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Advancing national Shared socioeconomic pathways (SSPs): A novel procedure applied to develop current Swiss SSPs

Pascal Tschumi, Irmi Seidl, Marco Pütz, Lena Gubler *

Swiss Federal Institute for Forest, Snow and Landscape Research, WSL, Zürcherstrasse 111, 8903 Birmensdorf, Switzerland

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ABSTRACT

Socioeconomic scenarios have become an important instrument for addressing present and potential future environmental challenges. Some of the most widely used socioeconomic scenarios are the global Shared Socioeconomic Pathways (SSPs), which were published in 2015 and have been extended to several geographical scales and sectors. Nonetheless, there are several needs for more useful and relevant SSPs. This article presents a novel procedure for developing national SSPs that addresses some of these needs, showing how it applies to Switzerland. The novelty of our procedure is the application of a composition-based scenario development approach (composing new scenarios from scratch) and to combine it with a derivation-based approach (deriving scenarios from existing ones by enriching them with, for example, national specificities) to develop national SSPs. Furthermore, the procedure fulfils three quality requirements for qualitative scenario development—interdisciplinarity, participation, and iterative quality controls—and meets three recommendations for more useful and relevant SSPs—developing SSP variants that are not covered by global SSPs, getting SSPs up to date, and enriching SSPs with perspectives from different societal groups to improve the inclusiveness of scenarios. We develop national SSPs for Switzerland (SSPs-CH) from scratch, incorporating these requirements and recommendations. Our procedure results in a new SSP variant (SSP0-CH: Frugal Switzerland), an altered SSP5 (SSP5-CH: Resource-Intensive Switzerland), and three SSP-CH scenarios that can easily be compared with global scenarios (SSP1, SSP3, and SSP4). No SSP-CH correlates with global SSP2. The process we developed uniquely combines different approaches and methods, and it proves to be viable for providing comprehensive, up to date scenarios.

1. Introduction

Addressing environmental challenges, such as climate change, and their detrimental social and economic consequences, is now a critical issue. Policymakers and other stakeholders who aim to explore alternative ways of addressing such challenges tend to rely on socioeconomic scenarios that depict disparate versions of the future and consider multiple social, economic, and environmental drivers (Elsawah et al., 2020; Hauck et al., 2019; Pereira et al., 2020; Riahi et al., 2017; Rosa et al., 2017; Wiebe et al., 2018). Some of the most widely used socioeconomic scenarios are the Shared Socioeconomic Pathways (SSPs), which were published in 2015 for the sixth assessment report of the Intergovernmental Panel on Climate Change (O'Neill et al., 2017). The SSPs are components of the SSP-Representative Concentration Pathway (RCP) framework, which is 'a set of alternative socioeconomic development pathways (SSPs) and atmospheric concentration pathways (RCPs) with their associated climate change outcomes' (O'Neill et al., 2020, p. 1074). These scenarios were initially developed at the global level. In the meantime, national and sectoral versions have been created (e.g. Karner et al., 2024; Lehtonen et al., 2021; Pedde et al., 2021, 2025; Reimann et al., 2021; Vafeidis et al., 2024; Zandersen et al., 2019). No Swiss SSPs have yet been developed, although Swiss SSPs could mirror the country's political, societal, and economic particularities, as well as its complex responses to global change due to its topographical and geographical conditions. This lack of Swiss SSPs, the intention to support the Swiss federal administration in making long-term policy decisions, and the scientific community's wish to have specific Swiss scenarios for modelling various themes (e.g. landscapes, climate change, and water cycles) led the authors to develop Swiss-specific SSPs and present the procedure in this article. This endeavour also included modelling greenhouse gas emissions and land use, which this article does not address.

* Corresponding author.
E-mail addresses: pascal.tschumi@wsl.ch (P. Tschumi), irmi.seidl@wsl.ch (I. Seidl), marco.puetz@wsl.ch (M. Pütz), lena.gubler@wsl.ch (L. Gubler).

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O'Neill et al. (2020) have since identified needs[1] to enhance the relevance and usefulness of the SSP-RCP (SSP-Representative Concentration Pathway) framework. This article presents a novel procedure for developing national SSPs that addresses three of the seven identified needs, showing how the procedure applies to Switzerland. Need 2 is to improve regional applicability, need 5 is to capture relevant perspectives, and need 6 is to keep scenarios up to date. Our procedure follows several of O'Neill et al.'s (2020) recommendations for addressing these needs: 'development of SSP variants' (p. 1079) that are not covered by global SSPs (addresses needs 2 and 5), 'keep SSPs up to date' (p. 1080) by considering the present situation in the ideation of future development (addresses need 6), and enriching the scenario development process with 'perspectives from … different societal groups' (p.1080) (addresses need 5).

Our procedure combines composition- and derivation-based scenario development approaches. Composition-based scenario development approaches allow completely new scenarios to be created (in an inductive manner; Fink & Siebe, 2011, 2016; Heinecke, 2006) by combining plausible factor developments that can significantly influence the scenario field. The number and content of the resulting scenarios are not determined by boundary conditions derived from baseline scenarios, such as global SSPs, since no baseline scenarios are used. Instead, composition-based approaches are open-ended to derive a diverse set of SSPs and improve SSP relevance (O'Neill et al., 2020). Therefore, SSP variants can be developed that 'cover a wider range of worldviews or perspectives' (O'Neill et al., 2020, p. 1079), including variants 'where all the Sustainable Development Goals (SDGs) are met' (p. 1079) and variants 'that explore a range of plausible but widely different societal futures' (p. 1080), such as 'futures with no or limited growth in high-income countries' (p. 1080). Furthermore, composition-based approaches allow the current situation to be integrated into the ideation of future developments by engaging experts who are familiar with current developments.

Our procedure produces currently plausible scenarios and thereby complies with the recommendation to keep SSPs up to date (although we provide a one-time update rather than a 'process for regular updates of the SSPs', O'Neill et al., 2020, p. 1080). While the 2015 SSPs, 'as broader, qualitative descriptions of long-term alternative futures … are less susceptible to changing conditions in the near term' (O'Neill et al., 2020, p. 1080), we think that almost 10 years after their introduction, 'new types of societal futures that become relevant to research or policy' (O'Neill et al., 2020, p. 1080) must be considered. Indeed, recent regional, local, and sectoral SSP developments do not explicitly focus on present conditions in the ideation of future developments (although they may do so implicitly because they attempt to capture regional, local, and sector-specific characteristics and developments through participatory methods, such as stakeholder workshops; Karner et al., 2024; Lehtonen et al., 2021; Pedde et al., 2021; Reimann et al., 2021; Vafeidis et al., 2024; Zandersen et al., 2019). However, such considerations have a limited impact on the development of topicality of regional, local, or sectoral SSPs because they use global SSPs as boundary conditions. This limits the extent to which new, currently relevant perspectives can be incorporated, as the baseline scenarios (global SSPs) are set. In other words, the scenario logic and main development lines (e.g. consumerism, polarisation, sustainability, globalisation, isolation, rivalry, etc.) remain unaltered. However, as mentioned previously, our composition-based approach works without boundary conditions. Thus, using our procedure, considering the present situation can lead to new SSPs based on relevant perspectives that depart from global SSP logic and main development lines.

