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Perspective

Climate change scenario services: From science to facilitating action

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SUMMARY

The goal of limiting global warming to well below 2°C as set out in the Paris Agreement calls for a strategic assessment of societal pathways and policy strategies. Besides policy makers, new powerful actors from the private sector, including finance, have stepped up to engage in forward-looking assessments of a Paris-compliant and climate-resilient future. Climate change scenarios have addressed this demand by providing scientific insights on the possible pathways ahead to limit warming in line with the Paris climate goal. Despite the increased interest, the potential of climate change scenarios has not been fully unleashed, mostly due to a lack of an intermediary service that provides guidance and access to climate change scenarios. This perspective presents the concept of a climate change scenario service, its components, and a prototypical implementation to overcome this shortcoming aiming to make scenarios accessible to a broader audience of societal actors and decision makers.

INTRODUCTION

Tackling climate change and its impacts needs well-informed and concerted action between a variety of actors from different sectors of society. Furthermore, response strategies to climate change need to be embedded in the multi-objective context of environmental, societal, technical, and economic developments, the future of which is inherently uncertain. This is reinforced by the fact that the choice of specific pathways comes with trade-offs and depends on the preferences of a variety of societal actors. Climate change scenarios have been a central tool for climate change research for decades. They describe plausible, coherent, and internally consistent paths of climate change futures. Because we cannot know the future with certainty, climate change scenarios structure the uncertainty with scientific rigor to explore "What could happen?" and to support planning of "What should happen?" Thus, scenarios serve in two ways: first, diverse actor groups (politics, business, science, society) can coordinate their thinking from different perspectives, develop a common understanding of the situation and co-produce new knowledge. Second, climate change scenarios can support strategic planning from a multi-objective perspective and under uncertainty, in laying out different pathways and implied trade-offs.

In this perspective we conceptualize a climate change scenario service (Figure 1) that aims to make scenarios more accessible and to serve as a tool of discourse and strategic planning to a broad user community. We further present a prototypical implementation, the SENSES toolkit (Figure S1). The SENSES toolkit implements central components of the wide-ranging service concept. It comes with a focus on mitigation scenarios, as these are strongly underrepresented in the arena of climate services, but also contains material for impact projections and adaptation scenarios.

Several scenario types are emerging in coordinated efforts to consistently address different aspects of climate change. Climate change projections (see CMIP [coupled model intercomparison project] family[1,2]) help to understand past, present, and future climate changes. Impact projections, e.g., from the ISIMIP project,[3–5] serve as basis for understanding potential biophysical and socio-economic impacts of climate change. The shared socioeconomic pathways[6–9] (SSPs) facilitate the assessment of different socio-economic futures, i.e., the development of key societal drivers of human interference with the climate system. Mitigation scenarios strategically assess responses and their implications toward limiting human-made climate change, mostly from a global perspective,[10–12] but increasingly also from a national view.[13,14] Adaptation scenarios describe actions for adjustment to impacts of climate change.[15–17] Comprehensive assessment by these scenarios is supported by the increased interconnectedness—e.g., the recent ScenarioMIP[18] project and the work of Gidden et al.[19] provide a link from the SSPs to climate change and impact projections. For adaptation scenarios, which are mostly used sub-globally to locally, efforts to link them to across scales[20] and to mitigation scenarios[21,22]

