaluate opportunities for estimating impact functional forms. This would not be a substitute for detailed impacts and risk analyses needed to inform adaptation but could provide aggregate impact-driver relationships helpful to climate policy.

- Run IAMs with and without impacts then sectoral impact modules could be used for comparison - new analysis to have both scenarios with and without impacts

- There is a research community opportunity to develop a climate translation resource for mapping the impacts literature input climate projections to CCDs and vice versa to facilitate integration.

- Consistent assessment of scenarios across WGs

- Explore opportunities for the consistent use of scenarios across WGs for enhanced integration of future assessment across WGs.

- A core set of scenarios—climate with socioeconomic uncertainty—across WGs may need to include more policy-relevant ones including close to current policy or NDCs, and different levels of overshoot (particularly for 1.5°C global warming), and consideration of pathway likelihood and plausibility

- Explore opportunities, challenges, and limitations for socioeconomic scenario standardization and capturing uncertainty relevant to adaptation, mitigation, and risk.

- Representative Agricultural Pathways (RAPs) could serve as an additional dimension of scenario analysis covering the agricultural and food systems. These cannot be comprehensive given the wide diversity of detail needed for scenarios at different scales and levels of sectoral complexity examined, but a coherent set of storylines and a common framework would go a long way to establishing useful scenario assessments. There is a great need to provide practical limits to productivity increases that are often assumed in Integrated Assessment Models, including biophysical limitations as well as the practicality of large-scale deployment of intensification approaches that would have other devastating impacts on the environment.

- SSPs would have to be expanded to include ocean and fishery scenarios

- Broadening the perspective by producing more integrated ocean-related scenarios that can better fit societal needs of projections (even in ocean's modeling community silos-approach of modeling questions and does not integrate).

Additional types of societal pathways or integrated scenarios not represented in SSPs

- Missing dimensions in SSPs: SRES B2 (a more divided, but ecologically-minded world) was an interesting and "recognizable" worldview that is not really reproduced in the SSP suite, even as an SSP1 variant. The "Archetypes" approach can be useful for identifying these types of worldviews from existing published global scenarios. Other ideas were also discussed.

- Use of wildcards: SSPs can be used as or provide context for "Wildcards" (or also expressed as climate impact storylines in other work). The idea is to use well-defined cases that resonate with stakeholders but can also allow for rich exploration of potential stakeholder responses.

- Our session identified multiple ways to go forward, including the development of alternative GDP scenarios, update macroeconomic modules, link existing IAMs with other models, standalone assessments of multi-sector macroecomics, and address the complementarity question with different models.

- An SSP scenario that does not automatically associate high human development and environmental sustainability with high economic growth would be a useful extension of the scenario space (see above, and also session #37).

- Extending justice principles beyond a utilitarian focus, which is currently most often used in IAM, and applying them in model analysis shows other trajectories of CO2 emissions and temperature increases. This provides important insights into how much of inequality might be inevitable and how much is intrinsic model property. By looking at different justice principles, research presented in this session addressed the questions of how mitigation policies may be more equitable in distributing the benefits and burdens of climate change policies while also being robust. More nuanced scenarios taking a wider variety of uncertainties into account, specific to local contexts, can also be helpful.

- Consider scenarios currently missing from the SSPs that pair high international connectivity in one aspect with low connectivity in another.

Improved communication

- There are big questions for a scenario framework in terms of the utility of generating scenarios until 2100 in a rapidly changing policy landscape. The WG3 IMPs might provide a good starting point for much more fine-grained analysis on some of the key policy questions - outlining the implications of different policy options in rather concrete terms.

- More generally, there is a question about the scenario positivism that should be reflected upon also from within the community. The SSP-RCP Framework not including climate or any other shocks shows 'progress' even under the most pessimistic

scenarios. A global pandemic, a large-scale territorial war, an energy crisis and the third global economic crisis upon us in 15 years this requires some revision. In particular, as climate acts as a threat multiplier with other crises. A 'orderly' view of the future as produced by IAMs will miss that key part of the picture.

- Decrease complexity/communicate scenarios better: use of visual tools to make information more digestible

- On the other hand, there is the need to contextualize scenarios more, resulting in a likely increase in complexity, e.g., by using 'scenarios of outcomes' that describe more realistic, integrated futures

Scenario development approaches

- Consider how more diverse scenario methods that invite creativity (including possibly questioning or expanding the framing of SSP-RCPs) might be recognized or incorporated into the SSP-RCP assessment/update process. The Scenarios Forum is a natural place to engage such considerations, as is happening already. This addresses two research gaps: (a) diverse methods help us anticipate the novel and difficult-to-imagine conditions of life under climate change and (b) science communication of these futures in ways that render them more tangible and 'real' (e.g., social simulations) for knowledge users. Many of these methods focus on bringing in perspectives that are often marginalized from scenarios discussion in the scientific community, producing unique insights about possible futures. Such methods also help expose what is 'missing' from the SSP-RCP-SPA framework, offering insight into complementary processes.

- More effective methods of drawing on the rapidly expanding scenario-based literature, including machine learning approaches

- Steer use of scenarios towards users: research focus has different needs than stakeholders → perspective change needed

Projects

- Projects: IMAGINE project. Individual activities by national teams. Global Narratives (add paragraph). work will inform the GST. Policy follow-up by others too (Gunnar, Haewon). Continued engagement.

- This session was part of ongoing discussions within the H2020 PROVIDE project and will greatly inform the developments under this project.

- One of the most concrete advances is the continuation of the SHAPE project, of which one of the sustainable development pathways under development will have a post-growth GDP pathway.

- Some of these initiatives will feed into the WorldTrans Horizon Europe project (2023-26) in exploring closer links between human and Earth systems. We will report back to the MESH and AIMES steering groups on the outcomes from this session. We have no plans as yet for a community write-up (will depend on time).

- Systematic analysis of feasibility is currently undertaken in ENGAGE and MANIFEST projects.

- Work within the EU H2020 CASCADES project to summarize findings from multiple case studies that have explored future cross-border climate risk using various scenario approaches

- Work with the EDHEC-Risk Climate Impact (ERCII) research center to complement RCP-SSPs narratives with the role of finance (enabler/barrier) and climate risks, and their interplay

- Work on this topic continues within AgMIP, and there are new projects to formalize the RAPs process on national scales across Africa and South Asia. Increased focus on systemic connections has fostered systemic thinking and therefore highlighted the need for elaboration that allows sectors to be better represented and connected for proactive planning.

- The presenters and organizers have decided to stay in touch and be informed about any further developments on quantitative scenarios for adaptation and adaptive capacity and collaborate in the future. Specifically, there will be a Comment on adaptation and adaptive capacity in IAMs.

- There are some informal plans to continue this type of discussion among economics groups and gradually provide more economic information related to the SSPs; the GTAP consortium is likely to coordinate this discussion.

- Various communities are following different streams of work (from extension and quantification of SSP-RCP-based scenarios, to the development of novel scenarios) and bridges are regularly created around IPBES assessment cycles (e.g., regional and global assessments, thematic assessments on model and scenarios, pollination, values, sustainable use of resources, etc.), as well as IPCC assessment cycles (e.g., joint IPCC-IPBES workshop, IPCC assessment reports, etc.) and additional activities such as ISIMIP. Efforts are ongoing to more closely connect these communities to the broader set of communities working with the SSP-RCP scenario framework, including a plenary talk from P. Harrison and a specific workshop (Session 51) during this scenario forum, as well as further steps to create a community of practice around coupling biodiversity and climate scenarios for sustainable and transformative futures.

Meetings

- Need to organize a more extensive meeting to take this forward, necessarily involving leaders of other MIPs and also bridging to the community the develops inputs for ESMs.

- A follow-up workshop is in preparation for Fall/Winter 2022, led by IDOS (Leininger) and PRIO (Buhaug/Gilmore).

- ISIE-SEM Conference 2022 http://www.isiesem2022.org/
  We are proposing emulators sessions at IAMC, AGU. A meeting to explore the next phase of CMIP/ScenarioMIP may also benefit from the participation of emulator developers.

- There will be another session on Physical Climate Storylines at the 2022 meeting of the European Meteorological Society in Bonn but with different contributors: https://meetingorganizer.copernicus.org/EMS2022/session/44463 . Taro Kunimitsu's talk will be submitted as a publication, as well as the other contributions to the session as far as I am aware.

- We are planning to start a community of practice around coupling biodiversity and climate scenarios for sustainable and transformative futures. In parallel to the digital and in-person exchange with participants of the Scenarios Forum, we initiated similar exchange with the broader biodiversity scenarios and modelling community on the need for coupled biodiversity and climate scenarios, their desirable characteristics and means for developing them, and biodiversity policies for the SPA (Shared Policy Assumptions). This was also as a follow-up of the second IPBES Modellers Workshop in April 2022 where the experts in the SSP-RCP community suggested these as ways forward in co-developing coupled climate and biodiversity scenarios for ongoing assessments of IPCC and IPBES and policy frameworks such as Paris Agreement, CBD Global Biodiversity Framework and the UN Sustainable Development Goals.

- An ICONICS webinar will be held in October 2022 on the communication of scenarios. This will include outcomes of a project that is being undertaken by the WGI Technical Support Unit in collaboration with the Reuters Institute for the Study of Journalism.

- A related discussion is suggested to take place at the 2022 IAMC conference.

- An IPCC Workshop on scenarios is being planned by the three WGs for early 2023.

Publications

- Reflexivity: There have also been informal conversations about a possible follow-up publication, which might be pursued starting fall 2022.

- IDOS (Hernandez) and PRIO/Carleton (Gilmore) are separately developing a workshop paper that summarizes the panel discussion. It is anticipated that this will also be a journal article that brings the key findings into peer reviewed press.

- Joint publication: The Pedde et al. review paper is still to be finalized, and may require some updating based on this meeting

- Methodological comparisons: Novel methods, particularly including Cross Impact Balance (CIB) analysis and Fuzzy Cognitive Mapping (FCM) will be compared and discussed as tools to develop local scenarios. The aim is to produce practical manuals for the use of these tools.

- During the discussion it was suggested to write an "SDG research agenda" paper that takes up the discussion points from the session and at other fora, and formulates suggestions for a way forward.

- A special issue of Frontiers In Environmental Science is planned on the topic of *Stakeholder-Engaged Integrated Assessment Modelling for Global Scenarios in a Changing World* and edited by Jeffrey M Bielicki and Douglas Jackson-Smith (co-chairs of session #29) and Sibel Eker and Sarah Elisabeth Cornell (co-chairs of this session, #52).

- A commentary is planned to summarize the use of scenarios in the AR6 and discuss challenges, hindrances and opportunities to inform preparations for the AR7. This may discuss increased integration, the modes of working in the assessment process across the WGs and in relation to the underlying community, knowledge gaps and IPCC audience interests and needs for scenario-based information.

- Events are planned for COP27 on the WGIII assessment of scenarios and on the use and communication of scenarios by policymakers.

- We plan to write a perspective piece on the need for more gender-related work in scenarios.

- EU Climate Risk Assessment: One participant (Hans Martin Fuessel) is leading this assessment and actively considering lessons learned from the IPCC scenario experience and other scenario work on synthesizing and communicating risk

- We are planning to have a model intercomparison paper based on this session.

- There is a new section of Frontiers in Climate on climate mobility, and we may organize a research topic (special issue) on the subject.

- A paper is planned on the updated SSP literature database, led by Carole Green

Appendix IV: Session organizer questionnaire and feedback

Please summarize highlights of your session at the Scenarios Forum. You should include whatever content you feel is most important to communicate the results of the session, but we ask that at a minimum you address the questions below. We envision your response to be about 2 pages in length.

These session summaries are intended to capture outcomes, insights, and progress made at the Forum and will be included as an annex to the Meeting Report. They will also be used to help provide a higher-level overview of meeting outcomes in the Meeting Report, which will be written by the Scientific Steering Committee, possibly with additional meeting participants. Any use of the content of session summaries for the Meeting Report or a synthesis paper on the status and outlook of the scenario process will be properly credited.

Session name:

Session organizer(s):

1. What particularly notable advances have been made in the topic area of this session that involved using or further developing the SSP-RCP or other (please specify) scenario frameworks?

2. What features[1] of the SSP-RCP or other scenario frameworks helped or hindered progress in the topic area of this session?

3. What key modifications, additions to, or extensions of the scenario framework would be most helpful for future work in the topic area of this session, and what research gaps

would they address?

4. What are other key highlights from your session?

5. What audiences (researchers, practitioners, policymakers) do you think would most benefit from the scenario-related work in the topic area of this session?

6. What plans for follow-up activities (meetings, publications, projects, etc.) related to the topic area of this session are you aware of?

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[1] By "features," we mean elements like narratives, quantitative drivers, or IAM scenarios, or aspects of the framework like the matrix approach to combining socioeconomic and climate information, or the spanning of uncertainty in challenges to adaptation/mitigation.

Session ID # 6: Non-CO2 emissions

Session name: The role of non-CO2 greenhouse gas emissions in mitigation scenarios and climate change

Session organizer(s): Lena Höglund-Isaksson (IIASA)

1. **What particularly notable advances have been made in the topic area of this session that involved using or further developing the SSP-RCP or other (please specify) scenario frameworks?**

- The presentations of **Yang Ou** (GCAM) and **Jared Creason** (USEPA) showed recent updates of non-CO2 scenarios and mitigation cost curves. The full systems integration in the GCAM model, from economic activities and sector-based mitigation to climate change impacts, can be highlighted as it allows for an assessment of the *climate impact of delaying action on non-CO2 mitigation*.

- *Uncertainty ranges* in non-CO2 mitigation have been notoriously overlooked in the past. **Mathijs Harmsen** presented work under the NAVIGATE IAM model development project to provide an estimate of the total uncertainty in non-CO2 mitigation, by updating recently developed non-CO2 MAC curves and complementing these with a set of optimistic" and "pessimistic" MACs, with high and low mitigation potentials, respectively. The use of Monte-Carlo simulation in this analysis was well received by the **Session audience**, which also recognized the need to determine uncertainty ranges for non-CO2 mitigation.

- **Laura Wilcox** brought an important but largely overlooked topic to the Session, namely the *role of regional changes in atmospheric aerosols on regional near-term climate risks*. The complex and diverse regional responses to changes in atmospheric aerosol loadings are still largely neglected in the tools and metrics currently used in policy-facing evaluations of near-term climate risks - including the IPCC 6th Assessment Report. There is now comprehensive evidence that regional changes in aerosol emissions can drive significant trends in temperature and hydroclimate, at the local to the global scale. Neglecting or oversimplifying regional aerosol effects, whether near to the emission sources or remotely, in near-term climate risk assessments therefore constitutes a blindspot in society's ability to adapt to and prepare for future climate change. The **Session audience** agreed on the urgency of improving the inclusion of aerosols, with a focus on the local to regional scales, in scenario developments.

- **Daniel Johansson** presented an estimation of the social cost of methane (SCM), which expresses the climate damage cost associated with an additional tonne of methane emitted, as an alternative metric to GWP-100 that can be used to design policies to reduce the emissions of this gas. The **Session audience** agreed on the usefulness of the *SCM as an alternative to GWP-100*, however, also raised the issue of the sensitivity of SCM to the definition (what factors are included/excluded) of the underlying damage function.

2. **What features of the SSP-RCP or other scenario frameworks helped or hindered progress in the topic area of this session?**

   Several of the presented papers had made use of SSP scenarios as input to their analysis.

3. **What key modifications, additions to, or extensions of the scenario framework would be most helpful for future work in the topic area of this session, and what research gaps would they address?**

- The scenario framework ought better to consider the climate impact of regional aerosols, as shown by Laura Wilcox
- The importance of going beyond technical mitigation measures to overcome barriers to non-CO2 mitigation, i.e., addressing also institutional and governance barriers. Currently this is not widely considered in the non-CO2 modeling community.
- Need to improve representation of F-gas emissions and mitigation in scenarios

4. **What are other key highlights from your session?**

- The urgency of addressing the regional aerosol changes on climate impact stood out as particularly important
- The importance of finding good ways to communicate the implications for policy-makers of the timing of non-CO2 mitigation and its role to reduce short-term warming.

5. **What audiences (researchers, practitioners, policymakers) do you think would most benefit from the scenario-related work in the topic area of this session?**

   All of these audiences, but important to find good ways to communicate to these different audiences.

6. **What plans for follow-up activities (meetings, publications, projects, etc.) related to the topic area of this session are you aware of?**

   No such activities were discussed explicitly during the Session.

SCENARIOS FORUM 2022

Session ID # 7: National Decarbonization

Session name: National deep decarbonization scenarios: policy analysis and global narratives

Session organizer(s): Johannes Svensson and Daniel Buira

1. **What particularly notable advances have been made in the topic area of this session that involved using or further developing the SSP-RCP or other (please specify) scenario frameworks?**

   Further detail by focussing on national level - allows for depicting country specific details / pathways on how to reach climate targets. Highlights mitigation options and choices. Scenario framework provides

2. **What features[1] of the SSP-RCP or other scenario frameworks helped or hindered progress in the topic area of this session?**

   Little explicit use of SSPs/RCPs. However, narratives & IAM scenarios were developed at the national scale and based on national circumstances under an SSP2-like world. SSP1? Requires lifestyle change, and this is not included in many of the studies.

3. **What key modifications, additions to, or extensions of the scenario framework would be most helpful for future work in the topic area of this session, and what research gaps would they address?**

- Global Narratives, SSP not equipped to inform policy in a detailed manner.
- Country scenarios explore how to get to a certain target. SSPs is to check what climate we're getting under certain assumptions
- SSPs don't dive into dynamics. Very high-level. They don't detail a roadmap.
- Discussion on why we need national models. They capture country specific dynamics, data, trends, culture better.

4. **What are other key highlights from your session?**

- Discussion on why we need national models. They capture country specific dynamics, data, trends, culture better. Makes it much easier to engage with policymakers.
- Paradigm shift from rate of reduction to a certain year to what year to you reach neutrality
- Important to have different scenarios to the same goal. Important if you want to be policy relevant. Enables a different kind of risk exploration.

5. **What audiences (researchers, practitioners, policymakers) do you think would most benefit from the scenario-related work in the topic area of this session?**

- Researchers: Exchange on best practices of national level scenarios
- Policy makers: Scenarios (national models or global models with enhanced national analysis) are very specific, give guidance on concrete pathways

6. **What plans for follow-up activities (meetings, publications, projects, etc.) related to the topic area of this session are you aware of?**

   Projects: IMAGINE project. Individual activities by national teams. Global Narratives (add paragraph). work will inform the GST. Policy follow-up by others too (Gunnar, Haewon). Continued engagement.

Session ID # 8: National Scale

Session name: Challenges and opportunities in constructing national scale scenarios from the SSPs/RCPs

Session organizer(s): Mark Rounsevell, Paula Harrison & Rob Dunford (note taking by Simona Pedde)

Overview of the session

Speaker 1: Paula Harrison - UK-SSPs

Participatory process to co-develop SSP narratives and quantitative trends at the national scale for the UK

- Why develop them? Complementary to Climate projections for the UK (UKCP18). Also, common scenario framework and embedded in the global context. It also ensures subsequent research in the UKCRA
- Extensions: Spatial, temporal and sectoral extensions. Applicable to the wider UK community. Bits of information and people from all the relevant sectors. Users can develop further extensions
- Approach: participatory
- Part 1: UK-SCAPE project* workshop and questionnaires
- Part 2: Climate Resilience SPF project. Stakeholder workshop, semi-structured interviews, questionnaire
- First, identify UK-specific socio-economic drivers. First live with post-its and then online with word-clouds. The output from the first workshop was combined after. We looked at different polarities
- In the first physical workshop, stakeholders brainstormed events. 1 draft narratives, checked via questionnaire. UK-SCAPE SSP-narratives.
- In the second online workshop stakeholders started with the narratives and then elaborated them.

Results:

- 5-6 pages narratives, in 3 three time slices and then paragraphs specific for the nations in the UK.
- System diagrams to visualize the narratives, using vue software.

- Tables of semi-quantitative trends. We used GDP and population trends from the IIASA database. The rest was done by project teams
- Final selection of socio-economic variables that we thought the community would need.
- Final example of the master table of trends
- The final product is the quantification of the variables, modelled via different modelling approaches
- For each quantified variables Spatially explicitly There's an indicator, Resolution: Legend unit
- The only simulation including socio-economic and climate is the agent based model CRAFTY-GB land-use. Population and planning policies drive the land-use systems

Q&A:

- How they were taken up in policy? Possible to know in some years. We had lots of involvement from policy-makers. We had stakeholders that wanted us to stick with the global SSPs
- How do you introduce the SSPs? We let the stakeholders brainstorm and then introduce the SSP narratives. In SSP3 you can see the fragmentation internally as well.
- 14 drivers: were they incorporated? What happened to Northern Ireland? What is Regional Rivalry? They didn't know what categories beforehand. Crafty was just a modelling issue.

Speaker 2: Anna Lipsanen – The future of health and social welfare in Finland

- SSP extensions = detailed regional/sectoral view of future development
- Challenges – interpreting global at regional scale, co-production with stakeholders
- PLUMES project
    - To co-create broad extensions of SSPs for HSW sector
- Workshop in May 2019 in Helsinki, ~40 stakeholders from public and private healthcare providers, ministries, municipalities, research and care orgs
    - Structured by 3 perspectives (citizens, service providers and DMs) and 5 sectors (environment, etc) -> Matrix

- Workshop with 4 facilitators
    - Predetermined representatives in each group, in Finnish,
    - Posters on global and European SSPs given in advance plus basic info on pop, etc in Finland
- Steps:
    - Choice of SSPs
    - Specification of themes and perspectives, identification of participants
    - Facilitate workshop
    - Stakeholder feedback on workshop
    - Coding and analysis of workshop outputs; drafting of full narratives; consistency checks
    - Iterations of draft narratives with stakeholders
    - Final SSP narratives for Finland with detailed results and summary trends
- Input from researchers in all steps
- Narratives were 1.5 page each
- Next steps:
    - Finalising analysis of narratives vs global and sectoral SSPs
    - Developing basis of quantified exposure and vulnerability indicators
    - Narratives reported in paper and on national climate change portal
- Hope that the narratives will be used to provide a future context for climate change adaptation and mitigation decisions
- Stakeholder heavily involved providing relevance, legitimacy and salience

Questions:

- Quantification planned – will this be another stakeholder process?
    - We didn't ask anything on this in the stakeholder workshop. We plan to focus on just a few variables as we can't involve the stakeholders anymore
- 3 perspectives – where are these at the end in the narratives?
    - Narratives categories by themes, perspectives are merged into the themes to ensure they are all dealt with
- If want to take further to other sectors, would you start from the themes or the finalized narratives?

  - First steps of making a regional effort on SSPs. Themes within a systems to provide stakeholders some context. Stakeholders need to be identified depending on the sector. Not one size fits all.

  - May have to adjust the narratives

- There is a study on quantified health risks for Finland – have you looked at this to see if there approach to quantification may be useful.

Speaker 3: Andy Challinor – Stakeholder-driven scenarios for national-scale climate-driven nutrition

- Policy pathways for agri-food systems that are evidence based
- Developed the integrated Future Estimator for Emissions and Diets (iFEED)
- Rationale – open, inclusive, combining models with wider expertise and data, useful for problems that can only be partially modelled, flexible approach that can target appropriate degree of complexity
- Parallel line of evidence to IAMs
- Steps:
  - Scenario workshop
  - Integrated modelling
  - Integration workshop
  - Online results presentation
  - Stakeholder input at all 4 steps; research and practice input into integration workshops
- Followed IPCC language on confidence statements on high/low agreement and robustness to produce a set of texts
- Example for Zambia:
  - Not SSPs, but could be mapped onto their axis
  - Climate risk (high & Low) vs Market connectivity (high & low)
  - Looked at how domestic production and trade interacts using Chatham House
- Summary:
  - 1 tool
  - 4 country policy docs (South Africa x 2, Malawi, Zambia)
  - 16 scenarios docs (4 scenarios = solitude & self-sufficiency, isolation & , road to hell,)
  - 1250 implication statements
  - Millions of model simulations across the four scenarios
  - 4 participatory workshops

- Nutrition and trade implications – some counter-intuitive, but can be explained when dig into detail of the nutrients that improve/decline under high/low climate risk
- Future research directions:
    - Application to cascading risks
    - Integrating bottom-up disruptive scenarios in Kenya and cross-scale modelling approaches

Questions:

- How dependent are the counterintuitive results where nutrition improves under high climate risk dependent on trade-offs?
    - Yes environmental degradation, soil health, emissions
- How did you connect the stakeholder input to the integrated modelling?
    - Asked them very specific questions, e.g. will agricultural land area increase/decrease, by how much? Aided by pandemic in that zoom meeting where people could provide the inputs
- How did you harmonize the inputs across stakeholders?
    - Project team had a first go and then iterated with stakeholders. Small groups of ~15 people, so iteration was possible. Open doors towards policy dialogue.