Composition-based approaches typically rely on experts to develop scenarios (59 experts participated in our scenario development). The participation of other actor groups is thus limited, leaving O'Neill et al.'s (2020) recommendation to enrich SSPs with perspectives from different societal groups to improve scenario inclusiveness unaddressed. Therefore, after applying the composition-based scenario development approach, we applied a derivation-based scenario development approach to derive a set of scenarios from existing ones and enrich them. In our case, the set of scenarios corresponded to the raw scenarios developed using the composition-based approach. Derivation-based approaches are less complex than composition-based approaches and are suitable for involving many different stakeholders. We enriched the raw scenarios with the results from five workshops involving 85 stakeholders with diverse personal and professional backgrounds. The recommendation to enrich SSPs with perspectives from different societal groups to improve scenario inclusiveness (O'Neill et al., 2020) is essentially a recommendation to fulfil the quality requirement of participation in scenario development processes (Mitter et al., 2019), which is crucial for improving the legitimacy, salience (Alcamo & Henrichs, 2008; Priess & Hauck, 2014), relevance, and credibility of scenarios (O'Neill et al., 2020). Our scenario development procedure also aligns with two other quality requirements that are important for developing scientifically sound scenarios: 1) interdisciplinarity, which refers to scientists from different disciplines cooperating in scenario development to integrate knowledge and perspectives from different fields and 2) iterative quality controls, which are systematic, repeated quality checks at critical stages of the scenario development process (Mitter et al., 2019; Priess & Hauck, 2014).

The aim of this article is to propose a new scenario development procedure, which we designed to fulfil the three important quality requirements (interdisciplinarity, participation, and iterative quality controls) and meet the need for more relevant and useful SSPs (O'Neill et al., 2020). This article comprehensively introduces our new procedure and explains how we applied it between January 2023 and July 2024 to develop SSPs for Switzerland.

We contend that comprehensive descriptions of scenario development procedures are needed, since they are rare in the extant literature on regional, local, and sectoral SSPs but are vital for advancing the development of currently plausible, scientifically sound, and useful SSPs. In the next section, before presenting our procedure, we introduce the three quality requirements for scenario development and the two basic approaches used to develop qualitative socioeconomic scenarios, namely composition- and derivation-based approaches. Thereafter, we discuss the implications of our procedure for the three main quality requirements and how our procedure fulfils O'Neill et al.'s (2020) recommendation to develop more relevant and useful SSPs. Finally, we draw some conclusions.

2. Quality requirements and approaches for developing qualitative socioeconomic scenarios

2.1. Quality requirements for qualitative scenario development

Scholarly debates on scenario development suggest that quality requirements should be incorporated into the scenario development process to achieve legitimate, salient, plausible, and consistent results (Alcamo & Henrichs, 2008; Mitter et al., 2019; Priess & Hauck, 2014). First, the development process should be *interdisciplinary* (Mitter et al., 2019), allowing diverse aspects of socioeconomic systems to be discussed, and knowledge and perspectives from diverse fields should be integrated to produce scenarios that can be used by, among others, scientists from various disciplines (Mitter et al., 2019; Priess & Hauck, 2014).

Second, the process should be *participatory*, involving scientific and non-scientific actors, such as policymakers and civil society, business,

[1] O'Neill et al. (2020) formulated seven needs (Table 1, p. 1078) to improve SSP relevance, as follows: 1) improve climate/societal integration, 2) improve regional applicability, 3) improve relevance beyond climate, 4) improve use in policy research, 5) capture relevant perspectives, 6) keep scenarios up to date, and 7) improve relevance for users.

and third-sector actors (Alcamo & Henrichs, 2008; Mitter et al., 2019; Priess & Hauck, 2014). Participation increases the legitimacy and transparency of scenarios throughout their development (Alcamo & Henrichs, 2008; Kosow & León, 2015; Siebenhüner, 2003), elicits different perspectives, and ensures the accessibility and usefulness of final scenarios for public decision-making (Alcamo & Henrichs, 2008; Elsawah et al., 2020; Kosow & León, 2015; Siebenhüner, 2003), as well as their salience—their relevance and comprehensibility (Alcamo & Henrichs, 2008; Cash et al., 2003; Siebenhüner, 2003). Participation also encourages diverse actors to engage in creative thinking, combine different expertise, and integrate relevant knowledge (Alcamo & Henrichs, 2008; Mitter et al., 2019; Priess & Hauck, 2014). Broad participation increases the richness of scenarios to ensure that they provide a comprehensive picture of possible futures and address multiple drivers of socioeconomic change that affect the system of interest (Alcamo & Henrichs, 2008; Mitter et al., 2019).

Third, *iterative quality controls*—systematic and repeated quality checks carried out during scenario development—are essential. These checks involve both internal reviews and feedback from the core scenario development team, as well as external reviews and feedback from people outside it. Such checks are repeated until a consolidated result is reached (Mitter et al., 2019; Priess & Hauck, 2014). Iterative quality controls are vital because scenario development involves several consecutive cumulative steps. They enhance the scenarios' legitimacy and salience, especially when external actors review the results (Alcamo & Henrichs, 2008; Mitter et al., 2019; Priess & Hauck, 2014), facilitating the development of plausible scenarios that represent potential futures based on current knowledge and understanding of processes and their causalities (Alcamo & Henrichs, 2008; Mitter et al., 2019; Voros, 2003). However, the major role of iterative quality controls is to ensure scenario consistency (Mitter et al., 2019; Priess & Hauck, 2014).

2.2. Approaches to developing qualitative socioeconomic scenarios

2.2.1. Composition-based approach

Composition-based scenario development approaches allow completely new scenarios to be developed. We use the term *composition-based* in this article to describe approaches that facilitate the inductive design of new scenarios from scratch (Fink & Siebe, 2011, 2016; Heinecke, 2006). In these approaches, the number of scenarios and main development lines are not constrained by predetermined settings, such as normative stances (e.g. desired or undesired scenarios) or boundary conditions drawn from baseline scenarios.

Two widely used composition-based scenario development methods are cross-impact analysis and consistency analysis. Both methods, which will be described later, are used to identify key factors that most significantly influence the scenario field under consideration while also being influenced by the field itself (Fink & Siebe, 2011, 2016; Kosow & Gaßner, 2007).[2]

In a cross-impact analysis, the key factors' possible future values are determined and then assigned an estimated probability of occurrence independent of all other values (Gordon, 1994; Schweizer & Kurniawan, 2016). Subsequently, conditional probabilities are calculated to produce two probability estimations: 1) a probability estimation of one value if another value occurs, and 2) a probability if both values occur. The scenarios represent the most probable combinations of values, which are calculated based on a cross-impact analysis algorithm.

The consistency analysis method formulates a set of qualitative future projections for each key factor, evaluates the strength of the consistency of each pair of key factor projections (Fink & Siebe, 2011, 2016; Heinecke, 2006), and clusters the most consistent projections. Researchers then use these clustered projections to create scenarios (Fink & Siebe, 2011, 2016; Kosow & Gaßner, 2007). Unlike cross-impact analysis, the resulting scenarios are not based on probabilities; that is, they are not the most probable but the most consistent. Hence, the span of plausible and conceivable futures described by the scenarios is broad—many alternative and differentiated scenarios are created. This corresponded with our scenario development goal of designing internally consistent socioeconomic scenarios that spanned a wide range of possible future developments. Thus, we chose to apply the consistency analysis method to develop the raw scenarios for our SSPs-CH (see Section 3).