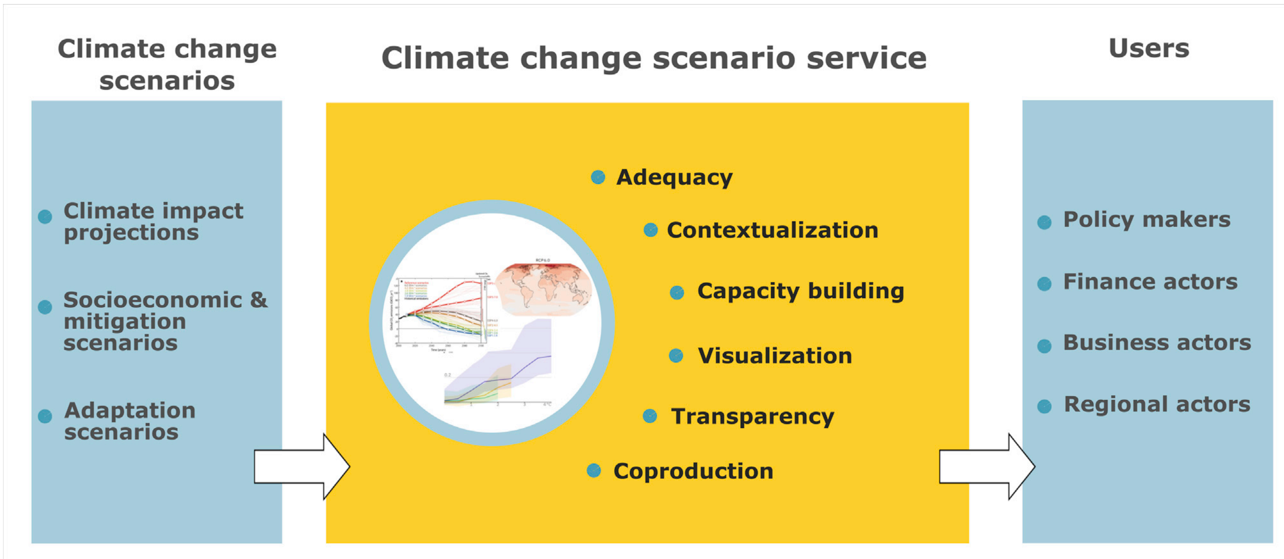

Figure 1. Vision and concept of a climate change scenario service with its essential components
As an intermediary service structure, it allows a broader user community of policy makers, business, finance, and regional actors to access and use state-of-the-art climate change scenario information meaningfully.

are also advancing. These developments have made scenarios increasingly attractive to be used also on more granular scales.

For policy makers, climate change scenarios have a successful history, as exemplified by their use in assessments of the Intergovernmental Panel of Climate Change,[23,24] international climate negotiations, recent formulation of national mid-century strategies, and adaptation planning. Demand for climate change scenarios by policy makers and other civil society actors to address questions about policy entry points to deep decarbonization pathways,[25] the impact of delayed action,[26–28] extent of technology transformations, the necessity, availability, and side effects of carbon dioxide removal techniques,[29–31] demand side versus supply side options for mitigation,[32,33] and implications for sustainable development,[34,35] and inequality is growing.[36,37] Up to now policy makers have mostly received support from this area via assessment reports, policy briefs, or direct ad hoc advice. A foundation for systematized scenario-based advice has been lacking so far.

A growing and influential user group comes from the business and finance sectors. These groups demand climate change scenarios to inform alignment and risk assessment.[38–40] For assessing the alignment of investment plans with climate goals, corporate strategies are evaluated against pathways limiting global surface warming to well below 2°C[41] (e.g., by the Science-Based Targets Initiative and the Carbon Disclosure Project). The assessment of climate-related risks includes the exposure of people and assets to a changing climate frequently named "physical risk assessment" as well as the risk from evolving climate policy regimes also called "transition risk assessment." In particular, central banks and regulators, but also private consulting companies, are pushing the use of scenarios for climate-related financial risk assessment (e.g., the Task-Force on Climate-Related Financial Disclosures and the Network for Greening the Financial System [NGFS]). Financial markets influence substantial amounts of CO_2 emissions and are considered as "very rapid" social tipping element for stabilizing Earth's climate.[42] They should receive support from the best science available.