Panel discussion with the three speakers

1. Were they stakeholders that questioned the SSPs themselves? If it happened how you dealt with them?
    - Anna: we just introduced them without previous knowledge. There was some disagreement, but we facilitated the process.
    - Paula: they were accepted. Recognised as big gap. We had discussions within SSPs. In other contexts takeholders struggle in future mindset
2. I'm applying UK-SSPs. When I read narratives of UK-SSPs, I read a novel. How do you manage that? Some people might lack a future mindset, how to deal?
    - Andy: statements are calibrated. Assessment of robustness, IPCC-type of statements. We cantegorise statements under different headings. More atomised In practice they can still be hard to use. Maybe a way in-between long narratives and atomised approach
    - Anna: The 7-steps to heaven was a way to make the process more manageable. We used qualitatively analysis, and used stakeholders that could validate results. We wouldn't aim for novels.

- Paula: UK ones was shorter. We could capture online much more material. When we made multiple matrices the narratives became longer and longer. Both workshop wanted them to be transformative. Second question, sometimes you have to be blunt. You can ask policy questions and get the think in the scenario terms

3. Selecting stakeholders, whether they have worldviews from the UK visions? Participants can come from the local scale or national scale.

    - Paula: we agree on a set of criteria. Going through the list of stakeholders. With online we can add more people. However, online it was 8.5 hours spread in four days. We kept distractions short. Keep detailed notes. In terms of representation: key role of facilitation, to ensure everyone has a voice. Everyone brings different experience, but that's good.

    - Andy: on selection —> we relied on our partners. We wanted people that were willing to engage. Large group, some really want to have a conversation and those were key. The national versus local, we didn't have a discussion on this.

4. Question to Finland colleagues. Which role did the role of inflation etc on SSP3 have? Quite interestingly, we talk about validity and timing of the workshop. Is it worth to do it after two years or three and check?

    - Anna: the economic side revolved around the healthcare system. In terms of inflation it didn't incur. Economic development was touched, but not there. About the stakeholder engagement: also stakeholder fatigue and they relate to everyday work

    - Paula: on the time-component. It really played a role. Agree. First workshop was Brexit, the second there was pandemic. So facilitation has to help by stopping this a bit. In the second workshop, we got an uncertainty "response to global shocks" that was there. But we managed not to be taken over by Covid.

SCENARIOS FORUM 2022

Session ID # 10: Finance

Session name: Building better climate scenarios for supervisors, private sector financial institutions, and development institutions

No session feedback form provided
Session not recorded as it was organized under Chatham House Rules

SCENARIOS FORUM 2022

Session ID # 12: Reflexivity

Session name: Reflexivity for sustainable and equitable futures: broadening scenario inputs for linkages across methods, scales, and levels

Session organizer(s): Anita Lazurko, Vanessa Schweizer

1. **What particularly notable advances have been made in the topic area of this session that involved using or further developing the SSP-RCP or other (please specify) scenario frameworks?**

   All scenarios are framed by their purpose, the context in which they are produced, and the contexts in which they are used. The SSP-RCP scenario framework primarily serves the purpose of organizing scientific research across the three Working Groups of the IPCC and is used by scientists. However, decisions about how societies will 'live with climate change' happen outside of the IPCC. Thus considerations should be made about how more diverse scenario methods that invite creativity (including possibly questioning or expanding the framing of SSP-RCPs) might be recognized or incorporated.

2. **What features[1] of the SSP-RCP or other scenario frameworks helped or hindered progress in the topic area of this session?**

   Responses to Question 2 are an amalgamation of sentiments from the session as well as the individual reflections of organizers after the session.

   <u>Features that help</u>

   - Matrix architecture
   - Narratives, qualitative elements (what Kasper Kok called "tables" in his plenary remarks), quantifications. The different parts of the SSP-RCP Framework can be used as needed.
   - SSP-RCP scenarios and their application are a "community activity" with broad definition of 'community' (e.g. Scenarios Forum attendees)
   - Community "standards" help with interoperability of quantifications. *However, this feature also acts as a hindrance, as described below.*
   - Lack of guidance. With no formal guidance, SSP-RCP users experiment. *However, this feature also acts as a hindrance, as described below.*

   <u>Features that hinder</u>

   - Marker scenarios. These act as anchors in the scenario space, where exploration of the wider space is what is desired.
   - Community "standards" introduce requirements for scenarios or scenario elements to be shared, which may discourage reflexivity.

- Lack of guidance. With no formal guidance, SSP-RCP users may employ/develop bad habits

3. **What key modifications, additions to, or extensions of the scenario framework would be most helpful for future work in the topic area of this session, and what research gaps would they address?**

   Two key recommendations (again an amalgamation of sentiments from the session as well as the individual reflections of organizers after the session):

   a. **Consider how more diverse scenario methods that invite creativity (including possibly questioning or expanding the framing of SSP-RCPs) might be recognized or incorporated into the SSP-RCP assessment/update process.** The Scenarios Forum is a natural place to engage such considerations, as is happening already. This addresses two research gaps: (a) diverse methods help us anticipate the novel and difficult-to-imagine conditions of life under climate change and (b) science communication of these futures in ways that render them more tangible and 'real' (e.g., social simulations) for knowledge users. Many of these methods focus on bringing in perspectives that are often marginalized from scenarios discussion in the scientific community, producing unique insights about possible futures. Such methods also help expose what is 'missing' from the SSP-RCP-SPA framework, offering insight into complementary processes.

   b. **Develop guidance for utilization of the SSP-RCP Framework that is also explicit about the need for reflexivity.** Suggestions for what should be included in such guidance:

      i. Description of intended use of SSP-RCP framework. Such "normal science" is important to continue. The purpose of this description would be to address/correct confusion or 'bad habits' that might be emerging in the scientific community. Target audiences would be scientists in WGs I-III, scientific assessors (e.g. IPCC, authors of national assessments of climate change)

      ii. **Explicit recognition of need for reflexivit**y: Explicitly call for **variants** beyond marker scenarios and scenario innovations. This creates a recognized avenue for "post-normal science", which is also needed. Target audiences: Modelers in WGs I-III, researchers/creatives 'outside' scenarios community

         (a) To help create avenues for such creative, inclusive, and reflexive scenario work to be incorporated into global scenario processes, the types of scenario activities that are most appropriate for what research questions/areas might be mapped out, e.g., we are departing from BAU. What futures represent incremental change, radical change? And what kinds of change? Technological? Social? Values?

         (b) For scenario innovations, especially with respect to arguing that the SSP-RCP Framework itself (or modeling approaches) should change, it would be helpful to demonstrate what changes would matter for analytical

results and how the innovation might be implemented (e.g. data 'hand-off', model linking, coupling)

4. **What are other key highlights from your session?**

   N/A

5. **What audiences (researchers, practitioners, policymakers) do you think would most benefit from the scenario-related work in the topic area of this session?**

   All audiences and for different reasons as summarized below.

   a. Researchers and practitioners: It became clear at the forum that there is some confusion about the intended use of the SSP-RCPs, so this should be reiterated. Arguably, abiding by the intended use of the SSP-RCPs is "normal science" (see Thomas Kuhn). However, as the energy transition gets underway and we learn how to 'live with climate change', we will be learning by doing, sometimes with high-stakes (i.e. post-normal science, or PNS). Scientists and practitioners also need guidance on how to do PNS, which requires reflexivity.

   b. Policymakers: Some policymakers (or other opinion leaders) may not have internalized the risks of climate change or the scale of the transitions that are needed. Potentially, more immersive approaches to scenarios (i.e. from the humanities, narrative and dramatic traditions) may be more effective for initiating reflexivity around the topic. The learning that such audiences undertake tends to feed back to the scenario developers, i.e. researchers.

6. **What plans for follow-up activities (meetings, publications, projects, etc.) related to the topic area of this session are you aware of?**

   No formal follow-up activities are planned, but here are some related activities in which the session organizers will be participating:

   - International Environmental Modeling and Software Society (iEMSs) 2022 Congress, Session A6, CIB (cross-impact balances) state of the art and future avenues, July 7, 2022
   - Community Climate Interventions Scenario Workshop, Oct. 31 - Nov. 2, 2022

   There have also been informal conversations about a possible follow-up publication, which might be pursued starting fall 2022.

SCENARIOS FORUM 2022

Session ID # 15: Adaptation

Session name: Quantitative scenarios for adaptation and adaptive capacity

Session organizer(s): Nicole van Maanen, Tabea Lissner & Marina Andrijevic

1. **What particularly notable advances have been made in the topic area of this session that involved using or further developing the SSP-RCP or other (please specify) scenario frameworks?**

   We discussed the currently limited availability of quantified dimensions within the SSPs (e.g., awareness) that would allow a broader understanding of adaptive capacity. Further, the limited spatial scale of those variables were discussed. We also spoke about the limited SSP scenarios and that there should be more scenarios closer to SSP1 in terms of their socioeconomic storyline.

2. **What features[1] of the SSP-RCP or other scenario frameworks helped or hindered progress in the topic area of this session?**

   The quantified dimensions of the SSPs (education, population, gdp, governance, gender inequality and others) were useful for the development of quantitative scenarios for adaptation and adaptive capacity.

3. **What key modifications, additions to, or extensions of the scenario framework would be most helpful for future work in the topic area of this session, and what research gaps would they address?**

   Please see above (extension of quantified dimensions within the SSPs and additional sustainability scenarios)

4. **What are other key highlights from your session?**

   Discussion with other young researchers working on topics related to adaptation and adaptive capacity was a highlight for all participants, as many of us were not aware of the multiple research strands around the topic and will collaborate in the future.

5. **What audiences (researchers, practitioners, policymakers) do you think would most benefit from the scenario-related work in the topic area of this session?**

   Modeling teams could be interested and should start thinking about how they could best include components of adaptation and adaptive capacity within their models (specifically IAMs) - what are the entry-points and how should adaptation ideally be represented for a useful inclusion in the models.

6. **What plans for follow-up activities (meetings, publications, projects, etc.) related to the topic area of this session are you aware of?**

   The presenters and organizers have decided to stay in touch and be informed about any further developments on quantitative scenarios for adaptation and adaptive capacity and collaborate in the future. Specifically, there will be a Comment on adaptation and adaptive capacity in IAMs.

SCENARIOS FORUM 2022

Session ID # 16: CMIP6/7

Session name: CMIP6-CMIP7

Session organizer(s): : Claudia Tebaldi[1], Bjørn H. Samset[2], Brian O'Neill[3], Jean-Francois Lamarque[4], Detlef van Vuuren[5], and Laura Wilcox[7]

Institutional Affiliation(s): Lawrence Berkeley National Laboratory[1], CICERO Center for International Climate Research[2], Pacific Northwest National Laboratory[3], Climate & Global Dynamics (CGD-NCAR)[4], Netherlands Environmental Assessment Agency[5], University of Reading[7]

1. **What particularly notable advances have been made in the topic area of this session that involved using or further developing the SSP-RCP or other (please specify) scenario frameworks?**

   The session took stock of the use of the SSP-RCP scenarios in CMIP6, ScenarioMIP and complementary MIPs (e.g., AerChemMIP, LUMIP, C4MIP etc.) and looked ahead at their use in the next phase, CMIP7, which is starting now.

2. **What features[1] of the SSP-RCP or other scenario frameworks helped or hindered progress in the topic area of this session?**

   The use of a number of SSP-RCP trajectories in Tier 1 and Tier 2 of ScenarioMIP supported the work of the WG1-type community, and will do so for a long time, given the 12PBs of data produced. The timeline of development of trajectories of forcings is problematic, and the process itself can use improvements in automatization, updates, concerted testing and refinement of the hand-off of the trajectories from the IAM community to the ESM community. Some voiced the point that the more policy relevant issues appeared to be suboptimally addressed by the chosen scenarios, with less focus on the lower end than needed (SSP1-1.9 in Tier 2) and the need of more overshoots.

3. **What key modifications, additions to, or extensions of the scenario framework would be most helpful for future work in the topic area of this session, and what research gaps would they address?**

   More lower end/overshoots, better exploration of alternative mixes of carbon capture (BECCS/DAC), better modeling of the possible feedbacks from the C-cycle; better exploration of the role of SLCFs. All these suggestions stem from a larger issue identified in particular by Ben Sanderson in his talk: The current SSP/RCP matrix provides a climate axis which is a convolution of technical policy implementation and climate feedback. The structure is logical in the context of IAMs producing a variety of simulations coupled to a single simple climate model, but fails to make use of the diversity of response - both global and regional - which is represented within the CMIP ensemble. ESMs have the capacity to inform the uncertainty in global response to a given implemented technical emissions and land use scenario - but this information is highly suppressed in the aggregated climate forcing axis of the SSP/RCP matrix, condemned to the small subset of scenarios and models which run C4MIP - and even for

those models, we don't have a detailed understanding of land use implementation sensitivities for carbon budgets. In short - we've created a scenario framework which, by construction, fails to take advantage of the added value that ESMs bring to our understanding of the uncertainties in the problem.

Separately, the observation was (re-)made (during the ICONICS webinar on key insights from SF2022) that the problem of rapid outdating of scenarios is slightly self-inflicted, by the structural choice to optimise scenarios from the date of initialization of the IAM. An alternative framework where current policies in the near term decay to model optimised policies in the medium and long term might provide a more useful ensemble on the timescale of a CMIP/IPCC cycle.

4. **What are other key highlights from your session?**

Need for extensive collaboration across communities for the development and delivery of scenarios; need for using ESMs in emission-driven mode; need for different MIPs to collaborate; need for deploying the power of a hierarchy of models, including emulators.

Need not to forget about higher scenarios and concentration-driven experiments, which still have their place.

Need to build on what is already there (CMIP6), rather than scratch it and start anew.

5. **What audiences (researchers, practitioners, policymakers) do you think would most benefit from the scenario-related work in the topic area of this session?**

The CMIP audience covers scientists across the physical climate/IAV and mitigation sciences spectra, plus practitioners (climate services, stakeholders, planners, and policymakers at all levels from local to national and international), and they would all benefit from a more effective process, and from a renewed design able to answer timely questions about feasibility and effect of different mitigation choices.

6. **What plans for follow-up activities (meetings, publications, projects, etc.) related to the topic area of this session are you aware of?**

Need to organize a more extensive meeting to take this forward, necessarily involving leaders of other MIPs and also bridging to the community that develops inputs for ESMs.

SCENARIOS FORUM 2022

Session ID # 17: Pop and economic projections

No session feedback form provided

SCENARIOS FORUM 2022

Session ID # 20: CDR

No session feedback form provided

Session recording not available due to recovery from power outage

SCENARIOS FORUM 2022

Session ID # 21: Non-state actors

No session feedback form provided

SCENARIOS FORUM 2022

Session ID # 22: Integrated Scenarios

Session name: Integrated scenarios of impacts, mitigation and adaptation

Session organizer(s): Franziska Piontek[1], Celine Guivarch[2], Jun'ya Takakura[3], Detlef van Vuuren[4], Massimo Tavoni[5], Kiyoshi Takahashi[3]

Institutional Affiliation(s): Potsdam Institute for Climate Impact Research[1], International Center for Development and Environment[2], National Institute for Environmental Studies Japan[3], Netherlands Environmental Assessment Agency[4], and RFF-CMCC European Institute on Economics and the Environment[5]

1. **What particularly notable advances have been made in the topic area of this session that involved using or further developing the SSP-RCP or other (please specify) scenario frameworks?**

   The session and many discussions revealed that there is a general move in the community towards scenarios including climate change impacts (and adaptation). Many process-based IAMs are now working to include impacts (both in the form of aggregate damage functions and bottom-up channel-specific impacts, e.g. on water, energy and land sectors), which would allow the provision of integrated SSP-based scenarios. CBA-type IAMs calibrated to the SSPs are becoming available (RICE50+, MIMOSA, DICE), bridging the gap between the two IAM types.

2. **What features of the SSP-RCP or other scenario frameworks helped or hindered progress in the topic area of this session?**

   The application of the SSP-RCP Framework in impact modeling and research allows the consistent use of impacts in IAMs. At the same time, the step in particular towards economic impacts is still difficult to make.

3. **What key modifications, additions to, or extensions of the scenario framework would be most helpful for future work in the topic area of this session, and what research gaps would they address?**

   The impact community often lacks necessary quantified input data in the SSP framework, e.g. high resolution GDP and population data or other inputs consistent with the mitigation scenarios. Adaptation needs to be conceptualized in the framework, e.g. through SPAs, to channel developing efforts to include adaptation in the models in a harmonized way.

4. **What are other key highlights from your session?**

Given the uncertainties and multitude of impacts, different use cases would require different setups which should be stakeholder-driven. However, this should be coordinated across communities to avoid stakeholder fatigue.

Feedbacks to earth system models need to be discussed.

5. **What audiences (researchers, practitioners, policymakers) do you think would most benefit from the scenario-related work in the topic area of this session?**

   Policymakers, as integrated scenarios will allow to quantify benefits of mitigation. The work on adaptation would benefit researchers preparing for the next step of integration, meaning mitigation, impacts and adaptation. A harmonized concept and approach will allow better synthesis also thinking towards AR7. It will also benefit adaptation and mitigation practitioners by providing consistent global scenarios which can be used to frame national/local studies.

6. **What plans for follow-up activities (meetings, publications, projects, etc.) related to the topic area of this session are you aware of?**

   Currently none, though it is part of different projects and proposals. More discussions and work with the impact community (e.g. ISIMIP) would be crucial, the planned accompanying workshop session would have been very helpful (though did not receive enough submissions).

Session ID # 23: Socio-political

Session name: Improving the representation and usability of socio-political factors in the Shared Socioeconomic Pathways (SSPs)

Session organizer(s): Elisabeth Gilmore, Ariel Hernandez, Ines Dombrowsky

1. **What particularly notable advances have been made in the topic area of this session that involved using or further developing the SSP-RCP or other (please specify) scenario frameworks?**

   This session convened social scientists to identify and critique how social sciences can inform the SSPs, specifically as it relates to quantifying the sociopolitical factors that are important explaining variations in climate action and the achievement of the Sustainable Development Goals (SDGs) currently and in the future. Main advances articulated in this session include:

   The development and expansion of the knowledge basis of how sociopolitical factors influence climate action. Key examples related to **political development** include:
   1) Political institutions and governance structures - including features like rule of law - that can facilitate or hinder the implementation of policies and 2) Peace and security as prerequisites for (climate) policy commitment and implementation as well as facilitating adaptation to climate change, reducing vulnerability and reducing climate risks.

   The desirability and ability of quantifying these sociopolitical factors in the SSP framework was elaborated. While individual events may act as shocks, likelihoods or underlying risks are more stable. These factors could be estimated through their relationships with other quantified variables in the SSPs. This would also have the benefit of implying an increased internal consistency of the SSPs into the sociopolitical space that presently relies primarily on narratives that may or may not be consistent with the quantified factors. In particular, work and datasets that underpin quantitative political science may present opportunities for quantifying features, including datasets like Varieties of Democracy (V-Dem) [https://v-dem.net]. This dataset distinguishes across a range of concepts of democracy and the system of rule.

   Significant advances were observed on how scenarios can be fed into the policy process by informing decision-makers of what would happen under certain assumptions and assuming some policies. Here, narratives become a core part of scenarios to inform quantitative projections. While scenarios have some elements of prediction in order to maintain relevance, they should be differentiated from predictions and forecasting. In addition, the narratives and the related scenarios have opened up direct communication channels with policy-makers. At the same time, they connect the different groups of stakeholders and researchers and bridge across scales from global to local. The improvement of narratives can help address some limitations of scenarios as well as develop arguments and produce the evidence to be able to change political and economic structures.

The need to and challenges for model transformations that encompass the wide range of societal and political futures that move outside of present configurations. The deep transformation in multiple social institutions and society may be both positive and negative in terms of means and end. On one hand, deep transformations are needed to enable inclusive growth by shifting paradigms that have so far excluded parts of the society. On the other hand, to initiate deep transformations, corrections of "historical wrongs" or rupture with existing values such as techno-optimism and the primacy of material progress are inevitable, which may entail new privileges and systematic bias for certain groups that may be counterintuitive to justice and fairness.

The normativity of pathways of transformations towards sustainability was presented and debated upon to challenge the assumed dominance of the socio-technical change or technological viewpoint in the SSPs, which is often assumed by the modeling community. In order to have a perspective of the whole society, this technological viewpoint should be complemented by a transdisciplinary approach that encompasses perspectives from politics, economics, psychoanalysis, pedagogy, historical analysis, religious studies, sociology and other disciplines.

Sociopolitical developments also occur in rich environments. For example, the need to manage the digital revolution and/or the second seed machine age was recognized as both an opportunity and potential source of intertwined problems. This could be true for any number of emerging phenomena that may produce societal transformations.

2. **What features[1] of the SSP-RCP or other scenario frameworks helped or hindered progress in the topic area of this session?**

The panel represented a range of social science disciplines and perspectives. Key contested issues elaborated by this group are the predictability of social sciences, the desirability of scenarios and their purpose. Some scholars criticize the "forecasting" or "predictive" capacity or function of social sciences as well as of models and scenarios. Alternatively, models and scenarios supported by social science theories are justified by the need to help policymakers make sound decisions based on what could happen. Other panel participants argue that these models and scenarios should be benchmarks to achieve the normative goals set by the society that are followed by transactions.

The panel members also identified weaknesses in the existing scenarios. Currently, many modelers rely on the quantified core scenarios, namely GDP, to represent development and other institutional factors. GDP per capita is the mostly used proxy for vulnerability in the SSP framework as an indicator of economic level of development.

However, GDP per capita is an incomplete proxy for vulnerability. It also obscures distributional issues and inequality within countries. The implications is that SSP based impact assessments are quite likely to underestimate future risks and future impacts. The lack of more specific information about the types of governance and institutions in the current SSPs has the effect of assuming that climate policies and their effectiveness are neutral with respect to political system and structure. An example is that modelers may be implicitly assuming that all countries follow "democratic" practices. While scenarios of sustainable futures foresee democratic systems ("democratic peace") as

consistent with the absence or low number of armed conflicts, with more than 70% of the global population now living in autocracies, this assumption could undermine the credibility of scenarios and models. This assumption seems to ignore political variations and political development and therefore cannot fully capture the vulnerability of societies, which explain outcome variations from climate hazards.

3. **What key modifications, additions to, or extensions of the scenario framework would be most helpful for future work in the topic area of this session, and what research gaps would they address?**

   The existing SSPs can be augmented to integrate political development as well as an extended set of scenarios (including sub-regional) that examine a wider range of sociopolitical futures could be developed.

   Political development factors can be estimated as a function of existing SSP projections. This approach has been employed to develop estimates of future armed conflict risks along the SSPs that are consistent with the empirical relationships between armed conflict and features of development in the SSPs (e.g. GDP, population and education). Similarly approaches have also been employed to develop consistent futures for SDG indicators and other institutional factors.

   Political (and socio-economic) development can also be described as endogenous processes that interact with the core quantified features of the GDP. These formulations are more consistent with the theoretical understanding of the interdependence between economic and political developments. This approach enables feedback effects between economic and political developments (e.g., educational attainment). This, however, will also require more sophisticated modeling approaches, including simulation and coupling with other models and modelers.

   Finally, the narratives currently embedded in the SSPs can be expanded to better capture political futures. Not all information can be captured quantitatively - for example, where changes that are outside of the empirical record or other specific contextual information is desired. Social sciences can be especially informative in these cases to identify relevant historical analogies, identify and minimize biases that may hinder the development of narratives as well as identify best practices for engaging with all relevant voices.

4. **What are other key highlights from your session?**

   The importance of facilitated, open dialogue between scientists and decision-makers across disciplines and perspectives is critical for enhancing the credibility and salience of future scenarios development for sociopolitical futures. Developing shared vocabulary and perspectives as well as engaging in research and knowledge generation across different groups is fundamental to this goal. More opportunities for continued interaction and learning is needed.

5. **What audiences (researchers, practitioners, policymakers) do you think would most benefit from the scenario-related work in the topic area of this session?**

The key audience for this workshop was scholars across the social sciences who focus on socio-political developments. This includes a wide range of disciplinary and interdisciplinary researchers, expanding from political scientists to historians, religious scholars, sociologists, and cultural anthropologists. This work is also central to many researchers on the science-policy interface who are interested in extending their modeling on climate policy and action to incorporate the key role of institutions. This information should also be important to decision- and policy-makers who need to account for these dimensions in their evaluations of the vulnerability and effectiveness of societal and climate interventions.

6. **What plans for follow-up activities (meetings, publications, projects, etc.) related to the topic area of this session are you aware of?**

   A follow-up workshop is in preparation for Fall/Winter 2022, led by IDOS (Leininger) and PRIO (Buhaug/Gilmore).

   IDOS (Hernandez) and PRIO/Carleton (Gilmore) are separately developing a workshop paper that summarizes the panel discussion. It is anticipated that this will also be a journal article that brings the key findings into peer reviewed press.

   Other efforts to further the awareness and development of a sociopolitical research community for the SSPs are also in progress. Notably, Hernandez is developing a series of recorded interviews of selected social scientists and modelers elaborating on certain issues related to the topic of the session.