Note that composition-based scenario development approaches differ from bottom-up approaches. In the latter, scenarios are constructed by extending case studies and/or localised data (Pedde et al., 2025), and the resulting developments may be constrained by normative stances or boundary conditions derived from global SSPs or sectoral, national, and regional SSPs (e.g. Karner et al., 2024; Lehtonen et al., 2021; Zandersen et al., 2019). The resulting scenario logic and main development lines thus remain the same as those for global SSPs. Even new, currently relevant perspectives considered during scenario development can only be added to the existing frame provided by global SSPs. In contrast, composition-based scenario development approaches allow the creation of new scenarios independent of any other scenarios and permit current relevant perspectives to shape the scenario logic and main development lines.

2.2.2. Derivation-based approach

In composition-based approaches, the field of possible development is broad because there are no boundary conditions. Hence, individuals (usually experts) are called upon to grasp and interpret the scenario fields (Fink & Siebe, 2016; Kosow & Gaßner, 2007), limiting the participation of other actor groups and leaving recommendations for improving inclusiveness (O'Neill et al., 2020) unaddressed. Scenario inclusiveness is better achieved through derivation-based approaches, which permit scenarios to be derived from the predetermined main development lines pertaining to existing scenarios, thus reducing scenario development complexity. Such approaches are suitable for involving many different stakeholders without the risk of confusion due to different perceptions of words or concepts (Kok et al., 2007) or limited understanding of system interrelationships and feedback (Rounsevell & Metzger, 2010). Derivation-based scenario development approaches can be applied after composition-based approaches if the scenarios resulting from the composition-based approach predetermine the number and main development lines. Derivation-based approaches are designed to develop scenarios that comply with such predefined conditions. The methods are usually characterised by 'the explicit implementation of creative techniques, intuition, and implicit knowledge' (Kosow & Gaßner, 2007, p. 61). Examples of these methods include morphological analysis (Marthaler et al., 2020), archetypes methods (Fergnani & Jackson, 2019), and the Three Horizons technique (Sharpe et al., 2016). They are usually applied to stakeholder workshops in which knowledge is shared, opinions are exchanged, and consensus is reached (Andersen et al., 2021; Priess & Hauck, 2014).

3. Developing SSPs for Switzerland

3.1. Overview

Our procedure meets the three quality requirements discussed in Section 2.1 and follows O'Neill et al.'s (2020) three recommendations for addressing the overall goal of 'increasing the usefulness and relevance of the framework' (p. 1077): 1) developing SSP variants to obtain a more diverse set of global SSPs, 2) keeping SSPs up to date by considering the present situation in the ideation of future development, and 3) enriching the scenarios with perspectives from different societal groups to improve scenario inclusiveness.

Our procedure comprises four working steps (see Fig. 1) that address the three recommendations simultaneously: Step 1 describes the

[2] See Section 3.3.1 for the identification of factors and key factors.

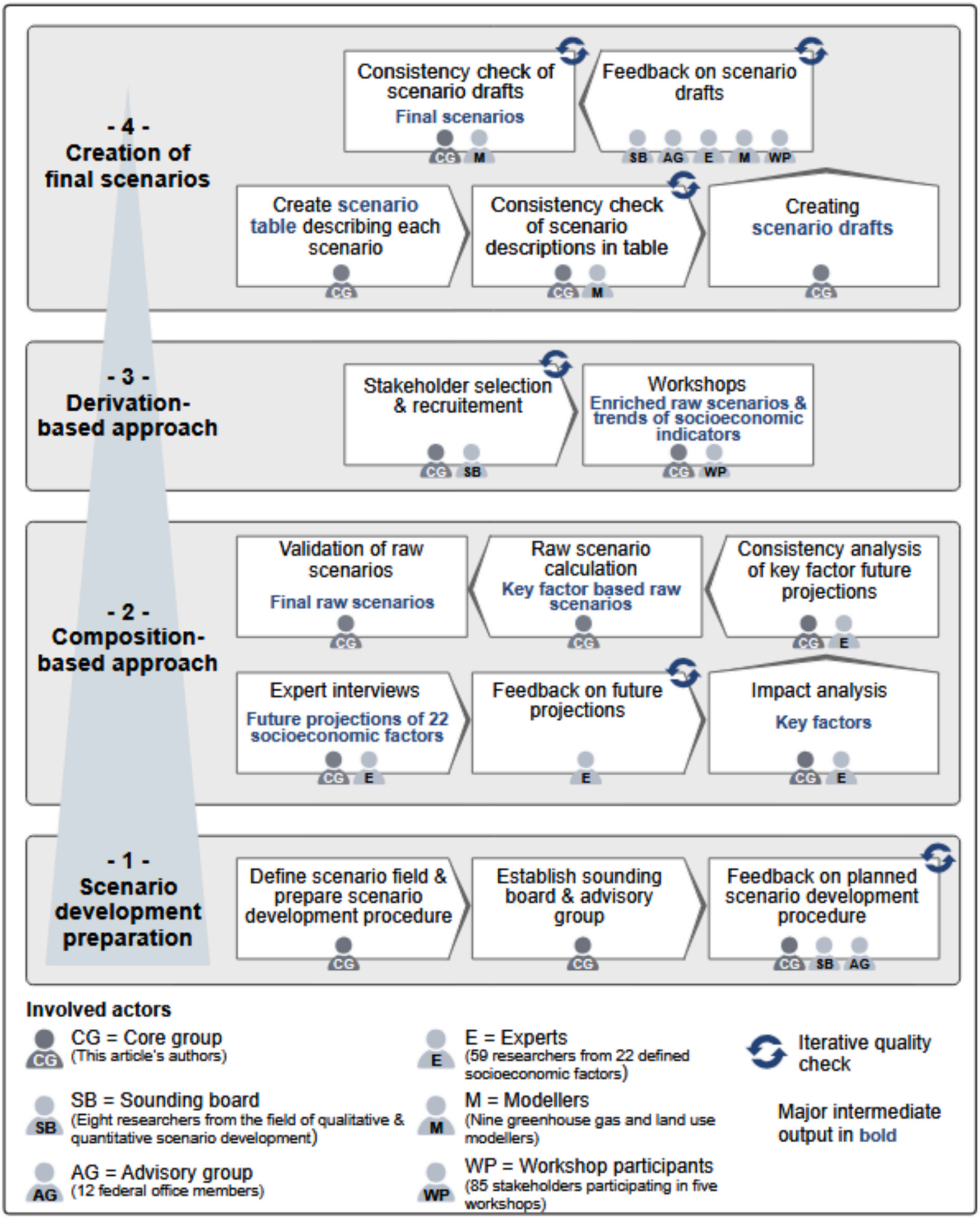

Fig. 1. Working steps, outputs, and actors involved in our scenario development procedure. Please start reading from the bottom.

scenario preparations. Step 2 presents our composition-based raw scenario development, which addresses the first two recommendations. This step largely following Fink and Siebe's (2016) scenario management, involving a consistency analysis of scenario development. Step 3 presents the derivation-based approach, which addresses the third recommendation. Step 4 describes the final scenario creation.