Climate change scenarios are not always directly usable and useful[43] because they need appropriate translation and communication[44] to the particular context they are used for, particularly policy scenarios, such as mitigation and adaptation scenarios. "Climate services" have seen substantial development in the past decade to bridge the usability gap[43] of climate science by providing "customised information services […] to end-users in the business domain, the public decision-making domain and to individuals."[45] Among others, important initiatives are the international Climate Services Partnership https://climate-services.org), the Global Framework for Climate Services (https://gfcs.wmo.int), and the Joint Programming Initiative (JPI) (http://www.jpi-climate.eu/home).[46] However, up to now climate services have focused on providing primary climate change information (e.g., from climate change projections about increased temperature, extreme precipitation) or impact projections of climate change (e.g., flooding, droughts) to inform protection and adaptation measures in specific sectors, such as agriculture and forestry, water, energy, and urban planning.[47–49] An analogous climate change scenario service for user-oriented provision of scenario information has not been available so far.

A NEW VISION AND CONCEPT OF CLIMATE CHANGE SCENARIO SERVICES

A climate change scenario service is conceptualized as a tool for strategic planning, but also as a tool of discourse to develop a common understanding among diverse actors. The service concept per se does not focus on specialized, individual user needs but rather opens up climate change scenarios for a broad range of societal actors and policy makers. Hereby, the audience groups can have a global but also regional perspective. In general, the available types of climate scenarios are "differently" suited for the individual users, e.g., mitigation scenarios tend to have more of a global focus, whereas adaptation scenarios have a granularity of being sub-national. Still, as mentioned above, mitigation scenarios increasingly serve on the national level[13,14] and adaptation scenarios link to the global information level. Even users at, e.g., a city level, can profit from having access to climate scenarios as these can serve as an overarching framework for co-production of scenario knowledge[50] and to coordinate thinking and discourse. For the development of the service concept, the well-known claim for salience, credibility, and legitimacy[43,44,51] of information in scientific knowledge services is central. There is a foundation for credibility and legitimacy of climate change scenarios with the longstanding use of climate scenarios in commonly accepted outlets, such as the IPCC reports. However, the aspect of salience, i.e., making climate change scenario content tangible and relevant to a broader audience, is very underdeveloped. The service aims to make scenarios more digestible and relevant, by disentangling the built-in complexity of scenarios and providing the content consequently linked to the user perspective. The service is conceptualized as a flexible living information system, where general concepts can be learned but are always linked with up-to-date scientific results. It employs effective means to communicate key insights to users of different backgrounds and with prior knowledge and gradually empowers users to contextualize and to use climate change scenarios. Strong attention is on the aspect that the information is correctly used and misconceptions are avoided. The concept presented here draws on results from a 3 year long co-creation process, where scientists and stakeholders from policy, business, and finance worked together to develop the requirements and properties of such a service. The results of this process flow into six essential components of a climate change scenario service that are described below (see also Figure 1).

Adequacy: the context of the scenarios has to be related to the reality of the users. Ideally, the information provided by the service directly starts from the perspective of typical user questions, and avoiding domain-specific jargon and assumptions. Question and answer need to be directly connected. In many cases, scientific information is presented unfiltered; without reinsuring it comprehensibly addresses the user questions. This bears the risk of making the information useless, leading to misconceptions or even misuse. In the best case, however, taking the effort to elicit the relevant user questions and compiling targeted information/data supports the convergence process between scientific output and user needs. The service has to provide adequate and actionable data that reflects the user's decision-making needs. A fully fledged service needs to cover information with realistic near-term trends, higher granularity, and precision for the individual sectors and regions.[38] Linking the scenario outcomes to commonly accepted benchmark scenarios will undermine their usability and establish trust. Matching these user needs will ultimately decide on the relevance of such a service, especially for the private sector.[51,52]

Contextualization: to ensure adequate and correct use of scenario information users must have the capacity to contextualize available scenario information properly, i.e., being able to answer questions, such as "Which information do they cover, and which not?" and "In which context are they defined?" In particular, scenarios should always be presented as sets; a single scenario will not provide a solid basis for decision-making and strategic planning. Key information is often conveyed by comparing different scenarios. Alternative pathways for different courses of action should be linked to underlying scenario and policy assumptions. Hence, scenarios have to be contextualized as outcomes of a set of assumptions to avoid misunderstanding or cherry-picking of information. Furthermore, pathways should be connected to an assessment of consequences to allow exploring trade-offs and synergies. This requires a basic scenario literacy of the user that the service must support. Hereby, a common challenge for scientists is to make the implicit explicit and not to leave out domain-specific self-evident facts that often turn out to be the central entry points.[51]