Session ID # 24: Transport

Session name: Scenario development and modeling that bridges scales and communities: the rich diversity of global transport futures

Session organizer(s): David McCollum1, Sonia Yeh2, Paul Kishimoto3, Bas van Ruijven3, Roberto Schaeffer4, Ioannis Tsiropoulos5

Institutional Affiliation(s): Oak Ridge National Laboratory1, Chalmers University2, International Institute for Applied Systems Analysis3, Alberto Luiz Coimbra Institute for Graduate Studies and Research in Engineering (COPPE)4, and E3 Modelling5

1. **What particularly notable advances have been made in the topic area of this session that involved using or further developing the SSP-RCP or other (please specify) scenario frameworks?**

   Discussion of the SSP-RCPs was notably absent in the session.

2. **What features[1] of the SSP-RCP or other scenario frameworks helped or hindered progress in the topic area of this session?**

   Lack of subnational detail hinders the use of SSP-RCPs in many transport models. But this also provides an opportunity for future work in this area.

3. **What key modifications, additions to, or extensions of the scenario framework would be most helpful for future work in the topic area of this session, and what research gaps would they address?**

   Integrated narratives and modeling of both passenger and freight transport would be a novel new area of exploration.

4. **What are other key highlights from your session?**

   ITF has a very thoughtful and effective global-to-subnational workflow that could be held up as a standard for others to emulate and further improve upon.

   India pkm is so uncertain. Different modeling teams in India make different base-year assumptions when calibrating their models. This feeds into future-year pkm, energy, etc. differences.

   Matteo (NREL) => He and his team do not necessarily feel constrained by US-focused data and, thus, what they can model in TEMPO. They took stock of the available data (e.g., NHTS, FAF) and used it to decide what characteristics of consumers and the vehicle fleet are most important to model.

   The SSP-RCP Framework was not mentioned at all during the talks. It only came up during the Q&A in reference to climate impacts and adaptation for transport infrastructure.

There is a recognition among some in the transport modeling community that the traditional way of partitioning passenger and freight sectors in models is a bit false, as the two areas depend on each other, in terms of underlying drivers and technology-fuel dynamics. However, it is difficult to model them together (i.e., making them dependent on each other. Definitely worth exploring in future research.

5. **What audiences (researchers, practitioners, policymakers) do you think would most benefit from the scenario-related work in the topic area of this session?**

   Researchers, policymakers, and corporate decisionmakers

6. **What plans for follow-up activities (meetings, publications, projects, etc.) related to the topic area of this session are you aware of?**

   None specifically, though the discussions will surely spill over into other venues, such as the next meeting of the International Transport Energy Modeling (iTEM) Consortium in Paris in July 2022.

SCENARIOS FORUM 2022

Session ID # 25: Distributional impacts

Session name: Poverty, inequality, distributional impacts of climate change mitigation and impacts
Session organizer(s): Shinichiro Fujimori1, Bjoern Soergel2, Jihoon Min3

Institutional Affiliation(s): Kyoto University1, Potsdam Institute for Climate Impact Research2, and International Institute for Applied Systems Analysis3

1. **What particularly notable advances have been made in the topic area of this session that involved using or further developing the SSP-RCP or other (please specify) scenario frameworks?**

   There are currently on-going (or somewhat already completed to some extent) modeling activities related to poverty and inequality representation in IAM community. In this session, there are multiple reports on such modeling activities as well as results of the application. This inspires the organizers to have first poverty model intercomparion study that would help to understand the interaction of climate change mitigation/impacts with poverty and inequality. The core scenario framework would be built upon exisiting SSP-RCP Framework using socioeconomic assumptions as well as the climate information associated with ScenarioMIP. Then, we may foresee that these modeling activities would contribute to the next generation of IAM outputs as a kind of standard scenarios set in the forthcoming community level pathways such as SSPs and RCPs. This would be expected to provide opportunities to be used among WGs in IPCC. In particular WG2 and WG3 would be relevant.

2. **What features[1] of the SSP-RCP or other scenario frameworks helped or hindered progress in the topic area of this session?**

   We anticipate two stages in this topic and they would have different role in SSP-RCP. At first, it would be basically a user of existing scenario framework and the next stage can be a scenario data provider as a kind of community level service.
   The first stage is as mentioned above, we expect to have a model intercomparison study that allows us to see the new IAM activities related to poverty and inequality. At this stage, SSP-RCP information would be used. For example, population, GDP, Gini coefficients and other relevant indicators would be directly fed into models that can be commonly shared among models. At that stage, we would also be able to explore what type of indicators or assessment could be available from these modeling activities.
   Secondly, after getting the above insights, we would be able to think about delivering a part of community level scenario information that can be further used by other researchers. For example, poverty headcount and number of people at risk of unger would be such strong candidates. They would eventually facilitate the further researches within IAMs but beyond that, it would also help to develop further modeling and policymakers.

3. **What key modifications, additions to, or extensions of the scenario framework would be most helpful for future work in the topic area of this session, and what research gaps would they address?**

   Narrowed SSP-RCP Framework does not include policy relevant to poverty and inequality which could happen simultaneously with climate policy and thus we may want to consider such additional intervention.

4. **What are other key highlights from your session?**

5. **What audiences (researchers, practitioners, policymakers) do you think would most benefit from the scenario-related work in the topic area of this session?**

   Climate policy makers but general development policy could be also relevant.

6. **What plans for follow-up activities (meetings, publications, projects, etc.) related to the topic area of this session are you aware of?**

   We are planning to have a model intercomparison paper based on this session.

SCENARIOS FORUM 2022

Session ID # 26: Regional socio-economic

Session Name: Applying global socio-economic scenarios for regional climate change impact and adaptation analysis

Session organizers: Kasper Kok and Timothy Carter

1. **What particularly notable advances have been made in the topic area of this session that involved using or further developing the SSP-RCP or other (please specify) scenario frameworks?**

- **People use the SSPs:** Notable is the sheer number of applications of the SSP-RCP Framework at regional level, with a strong increase over the last 2-3 years. This adds to the methodological and conceptual understanding at regional level.
- **Review paper**: Session 26 reported results from a review of 170 papers reporting regional downscaling and extensions with a narrative component. The review found an enormous variety of applications across many sectors. Many Session presentations offered examples of the methods reviewed in this paper.
- **Key role of participatory studies**: Participatory elements are common across nearly all examples presented, to ensure salience of the exercises and to gain legitimacy of the scenarios.
- **Other frameworks and approaches**: SSPs have been developed and/or applied using a variety of methods, methodologies, approaches, and frameworks. Notably, "scenario planning" has often been used as an approach to combine exploratory SSPs and normative adaptation/mitigation pathways to test robustness of actions and strategies.

2. **What features of the SSP-RCP or other scenario frameworks helped or hindered progress in the topic area of this session?**

- **Plausibility of scenarios:** This is an issue that arises often in participatory regional analysis. Issues include: SSPs requiring modification to retain credibility at local scale, space needed within narratives to allow different views of key terms such as "sustainability", difficulties to include scenarios that depart from national policies and plans in centrally-planned and other non-western societal models; the end-point of local scenarios may not adhere to an SSP mapping; and the long time horizon of 2100 which is often regarded as being too long.
- **Ill-advised SSP-based labelling of climate projections in CMIP6**: The recent adoption by IPCC WG I of an SSP-based description for the forcing trajectories used in CMIP6 implies that the only combinations of climate and socioeconomic futures allowable are those selected for the specification of radiative forcing. This undermines a basic principle of the SSP framework, that forcing levels can be matched with any SSP narrative for use in IAV analysis, Can some other labelling scheme be amended?
- **Number of SSPs**: There are limitations in many local studies on the number of scenarios that can be usefully deployed with stakeholders (typically 2-4; rarely 5)
- **RCP-SSP matrix excludes regionally useful combinations**: At regional and certainly at local level, none of the combinations in the RCP-SSP matrix need to be excluded, as

other developments can be assumed for the rest of the world. Combinations such as RCP8.5 x SSP1 are very useful to explore regionally.
- **Overall, the framework is useful for regional scenario development**. The SSP-RCP Framework has been sufficiently generic and flexible to allow for a broad range of regional applications,

3. **What key modifications, additions to, or extensions of the scenario framework would be most helpful for future work in the topic area of this session, and what research gaps would they address?**

- **Scalability of SSPs**: There are challenges in scaling up or down SSP quantitative information at intermediate time horizons and at different spatial scales.
- **Interest in probabilistic projections**: Socioeconomic projections can be expressed probabilistically in some situations (e.g. population). Relative uncertainty can be important to communicate in some situations
- **Shared climate policy assumptions (SPAs)**: SSPs are designed to map possibilities independent of climate and of policy. Shared climate policy assumptions (SPAs) bring in policy, but are somewhat neglected, especially for adaptation, though they have recently begun to find their way into the literature. Several ideas were explored for decoupling climate policy at local scale with that at global scale, which offers promising opportunities for extending the Scenarios Framework.
- **Missing dimensions in SSPs**: SRES B2 (a more divided, but ecologically-minded world) was an interesting and "recognisable" worldview that is not really reproduced in the SSP suite, even as an SSP1 variant. The "Archetypes" approach can be useful for identifying these types of worldviews from existing published global scenarios. Other ideas were also discussed.
- **Use of wildcards:** SSPs can be used as or provide context for "Wildcards" (or also expressed as climate impact storylines in other work). The idea is to use well-defined cases that resonate with stakeholders but can also allow for rich exploration of potential stakeholder responses.
- **Need for improved local-level socioeconomic data**: Several presentations and discussion points alluded to the need for quantitative data for defining vulnerability and exposure at municipal-scale. These data are often available, but in siloed, sectoral contexts that are difficult to locate and to integrate.

4. **What are other key highlights from your session?**

- **Stressing opportunities as well as risks:** There is a large emphasis in a lot of scenario work on damages, risks, adverse impacts, etc. Stakeholders might be motivated with more positive messages and opportunities to work with.
- **Uniformity of approaches and methods:** Despite the huge diversity of sectors, topics, case studies and aims of extending SSPs, the session showed how there is a primary approach common to most applications, including stakeholder engagement in developing narratives, quantitative modelling, and the use of SSPs to set the context for vulnerability and/or capacities to adapt/mitigate.

5. **What audiences (researchers, practitioners, policymakers) do you think would most benefit from the scenario-related work in the topic area of this session?**

- **Broad applicability**: All three audiences could benefit substantially from the efforts to extend SSPs. The research community can benefit from a better understanding of the methods, tools, and approaches applied. Much of the work is directly useful for practitioners as well through stakeholder engagement and local contextualization. Although policymakers might also benefit, there are only a few cases in which this has been achieved.
- **A tailored approach:** A science-based approach allows researchers to apply SSPs using scientific methods. However, it was observed that with policy makers the approach has to be different and the questions raised in a different way, often without even mentioning SSPs at all (at least initially).

6. **What plans for follow-up activities (meetings, publications, projects, etc.) related to the topic area of this session are you aware of?**

- **Joint publication**: The Pedde et al. review paper is still to be finalized, and may require some updating on the basis of this meeting
- **Methodological comparisons**: Novel methods, particularly including Cross Impact Balance (CIB) analysis and Fuzzy Cognitive Mapping (FCM) will be compared and discussed as tools to develop local scenarios. The aim is to produce practical manuals for the use of these tools.

Session ID # 29: Stakeholder participation

Session name: Learnings from stakeholder participation for the development and implementation of scenarios and long-term pathways towards sustainable systems
Lead organizer(s): Jeffrey M. Bielicki[1], Maria Diaz[2], Jan Steinhauser[3], and Douglas Jackson-Smith[1]
Institutional Affiliation(s): Ohio State University[1], Sustainable Development Solutions Network[2], International Institute for Applied Systems Analysis[3]

No answers provided to Questions 1-3

4) What are other key highlights from your session?

Stakeholder participation in scenario development is time-consuming but vital. It can ensure pathways test key scenarios and policy questions of interest to policymakers; input parameters are accurate and consistent with other government models; key stakeholders are aware of model capabilities and understand limitations; and stakeholders gain a deeper understanding of synergies and trade-offs.
Researchers often face the challenge to generate a mutually beneficial dialogue with stakeholders. The different approaches call for dialogue between model-based research (simplifies and narrows focus) and policymaking (results of numerous political and practical concerns).

The modelling process **needs to be legitimate**. Incorporating stakeholders from diverse groups, include their views are crucial to develop a comprehensive integrated picture. The selection of stakeholders, keeping their engagement through a long process, and maintaining breadth of perspectives when translating to quantitative scenarios is a crucial step for a successful participatory modelling exercise. Inclusivity willk help reflect the plurality of perspectives and the tensions between science and society about sustainability, including power imbalances.

The government stakeholders involved in the modelling process should be **capable of understanding** the purpose and further use of scenarios, they should be capable of handling complex interplays of drivers and impacts, and cover the expertise needed to map relevant trends and characteristics. Models need to be transparent and easily accesible (and understandable) to enable a fluid stakeholder interaction and co-development of scenarios.

The case of the Food, Agriculture, Biodiversity, Land-Use and bioEnergy (FABLE) Consortium demonstrates an example of how models can help bridge the gap between policy and science. In the case of Wales, the FABLE team of the UK engaged with the

government of Wales to align their their food and land-use systems to carbon emissions net-zero targets. The Welsh Government was pleased with the model because it reflected Welsh circumstances and policy priorities; it allowed policymakers to test their own scenarios beyond the UK government climate scenarios. The Welsh government found that consulting different departments to develop sustainable pathways opened up conversations about policy aspirations, synergies, and trade-offs (e.g., between climate, agriculture, biodiversity and health). Co-creation and engagament while adapting and parameterising the model helped policymakers to really understand the outputs and limitations of the model. Importantly, because of the co-creation process, the model answered specific policy questions with an urgent need for evidence.

5) **What audiences (researchers, practitioners, policymakers) do you think would most benefit from the scenario-related work in the topic area of this session?**

Policymakers and decisionmakers in government institutions that are involved in deciding sustainability targets and courses of action to meet these targets. Researchers would also benefit from this topic. Involving government stakeholders in the co-creation of scenarios can help ensure that the findings are not only scientific relevant, but also policy relevant. This can facilitate the applicability of the results into policy action.

6) **What plans for follow-up activities (meetings, publications, projects, etc.) related to the topic area of this session are you aware of?**

There is a Special Issue launched at Frontiers, 'Stakeholder-Engaged Integrated Assessment Modelling for Global Scenarios in a Changing World". https://www.frontiersin.org/research-topics/36816/stakeholder-engaged-integrated-assessment-modelling-for-global-scenarios-in-a-changing-world

SCENARIOS FORUM 2022

Session ID # 30: SSP Uncertainties

No session feedback provided

SCENARIOS FORUM 2022

Session ID # 31: Migration

Session name: Scenario-based approaches to modeling migration futures

Session organizer(s): Carsten Keßler, Bochum University, and Alex de Sherbinin, Columbia Climate School

1. **What particularly notable advances have been made in the topic area of this session that involved using or further developing the SSP-RCP or other (please specify) scenario frameworks?**

   The whole area of migration scenario development has expanded rapidly in the past 5 years, and this session represented an opportunity to learn about different modeling approaches in this nascent field, as well as the challenges faced by modelers.

2. **What features[1] of the SSP-RCP or other scenario frameworks helped or hindered progress in the topic area of this session?**

   Generally the SSP-RCP scenario framework helped insofar as it provided common inputs to otherwise disparate modeling methods.

3. **What key modifications, additions to, or extensions of the scenario framework would be most helpful for future work in the topic area of this session, and what research gaps would they address?**

   Probably the scenarios could use more explicit treatment of economic inequalities within countries. In addition, as discussed by Helene Benveniste in her presentation, there is a need for the SSPs to better account for the impact of migration in economic and demographic projections.

4. **What are other key highlights from your session?**

   Some key conclusions include:
   There is a need to embed future projections / scenario development in migration theory, as many existing efforts rely on simplistic push-pull models.
   There will be a “messy middle” between voluntary labor migration and direct displacement (forced migration) from climate impacts, and the amount of this “mixed” or “distress” migration will be a function of indirect climate impacts, conflict, governance, and other factors. Conflict and governance failures are more difficult to capture under current scenario frameworks.
   Models would do well to take these other factors into account and not assume a slow/linear progression migration related to climate impacts and societal changes

5. **What audiences (researchers, practitioners, policymakers) do you think would most benefit from the scenario-related work in the topic area of this session?**

   There is a very high demand among policy makers for results from migration modeling, since migration is of particular policy concern, but the work risks being politicized as long as global south-to-north migration is considered a “boogeyman”.

6. **What plans for follow-up activities (meetings, publications, projects, etc.) related to the topic area of this session are you aware of?**

   There is a new section of *Frontiers in Climate* on climate mobility, and we may organize a research topic (special issue) on the subject.

SCENARIOS FORUM 2022

Session ID # 32: Beyond illustrative

Session name: Beyond illustrative scenarios - novel approaches to assess future climate risks

Session organizer(s): Carl-Friedrich Schleussner and Joeri Rogelj

1. **What particularly notable advances have been made in the topic area of this session that involved using or further developing the SSP-RCP or other (please specify) scenario frameworks?**

   The objective of our (short) session was to look beyond existing frameworks and towards diverse application areas. Some commonalities have become apparent there for the needs of different stakeholder communities with regards to the need of assessing scenarios of evolution of specific future climate risks and understanding such risks in the context of avoidable and unavoidable by mitigation. Innovative approaches to for example reverse the impact chain have been presented. Key innovations presented integrate WG1-3 for example using emulator frameworks. This is a major direction for future research.

2. **What features[1] of the SSP-RCP or other scenario frameworks helped or hindered progress in the topic area of this session?**

   Discussions in this session have been more on the near-term until mid-century and related to rather 'incremental' mitigation benefits. The current SSP-RCP Framework contains is 'top-heavy' on unrealistically high emission scenarios and is thus not best equipped to answer questions like: What are the avoided impacts of 5 Gt CO2eq less emissions in 2030, or a 5 year earlier global net-zero date, or else.

3. **What key modifications, additions to, or extensions of the scenario framework would be most helpful for future work in the topic area of this session, and what research gaps would they address?**

   There are big questions for a scenario framework in terms of the utility of generating scenarios until 2100 in a rapidly changing policy landscape. The WG3 IMPs might provide a good starting point for much more fine-grained analysis on some of the key policy questions - outlining the implications of different policy options in rather concrete terms.

   More generally, there is a question about the scenario positivism that should be reflected upon also from within the community. The SSP-RCP Framework not including climate or any other shocks shows 'progress' even under the most pessimistic scenarios. A global pandemic, a large-scale territorial war, an energy crisis and the third global economic crisis upon us in 15 years this requires some revision. In particular, as climate acts as a threat multiplier with other crises. A 'orderly' view of the future as produced by IAMs will miss that key part of the picture.

4. **What are other key highlights from your session?**

5. What audiences (researchers, practitioners, policymakers) do you think would most benefit from the scenario-related work in the topic area of this session?

6. What plans for follow-up activities (meetings, publications, projects, etc.) related to the topic area of this session are you aware of?

This session was part of ongoing discussions within the H2020 PROVIDE project and will greatly inform the developments under this project.

SCENARIOS FORUM 2022

Session ID # 37: Post-growth

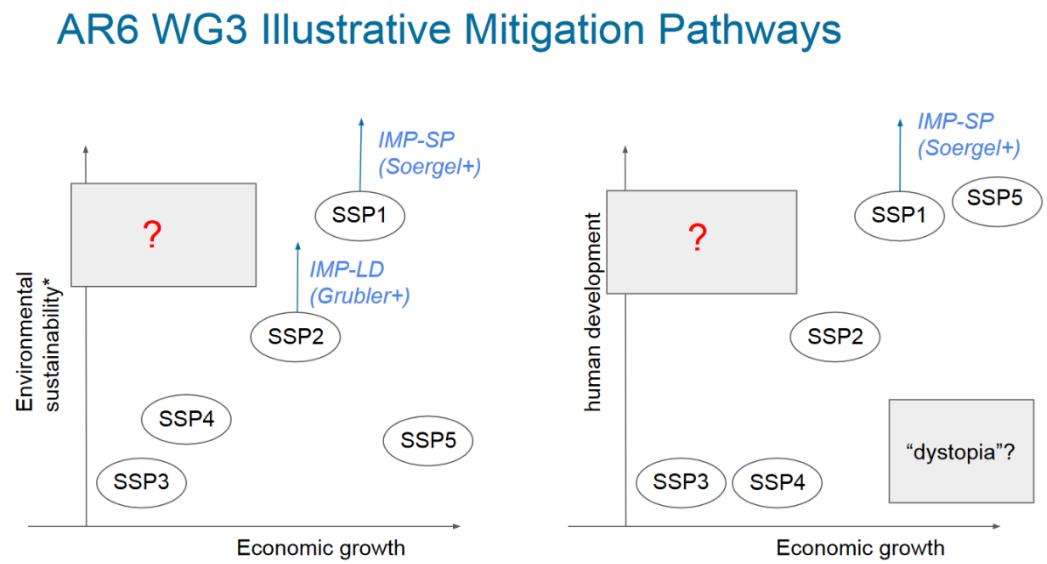
Session name: Economic pluralism and post-growth scenarios

Session organizer(s): Jarmo Kikstra, Jason Hickel, Bjoern Soergel.

Presenters: Julien Lefèvre, Bjoern Soergel, David Meng-Chuen Chen, Eric Kemp-Benedict, Mengyu Li.

1. **What particularly notable advances have been made in the topic area of this session that involved using or further developing the SSP-RCP or other (please specify) scenario frameworks?**

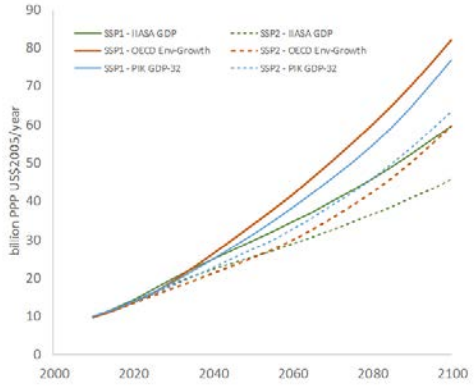
   This session discussed a previously identified a gap in the SSP-RCP Framework (see e.g. Keysser and Lenzen 2021 Nat. Comms, and Hickel et al. 2021 Nat. Energy), which is a positive modeled future with reduced economic growth (as illustrated by the presentation of Bjoern Soergel in this session, inspired by Otero et al. 2020 Conservation Letters, see figure below).

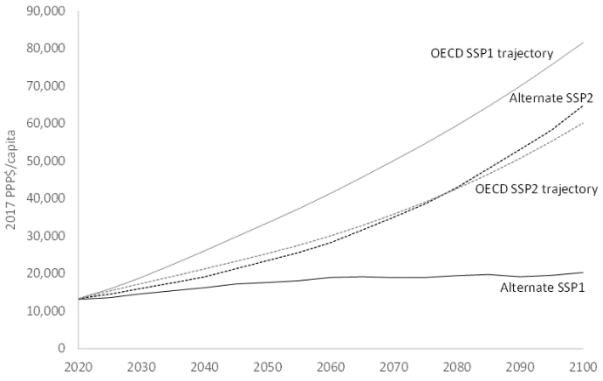


(*inspired by Otero et al. 2020)

2. **What features[1] of the SSP-RCP or other scenario frameworks helped or hindered progress in the topic area of this session?**

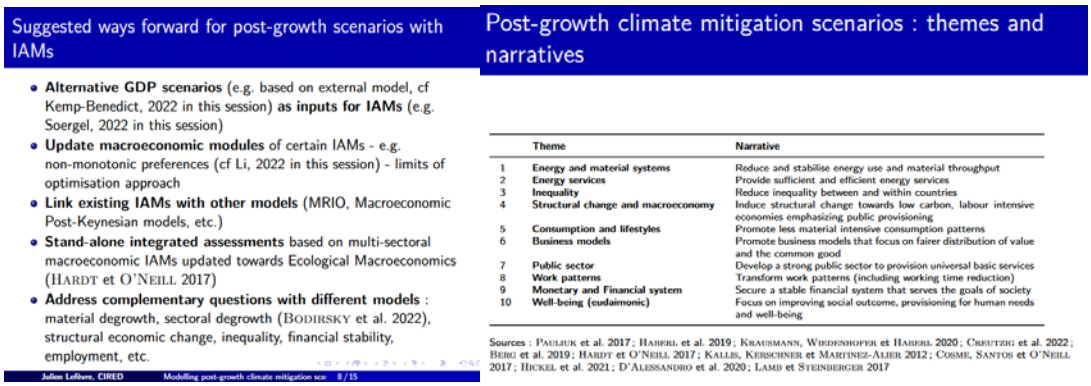
   The absence of a (positive) scenario that without strong increases in economic output. All exogenous economic model projections of a sustainable future see strong economic growth - but in the past decade a large degrowth/postgrowth literature has emerged that strongly questions the plausibility of such scenarios. The most important single factor here may have been the interpretation of SSP1 as a 'green growth' scenario by the marker implementation of IMAGE, as highlighted by presenter Eric Kemp-Benedict (see figure below).