3.2. *Step 1: Scenario development preparation*

Before undertaking actual scenario creation, one must define the major goal and purpose of developing the scenarios, their target groups, thematic foci, spatial and time scales, and the scenario type (Elsawah et al., 2020; Mitter et al., 2019). Our major goal in developing SSPs for Switzerland was to provide currently plausible, scientifically sound, legitimate, and salient scenarios for use by scientists and policymakers. Specifically, our scenario development was part of a research project that used the final scenarios to model future Swiss greenhouse gas emissions and land use. As part of the research project, the scenarios were complemented by different Shared Policy Assumptions (SPAs; Kriegler et al., 2014)—future policy mixes for climate mitigation. The first main target group for the scenarios are scientists who are investigating climate change and other major societal challenges, such as demographic changes or food security. The second main target group are policymakers who are interested in understanding and averting the potentially detrimental consequences of these challenges. In line with the SSPs, we chose the thematic focus of socioeconomics after considering all the major factors that influence the Swiss socioeconomic system. The spatial scale was Switzerland. The timeline we set for the scenarios is up to 2100 to align with global SSPs. The scenario type we aimed to develop was qualitative (i.e. a text- and graphic-based description of scenarios; Alcamo et al., 2008), again aligning with global SSPs.

As iterative quality controls (Mitter et al., 2019; Priess & Hauck, 2014; see Section 2.1), we established two external feedback groups before starting the scenario development. The first group was an advisory group comprising 12 members from five federal offices,[3] each with experience in scenarios or risk analysis relating to climate, energy, the population, the economy, or mobility. We asked them for feedback on our planned major steps and interim results. Additionally, we established a sounding board of eight scientists who worked on qualitative and quantitative scenario development. They advised us and offered feedback on our working steps and interim results.

3.3. Step 2: Composition-based approach—raw scenario development

3.3.1. Determining factors as a basis for expert interviews and the creation of future projections

The first step in composition-based scenario development is to identify the factors that cover significant portions of a socioeconomic system (in our case, the Swiss system). We identified 22 factors through a literature review[4] to represent our scenario field (Fink & Siebe, 2016; Kosow & Gaßner, 2007). Each factor was expected to influence the overall socioeconomic system and was discussed in subsequent interviews with a pair of experts. The goal of the interviews was to create future projections for these factors, which we could use for raw scenario calculations (see Section 3.3.3). We chose the experts according to their scientific knowledge of the 22 factors; each expert was active in academia, familiar with current developments, and could consider these in their projections. The experts were scientists from 20 Swiss universities, universities of applied sciences and other public research institutions. Between April and August 2023, we conducted one to three interviews for each factor, resulting in a total of 30 interviews with 59 experts. Each interview, except for three, was conducted with at least two experts to spark the participants' creativity and joint development of ideas.

In the interviews, we applied the 2 × 2 scenario-axes technique (Rhydderch, 2017; van 't Klooster & van Asselt, 2006), with four quadrants representing future projections spanning two axes with different values. To define the axes, we asked the experts to select two major developments related to their assigned factor that they thought would create the greatest uncertainty for future trends. For example, regarding the population and immigration factor, the most uncertain developments could concern *Swiss family policy* and *migration*, which would become the axes (see Fig. 2). Thus, all axes were factor-specific. To define the axis values at the tails, we asked the experts to define two qualitative values for each of the two axes, with the two values defining a continuum along which the axis could lie (see Fig. 2). Based on these axes and values, the experts created four future projections, one in each quadrant (in one case, two; in one case, three; and in six cases, five). All the experts were provided with the final version of their factor projections for feedback.

3.3.2. Identifying key factors

For the scenario calculation, we identified key factors from the 22 factors (footnote 3) by performing an influence analysis of all factors (Fink & Siebe, 2016). To conduct the analysis, at the end of each interview, we asked the experts to rate, on a scale of 0 (no influence) to 3 (very strong influence), the current strength of their factor's influence on the other 21 factors, and the strength of the other 21 factors' influence on their factor, independent of any future projections discussed. The nine factors that received the highest scores for both influencing and being influenced by other factors were chosen as key factors: economic development, energy, democracy, digitalisation, mobility and traffic, population development and migration, social values, strength of the state, and Switzerland's relationship with the European Union (EU).

3.3.3. Consistency analysis and raw scenario calculation

The raw scenarios were based on future projections for the key factors (see Section 3.3.2; Fink & Siebe, 2016) and were obtained using ScMi AG's Scenario Manager™ software (Fink & Siebe, 2016), which calculates clusters of the most consistent projections based on the level of consistency among them. Note that the level of consistency had to be evaluated before the software calculation (Fink & Siebe, 2016). For this, 8 to 12 weeks after the interviews, we asked one expert from each pair to briefly describe how the axis values of the key factor they discussed (e.g. low/high) would develop, given the axis values for each of the other

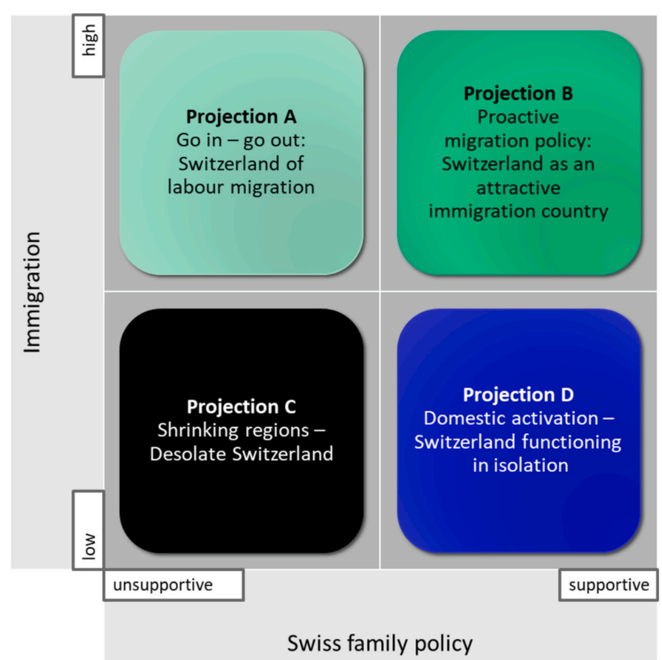

Fig. 2. Example of future projections for the population and immigration factor with the axes of uncertainty: 'Swiss family policy: unsupportive and supportive' and 'Migration: low and high'. All projections from the interviews can be found in the supplementary material.

[3] Federal offices for the environment, energy, spatial development, economic affairs, and statistics.

[4] These factors were agriculture, the care system and diversity, democracy and the functioning of political institutions and processes, digitalisation, the distribution of income and wealth, the economy, the education system and levels of qualification, energy, the geopolitical situation, the health system, internal security, international organisations and agreements, media and communication, mobility, the national budget, population development and migration, public administration, the CH–EU relationship, the role of the state, social cohesion and values, urbanisation and spatial planning, and work.

eight key factors' future projections (see Fig. 3).

The results were fed into the consistency assessment of ScMI AG's Scenario-Manager™ software (Fink & Siebe, 2016). The software calculated the consistency of the projections (of the nine key factors), which were determined by the axis values. The consistency was expressed as: 1) complete inconsistency, 2) partial inconsistency, 3) independent, 4) high consistency, and 5) very high consistency. However, this procedure can cause some projections to dominate, meaning that some projections are excluded from the raw scenarios. This occurred in our case. We aimed to avoid this, since all projections were considered conceivable by the experts (Fink & Siebe, 2016). Therefore, we made slight corrections to some consistency values. The calculation resulted in four raw scenarios with consistent key factor projections.