Capacity building and staged access: learning and capacity building tools thus have to be an essential part of effective climate change scenario services. Communicating climate change scenarios is challenging,[53–55] especially if a broad user group with different degrees of pre-knowledge ought to be received. We suggest a modular approach that provides staged access, i.e., with different levels of complexity: a first level of the staged access would serve novices or executive staff to build capacity on central concepts and insights. In an illustrative, tangible manner, general concepts (with longer scientific shelf life), relevant dimensions, and potential key levers can be understood. Focus should be on supporting the understanding of climate change scenarios rather than the pure communication of facts,[56] which can differ strongly across individual scenario outcomes. A second level would cater to advanced users: here, up-to-date scientific results can be explored. It can still provide guided learning by deeper insights and the contextualization of the multi-variate scenario content. But the focus is to provide a permanently relevant resource for users with recent state-of-the-art research. To help advanced users to independently navigate the multitude of scenario information, some tools for guidance and orientation should be provided. This can be finders based on or a careful choice of indicators or a typology[57,58] that reflect key characteristics of the scenarios. Ultimately, to make the offered data actionable, the second-level elements should provide download options, where the users have full access to the data just explored, i.e., download it and employ the information in their working environment.

Visualization: the extensive use of visualizations tailored to the requirements of scenario communication is essential. Visualization enhances the salience of features and characteristics, such as magnitudes, correlations, and trend breaks, and fosters actionable insights. The design guidelines of the service concept are strongly influenced by the visualization mantra of Ben Shneiderman[59] that overview ought to come first, and details shall follow on demand. This also supports the concept of staged access. Introductory concepts are given with intuitive visualizations, which provide overview, reduce complexity, and are compelling to foster uptake,[55] such as illustrations, animated visualizations, or interactive storytelling[60] (scrollytelling[61]). For the advanced exploration of scenario data and indicators, we follow the idea to avoid perceptual stress[62,63] by complex visualization techniques, such as dimension reduction, spider diagrams, or parallel coordinates. Instead, we promote comprehensive, but flexible, low-tech visualization techniques, such as dashboards or small multiples.[62] These techniques show data at high granularity and without loss of information, which is essential for the correct contextualization of scenarios.

Transparency: climate decision makers potentially deal with high-impact consequences. For actual strategic planning, transparency and trust building are central, supporting credibility and legitimacy for the uptake of information in their work. Transparency on the scenario generation process is important, from digestible documentation about the model setup with assumptions, the inner logic of scenario generation, to the implications of individual scenario pathways. This information constitutes significant meta-information for scenario use and should be made available together with actual scenario data, e.g., with additional resources and background material. Furthermore, it is important that users can increase their understanding of the differences between the models to establish trust in the scenarios. The provenance of any provided information and references to the respective academic literature should always be available to enhance the reproducibility from the source material.[64]

Co-production: co-production will remain central for climate change scenario uptake[65,66]: much of the scenario information is not yet adequate for users and co-production can serve as intermediary to bridge gaps of missing information, resolution, or even realism. In the discourse between practitioners and scientists the consistent, adequate narratives can be developed. We distinguish between two types of co-production: the first is co-producing new scenarios together with stakeholders, the second is co-producing knowledge from existing scenarios. To foster the co-production of climate knowledge, the elements of the platform should be flexibly tailored so that they can be employed in co-production processes. The use of the existing information in co-production processes can then feedback to science for the further development of relevant, but also credible and legitimate scenarios.