3. What key modifications, additions to, or extensions of the scenario framework would be most helpful for future work in the topic area of this session, and what research gaps would they address?

Our session identified multiple ways to go forward, including those identified by Julien Lefèvre to address the key themes from the post-growth literature (see below).



Suggested ways forward for post-growth scenarios with IAMs

- **Alternative GDP scenarios** (e.g. based on external model, cf Kemp-Benedict, 2022 in this session) **as inputs for IAMs** (e.g. Soergel, 2022 in this session)
- **Update macroeconomic modules** of certain IAMs - e.g. non-monotonic preferences (cf Li, 2022 in this session) - limits of optimisation approach
- **Link existing IAMs with other models** (MRIO, Macroeconomic Post-Keynesian models, etc.)
- **Stand-alone integrated assessments** based on multi-sectoral macroeconomic IAMs updated towards Ecological Macroeconomics (Hardt et O'Neill 2017)
- **Address complementary questions with different models** : material degrowth, sectoral degrowth (Bodirsky et al. 2022), structural economic change, inequality, financial stability, employment, etc.

Julien Lefèvre, CIRED Modelling post-growth climate mitigation sce 8 / 15

Post-growth climate mitigation scenarios : themes and narratives

	Theme	Narrative
1	**Energy and material systems**	Reduce and stabilise energy use and material throughput
2	**Energy services**	Provide sufficient and efficient energy services
3	**Inequality**	Reduce inequality between and within countries
4	**Structural change and macroeconomy**	Induce structural change towards low carbon, labour intensive economies emphasizing public provisioning
5	**Consumption and lifestyles**	Promote less material intensive consumption patterns
6	**Business models**	Promote business models that focus on fairer distribution of value and the common good
7	**Public sector**	Develop a strong public sector to provision universal basic services
8	**Work patterns**	Transform work patterns (including working time reduction)
9	**Monetary and Financial system**	Secure a stable financial system that serves the goals of society
10	**Well-being (eudaimonic)**	Focus on improving social outcome, provisioning for human needs and well-being

Sources : Paulik et al. 2017 ; Haberl et al. 2019 ; Krausmann, Wiedenhofer et Haberl 2020 ; Creutzig et al. 2022 ; Berg et al. 2019 ; Hardt et O'Neill 2017 ; Kallis, Kerschner et Martinez-Alier 2012 ; Cosme, Santos et O'Neill 2017 ; Hickel et al. 2021 ; D'Alessandro et al. 2020 ; Lamb et Steinberger 2017

4. What are other key highlights from your session?

Methodologically, the session achieved two things. (i) Firstly, it set the scene to identify possible different ways that post-growth scenarios can be developed with IAMs, drawing upon an understanding of the current gaps and capabilities of some existing IAMs. (ii) Secondly, the session identified multiple methods currently explored, being three different 'tweaks' or 'interventions'. The presentations of Eric Kemp-Benedict and Bjoern Soergel provided a new model and ad-hoc tweaks of exogenous GDP pathways, while the presentation of Mengyu Li explored changing the functional form of the utility function inside the economic optimization of an IAM. In addition, the work by David Meng-Chuen Chen showed a more detailed sectoral approach, where the relationship between GDP and food GHG emissions was explored.

Regarding content and targets, it was mentioned and agreed up on that these efforts (in (ii)) do not yet come close to capturing a broader part of the social science understanding

of the requirements for and characteristics of alternative transformation pathways. On top of that, the question was raised to what extent this strand of work could be and needs to be linked to impacts/adaptation/vulnerability when thinking about integrated scenarios.

5. **What audiences (researchers, practitioners, policymakers) do you think would most benefit from the scenario-related work in the topic area of this session?**

   At the short-term, IAM modellers that want to explore the post-growth scenario space. In the long run, such scenarios, when explored, offer more information on a scenario alternative that has so far been underlit, but is relevant to virtually all scenario users.

6. **What plans for follow-up activities (meetings, publications, projects, etc.) related to the topic area of this session are you aware of?**

   Follow-up activities like meetings, publications, or planned projects are not set in stone yet, and the organizers very much encourage engagement of the wider community with the topic. One of the most concrete advances is the continuation of the SHAPE project, of which one of the sustainable development pathways under development will have a post-growth GDP pathway. Additionally, the construction of an SSP GDP-growth model more focused on the role of labour could be useful alongside existing GDP pathways as exogenous trajectories of which SSP1 would be more in line with post-growth instead of green growth. Early discussions have also started on a community perspective that would analyse the gaps and capabilities of IAMs and set out a research agenda for modelling post-growth futures. Two further questions came up during the meeting and deserve attention in follow-up research activities. The first is that there is a need to acknowledge and improve the representation of global interregional economic and power differences, and how these dynamics could play a role in scenarios. The second would be exploring the potential and limitations of the speed at which transitions to a post-growth society could occur, taking into account feasibility constraints, inertia of social norms, and available and yet-to-be-developed policy instruments to bring about such change.

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[1] By “features,” we mean elements like narratives, quantitative drivers, or IAM scenarios, or aspects of the framework like the matrix approach to combining socioeconomic and climate information, or the spanning of uncertainty in challenges to adaptation/mitigation.

Session ID # 38: Beyond GDP

Session name: Beyond GDP: economic dimensions of integrated assessment scenarios

Session organizer(s): Dominique van der Mensbrugghe and Rob Dellink

1. **What particularly notable advances have been made in the topic area of this session that involved using or further developing the SSP-RCP or other (please specify) scenario frameworks?**

   The session highlighted various ways in which richer economic information can provide inputs to integrated assessment scenario frameworks. Models are getting better at integrating distributional aspects and inequality in scenarios, more structural features such as the shares of agriculture, manufacturing and services, more country-specific features such as the role of resource rents, and more demographic related economic impacts, such as the aging of populations. The session highlighted that the integration of economic and physical information is improving over time.

2. **What features[1] of the SSP-RCP or other scenario frameworks helped or hindered progress in the topic area of this session?**

   The discussion revealed that there is a significant group of researchers that feel there should be a degrowth/post-growth variant of SSP1. Further discussions on how to reconcile this type of scenario with mainstream economic modelling seem an interesting avenue for research.

3. **What key modifications, additions to, or extensions of the scenario framework would be most helpful for future work in the topic area of this session, and what research gaps would they address?**

   The session highlighted that a number of assumptions made in IAMs, for instance regarding international trade in energy, are not always clearly linked to the assumptions on trade in the economic models, including those used for projecting GDP in the SSPs. While there is some information on these aspects in the scenario narratives, more can be done to ensure consistency across models used for constructing integrated scenarios.

4. **What are other key highlights from your session?**

   The session highlighted the role of exchange rates, including the base year for constant prices and the Purchasing Power Parities used in GDP projections. It seems most integrated assessment modellers are aware of the issues involved, but perhaps not always attuned to the significance of this issue.

5. **What audiences (researchers, practitioners, policymakers) do you think would most benefit from the scenario-related work in the topic area of this session?**

   Researchers will benefit from richer economic information in IAM scenario. Policy makers benefit especially from more detailed insights into the socioeconomic consequences of scenarios, not least distributional impacts.

6. **What plans for follow-up activities (meetings, publications, projects, etc.) related to the topic area of this session are you aware of?**

   There are some informal plans to continue this type of discussion among economics groups and gradually provide more economic information related to the SSPs; the GTAP consortium is likely to coordinate this discussion.

Session ID # 42: Human-Earth

Session name: Session #42: "Human-Earth" Advances in human-Earth System interactions in scenario development

Session organizer(s): Chris Smith, Tokuta Yokohata, Hannah Liddy, Kaoru Tachiiri, Jarmo Kikstra

1. **What particularly notable advances have been made in the topic area of this session that involved using or further developing the SSP-RCP or other (please specify) scenario frameworks?**

   Over the last two years or so substantial advances have been made in coupling human and Earth system interactions using models of various complexities (Earth System Models with Integrated Assessment Models e.g. di Vittorio, Tachiiri; Systems Dynamics Models (Eker), agent-based land system models (Alexander, Perkins); simpler IAMs and climate model emulators (Gasser, Yang, Su)).

2. **What features[1] of the SSP-RCP or other scenario frameworks helped or hindered progress in the topic area of this session?**

   The current process of operation (i.e., first IAM community developed the scenarios and then passes them to the climate model community) may have room for improvement.

   For example, the fact that some variables are provided exogenously (population, education, urbanization, GDP) in the SSPs does potentially limit the exploration of the scenario space in our area which considers Earth System feedbacks on human societies. Taking a very simple example, a 3% per year sustained GDP growth over the course of the 21st century in SSP5-8.5 despite 4 to 5°C of warming seems rather implausible when we know that climate change is likely to bring devastation to whole regions under this level of warming by the end of the century, for example from large reductions in crop availability and climate damages from extreme weather. The economic feedback effects of high warming scenarios were studied by Woodard et al. (2019) in a simplified IAM, and shown to be significant. Models like FeliX (Eker) would have the ability for aspects of the system to interact with some of these components that are endogenously specified.

3. **What key modifications, additions to, or extensions of the scenario framework would be most helpful for future work in the topic area of this session, and what research gaps would they address?**

   The scenarios should allow (ideally, require) feedbacks from the climate system on to the energy-economic-human system. This is not an issue of the scenarios as they exist per se, but the tools used to evaluate them (IAMs and ESMs) currently don't talk to each other in the mainstream. WG1 and 2 communities should have interest in understanding how scenarios are developed, and in contributing to scenario development.

4. **What are other key highlights from your session?**

   It is shown that a combination of various approaches (ESM-IAM coupling, simple models, models of specific processes) is helpful for deep understanding of human-Earth system interaction. Differences in roles of each approach in the (grand) scenario development process could be better communicated.

5. **What audiences (researchers, practitioners, policymakers) do you think would most benefit from the scenario-related work in the topic area of this session?**

   The main beneficiaries are all of the above who would benefit from scenarios that better reflect the real world.

6. **What plans for follow-up activities (meetings, publications, projects, etc.) related to the topic area of this session are you aware of?**

   Some of these initiatives will feed into the WorldTrans Horizon Europe project (2023-26) in exploring closer links between human and Earth systems. We will report back to the MESH and AIMES steering groups on the outcomes from this session. We have no plans as yet for a community write-up (will depend on time).

SCENARIOS FORUM 2022

Session ID # 43: Materials

Session name: Scenarios of material stocks, flows, services, and practices: exploring nexus approaches to address climate change, air pollution and sustainability

Session organizer(s): Adriana Gómez-Sanabria, Helmut Haberl, Edgar Hertwitch

1. **What particularly notable advances have been made in the topic area of this session that involved using or further developing the SSP-RCP or other (please specify) scenario frameworks?**

- Development of scenarios integrating material supply and demand.
- Focus on the development of cities as an integrated way on how to manage material supply-demand - not just sectoral, but looking at interactions.
- Integration of service-stock-flow nexus. In that respect, the analysis of the building sector included, in addition to residential, non-residential buildings and timber supply-demand.
- Materials and energy flows were integrated to build the scenarios in the material cycle model.
- Evaluation of energy systems demand -settlement patterns and behavioral and social norms influencing transport and material intensity.

2. **What features[1] of the SSP-RCP or other scenario frameworks helped or hindered progress in the topic area of this session?**

- The SSP (population and GDP) were adopted to develop scenarios of climate neutrality.
- Message model hydrogen-based steel making is included in the scenario to evaluate the opportunities to make, for example, concrete and steel more environmentally friendly.
- SSP related land-use change and biodiversity.
- SSP narratives translated into farm decisions - energy policies, practices, prices.
- MatMat HIO model (Hybrid Input-Output)
- POLES model - stock-flows model.

3. **What key modifications, additions to, or extensions of the scenario framework would be most helpful for future work in the topic area of this session, and what research gaps would they address?**

- Moving beyond demand to interaction supply-demand scenarios
- Better integration of waste and wastewater sectors - to be able to assess circularity scenarios, including nutrient recovery.
- Better integration of social sciences to develop scenario narratives
- Agent-based models to simulate the behavior of individual agents like humans, business, institutions, etc.

4. **What are other key highlights from your session?**

- Timber demand is higher than timber supply - It will not be possible to substitute all concrete, but the idea is to use the maximum possible in an efficient way. . We need to think from the supply side.

- It is relevant to evaluate how stocks shape social practices everyday and how this interaction influences stock-flow constellations, which results in material and energy demand.

5. **What audiences (researchers, practitioners, policymakers) do you think would most benefit from the scenario-related work in the topic area of this session?**

- Industrial Ecology
- Sustainability and circular economy researchers

6. **What plans for follow-up activities (meetings, publications, projects, etc.) related to the topic area of this session are you aware of?**

   ISIE-SEM Conference 2022 http://www.isiesem2022.org/

Session ID # 46: Emulators

Session name: Emulators: new methods and role in integrating research across climate research communities

Session organizer(s): Claudia Tebaldi, Sonia Seneviratne

1. **What particularly notable advances have been made in the topic area of this session that involved using or further developing the SSP-RCP or other (please specify) scenario frameworks?**

   It appears as there is great momentum in the development of emulators, both the type that facilitates WG1-WG2 connections and the type that supports WG1-WG3 connections.

   The session covered both, and the presentations displayed clear advances and new capabilities, with a substantial community working on these issues, especially for the simple climate models/ emulators like MAGICC/FAIR etc. But there also seems to be important progress, in fact I would define it a leap, in the development of emulators that serve impact research.

   In both cases, this work will allow exploring/organizing/categorizing/filling-in the space of SSP-RCP scenarios. It will facilitate their policy relevance and their use for impact research.

2. **What features[1] of the SSP-RCP or other scenario frameworks helped or hindered progress in the topic area of this session?**

   The SSP-RCP Framework provides a flexible space within which some of these emulators can work, exploring ranges, characterizing scenarios in terms of their GWL attainments. In terms of training emulators for policy relevant scenarios like overshoots, the relative scarcity of this type of scenarios in the current main products (like the scenarios that were run by ESMs in ScenarioMIP) hinders the emulation of a larger number of OS trajectories.

3. **What key modifications, additions to, or extensions of the scenario framework would be most helpful for future work in the topic area of this session, and what research gaps would they address?**

   The session clarified the need of thinking holistically about the choice/development of scenarios and the use of emulators, now that the latter seem to have stepped up to the plate more reliably. Therefore as we look at further scenario development, especially the kind of products that support ESM experiments, the capabilities of emulators and their training needs should be taken into account.

4. **What are other key highlights from your session?**

   New emulators are being developed for IAM outputs.
   Emulators like STITCHES and MESMER-M/X could be used in a complementary manner.

5. **What audiences (researchers, practitioners, policymakers) do you think would most benefit from the scenario-related work in the topic area of this session?**

   Impact researchers and policy makers are the more direct audiences. Simple models and the way they are used to connect WG1 and WG3 type of research also benefit those research communities.

6. **What plans for follow-up activities (meetings, publications, projects, etc.) related to the topic area of this session are you aware of?**

   We are proposing emulators sessions at IAMC, AGU. A meeting to explore the next phase of CMIP/ScenarioMIP may also benefit from the participation of emulator developers.

SCENARIOS FORUM 2022

Session ID # 47: Modeling SDGs

Session name: Modelling integrated scenarios for reaching climate and sustainable development goals

Session organizer(s): Bjoern Soergel, Elmar Kriegler, Sebastian Rauner, Detlef van Vuuren, Geanderson Ambrósio, and Bas van Ruijven

1. **What particularly notable advances have been made in the topic area of this session that involved using or further developing the SSP-RCP or other (please specify) scenario frameworks?**

   A systematic literature review (presentation Detlef van Vuuren) found 140 scenario papers that model progress towards multiple SDGs - with SDG coverage ranging from a few SDGs (e.g. climate action synergies and trade-offs, CLEW nexus papers) to one paper covering all 17 SDGs (presentation Bjoern Soergel). Many of these papers use the SSP-RCP framework, e.g. by using the marker SSP-RCP scenarios as reference points for comparison (presentation Enayat Moallemi), or by modelling SDG-oriented pathways as extensions of the SSP-RCP space (presentation BS).

   While the initial SSP-RCP Framework was developed by the IAM community, there is also a growing number of system dynamics models employed for quantifying SDG pathways. This involved both global analyses (presentation EM), and regional studies (presentations of Poornima Kumar for India, and Alize le Roux for Africa).
   However, so far most individual modelling studies have selected target and indicator coverage also based on the capabilities of their respective modelling framework. Working towards a common understanding of the target space, condensing the broad SDG space with 17 goals and 169 targets into a smaller number of targets that can be modelled (presentation DvV), is therefore also an important advance.

2. **What features[1] of the SSP-RCP or other scenario frameworks helped or hindered progress in the topic area of this session?**

   Helping progress:

   - SSP-RCP provides a common framework for scenario analysis.
   - Despite their background as scenarios for climate-energy-land modelling, the SSPs also provide a largely consistent set of narratives, population and demographics, education, economic development, etc., so several additional SDG dimensions are covered.

   Hindering progress:

   - Only one of the SSPs, SSP1, is to some extent aligned with the SDGs. Together with the GDP quantifications - which interpret SSP1 as a green growth scenario - this arguably provides a too narrow perspective on pursuing sustainable development, not reflecting different societal perspectives (presentation BS).

3. **What key modifications, additions to, or extensions of the scenario framework would be most helpful for future work in the topic area of this session, and what research gaps would they address?**

   An SSP scenario that does not automatically associate high human development and environmental sustainability with high economic growth would be a useful extension of the scenario space (see above, and also session #37).

   Future versions of the scenario framework should also target a better representation of social science, societal dynamics, the role of institutions etc. in scenarios and models. One example is that many IAMs do not cover institutional quality at all - despite its key enabling role for transformative change. Similarly, education and gender equality are rarely covered explicitly in modelling exercises. Also with respect to societal dynamics (e.g. concerning the adoption of healthy and sustainable diets), most models do not resolve the underlying policies or mechanism.

4. **What are other key highlights from your session?**

   The different modelling approaches (optimizing IAMs vs. system dynamics models) also fostered a conversion on their respective strengths and weaknesses (e.g: one question from the audience was on the validation of feedback dynamics in system dynamics models).

   Besides that, it was important to have the two regional studies (presentations PK, AR) focusing on SDG-oriented development in their respective Global South countries/regions. As most large scenario studies originate from researchers at institutions in the Global North, it is important to strengthen also the Global South perspective.

5. **What audiences (researchers, practitioners, policymakers) do you think would most benefit from the scenario-related work in the topic area of this session?**

   The SDG-oriented modelling is useful for researchers, practitioners and policymakers alike. For the latter two, SDG-oriented scenarios can help to navigate multiple, and sometimes conflicting targets. However, one participant in the discussion also argued that while the SDG-oriented modelling research is certainly useful, the SDGs might not be the most useful framing when communicating with policymakers in many countries.

6. **What plans for follow-up activities (meetings, publications, projects, etc.) related to the topic area of this session are you aware of?**

   During the discussion, it was suggested to write an “SDG research agenda” paper that takes up the discussion points from the session and at other fora, and formulates suggestions for a way forward.

Session ID # 48: Feasibility

Session name: Feasibility of scenarios
Session organizer(s): Aleh Cherp (Central European University (Austria) and Lund University (Sweden)), Jessica Jewell (Chalmers University of Technology (Sweden) and the University of Bergen (Norway))

1. **What particularly notable advances have been made in the topic area of this session that involved using or further developing the SSP-RCP or other (please specify) scenario frameworks?**

   As policy makers and other social actors become increasingly aware of the risks of climate change and the need to mitigate these risk, the issue of feasibility become increasingly important. Yet, the existing SSP-RCP scenario frameworks have serious limitations in addressing feasibility defined by the IPCC as "*the potential for a mitigation or adaptation option to be implemented".*
   The session advanced the 'outside view' where feasibility is assessed by a systematic process of building 'feasibility spaces' based on empirical evidence from outside of the models and scenarios and then mapping the outcomes of scenarios onto these feasibility spaces.
   The 'inside view' where feasibility can be advanced by improving the sophistication and accuracy of the models used for scenario construction and increasing the number of scenarios was also discussed in the session.

2. **What features[1] of the SSP-RCP or other scenario frameworks helped or hindered progress in the topic area of this session?**

   The dominating scenario frameworks support assessment of feasibility by an increasingly accurate and detailed description of the levels of implementation of climate mitigation solutions compatible with various temperature or other social goals.
   At the same time, the existing Scenarios Framework hinder assessment of feasibility by:
   - a lack of probabilistic assessments of the future: while scenarios provide increasingly detailed and numerous descriptions of futures under different assumptions, the probability of these assumptions is rarely rigorously assessed;
   - the side-effect of increasing sophistication of models including through incorporation of 'barriers' and 'enablers' is a bias towards the factors which can be modelled and quantified rather than on those that have most effects on real-life feasibility;
   - passing the task of feasibility assessment to policy makers and other social actors involved in implementing climate solutions and thus ascribing the potential of implementation to political will, choice, and skill of implementors rather than to the feasibility of the solution.

3. **What key modifications, additions to, or extensions of the scenario framework would be most helpful for future work in the topic area of this session, and what research gaps would they address?**

   The key development area is enhancing probabilistic elements in scenarios, particularly through incorporating the 'outside view' based on empirical evidence outside of the scenario framework. The dominant paradigm in scenario analysis is to shy away from probabilistic analysis and analysis of likelihood and to outsource feasibility assessment to the policymakers. For example, a final plenary keynote contained a suggestion to "throw ideas over the fence" and allow policy-makers assess what is feasible, which was in contrast to the approach on science-policy interaction in the area of feasibility used in most Session #48 contributions .

4. **What are other key highlights from your session?**

   The session contained 10 talks and 3 posters which provided findings related to several specific climate mitigation solutions including development of nuclear and renewable power globally, decarbonising of electricity system in G7, coal phase-out, energy demand, reduction of carbon intensity, achieving EU hydrogen targets

5. **What audiences (researchers, practitioners, policymakers) do you think would most benefit from the scenario-related work in the topic area of this session?**

   The findings of this session can be of use to a wide range of scenario researchers and policy makers and social actors either involved in implementation of climate solutions or planning for different levels of temperature change

6. **What plans for follow-up activities (meetings, publications, projects, etc.) related to the topic area of this session are you aware of?**

   Systematic analysis of feasibility is currently undertaken in ENGAGE and MANIFEST projects.

Session ID # 50: Biodiversity

Session name: **Session ID # 50: New and on-going work on scenarios for biodiversity & nature contributions to people**
Session organizer(s): David Leclere (IIASA), Rob Alkemade (WUR), Detlef van Vuuren (PBL)

1. **What particularly notable advances have been made in the topic area of this session that involved using or further developing the SSP-RCP or other (please specify) scenario frameworks?**

   3 advances:

   a) Development of new scenarios extending SSP-RCP Framework with novel aspects related to more ambition versions of SSP storylines (e.g., increased conservation and restoration efforts, shifts to more sustainable diets, new sectors (fisheries and aquaculture with the OSPs, agriculture with the AgriSSPs), or spatial scales (e.g., EU-Agri-SSPs, FOLU scenarios, local scenarios in various)

   b) Development of new scenarios independent from SSP-RCP Framework (IAS scenarios, local scenarios, Nature Futures)

   c) Quantification of novel aspects not covered by SSP-RCP applications (e.g., biodiversity, NCPs, etc.) and of interaction between SSP-RCPs and global biodiversity pathways (e.g., bending the curve scenarios combined with RCP1p9)

2. **What features[1] of the SSP-RCP or other scenario frameworks helped or hindered progress in the topic area of this session?**

   The main help of the SSP-RCP Framework is that it obviously presented an enormous basis of information as input for biodiversity assessments (land use, economic activity, climate change, pollution). However, also three types of limitations emerged from the presentations. First, the storylines of the SSP-RCP Framework were not covering all relevant sectors / dimensions (e.g., need for new storylines on fisheries and aquaculture, on drivers of biological invasions) and spatial scales (e.g., regional to national to landscape scale). Second, the current quantifications of the SSP-RCP Framework focus on climate. Therefore, the outcomes are often incompatible with 2050 vision adopted by the Convention on Biological Diversity, and do not map on to the outcome space targeted by the new scenario framework developed by IPBES (Nature Future framework). The Nature Future Framework has the advantage of being directly focused on biodiversity - but the possible downside is that it is not clear how it alligns with the SSP/RCP framework, risking that independent quantifications are necessary for the drivers. Third, the SSP-RCP scenario framework does not explore in sufficient detail the processes enabling transformative change, required to reach the 2050 CBD vision and on which the Nature Futures scenario framework focuses.

3. **What key modifications, additions to, or extensions of the scenario framework would be most helpful for future work in the topic area of this session, and what research gaps would they address?**

   a) large extensions in sectoral / spatial details, b) A more sustainable scenario and c) deep dive into processes enabling transformative change. It would also be interesting to explore further how the NFF and SSP-RCP Framework may or may not allign.

4. **What are other key highlights from your session?**

   Upcoming work on biodiversity impacts seems promissing. Area is developing.