3.3.4. Raw scenario validation

After calculating the raw scenarios, it was important to qualitatively check whether any basic development lines (e.g. unequal wealth distribution) that were repeatedly reflected in the key factors' axes were missing from the raw scenarios (Fink & Siebe, 2016). We found that social and economic inequality was an issue for three key factor projections (out of nine), but this was not a basic development line in any of the raw scenarios. According to Fink and Siebe (2016), if the basic development lines of raw scenario projections are missing, it is possible to create an additional raw scenario without calculating a new raw scenario by hand-selecting consistent projections. However, this procedure involves the risk of the additional scenario being less consistent than the others. We decided to accept this risk of low consistency, since we planned to conduct a comprehensive consistency check in Step 4 (see Section 3.5). Nevertheless, to minimise the risk, we based our selection of projections on an existing socioeconomic scenario in which inequality was a basic development line, namely the European SSP4, which depicts a concentration of political and economic power and an unequal distribution of wealth and opportunities (Kok et al., 2019). We then matched future projections of the key factors and combined these projections into a further raw scenario. This resulted in five raw scenarios.

3.4. Step 3: Derivation-based approach

To enrich the raw scenarios with perspectives from different societal groups and hence improve the inclusiveness of the scenarios (O'Neill et al., 2020), we applied a derivation-based scenario development approach after the composition-based one. We conducted five stakeholder workshops in which we applied methods of this derivation-based approach.

3.4.1. Stakeholder selection

For stakeholder selection, we established criteria that aligned with our scenario development goal (Alcamo & Henrichs, 2008; Mitter et al., 2019) of serving various stakeholders. Therefore, we aimed to recruit a broad array of stakeholder groups, drawing on the stakeholder types identified by Andersen et al. (2021): representatives from political administrations, science, businesses/enterprises, third-sector organisations (non-governmental organisations, political parties, interest groups, etc.), civil society, and remarkable people who could contribute creativity and diverse thinking, such as design thinkers. Among the participants in the first four groups (political administrations, science, businesses, and third-sector organisations), at least one participant had to be affiliated with one of the following relevant sectors of the scenario field: agriculture, economics/trade, culture, demography/migration, energy supply, finance/insurance, food and nutrition, healthcare, infrastructure/traffic, nature protection, safety and defence or civil protection, or the social sector.

In addition to the core group, the sounding board supported stakeholder recruitment by providing valuable feedback on selected stakeholder types. The stakeholders were not intended to be representatives of Swiss society. Overall, we identified and invited stakeholders to the workshops through our various social networks and by reaching out to previously unknown people and institutions to ensure that a broad range of stakeholders was represented. In total, 85 stakeholders participated. The distributions were as follows: age: 13 % $<$ 35 years, 69 % 35–55 years, 18 % $>$ 55 years; gender distribution: 45 % female, 55 % male; language background: 84 % German speakers, 16 % French speakers; stakeholder group affiliation: 16 % representatives of administrations, 31 % science, 29 % businesses/enterprises, 9 % third-sector organisations (NGOs, political parties, interest groups, etc.); 12 % civil society, and 5 % remarkable people. We held five workshops with 14–20 participants per workshop, four conducted in German and one in French, since around 60 % of the Swiss population speaks German, 20 % speaks French, and the rest are Italian- or Rhaeto-Romanic speakers (many of whom also speak one of the two dominant languages). One to two modellers from the project team participated in each workshop to ensure that factor data were collected for the subsequent modelling of

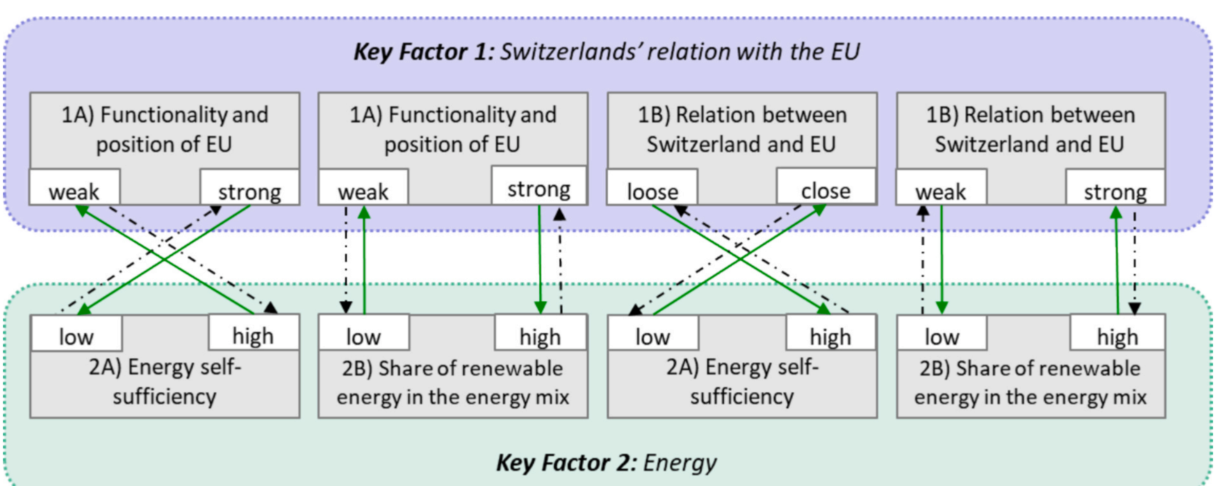

Fig. 3. Exemplary relationship analysis regarding two key factors (1. Switzerland's relation with the EU and 2. Energy), and their respective two axes (1A: Functionality and position of the EU, 1B: Relations between Switzerland and the EU, 2A: Energy self-sufficiency, and 2B: Share of renewable energy in the energy mix) and the axes' values at the extreme (1Av—weak versus strong, 2Av—low versus high, 1Bv—loose versus close, and 2Bv—low versus high). The experts evaluated the logical connections (and their directions) between the axis values of their key factor with the axis values of the other eight key factors as follows: green line—a relationship between axis values, dotted line—no relationship, and no line—no logical connection. (Own figure, based on Scenario Management International AG, 2020). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

greenhouse gas emissions and land use (see the next section) and to improve the modellers' understanding of how the scenarios were created.

3.4.2. Workshop design

As mentioned previously, the aim of the workshops was to enrich the raw scenarios by incorporating the perspectives of a wide range of stakeholder groups. We obtained these perspectives by applying the Three Horizons technique (Sharpe et al., 2016) and assigning various group and individual tasks to the participants.

Each workshop participant was randomly assigned to one of the five raw scenarios; the resulting groups remained together throughout the workshop and elaborated on their specific scenarios. The Three Horizons technique (Sharpe et al., 2016) involved first discussing the factors that influenced the present situation, independent of any scenario (in our case, the factors that influenced Swiss society and the economy; Horizon 1, see Fig. 4). Next, the socioeconomic conditions in the year 2100 (Horizon 3) were identified. To stimulate the imagining of a possible future in 2100, each group was introduced to its raw scenario through a short fictitious radio programme focusing on the scenario's core elements. To further foster imagination, written questions related to the corresponding raw scenario were provided. Finally, the groups discussed the developments that would need to occur to achieve the 2100 scenario (Horizon 2).

To deepen and complement these visions of the future and the associated discussions, the participants were given two additional tasks. First, they were asked to estimate trends individually for 11 modelling factors[5] that we had selected in consultation with the modellers. These trends covered the period from now (2023) until 2100 and ranged from −3 (a very strong decrease compared to the present day) to + 3 (a very strong increase). Each group then combined these estimations to create one overall trend (following the method described by Pedde et al., 2019).