Still, the question remains of where and how this service would be set up. Concretely, three options arise to enable a system-wide approach. The first could be a central knowledge hub that collects, processes, and maintains the information and interfaces. The second could be a fully distributed approach, where applications, such as the SENSES toolkit, can serve as an example and provide open source software for other participants to also develop comparable service elements. This would speak to the large amount of scenarios that exist and the diverse user needs. A third option is a hybrid approach: taking a distributed service landscape but having it fulfill community-wide accepted quality standards. This would require a minimum of institutional setup curating the elements taken up, to ensure quality, credibility, and legitimacy. Furthermore, basic guidance and orientation to the individual services should be given, e.g., a learn portal providing an overview and keyword search for topics, stakeholder groups, data, and statistics (last update, number of users, and similar).

A PROTOTYPICAL IMPLEMENTATION OF A NOVEL CLIMATE CHANGE SCENARIO SERVICE: THE SENSES TOOLKIT

The SENSES toolkit is a prototypical implementation of a climate change scenario service as conceptualized above. It is an open, available-online platform that includes user-centered scenario communication tools and practical support for co-production. It aims at three key user groups: national and international climate policy makers, regional climate scenario users, and businesses and financial actors. In its first realization, it comes with a focus on global mitigation scenarios, but connects to climate impact and adaptation information. User needs for communication concepts and user questions about relevant topics were co-produced in close cooperation with representative stakeholders from all actor groups to ensure that the toolkit supports the uptake by a broader community.

The toolkit concept incorporates flexible, staged access for varying levels of user knowledge with modules at different stages of complexity[67] (Figure 2). The user is increasingly empowered to contextualize the scenario information—from understanding central topics ("LEARN") to getting a hold on increasingly complex information, landing down at expert knowledge with a focus on granularity and topicality of the data ("EXPLORE"). In the following, we detail how the properties of a climate change scenario service come to life in the individual modules of the toolkit. These modules are all referenced in the supplemental information given in the text and the reader is encouraged to go through those modules on the web as supplementary information for the discussion here.

Learn modules address the capacity building and contextualization aspects in the toolkit at the first complexity level. The information is provided by user-friendly, digestible modules, which contain highly processed visualizations and capacity-building material. Users get a general overview on scenario approaches, the spectrum of climate change scenarios, and how they are addressing selected user questions (for details please see Note S1). The content is given in a linear, illustrative format. Well-dosed interactivity supports the correct understanding of the nature of the scenario information and how it informs strategic planning. The time spent with a learn module is approximately 20 min. The modules are complemented by a link for further exploration, download material, and references.

Explore modules cater to the level of advanced users and cover multiple properties of an effective climate change scenario service. Most explore modules are linked to learn modules supporting capacity building with deeper insights. They also contribute to the adequacy aspect in providing up-to-date, more data-centric, climate change scenario information. The explore modules are designed in a self-contained manner, allowing advanced users to directly start at the exploration level, to access scientific information, and download and employ it in their user environment. We distinguish two types of explore modules: guided and open explore modules.

Guided explore modules (GEMs): GEMs directly link a compilation of selected sets of scenarios and variables to specific user questions. This supports capacity building—besides being presented relevant data, the user implicitly learns which scenarios and variables answer which question. This helps to overcome the issue of implicit knowledge and scientific jargon. Contextualization of scenarios is supported by displaying the corresponding assumptions, alternative courses of action, and associated consequences. These data are connected in the flexible low-tech format of small multiples,[62] which helps to compare multiple contextual aspects. Most GEMs are connected to learn modules and allow a deep dive into actionable data. For a concrete, detailed example please refer to Figure S2 and Note S2. All GEMs provide data download functionality and the link to the original dataset for full exploration, e.g., in the IAMC 1.5°C scenario explorer[68] database (see Figure S2 second from right). The data in GEMs are permanently updated, which in turn enhances the sustainability of the toolkit in being driven by active research[69] and remaining a relevant source.