5. **What audiences (researchers, practitioners, policymakers) do you think would most benefit from the scenario-related work in the topic area of this session?**

   The scenarios developed for biodiversity and nature contribution to people generally evolve towards the consideration of multiple scales (including smaller scales than those typically explored with the SSP-RCP scenario framework), the investigation of feedbacks between natural and human systems, of synergies and trade-offs between biodiversity, NCPs and other societal goals, of the role of values in shaping decisions, and of leverage points for transformative change. As such they will be of interest to a broad range of researchers and policymakers interested in broad sustainability pathways at global to local scale, in the dynamics of socio-ecological systems, as well as concrete policies questions related to nexus thinking, social and environmental justice and transformative change.

6. **What plans for follow-up activities (meetings, publications, projects, etc.) related to the topic area of this session are you aware of?**

   Various communities are following different streams of work (from extension and quantification of SSP-RCP-based scenarios, to the development of novel scenarios) and bridges are regularly created around IPBES assessment cycles (e.g., regional and global assessments, thematic assessments on model and scenarios, pollination, values, sustainable use of resources, etc.), as well as IPCC assessment cycles (e.g., joint IPCC-IPBES workshop, IPCC assessment reports, etc.) and additional activities such as ISIMIP. Efforts are ongoing to more closely connect these communities to the broader set of communities working with the SSP-RCP scenario framework, including a plenary talk from P. Harrison and a specific workshop (Session 51) during this scenario forum, as well as further steps to create a community of practice around coupling biodiversity and climate scenarios for sustainable and transformative futures.

SCENARIOS FORUM 2022

Session ID # 51: Physical Storylines

Session name: Physical climate storylines: applications and perspectives

Session organizer(s): Marina Baldissera Pacchetti

1. **What particularly notable advances have been made in the topic area of this session that involved using or further developing the SSP-RCP or other (please specify) scenario frameworks?**

   N/A

2. **What features[1] of the SSP-RCP or other scenario frameworks helped or hindered progress in the topic area of this session?**

   N/A

3. **What key modifications, additions to, or extensions of the scenario framework would be most helpful for future work in the topic area of this session, and what research gaps would they address?**

   N/A

4. **What are other key highlights from your session?**

   One great talk by Nina Pirttioja showed how one can meaningfully engage with stakeholders to generate forward looking information about climate hazards and its societal impact, as well as adaptation measures (usually implied in SSP-RCP scenarios), in a way that is relevant to the local stakeholders. This kind of approach is crucial for closing the so-called science-policy gap and support meaningful action and resilience-building.

   Another talk by Taro Kunimitsu showed how one can operationalize so-called “climate storylines” by using causal networks. This operationalization also allows for generating user-tailored information.

5. **What audiences (researchers, practitioners, policymakers) do you think would most benefit from the scenario-related work in the topic area of this session?**

   Researchers probably benefited the most by observing how other researchers engaged with stakeholders.

6. **What plans for follow-up activities (meetings, publications, projects, etc.) related to the topic area of this session are you aware of?**

   There will be another session on Physical Climate Storylines at the 2022 meeting of the

European Meteorological Society in Bonn but with different contributors: https://meetingorganizer.copernicus.org/EMS2022/session/44463 . Taro Kunimitsu's talk will be submitted as a publication, as well as the other contributions to the session as far as I am aware.

Session ID # 52: Target-seeking

Session name: Interacting with integrated assessment models for target-seeking under uncertainty

Session organizer(s): Sibel Eker, Sarah Cornell, Merle Remy, and Jan Kwakkel

1. **What particularly notable advances have been made in the topic area of this session that involved using or further developing the SSP-RCP or other (please specify) scenario frameworks?**

   One talk looked at evaluating and expanding justice principles in IAM, using SSP scenarios. The research found that different justice principles result in different CO2 and temperature increases when applied to the regional RICE model. Notably, many integrated assessment models implicitly or explicitly adopt the utilitarian justice principle which results in comparably high emissions and temperature increases. It was shown that other justice principles, like prioritarianism, result in less emissions and lower global temperature, keeping up with the Paris agreement targets.

   Another talk looked at the development of new target-seeking scenarios, the Sustainable Development Pathways (SDPs). The narratives of the SDPs have been developed by adopting the branching-point approach of Aguiar et al. (2020). The SDP narratives result from the combination of different action options towards sustainable development. They address a greater number of topics relevant to sustainable development and explicitly integrate diverging views on how to achieve sustainable development. The narratives are therefore more nuanced, going beyond a 4-field-matrix scenario framework.

2. **What features[1] of the SSP-RCP or other scenario frameworks helped or hindered progress in the topic area of this session?**

   The SSP-RCP Framework was not the main method of studies presented in this session, perhaps because of the session's focus on social aspects and regional perspectives at higher granularity and over a broader swathe of sustainability concerns (2030 Agenda) than the SSP-RCP Framework can offer. For instance, one of the presentations was about the assessment of infrastructure investments by World Bank in a specific country. We learned that they prefer to use scenarios from country studies with more granularity and country input, for instance available technology, future costs, political feasibility, preferences.

3. **What key modifications, additions to, or extensions of the scenario framework would be most helpful for future work in the topic area of this session, and what research gaps would they address?**

   Extending justice principles beyond a utilitarian focus, which is currently most often used in IAM, and applying them in model analysis shows other trajectories of CO2 emissions and temperature increases. This provides important insights into how much of inequality might be inevitable and how much is intrinsic model property. By looking at

different justice principles, research presented in this session addressed the questions of how mitigation policies may be more equitable in distributing the benefits and burdens of climate change policies while also being robust. More nuanced scenarios *taking a wider variety of uncertainties* into account, specific to local contexts, can also be helpful.

4. What are other key highlights from your session?

Other highlights that were not directly related to the SSP-RCP Framework or its development include:

1. An empirical analysis of the use of scenario tools and interfaces, in this case the interactive tool "Riskmeter": The research examined on the one hand whether stakeholder engagement enabled by such tools can enrich large ensembles of model-based scenarios. In short, stakeholders (here: "citizens") showed different preferences for energy scenarios compared to model-based scenarios that had been developed by different organizations. Thus, stakeholder engagement via tools such as the "Riskmeter" can enrich scenario analysis. On the other hand, the research looked at whether interactive tools like the "Riskmeter" perform better for stakeholder understanding of modeling results and scenarios, compared to "standard", static communication (in this case a webpage describing four scenarios and storylines). It was shown that there was no measurable advantage using the interactive scenario tool over the static format. This might have been due to users being overwhelmed by the breadth of information provided by the interactive tool. However, there might be a learning effect over time resulting in better use and understanding of tools like the "Riskmeter", thus it was recommended to repeat the study in the future.

2. A case study where country-specific low-carbon development pathway scenarios were applied to assess the consistency of a "real-world" investment project or development activity with low carbon objectives. The study showed an example of how scenarios can be used to guide decision-making for infrastructure investment, considering potential risks of carbon lock in and the transition time horizon for low carbon adoption.

   Two posters:
   1) Presenting SWIM (Scalable World Interactive Model): an interactive webpage allowing users to explore policy options and scientific uncertainties by adjusting a multitude of parameters with immediate response of plots showing for example socio-economic, climate and land use data.
   2) Presenting a robustness analysis of economically optimal mitigations

5. **What audiences (researchers, practitioners, policymakers) do you think would most benefit from the scenario-related work in the topic area of this session?**

   All mentioned audiences would benefit from the work that has been presented in this session. The scenario research community might particularly benefit from insights about expanding justice principles in IAM, insights into how non-modelers make use of scenario interfaces for informational purposes (and required improvement of these interfaces), as well as the branching-point approach as a tool that may help increase transparency and participation in scenario development.

   Practitioners can make use of the scenario interfaces (Riskmeter, Scenario Explorer, SENSES toolkit, My 2050 UK calculator, Swiss EnergyScope, I2AM Paris platform, SWIM) that have been presented in the session. Moreover, the presented case study on the use of decarbonization scenarios to assess a development project's consistency with low carbon goals gives insights particularly relevant for the financing of large-scale projects.

6. **What plans for follow-up activities (meetings, publications, projects, etc.) related to the topic area of this session are you aware of?**

   A special issue of Frontiers In Environmental Science is planned on the topic of *Stakeholder-Engaged Integrated Assessment Modelling for Global Scenarios in a Changing World* and edited by Jeffrey M Bielicki and Douglas Jackson-Smith (co-chairs of session #29) and Sibel Eker and Sarah Elisabeth Cornell (co-chairs of this session, #52).

SCENARIOS FORUM 2022

Session ID # 56: Global South

No session feedback provided

Session ID # 59: Climate and Biodiversity

Session name: Catalyzing climate and biodiversity coupled scenarios for assessments and policy

Session organizer(s): HyeJin Kim, Paula Harrison, Laura Pereira

1. **What particularly notable advances have been made in the topic area of this session that involved using or further developing the SSP-RCP or other (please specify) scenario frameworks?**

   This session focused on catalyzing biodiversity and climate coupled scenarios and most of the discussion was around using the SSP-RCP Scenarios Framework from the climate research community and the Nature Futures Framework (NFF) from the biodiversity research community. There has been an effort to test the SSP-RCP scenario framework with the NFF value perspectives, examining how each SSP scenario reflects and performs on the three nature value perspectives (intrinsic, utilitarian, relational) using a suite of existing indicators (Mark Rounsvell, KIT). Existing scenarios have been mapped to the NFF value perspectives, which identified gaps in the representation of relational and cultural values. New work partly addressing this gap is underway using the GLOBIO-IMAGE model to explore scenarios reflecting the Whole Earth and Half Earth concepts (Rob Alkemade, PBL). Extensions to the SSPs using participatory methods at the regional level have been instrumental in incorporating a greater diversity of locally or nationally relevant worldviews, knowledge and data in both qualitative and quantitative scenarios. Hence, regional SSP scenarios may map better to the three NFF value perspectives than global SSPs, which are simple sketches of the future that are very uniform in terms of the values/worldviews they represent (Simona Pedde, WUR). Illustrative NFF global narratives have been recently developed that describe futures for the three nature value perspectives (corners of the NFF triangle) and for three mixes of value perspectives (sides of the NFF triangle) to demonstrate how the NFF can be used to develop narratives (Laura Pereira, IPBES, Wits/SRC). An alternative approach is being tested to identify Sustainable Development Pathways (SDP), exploring different spatial land use configurations mitigating climate and biodiversity change trajectories using a broader range of indicators that improve the representation and accuracy of data, in particular on nature and its ecological feedbacks (Alexander Popp, PIK).

2. **What features[1] of the SSP-RCP or other scenario frameworks helped or hindered progress in the topic area of this session?**

   From the perspective of sustainability scenarios, the SSP-RCP scenarios do not represent or integrate alternative options for conserving and living in harmony with nature. This leaves nature and people as passive recipients of economic growth-driven socio-economic pathways. It is worth asking if these are the future we want for nature and people. The NFF aims to generate sustainable and transformative future scenarios with nature and people's relationship with nature at the center, reflecting diverse worldviews on multiple roles and benefits of nature. The NFF helps identify place-specific initiatives

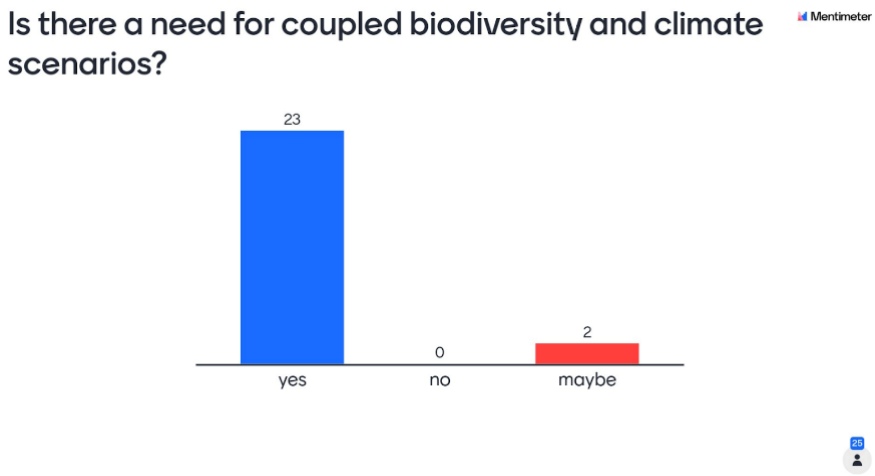
and interventions, small and large, that can be amplified in moving towards nature and people positive futures.

3. **What key modifications, additions to, or extensions of the scenario framework would be most helpful for future work in the topic area of this session, and what research gaps would they address?**

Alternative futures for nature, diverse values and benefits of nature, visions for living in harmony with nature, and nature-based solutions for climate mitigation and adaptation were identified as gaps in the SSPs-RCPs. These gaps could be addressed by the biodiversity and climate research communities, co-developing scenarios that prevent biodiversity loss and mitigate climate change to secure livelihoods and the wellbeing of the planet. This will require modifying, improving and integrating existing scenario and modelling frameworks in filling these critical gaps. Specifically, the SSP-RCP Framework could be made more relevant to other scientific communities by (i) relabelling the axes from "challenges to adaptation/mitigation" to something that is less climate-centred; (ii) adding new positive or desirable SSPs or variants of SSP1; (iii) extending SSP1-RCP1.9/2.6 with multiple pathways (possibly based on the NFF) by incorporating biodiversity policies into the Shared Policy Assumption (SPA); and (iv) defining alternative pathways that bring the five SSPs towards sustainable and desirable futures. The less desirable SSPs could also be linked to the NFF if used as disruptive scenarios that stress or provide obstacles for pathways to nature-positive and sustainable futures. Coupling the SSPs with the NFF would help to align the role of scenarios across the IPCC and IPBES assessments, as well as better enabling interlinkages and feedbacks between climate and biodiversity to be represented in scenarios and models.

4. **What are other key highlights from your session?**

A menti poll (www.menti.com/9345 7192) undertaken during the session supported the need for coupled climate and biodiversity scenarios (92% Yes, 0% No, 8% Maybe; n=25). We also asked participants what characteristics, methods, approaches are needed for biodiversity-climate coupled scenarios to be effective and useful? This resulted in the WordCloud below (n=24):



We need to think about what we develop scenarios for, how they are used, and what impact they bring to society and the planet. Diverse values and benefits of nature have been integrated and quantified in a broad suite of biodiversity and ecosystem services models, in particular intrinsic values (e.g., species richness, ecological integrity, genetic diversity) and instrumental values (e.g., pollination, nitrogen retention, environmental risk reduction). Relational values (e.g., social cohesion from nature-based solutions, life satisfaction from conserving and equally sharing nature) are least reflected in existing modelling frameworks. Today there is an overwhelming amount of in-situ and remote sensing data spatially and temporally, as well as empirical research from the natural and social sciences, that can generate knowledge on all three value perspectives in informing decisions of broader stakeholders on how they can contribute and act on achieving sustainable futures.

5. **What audiences (researchers, practitioners, policymakers) do you think would most benefit from the scenario-related work in the topic area of this session?**

Sustainability scenarios that the NFF aims to generate is, by design, participatory and inclusive, and can engage and inform all stakeholder groups (government, practitioners, researchers, and citizens including youth) relevant for the place and the context of its application.

6. **What plans for follow-up activities (meetings, publications, projects, etc.) related to the topic area of this session are you aware of?**

We are planning to start a community of practice around coupling biodiversity and climate scenarios for sustainable and transformative futures. In parallel to the digital and in-person exchange with participants of the Scenarios Forum, we initiated similar exchange with the broader biodiversity scenarios and modelling community on the need for coupled biodiversity and climate scenarios, their desirable characteristics and means for developing them, and biodiversity policies for the the SPA (Shared Policy Assumptions). This was also as a follow-up of the second IPBES Modellers Workshop in

April 2022 where the experts in the SSP-RCP community suggested these as ways forward in co-developing coupled climate and biodiversity scenarios for ongoing assessments of IPCC and IPBES and policy frameworks such as Paris Agreement, CBD Global Biodiversity Framework and the UN Sustainable Development Goals.

Session ID # 63: AR7 recommendations

Session name: Scenarios in IPCC assessments: lessons from AR6 and recommendations for AR7

Session organizer(s): Jan Fuglestvedt, Anna Pirani

The use of scenarios has been an integrating and cross-cutting element across the Working Groups (WGs) in the 6th cycle of the IPCC (AR6), with three Special Reports overseen by the three Working Groups (WGs), as well as the three WG reports and the coming Synthesis Report. Stronger collaboration and linkages across communities were developed thanks to the cross-cutting nature of the three Special Reports, and this was followed up in the writing of the three WG reports. IPCC WGI considered a core set of scenarios from the SSP framework from CMIP6, supplemented by RCPs from CMIP5. WGII used both SSPs and RCPs, and WGIII used scenarios from a database containing more than 2000 scenarios, complemented by bottom-up approaches.

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 and lessons learned that are useful for the AR7 cycle and beyond.

Three invited talks from representatives of the WGs considered:

- Brief highlights of key advances in scenarios and the assessment that have been important in the AR6
- How scenarios have underpinned key findings of the reports
- Recommendations for whether and how scenarios might be further used to strengthen coordination across chapters and Working Groups
- Key knowledge gaps and recommendations for future research directions in the context of scenarios
- Shortcomings in the current Scenarios Framework and/or scenarios-based literature that hinders wider use in assessment
- Insights for the role of scenarios in future assessments

The workshop ended with a discussion between the panel and all session participants of ideas and recommendations for strengthened coordination across the IPCC and its underlying scientific and technical communities, and will address how the use of scenarios can support addressing important climate research questions and the coming assessments from the IPCC.

1. **What particularly notable advances have been made in the topic area of this session that involved using or further developing the SSP-RCP or other (please specify) scenario frameworks?**

The IPCC Sixth Assessment Report (AR6) has been characterized by an unprecedented level of integration in the assessment of scenarios of possible climate (WGI), impacts and risks (WGII), and mitigation (WGIII) futures.

Illustrative climate scenarios were assessed with substantially reduced uncertainty using multiple lines of evidence - process understanding and theory, new methodologies, paleoclimate records, observational products, emulators (i.e. simple climate models) and complex Earth system models. Outcomes of the use of emulators - simple climate models - evaluated against assessed possible climate futures were used to directly assess illustrative mitigation scenarios. Impacts and future risks were assessed using multiple lines of evidence combining scenarios of future changes with process understanding, as well as conceptual framing of climate resilient development pathways. A cross-cutting assessment of avoided impacts and costs in relation to mitigation actions was undertaken.

Publications based on the SSP-RCP Framework represent a portion of the literature and analyses relevant to climate-related sciences and assessment with, for instance, additional scenarios, hybrid approaches (e.g., CMIP5 RCPs combined with SSP or other socioeconomic assumptions), and varying scopes of scenarios (e.g., spatial, temporal, economic, biophysical) a significant part of the literature.

2. **What features[1] of the SSP-RCP or other scenario frameworks helped or hindered progress in the topic area of this session?**

Issues related to timing have hindered or were challenging for the IPCC assessment.

Timing of the CMIP process and regional climate and impacts modeling efforts has meant that while the assessment of possible climate futures (WGI) and mitigation pathways (WGIII) was based on CMIP6, the literature available on regional climate (WGI) and impacts and future risks (WGII) modeling is generally based on CMIP5, particularly with RCP8.5. However, this was not a major hindrance since the scenario framework was designed to allow for using both CMIP5 and CMIP6 simulations (for example climate simulations based on RCP4.5 and SSP2-4.5 can be considered interchangeable for the purpose of assessing impacts associated with the 4.5 W/m^2 forcing pathway). Note that much of the impacts literature is not based on SSPs, e.g. using SRES. This can be addressed by binning SSP and SRES scenarios into common categories. Impact results are not equally available for all scenarios, so sometimes there can be gaps in the impacts literature, especially of large scale quantitative impact studies. Finally, higher resolution and scenarios tailored to analyses questions and scope, and scenarios exploring uncertainties beyond the SSP-RCP framework, will continue to be essential.

In addition, Global Warming Levels (GWLs) were found to be very useful for WGII AR6 integration and communications as Common Climate Dimensions (CCD), as well as for integration with the other WGs and connecting to and complementing scenarios. Among other things, GWLs provide an opportunity to explore hazard uncertainty via earth system variable ranges by GWL, as well as an opportunity to explore impacts exposure, vulnerability, and adaptation uncertainty and risk.

The ongoing WGI-WGIII handshake meant that WGIII Ch3 had access to one WGI emulator in time for the WGIII FOD, however changes to various parts of the WGI assessment (e.g. historical warming, radiative forcing, climate sensitivity), meant that final hand-over and choice of the WGI emulators for their use in Ch3 WGIII, occurred not long before the WGIII FGD submission – without delays to the WGIII schedule (e.g. COVID), the timing would have been even more challenging.

3. **What key modifications, additions to, or extensions of the scenario framework would be most helpful for future work in the topic area of this session, and what research gaps would they address?**

Enhanced integration of impacts

- Explore integration opportunities for bringing together the disparate impacts literature, including opportunities for using scenarios, GWLs and other common climate dimensions (CCD), climate projections, and climate projection-CCD mapping resources.
- Consistency in terms of potential baselines and characterizations of uncertainty to facilitate integration of socio-economic factors needed in impact and risk modeling and assessment.
- Directly include impacts into SSPs/ref scenarios/prep for CMIP i.e. make ISIMIP/ or equivalent an explicit part of the scenario process, along with narratives, drivers, IAM runs. Include impact model runs, coordinated model comparison runs for different types of impacts provided with the scenarios; like we do with climate models in the CMIP process, provided with scenarios.
- 'Impacts MIPs' - face methodological difficulties since results are often difficult to intercompare e.g. for damages and cost-benefit space of avoided impacts. More work is thus needed to develop community standards for impact definitions and reporting (similar to the work that has been done in IAM model comparisons). This would facilitate more systematic impact comparisons and permit to connect/integrate impacts better with the socioeconomic SSP projections and scenarios from WGIII.
- Bridging scales - tension for wanting to tell global stories but recognizing that impacts, risks, responses are mostly at local level. Scenarios are great with *global* stories, but at *local* level, you have to get into things that global scenarios can't necessarily provide.
- Explore impact emulators – discussions would be valuable with the impacts community, jointly with IAMs, and should also include WGII to evaluate opportunities for estimating impact functional forms. This would not be a substitute for detailed impacts and risk analyses needed to inform adaptation, but could provide aggregate impact-driver relationships helpful to climate policy.
- Run IAMs with and without impacts then sectoral impact modules could be used for comparison - new analysis to have both scenarios with and without impacts
- There is a research community opportunity to develop a climate translation resource for mapping the impacts literature input climate projections to CCDs and vice versa to facilitate integration.

Near-term information

- SSP-RCP Framework focuses on climate goals and forcing in 2100, however carbon neutrality and short term action has become bigger focus.
- Need for considering socioeconomic uncertainty in near term is critical - very few studies that combine SSPs with socioeconomic uncertainty with short term policy assessment.
- Need for better information on uncertainties from internal variability and in forcings from natural and anthropogenic aerosols in addition to socioeconomic uncertainty. The combined uncertainty information may have an implication for global stocktake.
- Need to update the socio-economic projections, e.g. covering COVID and other trends, in the medium terms also completely new projections.
- Important for understanding of potential risks and opportunities for adapting and mitigating.

Consistent assessment of scenarios across WGs

- Explore opportunities for the consistent use of scenarios across WGs for enhanced integration of future assessment across WGs.
- A core set of scenarios—climate with socioeconomic uncertainty—across WGs may need to include more policy-relevant ones including close to current policy or NDCs, and different levels of overshoot (particularly for 1.5°C global warming), and consideration of pathway likelihood and plausibility.
- Explore opportunities, challenges, and limitations for socioeconomic scenario standardization and capturing uncertainty relevant to adaptation, mitigation, and risk.

4. What are other key highlights from your session?

Recommendations and suggestions were made for improving the integrated way of working with scenarios across the three WGs. In particular, distinguishing the scenario database development from the assessment of the scenario-based literature, which has infrastructure and process needs to be implemented by the community.

A "live" emissions scenario database in support of the community scenario processes was proposed:

- The database would have the advantage that high-quality and most up-to-date information is available and can be used by user communities. In addition it has the advantage that incremental updates on regular basis are made in preparation of AR7 (instead of doing the whole job during and in parallel to the assessment)
- Community-led database, needs a framework/formalized process beyond infrastructure to give it legitimacy
- Vetting outside of the assessment process by peers, additional automated checks and processes for quality control and peer review
- Include climate model emulators to see the climate outcomes, and also impact emulators potentially.
- For AR6, tried to extend the scenario database to sectoral and national teams - time consuming, challenging to get data into shape, but good for more inclusion.

- How disruptive technology changes are addressed - more strict in filtering scenarios or a way to take into account what is in the pipeline.
- Prepare for SR cities - can urban emissions scenarios be vetted and included?