Second, the participants were asked to complete a questionnaire on particular aspects of the scenarios that might not have been discussed during the workshops (based on Pedde et al., 2020; see supplementary material). These data were then used to supplement the scenario descriptions in the next step (see Section 3.5).

3.5. Step 4: Creating the final scenarios

To formulate the final scenarios, we used the scenario elements drawn from the workshops and the future projections resulting from the composition-based approach and the raw scenarios.

Based on the Three Horizons technique, numerous scenario elements were identified for socioeconomic conditions in the year 2100. To categorise the scenario elements that were mentioned more than once, we created a table and assigned them to 22 factors. This enabled us to systematically describe the 22 factors and the scenario elements. We did this for each of the five raw scenarios. If a factor could not be described sufficiently, we incorporated information from the future projections that were developed during the expert interviews, as well as the data from the questionnaires and the trend estimations. The resulting table provides a highly resolved picture of each scenario. The core group (authors) and the modellers checked the table for consistency and produced scenario drafts. These were sent to the workshop participants, the interviewed experts, the sounding board, and the federal administration advisory group for feedback. We then adapted the scenarios accordingly. The core group and the modellers then checked the revised drafts for consistency again. After a final discussion within the core group, we corrected any remaining inconsistencies and produced the final scenarios. For a short version of the final scenarios, see Table 1.

3.6. Contrasting and designation of the scenarios

We juxtaposed the final scenarios with the EU Shared Socioeconomic Pathways (Eur-SSPs; see Table 2). The three scenarios (SSP1-CH, SSP3-CH, and SSP4-CH) are highly comparable with the three European SSP scenarios (Eur-SSP1, Eur-SSP3, and Eur-SSP4). For this reason, we have given them the same numbers. SSP5-CH resembled Eur-SSP5 only to a certain extent. Finally, the scenario that did not share any main development lines with the Eur-SSPs was assigned the number 0.

However, Swiss SSPs have, such as Eur-SSPs, no counterpart to the global SSP2. The absence of an SSP2 in our study is due to the chosen method of consistency analysis, which generates raw scenarios with clear main development lines, whereas the SSP2, as a middle-of-the-road scenario, lacks of such specific main development lines (Kok et al., 2019).

4. Discussion

In this section, we first discuss the implications of our procedure for the three main quality scenario development requirements—interdisciplinarity, participation, and iterative quality controls (see Section 2.1). Second, we discuss how we met O'Neill et al.'s (2020) recommendations to develop SSP variants that are not covered by global SSPs, to keep scenarios up to date by considering the present in the ideation of future developments, and to enrich scenarios with perspectives from different societal groups to improve scenario inclusiveness (Section 1). Third, we discuss our procedure's limitations.

4.1. Implications for quality requirements

To fulfil the quality requirement of interdisciplinarity, Mitter et al. (2019) recommended engaging a team of scientists from diverse disciplines in coordinating the scenario development process and discussing the socioeconomic system under consideration. We achieved this with an interdisciplinary core team and an interdisciplinary sounding board. Concurrently, we chose a composition-based scenario development approach and drew heavily on the experts' (i.e. scientists') knowledge of and perspectives on different fields. This allowed us to formulate future projections for key factors based on the experts' input when drafting the raw scenarios.

In terms of the quality requirement for participation, our procedure increased opportunities for diverse actors (experts, stakeholders, and the sounding board) to be spread across our procedural steps due to the successive nature of the composition- and derivation-based approaches. Indeed, although including representatives of diverse groups in a single working step (e.g. a workshop) can encourage creative thinking and ensure legitimacy (Alcamo & Henrichs, 2008; Mitter et al., 2019; Priess & Hauck, 2014), bringing together such actors in one step can create power imbalances and tensions (Bhave et al., 2016; Cairns et al., 2013). These could stem from widely differing perceptions of words or concepts (Kok et al., 2007) or from internal consistency problems arising from a limited understanding of the system's interrelationships and feedback loops (Rounsevell & Metzger, 2010). Such issues can be mitigated by competent facilitators (Elsawah et al., 2020) and by spreading the participation of specific groups across working steps. The latter is essential for the development of regional and national SSPs if they are to involve a significant number of actors and achieve high levels of legitimacy and salience. However, most regional and national SSPs do not involve actors to the extent that we did; instead, they hold workshops in which various stakeholder groups are represented (e.g. Hyytiäinen et al., 2022; Nilsson et al., 2017; Pedde et al., 2021; Rohat et al., 2019). Conversely, we deployed the actor groups successively across the

[5] These eleven modelling factors were air traffic, degree of urbanisation, economic output, freight transport, product lifespan, livestock, living space per capita, passenger transport, permanent resident population, production volume of energy-intensive companies (e.g. cement, steel, glass, paper, and chemical production), share of renewables in Swiss energy mix.

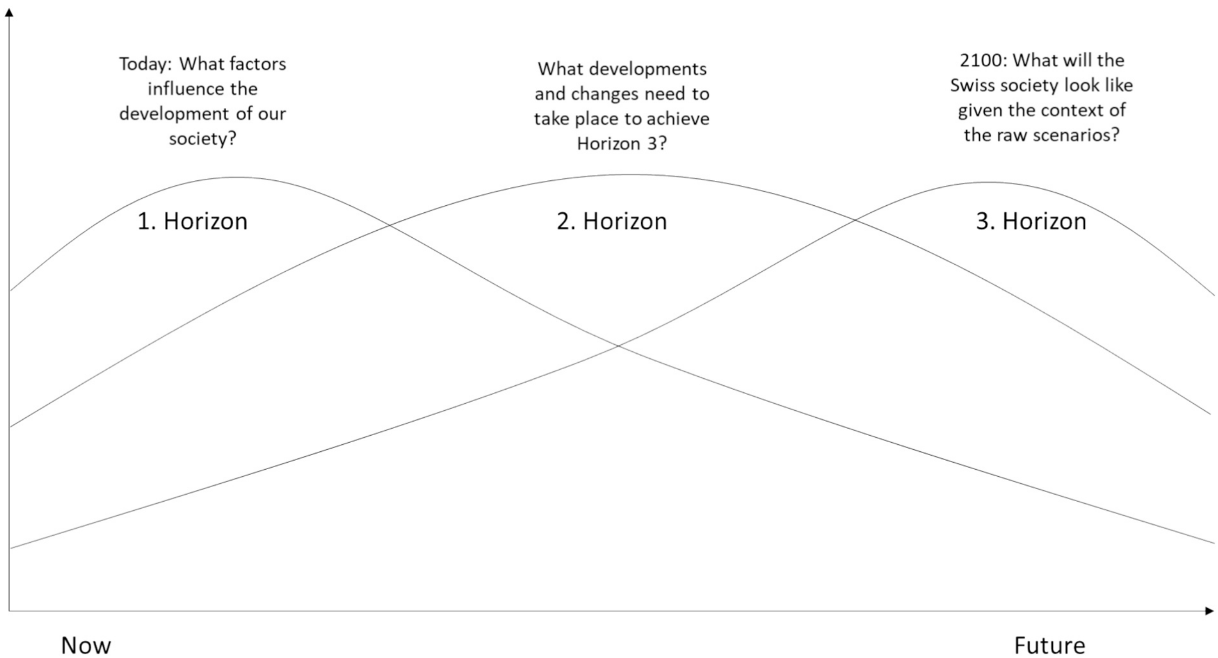

Fig. 4. The Three Horizons technique enriched the raw scenarios. (Own figure with our guiding questions based on Sharpe et al., 2016).