Open explore modules—the scenario finder: to enhance flexible access to the large space of available scenarios, a scenario finder (see Figure S3) provides guidance and orientation. Users can identify relevant mitigation scenarios along a set of (meta-) indicators. These indicators follow either a typology with discrete choices (e.g., ''below 2°C warming'') or they are quantitative indicators based on scenario variables. Users can browse through a large set of scenarios and filter according to their interest and assumptions. For instance, those who think that removing large amounts of carbon from the atmosphere in the future is unlikely can filter scenarios with a lower amount of bioenergy with carbon capture and storage. For the filtered scenarios a link to the IAMC 1.5°C scenario explorer[68] is provided for full datum access. A special advantage of the scenario finder for non-experts is that indicators also can be employed, which reflects scientifically accepted quantities for the feasibility of mitigation pathways.[70–72]

Open explore module (SENSES Earth): for the exploration of climate impact projections and consequences of different levels of warming on a national level, the SENSES toolkit provides the module SENSES Earth (Figure S4). This provides tangible information for alternative projections of different warming levels that affect land areas exposed to extreme events. The results can be transparently compared across different Earth system and impact models. The chosen mapping on a globe visualization is highly engaging[55] and allows to display a substantial amount of scalar information at the same time. It facilitates comparison across models and enhances transparency by giving users an intuitive insight to the given model spread and related uncertainty.

Transparency supporting elements: all modules provide references to the source data or links to download areas such that the presented information can be verified.[73] Scenario and model documentation are extensively given for users to quickly access the background information. Another important aspect for users is to get more transparency about the different model characteristics. Explore modules, such as the GEMs and SENSES Earth, support the understanding of differences and similarities for the different models.

Co-production: the interactive SENSES toolkit is designed to be used in a co-production environment, e.g., in a tutorial or workshop settings, where stakeholders meet scientists and together create new knowledge based on either existing scenarios or newly built scenarios. Its tools are used to facilitate the exchange and its modular structure allows to map the toolkit elements to specific interests of specific user groups. Hereby, the learn and explore modules play distinct and complementary roles. The learn modules provide overview and context, whereas the explore modules enhance hands-on access to the data and to compare scenarios. To support scientists, the toolkit also provides co-production manuals (see Note S3): one for the co-production of knowledge with decision makers with demand for global scale scenario information, e.g., international climate negotiators, and one manual for co-production with decision makers operating on a national or regional level aiming to coherently link local scenario processes with global scenarios.[74] The latter provides a contribution to bridge the gap between global information and regional and national needs. It distinguishes between information-scarce and information-rich contexts and provides respective alternatives to conduct scenario planning processes, mainly for impacts and adaptation studies. This is also detailed in two dedicated learn modules (please also see Note S3). In addition, a co-production finder allows to browse for co-production techniques and respective literature references according to characteristics, such as the project goal or the type of scenario knowledge generation.

In the SENSES context we focused on the co-production of knowledge and employed the following workshop structure with stakeholders with no or medium pre-knowledge: participants read the introductory learn module ''climate change scenario primer'' (see Note S1) before the workshop for basic knowledge about scenarios and to trigger first questions. During the workshop, the facilitators pick relevant topics of the learn modules and work through them with the participants. For example, the ''emissions gap module'' conveys the central challenge of becoming net zero, where a module, such as the ''electric future'' learn module (both see Note S1) is already targeted at sectoral and regional detail. The exploration modules then serve as structured basis for focused discussions that dive into scenario data. The GEMs, for example, provide a guided setting of decisive variables: after the emissions gap learn module the users have an understanding of the emissions development on global scale; in a guided exploration module they can then explore how this can look like in detail (for all GEMs, see Note S2) for the individual world regions; on a sector detail, they see, e.g., that that electricity needs to be decarbonized first, and industry, transport, and buildings electrified after—important for a global decision-making as well as for, e.g., a city planner. They can learn about interdependencies in scenarios, e.g., high fossil use requires a counter elements, such as carbon dioxide removal. Information like the sectoral pathways are as relevant on a global as on a national level. Seeing the data so concretely has sparked engaged and detailed discussions. Results from such co-production processes can and should feedback into science. Scientists not only gather what is needed by the users, but also insider knowledge, e.g., in mitigation scenarios a preference of the users for flows over stocks, or realistic price dynamics for the phase out of fossil fuels. Such feedback helps scientists to adapt research priorities to provide relevant and useful information.