Process

- The need for more deliberate, supportive leadership exploring and guiding the adoption of a scenario framework in the assessment from the very start.
- Build in scenario preparations formally into AR7 earlier in the timeline/structure of the assessment e.g. a report/workshop/technical report at the start to prepare the work for all three WGs.
    - A regular update process could be envisaged, coming from the community that could feed into a technical report on scenarios at the start before AR7, feeding into the AR7 more effectively.
- Importance of not losing institutional knowledge of authors involved in process so far alongside bringing in newcomers
- Prepare more for the parallel process that is inevitable given the need to make calls for scenarios to be submitted, and e.g. due to the WGI-WGIII handshake as experienced by CH3 WGIII waiting for WGI emulators to be finalized before the scenario classification could be also used by other chapters in WGIII.
- Expert meetings ahead of reports in AR7 - better to have more of these than SRs - e.g. scenarios, overshoot - to have meeting reports without approval processes to move things forward.
- Encourage the IPCC to consider adjusting the AR WG schedules to facilitate integration. Currently, the WG schedules are too close and constrain coordination, such as constraining WGII taking advantage of WGI's Atlas, and WGII and WGIII integrating mitigation, adaption, and development perspectives for assessing climate-resilient development.

5. What audiences (researchers, practitioners, policymakers) do you think would most benefit from the scenario-related work in the topic area of this session?

The research community will benefit from the recommendations for improved coordination and integration since this will support the identification of knowledge gaps and support progress. The policymaker audiences of the IPCC reports will benefit from these efforts that will support a policy relevant assessment.

6. What plans for follow-up activities (meetings, publications, projects, etc.) related to the topic area of this session are you aware of?

- A commentary is planned to summarize the use of scenarios in the AR6 and discuss challenges, hindrances and opportunities to inform preparations for the AR7. This may discuss increased integration, the modes of working in the assessment process across the WGs and in relation to the underlying community, knowledge gaps and IPCC audience interests and needs for scenario-based information.
- An ICONICS webinar will be held in October 2022 on the communication of scenarios. This will include outcomes of a project that is being undertaken by the

WGI Technical Support Unit in collaboration with the Reuters Institute for the Study of Journalism.

- Events are planned for COP27 on the WGIII assessment of scenarios and on the use and communication of scenarios by policymakers.
- A related discussion is suggested to take place at the 2022 IAMC conference.
- An IPCC Workshop on scenarios is being planned by the three WGs for early 2023.

A process for updating the quantitative socio-economic projections of the SSPs is under way.

SCENARIOS FORUM 2022

Session ID # 64: Lifestyle

No session feedback provided

Session ID # 66: Digitalization

Session name: Digitalization and scenarios
Session organizer(s): Charlie Wilson, Laurent Drouet

1. **What particularly notable advances have been made in the topic area of this session that involved using or further developing the SSP-RCP or other (please specify) scenario frameworks?**

   This session began by noting that "digital transformation is a megatrend that is fundamentally changing all economies and societies" (IPCC AR6 WG3 Technical Summary) and yet digitalization is scarcely mentioned in the SSP narratives paper (e.g., O'Neill et al. 2017) or in the long-tern pathways chapter of the recent IPCC assessment. The session concluded with a short discussion on the importance of better capturing digitalization in the SSP narrative framework and in derived modelling of future transformation pathways.

2. **What features[1] of the SSP-RCP or other scenario frameworks helped or hindered progress in the topic area of this session?**

   The absence of an explicit treatment of digitalization in SSP frameworks provides a tabula rasa on which to interpret the existing SSP narratives in terms of their implications for digitalization. What is not clear is whether the potentially large opportunities and risks (for mitigation) from digitalization should be treated as being within existing narratives or additional to existing narratives. The first approach implies digitalization simply adds interpretive detail to otherwise unchanged scenario narratives and derived modelling. The second approach implies digitalization modifies the scenario narratives and so requires a new wave of derived modelling.

3. **What key modifications, additions to, or extensions of the scenario framework would be most helpful for future work in the topic area of this session, and what research gaps would they address?**

   Digitalization is an economy-wide and society-wide transformative force (or 'general purpose technology') with major risks and opportunities for mitigation. Adding it in to the SSP framework would enable further narrative and modelling analysis of these risks and opportunities, and would help emphasise the importance of public policies for harnessing digitalization as a force for good.

4. **What are other key highlights from your session?**

   Digitalization has important implications for human agency and equity (both for better and for worse) as well as for energy and material demands. Consequently, effective governance of digitalization (including general purpose applications like AI) is critical.

5. **What audiences (researchers, practitioners, policymakers) do you think would most benefit from the scenario-related work in the topic area of this session?**

   Researchers working on SSP narratives and modelling with relevant for mitigation; policymakers at the interface between digitalization, energy and climate; and the ICT industry.

6. **What plans for follow-up activities (meetings, publications, projects, etc.) related to the topic area of this session are you aware of?**

   An ongoing programme of work to further embed the impacts of digitalization within mitigation pathways analysis.

SCENARIOS FORUM 2022

Session ID # 69: Cross-border

Session name: Exploring and expanding the cross-border dimensions of the SSPs

Session organizer(s): Stefan Fronzek, Magnus Benzie, Henrik Carlsen, Timothy Carter, Christopher Reyer (who prepared this document together with the speakers in this session Nina Knittel, Irene Monasterolo, Adrien Detges and Fanny Groundstroem)

1. **What particularly notable advances have been made in the topic area of this session that involved using or further developing the SSP-RCP or other (please specify) scenario frameworks?**

    a. The need to consider cross-border climate risks has increasingly been recognized.
    b. Both the transmission of climate risks across borders and responses to these depend on the level of how the world is connected e.g. through international trade, financial markets and issues related to migration and security.
    c. The SSPs define a wide range of international connectivity that allow to explore cross-border climate risks in contrasting contexts.
    d. The importance has been recognized of using climate scenarios for climate financial risk assessment and climate stress tests, by including acute impacts, their compounding effects and interaction with chronic impacts.
    e. There is emerging research using the SSP to project a broader range of security risks, including risks to human security, risks of violent conflict, and impacts on forced migration.

2. **What features[1] of the SSP-RCP or other scenario frameworks helped or hindered progress in the topic area of this session?**

    a. The SSP narratives and quantitative database provide information from which it is possible to derive insights on the extent and nature of connectivity; this provides essential context information for the study of cross-border climate impacts and the cross-border effects of adaptation.
    b. Some forms of international connectivity, for example finance, supply chains or relevance to specific sectors and explicit region-to-region connections, are not described in the SSP narratives, which hinders the study of cross-border dimensions.
    c. In particular, modeling of cross-border dynamics is hindered by the absence of quantitative data on inter-regional connectivity in the SSPs. The lack of finance and climate risks in SSPs hindered their research and policy relevance.
    d. The SSP-RCP Framework allows for a consistent comparison across modeling studies of different scopes and thereby helps to understand the relevance of cross-border impacts in an (inter-)national context.
    e. It is inherently difficult to quantify variables like social cohesion, let alone to project them into the future. This is an obstacle to studying security challenges within the SSP framework.

3. **What key modifications, additions to, or extensions of the scenario framework would be most helpful for future work in the topic area of this session, and what research gaps would they address?**

   a. Representing the finance sector by developing explicit elements e.g. of international finance markets for the SSP narratives, including a description of the role of finance, either as enabler or barrier, in the realization of the RCP-SSPs narrative.
   b. Improving and refining scenario descriptions of international connectivity (e.g. What free trade zones are in place? What are the regional zones for free movement of labour? Are there regional geopolitical blocks in place?) with explicit regional and sectoral extensions. Ideally, these extensions come with some quantifications.
   c. Consider scenarios currently missing from the SSPs that pair high international connectivity in one aspect with low connectivity in another.
   d. Introduce climate risks and their impacts to the realization of the RCP-SSPs narrative
   e. More differentiation between countries/world regions would be helpful to make projections in specific contexts.

4. **What are other key highlights from your session?**

   a. Cross-border climate change impacts matter and need to be considered in IAV research and in adaptation planning.
   b. SSP selection can make a significant difference to the outcomes of studies on cross-border climate impacts and cross-border effects of adaptation - probably a much greater difference than RCP selection.
   c. Some level of comparability between emerging studies in this area is possible given the adoption of a common conceptual framework (cf. Carter et al. 2021).
   d. Current RCP-SSP scenarios could lead to underestimate macroeconomic and financial losses from climate scenarios.
   e. SSPs can be used to study future security risks in connection with climate change. This area of research deserves more attention.

5. **What audiences (researchers, practitioners, policymakers) do you think would most benefit from the scenario-related work in the topic area of this session?**

   An improved and more explicit representation of international connectivity and cross-border climate impacts in scenarios will have benefits for:

   a. Practitioners, finance industry and policymakers involved in adaptation planning:
      - by raising awareness of the importance of looking beyond regional and national climate risks
      - by providing a set of analytical tools that allow to explore cross-border climate risks and develop appropriate responses
      - by providing more relevant risk scenarios to run climate stress tests that in turn influence the assessment of risks and opportunities for investors

   b. Researchers

- that develop regional extensions of the SSPs by getting the awareness and tools to include connections to the rest of the world most relevant for their region
- that study IAV at different scales and applying different methodologies (including quantitative modeling)
- Develop climate tail risk scenarios and assess their impact in the economy and finance

6. What plans for follow-up activities (meetings, publications, projects, etc.) related to the topic area of this session are you aware of?

a. Work within the EU H2020 CASCADES project to summarise findings from multiple case studies that have explored future cross-border climate risk using various scenario approaches

b. Work with the EDHEC-Risk Climate Impact (ERCII) research center to complement RCP-SSPs narratives with the role of finance (enabler/barrier) and climate risks, and their interplay

Session ID # 70: Low Energy Demand

No session feedback provided

Session ID # 82: Mitig/Adapt Capacity

Session name: Qualitative and quantitative approaches to represent regional capacity for mitigation and adaptation in the Shared Socioeconomic Pathways (SSPs)

Session organizer(s): Elina Brutschin[1], Silvia Pianta[2], and Felix Schenuit[3]

Institutional Affiliation(s): International Institute for Applied Systems Analysis[1], RFF-CMCC European Institute on Economics and the Environment[2], and Hamburg University[3]

1. **What particularly notable advances have been made in the topic area of this session that involved using or further developing the SSP-RCP or other (please specify) scenario frameworks?**

   More attention to insights from political science, particularly the role of state capacity but also regarding future implications on war and conflict along the SSP1 trajectory.

2. **What features[1] of the SSP-RCP or other scenario frameworks helped or hindered progress in the topic area of this session?**

   Especially GDP, education and other socio-economic indicators are extremely helpful for projections of other key variables of interest.

3. **What key modifications, additions to, or extensions of the scenario framework would be most helpful for future work in the topic area of this session, and what research gaps would they address?**

   An explicit attention to the quantification of variables such as governance and conflict under different SSPs and more updated data with possible feedbacks along key variables would be extremely useful.

4. **What are other key highlights from your session?**

   The main strength of the session was a very broad scope of research that tries to link political science insights with the ongoing work in climate science. We specifically focused on the important but also difficulty of long term projections of variables such as governance or institutional capacity.

5. **What audiences (researchers, practitioners, policymakers) do you think would most benefit from the scenario-related work in the topic area of this session?**

   I think that this session was of utmost importance for all different types of stakeholders as only a holistic and interdisciplinary approach can help address some of the key issues

pertaining to a successful implementation of climate policies.

6. **What plans for follow-up activities (meetings, publications, projects, etc.) related to the topic area of this session are you aware of?**

   Not aware of any plans yet.

SCENARIOS FORUM 2022

Session ID # 83: Agriculture

Session name: Representative Agricultural Pathways – Cross-scale and trans-disciplinary storylines for agricultural development and decision-making

Session organizer(s): Alex Ruane, NASA GISS, and Roberto Valdivia, Oregon State University

1. **What particularly notable advances have been made in the topic area of this session that involved using or further developing the SSP-RCP or other (please specify) scenario frameworks?**

   This session focused on regional and sector-specific extensions of the SSP-RCP Framework to agricultural applications. This often requires detailed elaboration of agricultural technologies, policies, and demand for food, fibre and other agricultural products. Changes in agricultural systems have been explored within the Agricultural Model Intercomparison and Improvement Project (AgMIP) using "Representative Agricutlural Pathways (RAPs)", and in this session we heard from many groups applying RAPs and similar scenarios to understand how climate change will interact with other pressures on future farming systems. The RAPs process sheds light on key aspects of agricultural systems change, and also allows for a quantification of trends and step changes for use in model applications that are coherent across scales and sectors. More work is needed to connect sectoral elaborations in a systems framework for the next generation of global and regional scenarios. The session highlighted the use of RAPs across scales and within a range of crop, livestock and economics models.

2. **What features[1] of the SSP-RCP or other scenario frameworks helped or hindered progress in the topic area of this session?**

   The SSP-RCP Framework has limited information about agricultural systems, which makes them insufficient for agricultural applications. Further information is needed about food demand, land use, bioenergy, agricultural technologies, and policies that subsidize or hinder certain practices. The RAPs approach could therefore serve as a framework for sectoral elaboration, although care is needed to ensure that assumptions made in one sector do not contradict those made in other sectors.

3. **What key modifications, additions to, or extensions of the scenario framework would be most helpful for future work in the topic area of this session, and what research gaps would they address?**

   Representative Agricultural Pathways (RAPs) could serve as an additional dimension of scenario analysis covering the agricultural and food systems. These cannot be comprehensive given the wide diversity of detail needed for scenarios at different scales and levels of sectoral complexity examined, but a coherent set of storylines and a common framework would go a long way to establishing useful scenario assessments. There is a great need to provide practical limits to productivity increases that are often assumed in Integrated Assessment Models, including biophysical

limitations as well as the practicality of large-scale deployment of intensification approaches that would have other devastating impacts on the environment.

4. **What are other key highlights from your session?**

   Agricultural scenarios are being developed and used from local to sub-national, national and global scales. The AgMIP community has produced a number of agricultural impact projections that can be used to represent land use pressures in conjunction with non-agricultural changes like water resource availability and competition, ecosystem protection, population displacement, and other systemic aspects. In many cases these projections were made explicitly for connection with Integrated Assessment Models, taking care to avoid double-counting of productivity increases, for example. The session also showed how RAPs affect crop and livestock systems and their interactions, underscoring the need to engage across and within sectors.

5. **What audiences (researchers, practitioners, policymakers) do you think would most benefit from the scenario-related work in the topic area of this session?**

   Food systems are critical to all aspects of society, and thus scenarios representing the future of agriculture are of interest to those within the agricultural sector and those directly affected by its outcomes. Scenarios-related work in this area could include major crop breeding and genetics companies, purveyors of agricultural technologies (e.g., John Deere), agricultural chemical companies (e.g., fertilizers, pesticides), conservation groups (worrying about agricultural encroachment on wild lands), and those interested in displaced peoples should food insecurity or non-viable agricultural lands disrupt currently populated zones.

6. **What plans for follow-up activities (meetings, publications, projects, etc.) related to the topic area of this session are you aware of?**

   Work on this topic continues within AgMIP, and there are new projects to formalize the RAPs process on national scales across Africa and South Asia. Increased focus on systemic connections has fostered systemic thinking and therefore highlighted the need for elaboration that allows sectors to be better represented and connected for proactive planning.

SCENARIOS FORUM 2022

Session ID # 85: Demographic projections

No session feedback provided

SCENARIOS FORUM 2022

Session ID # 93/94: Climate change and gender

Session name: Addressing the gender dimension in socioeconomic scenarios: policy and climate change impacts on gender equality & gender equality as a driver of change

Session organizer(s): Caroline Zimm, IIASA; Jonathan Moyer, University of Denver - Pardee Center

1. **What particularly notable advances have been made in the topic area of this session that involved using or further developing the SSP-RCP or other (please specify) scenario frameworks?**

   SSPs base elements on population projections provide sex-aggregated data which is being continuiously developed (e.g. updated). The sessions also highlighted various aspects of SSP development, pointing to how gender inclusion has direct effects on future challenges to mitigation and adaptation.

2. **What features[1] of the SSP-RCP or other scenario frameworks helped or hindered progress in the topic area of this session?**

   N.a. We saw many empirical applications of sex-aggregated data or related to gender inequality. It is a challenge that many IAMs do not in fact use the sex-aggregated information available for the SSPs.

3. **What key modifications, additions to, or extensions of the scenario framework would be most helpful for future work in the topic area of this session, and what research gaps would they address?**

   Explicitly mentioning of gender in SSP narratives, model development to account for sex-aggregated data, an effort to present a broader framework for how gender inclusion can be a component of future scenarios work. This all directly relates to conversations about the future of governance and democracy as well, or the political institutional components of future SSP work in particular.

4. **What are other key highlights from your session?**

   The session highlighted a variety of approaches to studying the role of gender in scenarios. Many researchers pointed to issues with data availability (though there was recognition that strides had been made). In terms of mitigation, many researchers highlighted a relationship between changing patterns of mitigation and gender-based drivers or outcomes. In terms of adaptation capacity, some researchers pointed to the importance of gender as a driver of adaptation capacity, but research also highlights the complexity of drawing clear conclusions because the role of gender in society as a driver of development is complex.

Very rich empirical basis available and further evolving.

5. **What audiences (researchers, practitioners, policymakers) do you think would most benefit from the scenario-related work in the topic area of this session?**

   All of the above. This is a very understudied area of development that has clear implications for future socioeconomic development. The role of gender in the study of development would be a particularly fruitful area of inquiry to further include in this scenario space.

6. **What plans for follow-up activities (meetings, publications, projects, etc.) related to the topic area of this session are you aware of?**

   We plan to write a perspective piece on the need for more gender-related work in scenarios.

SCENARIOS FORUM 2022

Session ID # 104: Subnational decarbonization

No session feedback provided

SCENARIOS FORUM 2022

Session ID # 201: Communication

Session name: Synthesis and communication of climate change risks in scientific assessments

Session organizer(s): Brian O'Neill, Lena Reimann, Kris Ebi

1. **What particularly notable advances have been made in the topic area of this session that involved using or further developing the SSP-RCP or other (please specify) scenario frameworks?**

- The need for automated (i.e. machine learning) approaches to systematically synthesize the exponentially increasing scenario literature
- The proposed development of community scenarios of outcomes for human well-being and ecosystem health that include adaptation, mitigation, climate change, and other socioeconomic factors.
- Identifying adaptation pathways (sequences of adaptation measures over time) and incorporating them in scenarios
- Integrating SSPs in the RFC burning embers framework by using them to characterize uncertainty in the global warming level at which transitions occur from one level of risk to the next

2. **What features[1] of the SSP-RCP or other scenario frameworks helped or hindered progress in the topic area of this session?**

- WGII of AR6 used a "scenario-neutral" approach in the RFC burning embers and other means of synthesizing risks. It is unclear exactly what aspects of the scenario framework may have hindered its broader use, since several individual chapters incorporated SSPs in burning embers explicitly. It is possible that the fact that a substantial amount of impacts literature uses other scenarios or does not draw on scenarios at all was perceived as an obstacle, despite solutions being available such as mapping other scenarios to the SSP-RCP framework.
- Limited uptake in other assessments such as those conducted by the EEA. This may have been hindered by a lack of SSP-based literature at the time of those assessments, whereas the EU Climate Risk Assessment currently in progress is exploring how to draw more substantially on the scenario literature. A key factor will be the availability of SSPs at the European scale.
- Despite increasing evidence (supported by the SSP framework) that socioeconomic factors are at least as important as warming levels in determining risks, there remains an emphasis on the climate system.

3. **What key modifications, additions to, or extensions of the scenario framework would be most helpful for future work in the topic area of this session, and what research gaps would they address?**

- More effective methods of drawing on the rapidly expanding scenario-based literature, including machine learning approaches

- Steer use of scenarios towards users: research focus has different needs than stakeholders → perspective change needed
- Decrease complexity/communicate scenarios better: use of visual tools to make information more digestible
- On the other hand, there is the need to contextualize scenarios more, resulting in a likely increase in complexity, e.g. by using 'scenarios of outcomes' that describe more realistic, integrated futures

4. What are other key highlights from your session?

- RFC burning embers are useful for synthesizing and communicating impacts, and continued evolution in this approach is promising
- Socioeconomic scenarios were not used in WGII of AR6 or in other assessments as a major means of synthesizing risks → encourage uptake of SSPs and SPAs in impacts research and assessment
- Importance to account for adaptation and mitigation in scenario-based approaches in a more explicit manner
- It is important to consider user needs to ensure uptake of scenarios and ease of use:
    - Make socioeconomic conditions more explicit in synthesis methods like RFC
    - Build on progress in health, food security, and regional assessments (e.g. Europe) in representing socioeconomic determinants of risk in burning ember diagrams

5. What audiences (researchers, practitioners, policymakers) do you think would most benefit from the scenario-related work in the topic area of this session?

- Practitioners and policymakers because the session focused mainly on how to synthesize and communicate scenario-based insights (discussions touched on the challenges of communicating the scenarios to policymakers)
- Scientific assessment processes including the IPCC and national or regional assessments

6. What plans for follow-up activities (meetings, publications, projects, etc.) related to the topic area of this session are you aware of?

- IPCC scenario workshop in early 2023 will address issues directly related to this session
- EU Climate Risk Assessment: One participant (Hans Martin Fuessel) is leading this assessment and actively considering lessons learned from the IPCC scenario experience and other scenario work on synthesizing and communicating risk

Session ID # 202: Development process

Session name: Improving the scenario development process
Session organizer(s): Detlef van Vuuren, Bas van Ruijven, Brian O'Neill

1. **What particularly notable advances have been made in the topic area of this session that involved using or further developing the SSP-RCP or other (please specify) scenario frameworks?**

   SSP literature database has been updated with more than 1500 additional papers covering 2020-2021, with a preliminary release available

   The concept of adding impacts to reference scenarios has been investigated, with a proposal made for specific types of impact scenarios we might adopt (in addition to no-impact reference scenarios): biophysical impacts, macro socio-economic impacts, and micro socio-economic impacts.

   The concept of adding mitigation policy to reference scenarios has been investigated, with a proposal made for a specific type of policy scenarios we might adopt: policy scenarios defined not by a limit on future forcing, relying on global coordination and universal carbon pricing, but rather by a set of realistic policy assumptions considered plausible

2. **What features of the SSP-RCP or other scenario frameworks helped or hindered progress in the topic area of this session?**

   Reference scenarios that do not include impacts or policies
   The lack of guidance for the IAV community on interpreting and using the scenario framework.

3. **What key modifications, additions to, or extensions of the scenario framework would be most helpful for future work in the topic area of this session, and what research gaps would they address?**

   Need to foster use in understudied regions and topic areas
   Clearer communication of SSP framework and elements, which would improve usage for example of extensions and at other scales
   Need guidance for IAV researchers on the use of the Scenarios Framework; the concept of limits to adaptation may be useful in facilitating this guidance. One problem is how users frame results of their work, for example characterizing SSP2-4.5 as a low emissions scenarios, or how to characterize results based on RCP8.5. It may be worthwhile to frame this as a scenario that is beyond some limits to adaptation. It may be

useful in the future to have a high scenario that is an “artificial experiment” for climate models, not as part of a scenario set for application to IAV.
Need development of additional reference scenarios that include impacts and/or policy, and this included adaptation as well as mitigation.

4. **What are other key highlights from your session?**

5. **What audiences (researchers, practitioners, policymakers) do you think would most benefit from the scenario-related work in the topic area of this session?**

   Scenario researchers and scientific assessments (particularly via the literature database and guidance for IAV researchers)
   Policymakers (particularly via impact and/or policy reference scenarios)

6. **What plans for follow-up activities (meetings, publications, projects, etc.) related to the topic area of this session are you aware of?**

   A paper is planned on the updated SSP literature database, led by Carole Green

SCENARIOS FORUM 2022

Session ID # 203: Oceans

Session name: Blue scenarios: ocean and fisheries in Earth System models

Session organizer(s): Mary Gasalla, Jessica Strefler, David Keller

1. **What particularly notable advances have been made in the topic area of this session that involved using or further developing the SSP-RCP or other (please specify) scenario frameworks?**

- Using SSP-RCP:
    - CdrMIP: Projections of ocean-CDR
    - FishMIP: Projections of fish biomass across the foodweb under different CC scenarios; Projections of fishery catch potential across regions
    - ESM work on Blue carbon
- Further development: Oceanic system pathways (OSPs) narratives to build policy-relevant scenarios

2. **What features[1] of the SSP-RCP or other scenario frameworks helped or hindered progress in the topic area of this session?**

- Projection of ocean biophysical variables
- No consideration of ocean and fishery scenarios

3. **What key modifications, additions to, or extensions of the scenario framework would be most helpful for future work in the topic area of this session, and what research gaps would they address?**

- SSPs would have to be expanded to include ocean and fishery scenarios
- Broadening the perspective by producing more integrated ocean-related scenarios that can better fit societal needs of projections (even in ocean's modeling community silos-approach of modeling questions and does not integrate).