Table 1
Short version of the five SSPs-CH. The full version of the five SSPs-CH is shown in the supplementary material.

SSP0-CH: Frugal Switzerland	The Swiss population is socially committed and organised in a spirit of solidarity. Consumption has fallen sharply, and income and assets are more evenly distributed; however, economic performance, financial prosperity, and living standards have declined. Trust in political institutions is high.
SSP1-CH: Efficient Switzerland	The Swiss economy is innovative, technologised, and highly efficient. Resource cycles are mainly closed. Economic growth is stable and moderate, with a considerable proportion of productivity gains redistributed to the population.
SSP3-CH: Conflict-prone Switzerland	Switzerland's political and economic relationships with other countries are weak. Political institutions function poorly, and the remaining state resources are used to maintain internal security. Family as an institution is becoming more important for social security.
SSP4-CH: Unequal Switzerland	Swiss society is divided. An internationally well-connected elite determines Switzerland's economic and political developments. Only a few benefit from the profits of a highly technologised economy. Large parts of the former middle class have disappeared.
SSP5-CH: Resource-intensive Switzerland	The rapidly growing economy, based on fossil fuels, brings prosperity to a growing population. People lead resource-intensive lifestyles. By the end of the century, the economy will shrink and become unstable due to rising resource prices and environmental costs. Protectionist measures are introduced. Switzerland is economically and politically isolated.

composition- and derivation-based approaches, thereby reducing the aforementioned problems of power imbalances, overly heterogeneous perceptions, and internal inconsistency. Some groups were over-represented in our workshops (e.g. scientists); however, we avoided power imbalances and tensions by moderating subgroups, thereby ensuring that all participants had the opportunity to express their visions and opinions. Consequently, the scenarios were enriched with the knowledge and perspectives of all groups, which enhanced the scenarios' legitimacy and salience.

Regarding the requirement for iterative quality controls, our scenario development procedure included steps that produced solid results on which to base the subsequent steps. These quality controls comprised external and internal reviews and feedback. Due to successive composition- and derivation-based approaches, our scenario development procedure involved more working steps than approaches that were purely composition- or derivation-based. First, we included an additional consistency check. In contrast to other approaches, which typically require one consistency check after the formulation of the key factor developments (composition-based; Fink & Siebe, 2016; Kosow & Gaßner, 2007) or after draft scenarios have been formulated (derivation-based; Mitter et al., 2019), our procedure required two consistency checks. We performed a consistency check during the composition-based approach and another after the results of the composition-based and derivation-based approaches were combined to create the final scenarios. Second, we implemented a step in which the results of the composition-based approach were combined with those of the derivation-based approach, resulting in the final scenario content (see Section 3.5).

4.2. Meeting recommendations to develop more relevant and useful SSPs

In the following section, we discuss how we met the three recommendations formulated by O'Neill et al. (2020) (see Section 3.1) to develop more relevant and useful SSPs. To address the first recommendation (to develop new SSP variants that are not covered by global SSPs), we opted for a composition-based scenario development approach and built scenarios from scratch so that these scenarios would be free from boundary conditions that would predetermine the scenarios' number and main development lines and, hence, would allow for new scenarios. Notably, our procedure resulted in the same number of SSPs-CH as global SSPs (five), with three following the main development lines. SSP1-CH and global SSP1 show green technologies and economic growth thriving, SSP3-CH and global SSP3 feature nationalism and ineffective institutions, and SSP4-CH and global SSP4 see inequality and a concentration of power prevailing. However, global SSP2, which is often considered a business-as-usual SSP, has no counterpart in the SSPs-CH. The other two SSPs-CH (SSP5-CH and SSP0-CH) follow the main development lines of global SSPs only partially or not at

Table 2
Contrasting the SSPs-CH with the Eur-SSPs (descriptions of Eur-SSPs based on Kok et al. 2019). For a simplified overview, the scenarios are presented in five dimensions.

Scenario	Ecological dimension	Political dimension	Economic dimension	Sociocultural dimension	Technological dimension	Comparability
Efficient Switzerland: SSP1-CH	High esteem for nature	Strong state, focus on public services, high international integration	Moderate but steady economic growth	Personal freedom and tolerance, low inequality	Highly innovative and efficient, leading position in green technologies	High
Eur-SSP1	High environmental respect	High quality of governance with a focus on sustainability and well-being, strong international cooperation	Steady economic development	Decreased social and economic inequalities	Highly efficient green technologies	
Conflict-prone Switzerland: SSP3-CH	Low value attributed to nature	Weak state, isolation	Declining economy, emigration	High cohesion in clan-like structures, rivalries between them	Old technologies, no innovation	High
Eur-SSP3	Low environmental respect	Weak institutions and governance structure, fragmented Europe, regional rivalry and conflicts	General lack of economic resources, brain-drain from Europe	Criminal organisations and corruption, phasing out of social security systems	Low level of technological development	
Unequal Switzerland: SSP4-CH	Low value attributed to nature	Strong state, small elite close to power	Growing, free markets, but only elite is benefitting from productivity gains	Deeply divided society; high proportion of population close to poverty line	Leading in (green) technologies, highly innovative	High (raw scenario SSP4-CH derived from Eur-SSP4 main development lines)
Eur-SSP4	Environmental awareness reflected only in the development of green technologies	Strong governance, power concentrated in a relatively small political and business elite	Strong economic development, strong international integration, oligarchy of green 'business developers'	Low social cohesion, stratified society	Market leader in (green) technologies, technology development strong in the high-tech economy	
Resource-intensive Switzerland: SSP5-CH	High degradation	Strong state till second half of century, weakened state thereafter	Strong economic growth till second half of century, then a decrease	Low social cohesion, fear of social decline	Old technologies, non-innovative	Weak
Eur-SSP5	High degradation	Strong state with focus on businesses	Growing strongly, free markets	Social sustainability, reduction of inequality	Highly innovative, strong and crucial technology development	
Frugal Switzerland: SSP0-CH	Sustainable land management, high value attributed to nature	Strong subsidiarity, strong trust in state	Reduced consumption, economic shrinking	High social cohesion, engaged society	Moderate technologisation, low-tech and social innovations	No counterpart; some matches with Eur-SSP1.

all: SSP5-CH shares global SSP5′s dependence on fossil fuels. However, in contrast to global SSPs, SSP5-CH's dependence resulted in an economic decline and destabilisation by the end of the century. SSP0-CH describes a declining emphasis on economic growth combined with a high level of well-being, which differs markedly from any global SSP development line. The existence of SSP5-CH and SSP0-CH suggests that our composition-based approach broadened the range of future scenarios compared to global SSPs. However, this approach did not generate a middle-of-the-road scenario (SSP2). We conclude that our composition-based approach allows for a wide range of views and perspectives, including unusual ones. In our experience, to achieve this, it was crucial to apply the 2 × 2 scenario-axes technique (Rhydderch, 2017; van 't Klooster & van Asselt, 2006) for all 22 factors, which led to a wide range of conceivable futures that do not merely continue current trends.