CONCLUSION AND OUTLOOK

The wide-ranging concept of climate change scenario service presented in this paper fills an important gap. It moves beyond ad hoc scenario provision and is conceptualized to enhance salience, credibility, and legitimacy of climate change scenarios. It is designed to match the needs of different societal actors and policy makers with a coordinated service infrastructure. The flexible, modular concept allows staged access, which supports capacity building for users with varying levels of prior knowledge. At the same time it is supposed to provide access to state-of-

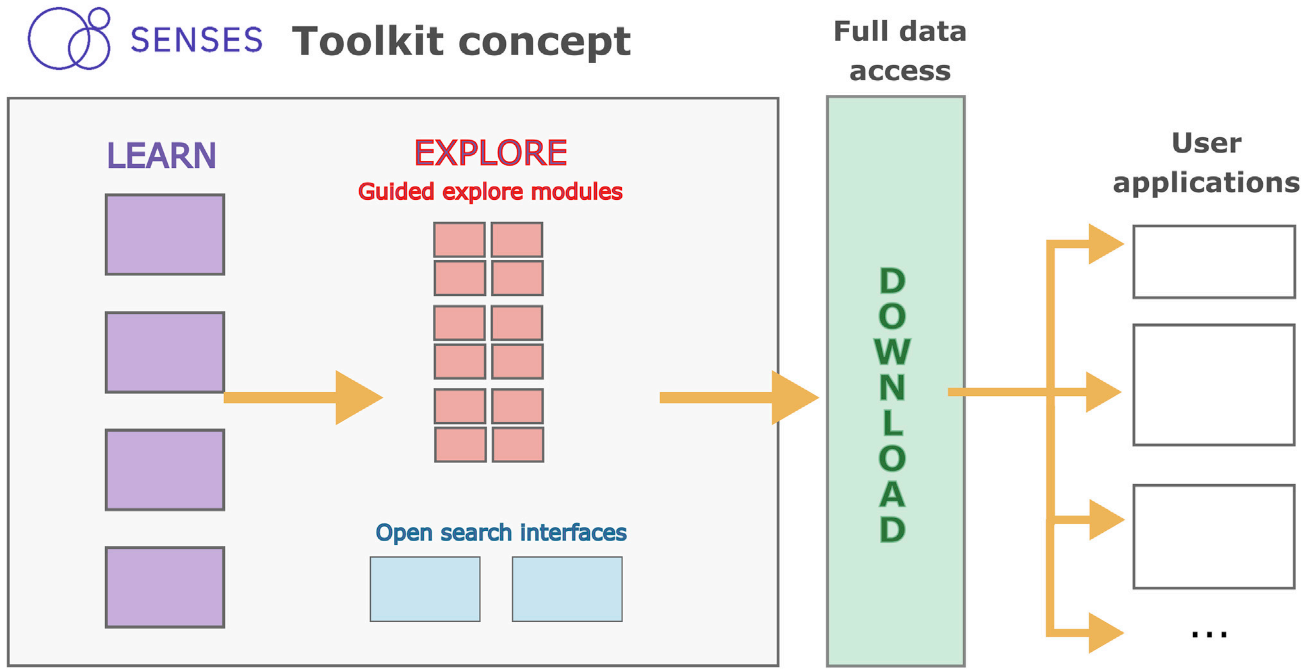

Figure 2. Information architecture of staged access in the SENSES toolkit
Introductory learn modules provide high-level information, exploration modules provide detailed, up-to date information. Users are empowered to understand and contextualize scenario information correctly. Finally, the raw data is linked and can be downloaded and employed in the user environment.