4. **What are other key highlights from your session?**

- First time that modelers from IAM, ESM, marine ecosystem/fisheries, social science communities came together to discuss scenarios improvement and further collaboration.
- We discussed (1) utility to better include Oceans in IAMs. (2) advances in better linking different (and so far disconnected) ocean-related MIPs and other modelling exercises into ESMs and IAMs. (3) ocean-CDR issues on policy misuse of model's outcomes.
- ESMs haven't run portfolios of CDR, don't know how additive they are. Need to figure out impacts first
- Inclusion of mCDR in IAMs can lead to multiple directions of learning:
    - For ESMs:

        - provide scenarios that include ocean CDR, which can then be used instead of very simplified diagnostic scenarios in the future.
    - For ocean models: also provide scenarios of how much e.g. alkalinity might be added in the future - ocean models can then clarify impacts on ecosystems
    - For IAMs:
        - Increase ocean components
        - analyse impacts of ocean CDR on energy and land systems, e.g. via reduction of BECCS and afforestation (--> reduced pressure on land), but also higher challenges due to more CDR deployment (--> discussion around mitigation deterrence)
- Further coupling of oceans and IAMs would be important to identify feedbacks and interlinkages:
    - Impact of ocean CDR on land and energy systems
    - Impact of different fishery scenarios on land systems (via changed food demand)
    - Impact of use of ocean biomass on land and energy systems
- No connection between fisheries and CDR yet, at least not in the models. Potential link: include pH in fishery models

5. **What audiences (researchers, practitioners, policymakers) do you think would most benefit from the scenario-related work in the topic area of this session?**

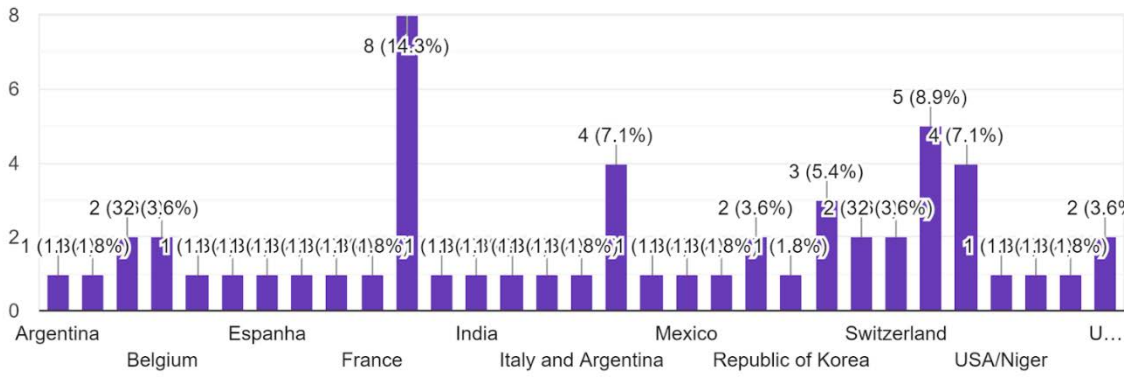
   For now researchers, as the main focus of this new development is a better representation of oceans and ocean scenarios in models and a better interaction between modeling communities

6. **What plans for follow-up activities (meetings, publications, projects, etc.) related to the topic area of this session are you aware of?**

Appendix V: Participant Survey

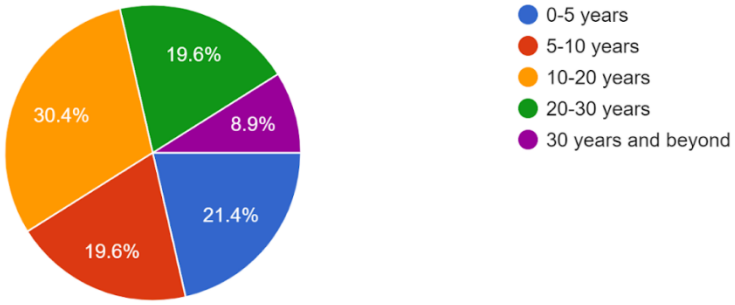
Country

56 responses



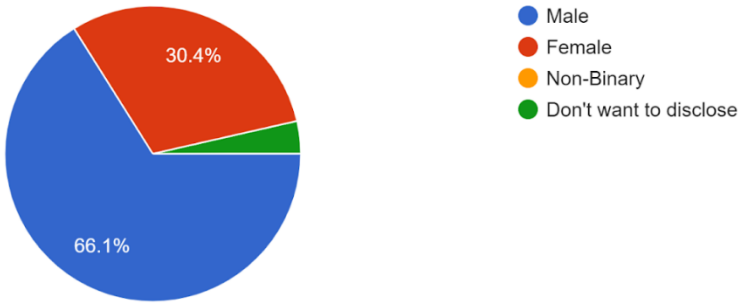
Total work experience in years (including PhD if applicable):

56 responses



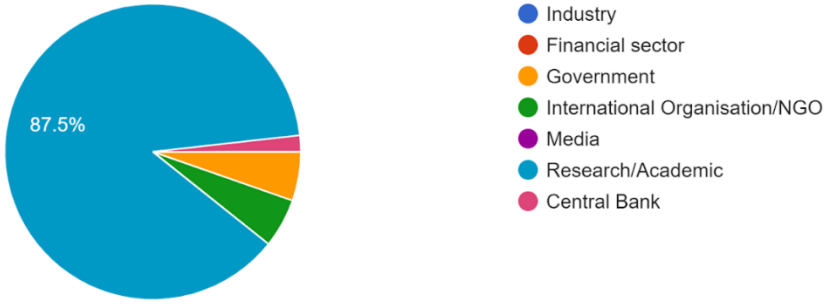
Gender:

56 responses



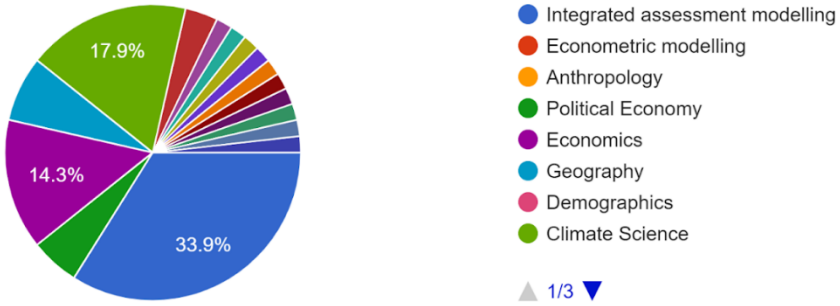
Please select which profession you identify most with

56 responses



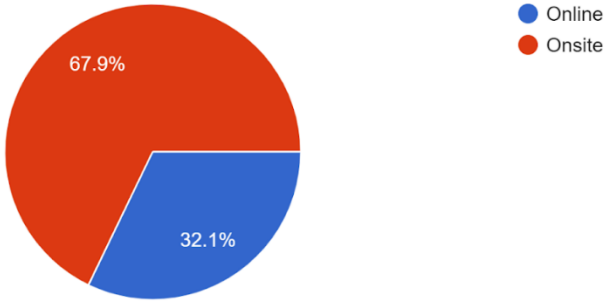
If you identify with Research/Academic profession, please select which discipline you most identify with

56 responses



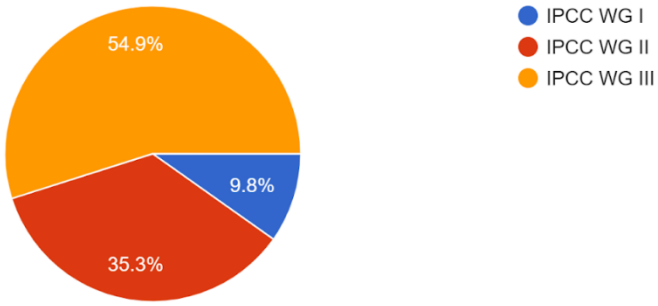
Did you participate Online or Onsite?

56 responses



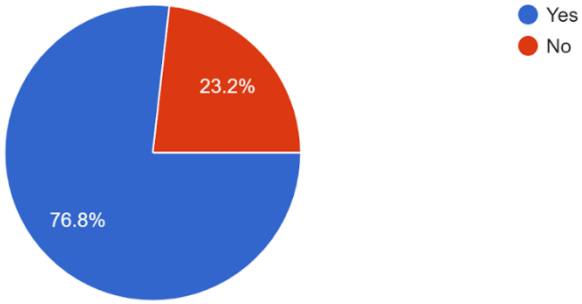
Do you identify yourself as typically in the domain of

51 responses



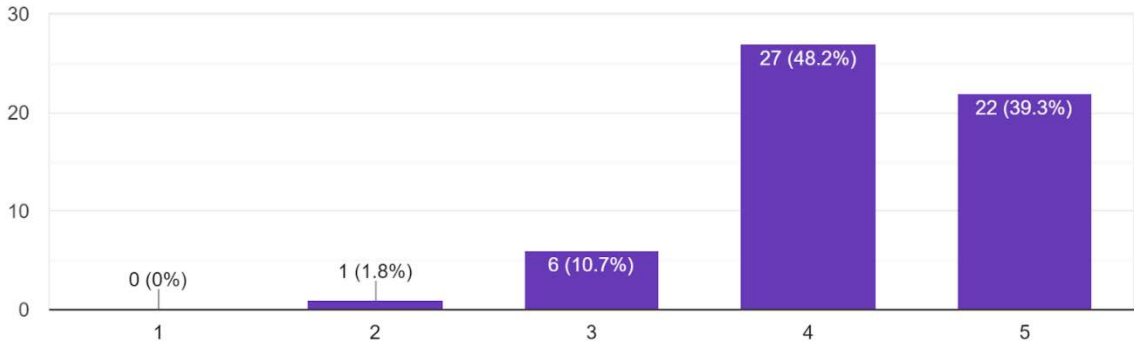
1. Is this your first Scenario Forum meeting?

56 responses



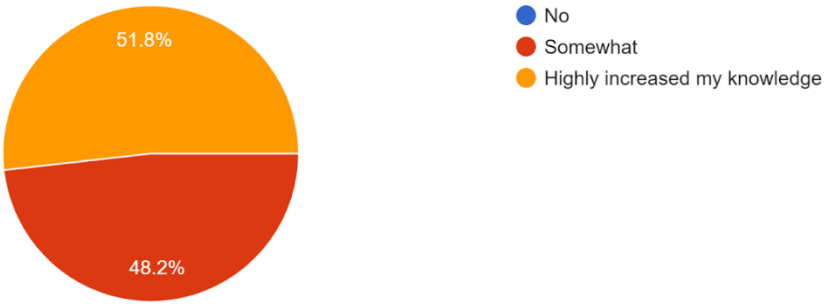
2. How would you rate this year's scenario forum meeting? 1 = Poor, 5= Excellent

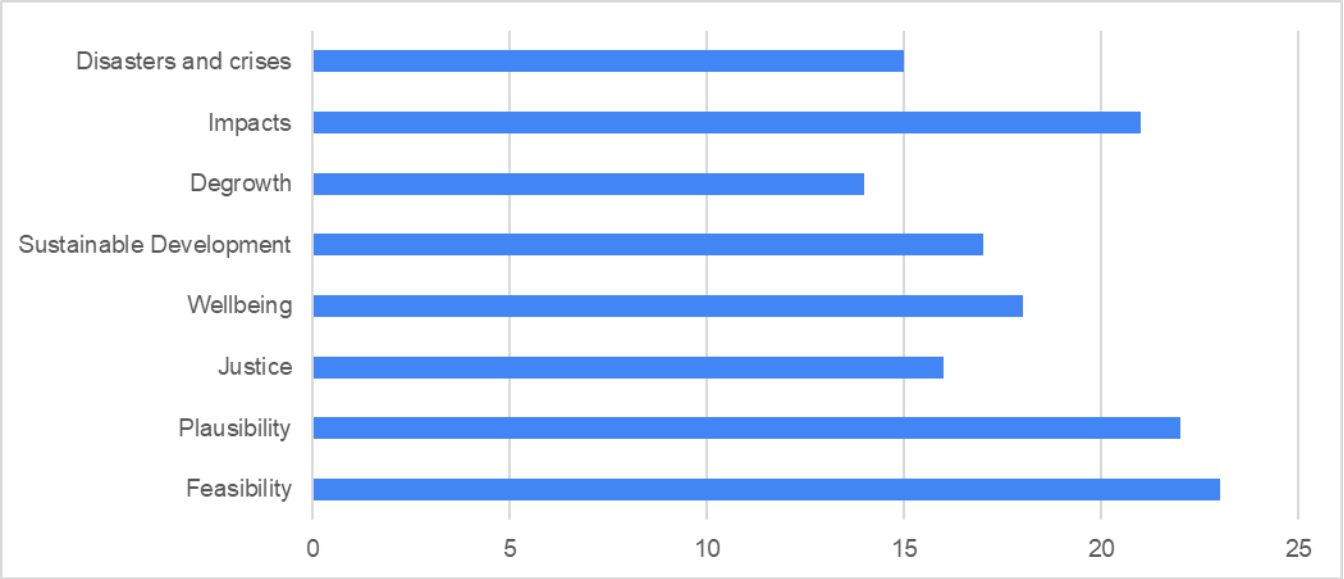
56 responses



3. Did the Scenario Forum improve your knowledge about various aspects of scenario framing and analysis?

56 responses

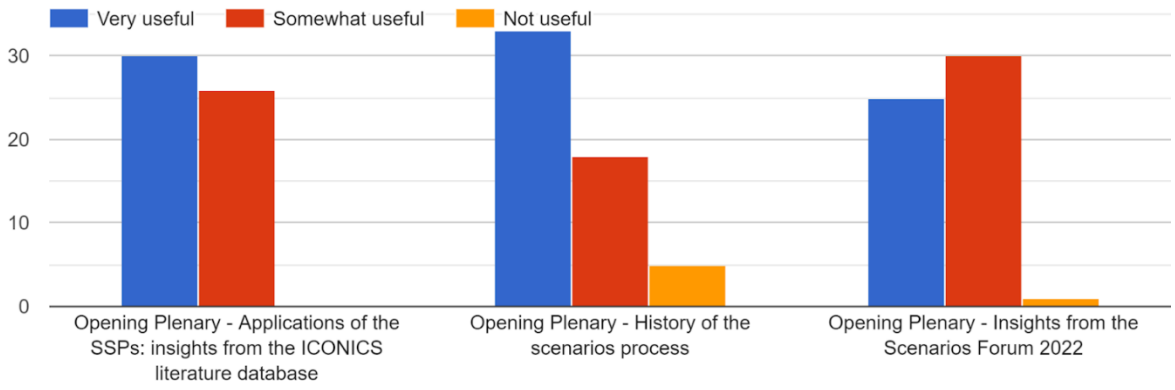




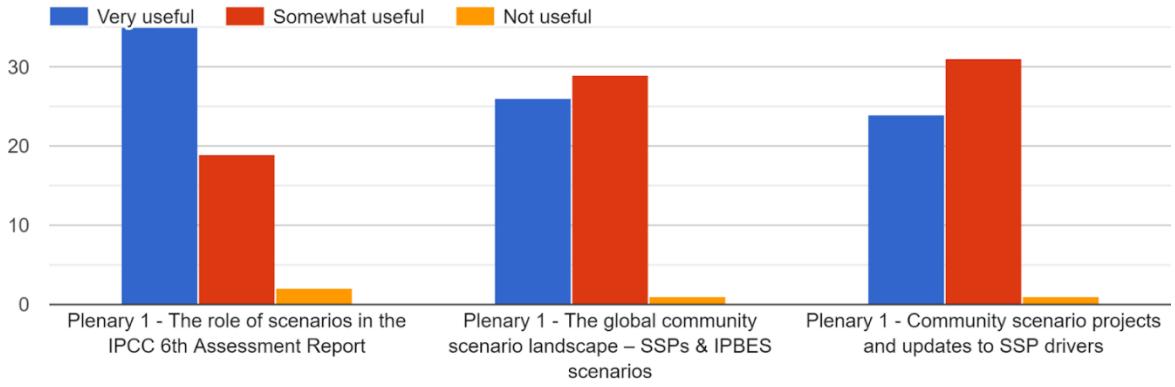
Ethical Aspects of Scenario Choice
Biodiversity
Diversity
Realism. I don't see that the internal coherence of scenarios (assumptions/developments in one area being compatible with those in other areas) and the coherence with the external world (linked to feasibility) is ensured. Some unrealistic scenarios (if clearly flagged) can be useful, but most of them just generate noise at best and confusion at worst.
Gender, Socio-political influences
Human-Earth connection and the cost-benefit aspects

Agency of actors other than national policymakers (especially corporates and the financial sector); non-linear technological change; optimistic scenarios that focus on opportunity and possibility
Overshoot, CDR, and SRM
Plausibility, Democracy/Governance
Societal-led innovation to speed up mitigation
Risk, vulnerability
Disasters and crises, Framing and local meaning
Usability among practitioners
Probability - quantify distributions of driver factor assumptions
Need to work on communication with policymakers/decisions makers?
A Moral Change. Ethics and Morality are contextual; now our context has dramatically changed and we should change our moral foundations too.
Low energy and materials
Population
Wild cards (adverse or beneficial)

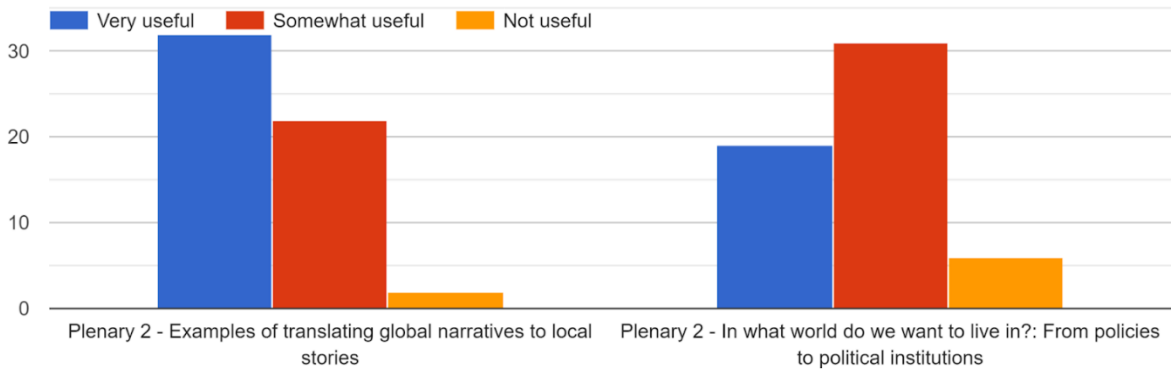
6. Opening Plenary - Status of Scenario Process - Rate the plenary sessions in order of their impact as per your assessment?[respondents can give only one rank to each session]



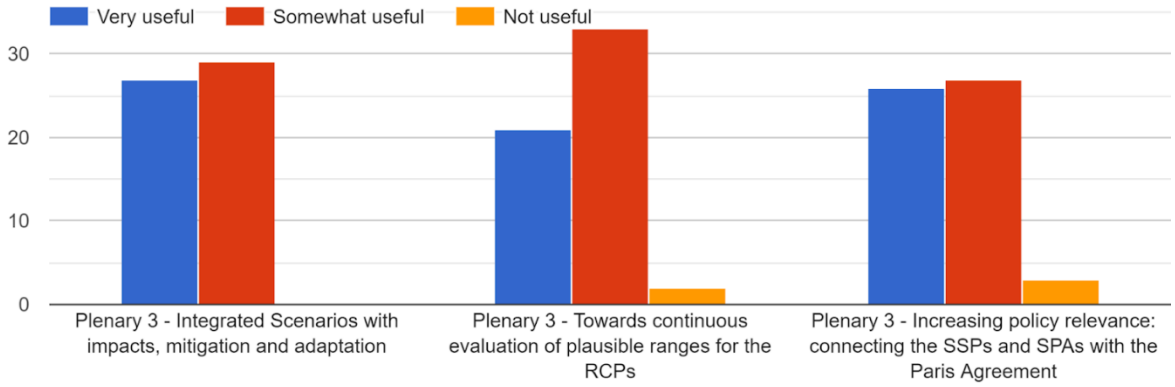
7. Plenary 1 - The role of community scenarios in IPCC and other global assessments - Rate the plenary sessions in order of their impact as per y...espondents can give only one rank to each session]



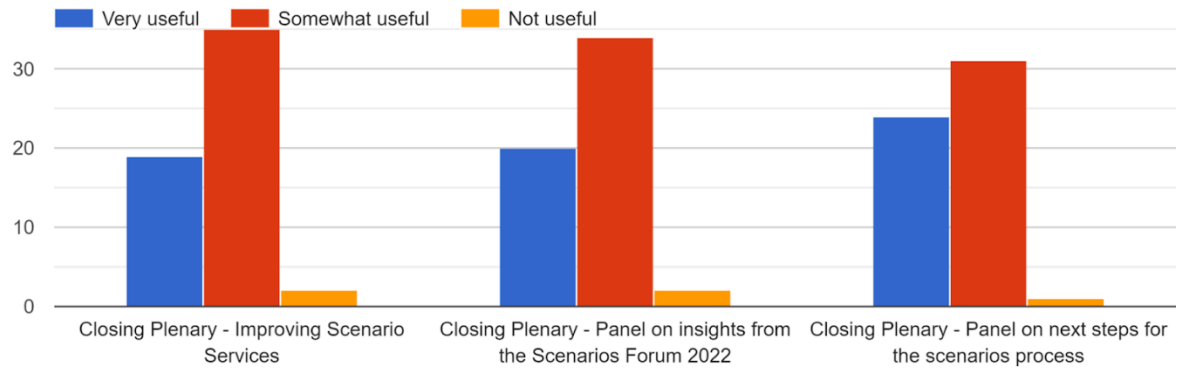
8. Plenary 2 - Frontiers in Scenarios 1 - Rate the plenary sessions in order of their impact as per your assessment?[respondents can give only one rank to each session]



9. Plenary 3 - Frontiers in Scenarios 2 - Rate the plenary sessions in order of their impact as per your assessment?[respondents can give only one rank to each session]

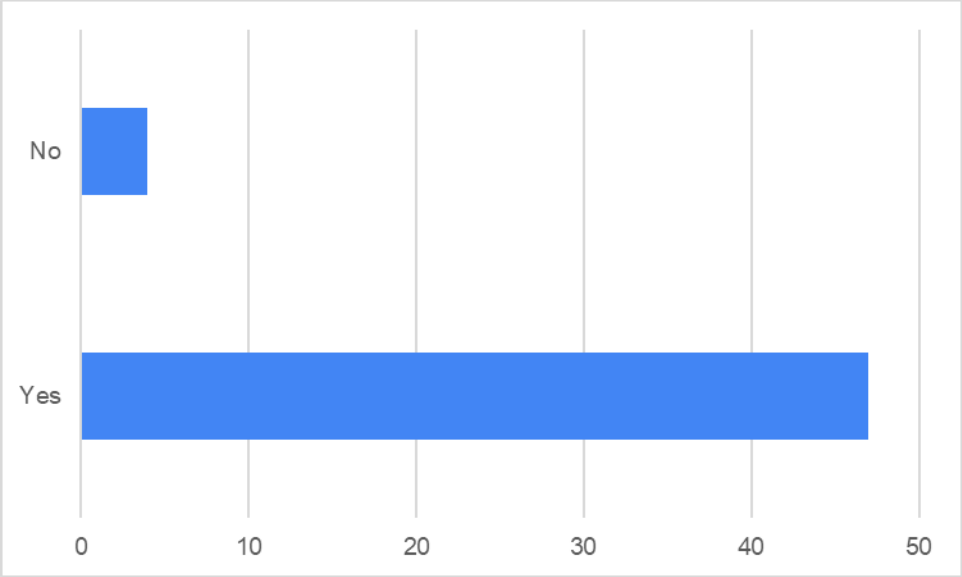


10. Closing Plenary - Status of Scenario Process - Rate the plenary sessions in order of their impact as per your assessment?[respondents can give only one rank to each session]



11. Was the content of the plenary presentations appropriate?

50 responses

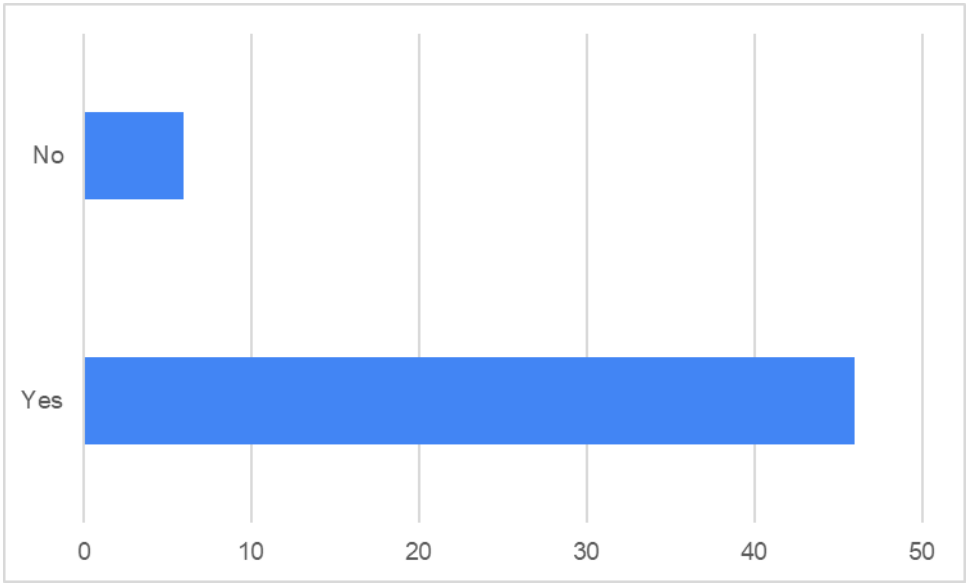


did not attend plenaries
No, some were a little off topic
Yes, I was appaled by the statements held by Julia Leiniger and colleague. Greater sensitivity to pluralist perspectives and awareness of one's own biases would be highly beneficial for future plenary speakers.
No, I think the DIE presentation can be introduced in individual sessions and spur discussion, but I don't feel comfortable having something that is not well agreed to be shown (not leaving much space for discussion) in the plenary session.
Yes; however, the plenary material was often quite detached from the substance of the parallel sessions.