We also used a composition-based approach to address the second recommendation (to keep the scenarios up to date). This approach ensured that the up-to-date knowledge of leading Swiss experts at the forefront up-of research was incorporated into the ideation of conceivable futures. Moreover, the composition-based approach did not constrain the incorporation of up to date expert knowledge because no boundary conditions delimited the extent of the knowledge and perspectives elicited. Boundary conditions derived from global SSPs developed a decade ago may hinder such incorporation. Even if boundary conditions derived from global SSPs are sometimes modified or complemented with local, regional, or sector-specific quantitative trends, drivers, indicators, or the development of existing regional, local, or sector-specific scenarios (e.g. Karner et al., 2024; Kok et al., 2019; Lehtonen et al., 2021; Mitter et al., 2020; Palazzo et al., 2017; Pedde et al., 2021; Reimann et al., 2021), up to date expert knowledge merely extends the baseline scenarios, which are predetermined by the global SSPs. It does not, however, fundamentally alter them. Indeed, SSP5-CH and SSP0-CH demonstrate that our composition-based approach resulted in new SSP variants and that the present situation was considered in the ideation of future developments. Economic growth loses importance in the SSP0-CH scenario, reflecting the discussions and developments of low economic growth that have recently been prominent in societal and academic discourses (e.g. OECD, 2020). SSP5-CH, showing the economy in decline by the end of the century due to fossil fuel dependence, assumes that continued fossil fuel reliance is incompatible with an innovative and prosperous economy—a notion that is not new but may be more relevant as greenhouse gas emissions continue to rise and the supply of natural resources becomes more volatile. Hence, the experts we interviewed, based on the composition-based approach, contributed their up-to-date knowledge to conceivable futures. However, it is unclear whether considering the present situation or conceiving of a multitude of futures induced by the 2 × 2 scenario-axes technique led to specific development lines for SSP5-CH and SSP0-CH.

To address the third recommendation (to enrich the scenarios with perspectives from different societal groups to improve scenario inclusiveness), we opted for a derivation-based approach and conducted workshops after applying the composition-based approach. Through the derivation-based approach, we fulfilled the quality requirement for participation (see Section 4.1). However, the participation of diverse actor groups alone would not have met the recommendation to enrich scenarios with different societal groups' perspectives. We assert the importance of *the way* in which different societal groups' perspectives were considered. In our workshops, participants were presented with the raw scenarios' main development lines, which resulted from the composition-based approach. These main development lines established the boundary conditions within which workshop participants formulated and further refined new ideas. Ideas and views that opposed these boundary conditions could have impeded the comparability and consistency of the final scenarios with the baseline scenarios (i.e. the raw scenarios; Frame et al., 2018; Mitter et al., 2020). However, such ideas and views are important for achieving legitimate, salient (Frame et al., 2018; Mitter et al., 2020; Pedde et al., 2021), and inclusive (O'Neill et al., 2020) scenarios. We included new content if it was mentioned in at least two different workshops, regardless of whether it opposed the main development lines of the raw scenarios. Interestingly, new content either aligned with the main development lines or contained deviations that did not contradict them. In any case, consistency was ensured by feedback loops. Most sectoral, regional, and national SSP developments do not mention whether or how they included opposing views, with few exceptions (Karner et al., 2024; Lehtonen et al., 2021).

4.3. Limitations

Our scenario development procedure produced salient and legitimate scenarios while also meeting three of O'Neill et al.'s (2020) recommendations. However, some limitations arose.

First, our procedure limited alignment with global SSPs by allowing for new or divergent ideas and versions of futures—as in the case of SSP0-CH and SSP5-CH. We preferred new variants of SSPs and up to date SSPs over such alignment according to our research objectives. Second, the involved public may experience research fatigue if they are involved in several working steps, as happened with the experts involved in the interviews and the consistency analysis of the composition-based approach (Section 3.3.3). However, the stakeholders involved in the workshops were highly motivated and genuinely interested in the outcomes. Third, the multiple stakeholder recruitment processes were time- and resource-consuming and may therefore have compromised the meeting of stakeholder selection criteria. Time and resource limitations would be more severe for continental or global scenarios. In such cases, recruitment would need to involve stakeholders from different nations with nonnational expertise, which could be difficult. O'Neill et al.'s (2020) recommendation to have more inclusive SSP development with SSP variants on a global scale and a broader set of boundary conditions for national, regional, and local applications may reach its limits. Fourth, our procedure does not offer a low-effort method for regularly updating existing scenarios, as suggested by O'Neill et al. (2020). Instead, it was primarily designed for a one-time update of the SSPs. Although O'Neill et al. (2020) considered that SSPs were not susceptible to changing conditions in the near term, they claimed that they would probably need to be modified, or new ones added, to account for new types of relevant societal futures. Ten years after the introduction of SSPs in a rapidly changing world, we consider it appropriate to invest time and effort in updating them.

5. Conclusion

We propose a scenario development procedure that complies with the demands for interdisciplinarity, participation, and adequate quality controls to develop national SSPs. It also meets O'Neill et al.'s (2020) following recommendations: keep scenarios up to date, develop SSP variants that are not covered by global SSPs, and include perspectives from different societal groups. We met the first and second recommendations by using the composition-based approach involving 59 experts at the forefront of research, which resulted in five SSPs, of which SSP0-CH and SSP5-CH departed from the main development lines of the Eur-SSPs (and thus global SSPs) and features a recent discussion in the literature (e.g. Kuhnhenn et al., 2018). We met the third recommendation through the derivation-based approach, which incorporated the ideas and perspectives of a wide range of stakeholders.

SSP0-CH and SSP5-CH deserve some further reflection as these scenarios depart from the main development lines of the Eur-SSPs (and thus global SSPs). SSP0-CH reflects the declining and/or negative growth rates of many economies. Modellers (e.g. Keyßer and Lenzen, 2021; Kuhnhenn, 2018; Lauer et al., 2025) demand the development of corresponding scenarios. We recommend that such scenarios be taken into account by scenario developers to better adapt models to possible pathways with declining or negative growth rates and to reflect the negative and positive effects of such scenarios on society. Based on this recommendation, the first modelling by our project partners is currently underway.

SSP5-CH describes a resource-intensive, fossil-fuel-oriented development in Switzerland, which, however, would lead to an unstable society in the second half of the century—unlike in Eur-SSP5 or global SSP5. This development of SSP5-CH resulted from our procedure, which incorporated a broad range of up-to-date knowledge. The experts and stakeholders could not imagine projections for a fossil-fuel-oriented and highly innovative society that would retain old technologies. However, SSP5-CH takes into account the environmental impacts of a fossil fuel-oriented society, probably because the imagination of experts and stakeholders is shaped by the spatial context—in our case, the national context. This led the experts and stakeholders to imagine that society will face multiple crises in the second half of the century whereas in the Eur5-SSP and global SSP5 the fossil fuel-oriented society remains stable. We assume that this spatial reference characterises national and regional SSPs. We recommend that the international community develop methods to establish such spatial references and consider spatial environmental impacts in scenarios.

An advantageous condition for the development of the Swiss SSP was that we could draw on a dense network of experts at the forefront of research and an informed and engaged civil society. This allowed us to develop topical, informed, and consistent versions of the future. Our procedure made use of this wealth of qualified input. To this end, we recommend allocating sufficient time and resources for the participatory process. We are convinced that our proposed, complex, and varied procedure will help others harness the potential of their experts and stakeholders, as well as their knowledge and perspectives, to envision well-founded potential pathways.

CRediT authorship contribution statement

Pascal Tschumi: Writing – original draft. **Irmi Seidl:** Writing – review & editing, Supervision. **Marco Pütz:** Writing – review & editing, Supervision. **Lena Gubler:** Writing – review & editing, Supervision.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.gloenvcha.2025.103105.

Data availability

Data will be made available on request.

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