the-art climate change scenario information. We believe services like this can support decision makers to correctly contextualize and employ climate change scenario information. The prototypical implementation in terms of the SENSES toolkit is a first step in the direction of a climate change scenario service. The SENSES toolkit operationalizes core elements of the concept and can serve as an example for such services to make climate change scenarios salient and actionable to a broader user group. It clearly does not yet fulfill all our service requirements and comes with a focus on contextualization, capacity building, and visualization. However, it was sufficient to generate interest among a range of stakeholders, who found the provided tools useful to further their understanding of scenario approaches and insights and share with colleagues. It has already served as a blueprint for the recently launched NGFS scenarios portal for financial climate risk assessment and alignment, with learn, explore, and datum access elements (https://www.ngfs.net/ngfs-scenarios-portal/). Still, for a fully fledged scenario service the aspects of transparency, adequacy, and co-production need more attention and innovation. To reach the full potential of the vision for a climate change scenario service infrastructure we see the following two critical areas for further development.

Establish a practice of climate change scenario services: it will be important to make climate change scenario services a recognized, central source for new and established user groups. This requires a dedicated service infrastructure pooling a broad range of scenario information and augmenting it with additional service layers. These layers could include, for example, tutorials to give users an entry point to understand the scope of scenarios and how to use them. The resource needs to be able to provide continuity of service beyond the usual lifespan of projects and over time should extend its scope and depth of scenario services. It is equally important to keep the scenario information relevant and up-to-date by rapid uptake of the latest climate scenario research and annual updates of key scenario products. Finally, the service needs to get traction with the users by constantly orienting it toward the evolving landscape of user needs from national and international climate policy making to financial risk assessment. The question if such a service would need a central knowledge hub or if it can be distributed system of services, e.g., an open or curated landscape of services, cannot be decided at this stage, as this will be influenced by potential funding, support, and contribution from the communities. We opt for basic institutional setup and curation at least to ensure quality, usability, and basal maintenance.

Organize the interface between scenario information and scenario service: co-production between stakeholders and science but also among scientists will continue to play an important role to increase the adequacy and relevance of the scenarios. Existing data and user needs often do not match yet. For example, financial regulators require information on unemployment rates or price inflation, or a person at a city scale will struggle with mitigation scenarios given in the IPCC SR1p5.[12] Co-production can alleviate the situation, e.g., to enhance the applicability to regional use cases, which has seen too little development to date[20,75–80] and to feedback into science for further development. Linking to commonly accepted reference data and indicators, such as to the broader sustainability agenda—e.g., to the Sustainable Development Goals of the 2030 Agenda[35,81–83] for policy makers, but also to commercial data, e.g., from the International Energy Agency or the Worldbank for users from the private sector, will increase the usefulness. Further connection to benchmark data, research, and co-production will build the bridge between user needs and provide added value[43] to the scenarios. A well-established climate change scenario service infrastructure could play an important role in coordinating these efforts.

Many modes of operations are possible for the above-presented service concept. We strongly advocate to keep such service(s) open access and not to bind essential climate scenario information to the ability to pay. Co-production will remain playing an important role to increase understanding, validity, and relevance. Although climate scenarios need to continue to be developed and improved, it is overdue to put them to better service for climate decision makers, stakeholders, and society. It will require active stewardship and considerable efforts toward improving means to communicate with the broader user community to provide an up-to-date and trustworthy climate change scenario service. But it is well worth the effort as such a service will improve the quality and usability of climate change scenario research and benefit a broad range of actors.

SUPPLEMENTAL INFORMATION

Supplemental information can be found online at https://doi.org/10.1016/j.oneear.2021.07.015.

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AUTHOR CONTRIBUTIONS

Conceptualization, C.A. and E.K., with support of the other authors; climate change scenarios, C.A., E.K., and V.K.; co-production, C.A., H.C., S.P., and K.K.; visualization, C.A. and B.M.; writing, all authors.

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