No

12. Was the format of the plenary sessions appropriate?

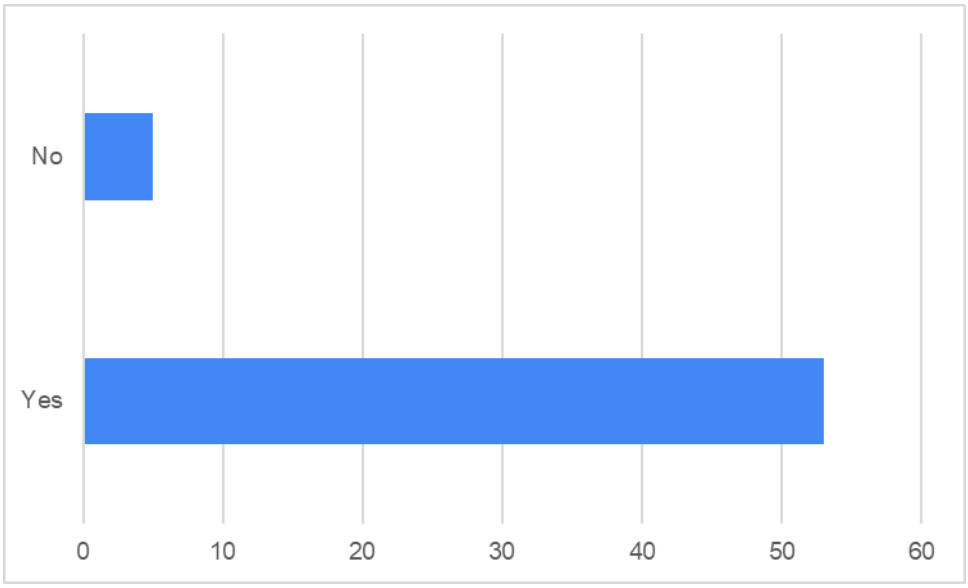
53 responses



Did not attend plenaries
There were too many, which didn't leave enough time for parallel sessions; there were several clashes
more time for questions and debate
As a virtual participant I found it difficult to hear and participate to the extent I normally would have liked to
More time for audience questions please
Plenary has too many people for most to participate - so reduce share of plenary, unless extend days of conference
Three simultaneous sessions is too much, leaves few attendants for at least one of them (even more so if one is far away)

15. As next steps from the Scenarios Forum there will be a meeting report and an ICONICS webinar to discuss the insights. The SSC is considering sev...k. Do you think these next steps are appropriate?

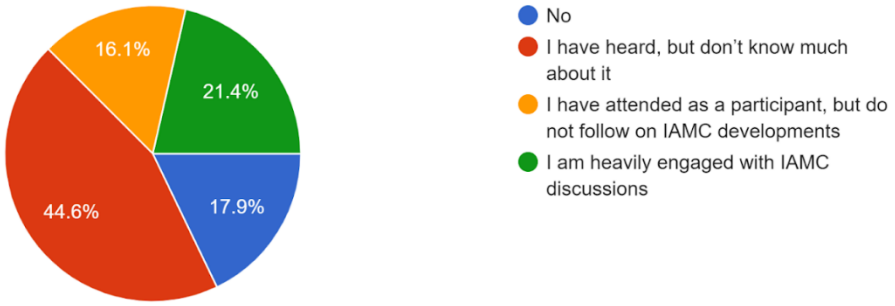
56 responses



I think there should also be documentation of this either on IIASA's website or ICONICs.
I don't know
It would be good if discussions on progress on aspects of the scenario framework are not only driven by the SCC, but that a diversity of views contributes to this.
It can be helpful to have these discussion in a more open forum. Can there be a continuous process (annual) to discuss improvement in the insgihts.More webinars for the research not part of the current set of scenario communities especially countries in the global South.
Yes, Papers should include people from outside the SCC, even potentially as leads

17.a. Are you also familiar with the Integrated Assessment Modelling Consortium (IAMC) meetings?

56 responses



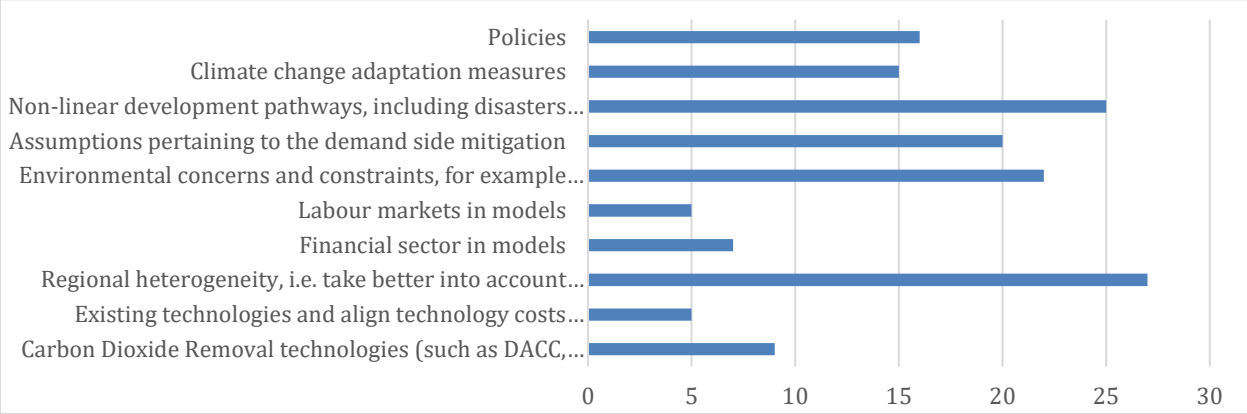
-
There are clear links, however I have the feeling that the process of scenario development is currently driven exclusively by the IAMC
Not familiar enough
Donn't know much about IAMC
Yes, very similar (Please explain how in Other), It all seems to be much the same group of people talking about much the same things
Dont know
I don't know
No, the two are very different (Please explain how in Other), Scenarios are being used and developed in IAV research which is often regional with strong support of stakeholder; these activities are not well addressed by global IAMs.
No, the two are very different (Please explain how in Other)
Yes, very similar (Please explain how in Other), Scenarios are still heavily dominated by IAMs, and IAM teams.
Not too sure
Not sufficiantly familiary with IAMC to comment
I have no opinion
Yes, very similar (Please explain how in Other)
quite similar, but the scenarios forum goes beyond intergrated assessment
No, the two are very different (Please explain how in Other), much broader audience of scenario forum is very useful
I cannot compare

No, the two are very different (Please explain how in Other), The Scenarios Forum appears more inclusive of scenarios developers of demographic and socioeconomic components (as opposed to just emissions scenarios), as well as of users of scenarios in general.
not familiar
I am not sure
I am not familiar with IAMC
n/a
n/a
No, the two are very different (Please explain how in Other), IAMC seems much more focused on energy modelling
No, the two are very different (Please explain how in Other), Scenario Forum are more insightful in discussion future potentials, while IAMC mostly focus on sharing results
Yes, very similar (Please explain how in Other)
No, the two are very different (Please explain how in Other)
No, the two are very different (Please explain how in Other)
-
Yes, very similar (Please explain how in Other)
Yes, very similar (Please explain how in Other), The ScenarioForum feels like a topic-focused little sister of the IAMC.
don't know
Yes, very similar (Please explain how in Other), Mostly similar participants and topics, slightly different focus from models to scenarios
I am not sure I know the difference but I am interested to know!
n/a
I'm not that familiar with IAMC
Somehow similar but with important differences
No, the two are very different (Please explain how in Other)
No, the two are very different (Please explain how in Other), The Scenarios Forum focused more on the scenarios themselves and the technical problems, while the IAMC offers more overall insights on the assessment (topics, knowledge, etc.).
I don't know
I see some differences in the audience and the focus on scenarios vs. modeling dynamics
Yes, very similar (Please explain how in Other)
Certainly an overlap, but different focus
Yes, very similar (Please explain how in Other), Much overlap people and tools, SF could have more specific goals
not familiar with IAMC
No, the two are very different (Please explain how in Other), I have not attended the IAMC, but understand it to be more narrow in topics and more closely related to scenario development.
No, the two are very different (Please explain how in Other), I may be wrong, however I found the IAMC focusses more on WG III and not on WGs/other community scenarios.
No idea.
Similar but different. Scenarios Forum is broader, involving WG1 and WG2 of IPCC
I am not familiar
Thier work is clearly related, but I see the IAMC as a more technical (and obviously IAM focused) sub-component of what is discussed at the scenarios forum. The SF is for a broader audience, with broader topics bieng discussed.
Yes, very similar (Please explain how in Other)
dont know
No, the two are very different (Please explain how in Other)

N/A
There is overlap but content and audiences differ
No, the two are very different (Please explain how in Other), IAMC does not directly address local IAV or climate science issues that are also strongly dependent on scenarios. Their focus tends to be on global IAMs and fairly long time horizons. Key stakeholders tend to be governments and international organisations rather than local, sectoral decision-makers.

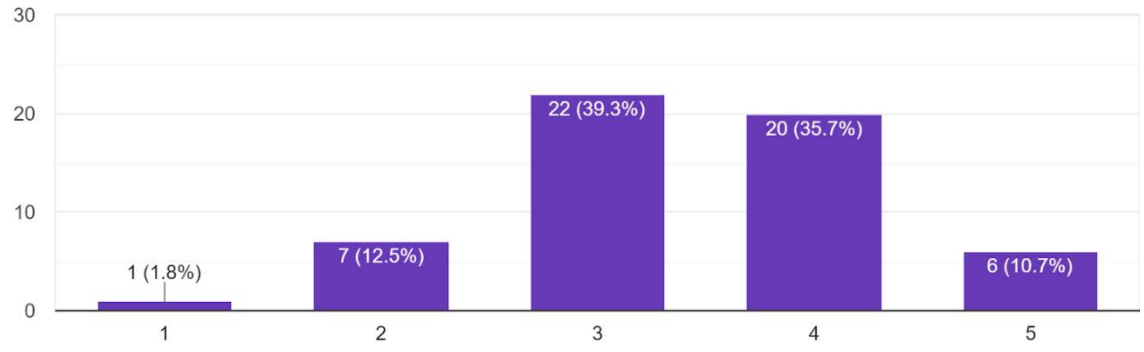
18. What do you think should be the priority for the next generation of IAMs? Improve the representation of (select at most three)

56 responses



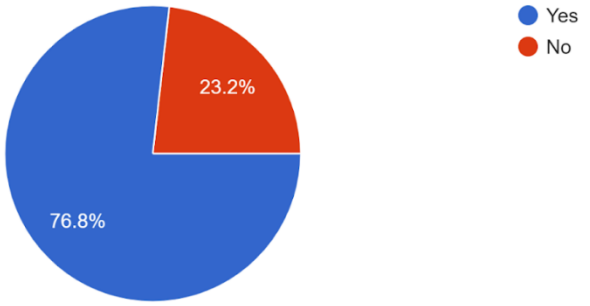
19. How would you rate your experience with the IIASA connect platform? 1 = Poor, 5= Excellent

56 responses



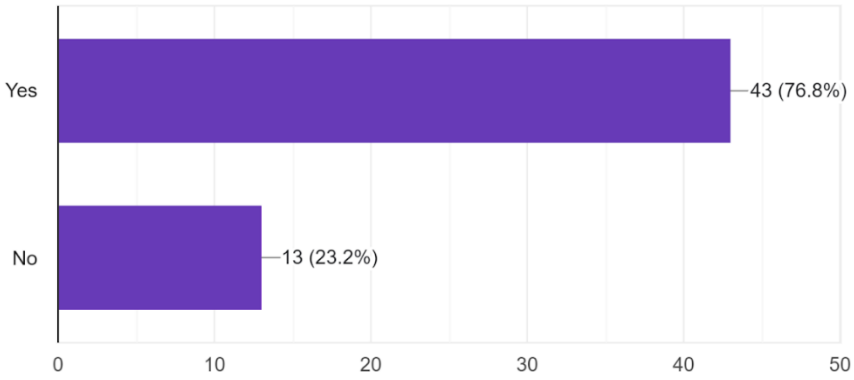
20. Do you feel the registration and logistical information were communicated clearly and in a timely manner?

56 responses



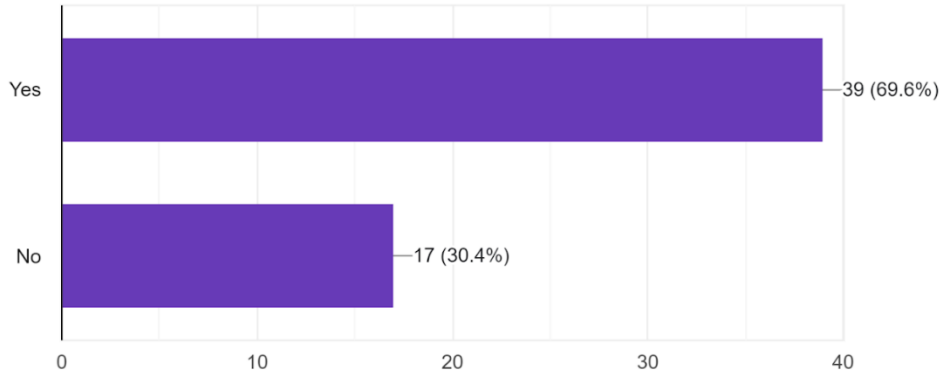
21. Was the number of parallel sessions appropriate?

56 responses



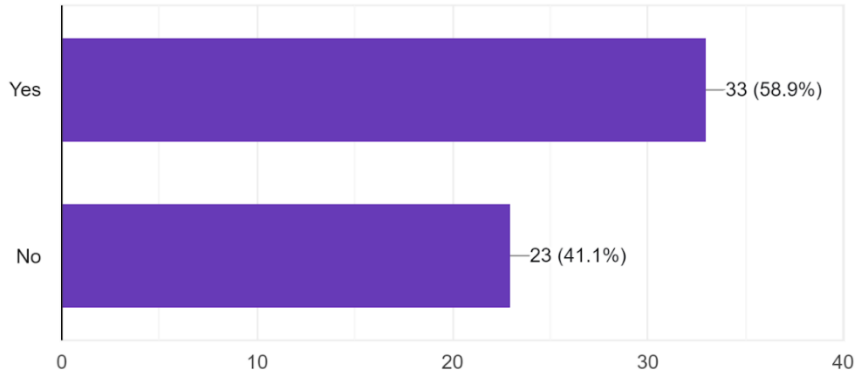
22. Fewer sessions in parallel would be needed if the Scenarios Forum were spread out over four days. Would you be interested to participate in a l...er Scenarios Forum with fewer sessions in parallel?

56 responses



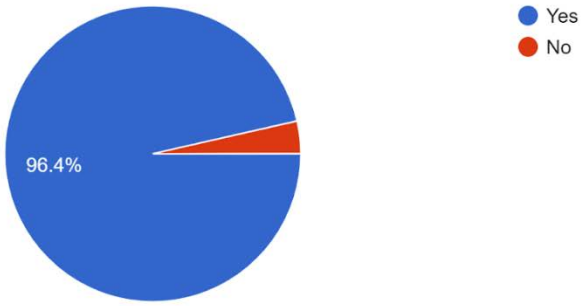
23. The Scenarios Forum 2022 experimented with a hybrid format where all speakers uploaded recordings of their presentations to the IIASA Conn...al meeting itself. Did you find this format useful?

56 responses



25. Would like to attend the next Scenarios Forum

56 responses



26. Do you have suggestions on how we can improve future Scenario Forum meetings?

-
NO
Allow more time for discussions at the end of sessions, especially ones which merit lots of discussion. Maybe even do more informal "workshops" on some subjects with some presentations to stimulate discussion but with ~1/2 the time dedicated to discussions. I'm thinking of topics like the next generation of scenarios and CMIP7 (the session on CMIP6/7 did have lots of time for discussion which was very useful; not sure if this was planned that way but other topics could benefit from this).
-
Make it hybrid.
Please work hard on making the setting of the meeting more attached to social and environmental responsibility and less elitist. Having BBQ of red meat after a session on societal dietary shift is not only morally weak but also, among other aspects, bad for the credibility of the meeting. Other aspects are the shuttle service to the airport being organised before the shuttle service to the train station and the luxury meeting venue.
There are always tradeoffs, but I know some people who couldn't make it to the meeting owing to the strict limits placed on number of sessions. In one instance, when others canceled and their session was accepted, they no longer could make it owing to the very high airfares when booking so close to the conference date. If everything is going to be available for viewing afterwards the number of competing sessions no longer is a big issue.
No
See above for technical issues. Content-wise I think not much to improve, though I attended only a fraction of sessions.
I would call for less time devoted to plenary: really I think we only need an opening and closing session, and the rest of the time should be to spread out the parallels a bit more so there is opportunity to see more sessions.
More exposure for the poster presenters. Maybe at the end of each session, highlight who has a poster and give them a 1 minute elevator pitch (or if on day 1 at the end of a plenary)
I thought you all did a great job
To receive regular emails during the Forum days informing about the sessions / panels on that particular day
engagement with users / different audiences of the SSPs would be helfpul for researchers. more time to discuss ideas. leave the posters for the full time and dont take them down after the poster session already.
See suggestion above on online participation

-
Even stronger representation/discussion of ecological issues (biodiversity, ecosystem services)
See question 24: please drop the recording requirements, just upload recordings of the in-person talks after the conference
yes, offer tutorials to shed light into the black boxes behind the IAMs
I think the number of parallel sessions was good for this one, but as the Scenario Community grows, it might be worth cutting down the number of parallel sessions. It would also be great to have the poster session given more time and in a more accessible area.
Allow more time for discussion.
no
You are doing a great job.
This is very minor but important: The Powerpoint presentations seemed to be set up to advance to the next slide automatically after x seconds. I noticed that this was very confusing for several presenters.
N/A
NA
More presentations from developing countries / Global South, both as (plenary) presenters and participants
Hold them every year perhaps. Also, it might be useful to send out a collection or repository of all the relevant published work by different participants ahead of time
No
See above
no
Overall it was a great meeting! It could be further improved by structuring the schedule of the sessions in a way that creates as little conflicts as possible (for instance avoiding showing social aspects/methods of scenario generation in parallel). Additionally, next forums could focus more on methodological aspects of scenarios as the scenarios forum can be a very influential conduit for improving the usefulness, usability and feasibility of scenarios.
Although I would attend a longer meeting because it was so interesting, perhaps with fewer parallel sessions it would be easier to attend the more tangential topics to my work, which I was also interested in. However, my brain was full by the end so I would worry that people would get conference fatigue over a longer meeting and would prefer more time to interact with each other than listening to many more talks.
More time for questions. More live discussions. Keep presentations shorter and more focused on key findings rather than background.
More time for discussions in the parallel sessions would be appreciated.
No
The content of many (or most) of the parallel sessions did not deal with SSP-RCPs. Hence, there was a bit of a disconnect between the plenary and parallel sessions.
The poster sessions could be more like what we had in the IAMC annual meeting last year.
conference dinner in different place
No, I thought it was a wonderfully run event, thank you IIASA team!
Hold in-person meetings once every two (or more) years to reduce the carbon footprint
No
Make it more a continuous process, we'll forget ideas for feedback by 2 years. Scenario development should also be faster, more continuous. ICONICS helps but is too much one-way communication from presenters. Engage more people from outside Europe and north America!
More time per presentation. Presentations often did not touch details on modelling and assumptions so that there were no discussions on these (most interesting) parts. When only results are presented sessions felt like an advertisement outlay. There were noticeable exemptions that were really interesting with large takeaways.

Workshop and research sessions were more or less structured the same way. I think the event would be more useful with a larger number of workshop sessions that are actually structured in a way to promote dialogue. This could be done with a very brief introduction and in-session activities that promote discussion among all attending participants, such as group discussions and digital polls.
Physical interaction provides space for collaboration, however this is lacking when one participates virtually. One of the sessions, we had certain technical issues with viewing of slides via livestream as we just observed the presenter. Back up of slides did help, however not everyone may have gone to back-up slides.
To ponder how to impact on public opinion tipping points.
More participation from Global South
fewer parallel sessions
Allow online participats to attent the workshops, even if only as "listeners"
easier access to playbacks
I found the submission process rather excluding with several predecided presentations and few open for people not involved/connected with organisers. It was difficult to find predefined sessions that suited my scenario-related research, and it appeared more uncertain to submit to open sessions, as the capacity was unclear.
Less parallel sessions.
N/A
Continue to make strong efforts to widen participation and topics. The more like IAMC the less valuable it is. Try to increase diversity of plenary speakers in all dimensions, including fields as well as gender/region.
Expand abstracts for pre-meeting discussion and only require single full presentations in each theme at the meeting itself. Use a stand-alone wensite to organise the Forum. IIASA Connect was a novel mechanism, but it contains other materials, communications and personal profiles around IIASA staff and visitors that really should be kept separate from those relevant to a specific meeting. I realise that there can be overlaps in interest at an institution like IIASA, but I still think the Forum should have a dedicated site of its own in operation, though with all technical options available (e.g. ability for online meetings of organisers, session leaders, sessions themselves, as well as guidance for participants using a range of devices)

27. Any additional comments

-
NO
No - thanks!
-
This questionnaire is very badly designed for capturing accurate feedback. It is not anonymised and requires me to comment on everything, including sessions I didn't go to, things I have no opinion on etc.
The projectors in some rooms were old and the colors were washed out.
Thanks a lot to the organizing committee, it was a great conference!
no
Actually the most useful three-day conference I've ever been to: there wasn't a dull moment and I wished I was able to see so much more but clashes made it impossible. Really very well organised.
A really brilliant meeting! Thank you
None
Congratulations fo the organization and the reach outt
great team effort! thanks for hosting it!
-
-

-
Thank you to the whole IIASA team! Always wonderful to be back
the logistics could have been less complicated, to many modellers involved:)?
This was a great meeting and lovely that IIASA hosted it, thank you to all the organizers!
Not enough consideration for resources (natural resources, raw materials). Neither in the scenarios themselves, nor in the meeting.
thanks for all your hard work organizing a large conference during a difficult time!
Well done to the organisers and to Faa and her team.
-
N/A
NA
None
All said, this was a fabulous event and I thank the organisers for all their efforts over the last few months. Looking forward to the best one very much!
No
I thoroughly enjoyed the conference
no
Nothing else, thank you :)!
I think it would be easier the format was kept similar but the meeting start on a Tuesday so that people could do all their travel in the working week. I could then have reduced my carbon footprint by doing both ways by train!
This is interesting and important work.
No
No
No
Thank you all every much for your support and your great works.
Thank you for excellent organisation.
None
Thanks to the organizers. Great venue and forum
-
Thankyou for organising inspiring event!
The admin Emails before the meeting were quite numerous, it would be good if these could be limited to a reasonable number.
The event would benefit from being extended to four days with fewer sessions in parallel and more "air" between sessions / shorter days. A lot of the interaction happen in the corridors or after the scheduled activities. The poster session was very good and gave rise to many interesting discussions. It could be extended and if the whole event is extended, it could be divided into two poster sessions.
At a given time, there was livestream of four sessions only. Can this be imprved and increased? During the power outage, is there a way to send an email in addition to comment on IIASA connect? I did try to pacify a couple of participants while using comment chat box in pleanary session agenda.
Thank you.
none
thank you so much for the opportunity to share and learn
As an online participant, I want to stress (and thank you) how useful and nice it was that during the Q&A sessions, there were multiple cameras, and online participants could see the audience. This may sound like a minor thing, but it vastly improved the online experience and made the forum much more engaging. Bravo - and I hope to see this becoming the standard.
access to papers which were presented should be easier

Good spirit, many useful discussions and nice people. The preparations could be smoother (unclear info, experimenting with hybrid, submissions premises....)
Thanks so much
No
Overall excellent meeting, very well organized and really important for the field. That said it is worth considering holding it every three years rather than two. Two years feels a little early.
The 2022 Forum was very well run and enjoyed a lot by all I have spoken to. I commend the organisers and all the assistants for their excellent work in making the meeting possible, especially given the challenges encountered during Day 2! Many thanks to all of you for making this possible.