

Understanding future climate risk - Co-designed applications for local decision making

Literature Review

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Abstract

This literature review examines the evolving challenge of producing climate information that is fit-for-purpose for decision-making, particularly in the context of compound climate events. While advances in climate modelling have improved the technical quality of projections, these outputs often fail to meet the practical needs of decision-makers operating across diverse sectors, scales, and governance contexts. The review synthesises literature across climate science, adaptation planning, and futures thinking to explore how scenario-based approaches—especially those incorporating qualitative and narrative elements—can better align with decision-making processes. Emphasis is placed on the limitations of the traditional approach of providing future climate information to decision-makers, and the value of co-designed, context-sensitive scenarios in addressing these gaps. By integrating systems thinking, stakeholder engagement, and alternative knowledge systems, this review highlights pathways for developing climate information that is not only scientifically credible but also usable, relevant, and responsive to real-world decision contexts.

1. Introduction

To respond effectively to our changing climate, decision-makers must be able to envision plausible futures. Climate scientists have developed science process-based models of the Earth's climate system to simulate how our broad climates systems may evolve under different greenhouse gas concentration scenarios. These outputs are often used to inform future planning and adaptation strategies at the regional and local scale. However, climate model outputs do not align with the scale and practical needs of decision-makers.

Several factors contribute to this disconnect. Currently global climate modelling efforts are limited by compute capability, and run at resolutions that are coarse compared to the needs of users. Further the science has not advanced to the level to capture the 'weather scale' features that are required for local projections, which impacts the ability represent compound or cascading events. These types of events are increasingly relevant in real-world climate risk contexts. Second, the sheer volume and diversity of outputs—across multiple models and emissions scenarios—can overwhelm users. Third, uncertainty and confidence levels attached to model outputs complicate interpretation.

A growing body of research on climate services emphasises the need to make climate information “useful, useable, and used” (Findlater et al., 2021). Yet progress has often focused on improving data rather than improving decisions. Bridging this gap requires approaches that go beyond applying climate model outputs to engage with the social, institutional, and cognitive dimensions of decision-making.

Australia’s [National Climate Risk Assessment \(NCRA\)](#) offers a national evidence base for understanding the country’s exposure to current and future climate risks. However, it remains silent on local-scale insights. By examining the limitations of conventional climate information and exploring co-designed, narrative-based approaches, this review addresses a critical gap—providing decision-relevant, locally contextualised climate risk understanding.

This review synthesises current literature across five key domains:

- Understanding decision maker needs for climate information
- Current approaches to delivering climate information and limitations in projecting compound events and cascading impacts
- Qualitative approaches to understanding climate risk
- Approaches to delivering future scenarios beyond climate contexts
- Developing and co-producing scenarios of compound events

This review addresses a critical challenge in climate adaptation planning: translating complex, uncertain climate data—particularly regarding compound events—into actionable insights for diverse decision-makers. By integrating narrative and qualitative approaches with traditional modelling, this review aims to support more robust, inclusive, and context-sensitive planning.

1.1. Methodology

This literature review adopted a thematic synthesis approach to examine the evolving understanding of climate risk, with a particular focus on compound climate events and their implications for decision-making. The review draws on peer-reviewed journal articles, policy reports, and grey literature published primarily between 2010 and 2025.

Sources were identified through targeted searches in academic databases such as Google Scholar, using keywords including *climate risk*, *compound events*, *climate adaptation*, *qualitative climate information*, and *decision-making*. Additional sources were included based on citation tracking and relevance to emerging themes, and further

sources were included as recommendations from experts. Some papers were sourced and synthesised using Consensus, an AI-powered search engine for research.

Inclusion criteria prioritised literature that addressed the intersection of climate science and decision-making, particularly studies that explored the limitations of quantitative models, the role of qualitative and narrative approaches, climate scenario development, ‘compound event’ climate information, communicating climate change information, decision making sciences, indigenous perspectives, and theories of conceptualising the future. Articles focused solely on physical climate modelling without reference to decision-making or these additional contexts were excluded.

The selected literature was analysed using thematic synthesis, identifying recurring concepts and organizing them into key themes. These themes informed the structure of the review, including sections on compound climate events, the use of qualitative information, and the role of narrative scenarios in climate risk communication and planning.

To assess the effectiveness of climate information in supporting adaptation planning, it is necessary to first examine the diverse and context-specific needs of decision-makers.

2. Understanding Decision-Maker needs for Climate Information

Policymakers face the challenge of making effective decisions within complex, interconnected systems, especially when addressing ‘wicked problems’ like climate change. Over time, climate change decision-making has evolved beyond policy to incorporate individual and organizational perspectives informed by decision science (Orlove, 2020), and decision-making processes—such as motivation, information use, and decision quality (Newell, 2022).

Yet decision makers are not a homogenous group. They operate at different levels of influence in a vertical hierarchy and influence different geographic scales and localities (e.g. national, state/territory/local gov). They also oversee different subject matter, such as water catchments, urban built environments, or socio-economic arenas, which overlap in complex three-dimensional ways.

This diversity in roles, responsibilities, and contexts means that the informational needs of decision makers are equally varied. As Dessai, Lu, and Risbey (2005) argue, the utility of climate information, particularly climate scenarios, depends heavily on the decision-making framework in use, the scale and scope of the decision, and the institutional capacity to interpret and apply such information. For instance, in top-down, scenario-driven approaches such as those aligned with the IPCC framework, decision makers may require detailed, model-based projections to inform long-term strategic planning. Conversely, in bottom-up or human development-oriented approaches, particularly in resource-constrained settings, decision makers often prioritise present-day vulnerabilities and adaptive capacity over speculative future scenarios. In such cases, climate scenarios may be of limited relevance or even absent from the planning process (Dessai et al., 2005).

Further complicating the landscape, Dessai et al. (2009) caution against over-reliance on increasingly precise climate predictions. They argue that the inherent uncertainties in climate modelling—stemming from chaotic system dynamics, knowledge gaps, and unpredictable socio-economic trajectories—limit the feasibility of prediction-based decision making. Instead, they advocate for robust decision-making frameworks that emphasise flexibility and resilience across a wide range of plausible futures. This approach shifts the focus from seeking predictive certainty to identifying strategies that perform well under diverse conditions, thereby aligning more closely with the real-world constraints and uncertainties faced by many decision makers.

Together, these perspectives highlight the importance of tailoring climate information to the specific decision context. Rather than assuming a universal need for more accurate predictions, effective climate adaptation planning requires a nuanced understanding of the decision environment, including the temporal and spatial scales involved, the nature of the risks, and the institutional capacity to act on available information (Dessai et al., 2005; Dessai et al., 2009).

2.1. Translating Climate Information: Knowledge Brokering and Communication

Effective climate decision-making depends not just on the quality of scientific data, but on how well it is communicated and contextualised. Research highlights that climate information must be credible (technically accurate), salient (relevant to users), and legitimate (developed through inclusive, transparent processes) to be actionable (Pacchetti et al., 2024; Meinke et al., 2006).

Traditional science communication often struggles with climate complexity—such as invisible causes, distant impacts, and probabilistic uncertainty—which can hinder public engagement and policy uptake (Moser, 2010; Fischhoff, 2018). To overcome this, knowledge brokering has emerged as a critical practice. Unlike one-way communication, it involves iterative, two-way engagement between scientists and users, helping translate data into decision-relevant insights (Feldman & Ingram, 2009; Kirchhoff et al., 2019).

Fit-for-purpose climate services require co-production with stakeholders, tailoring information to sector-specific needs and embedding it within existing governance systems (Soares et al., 2018). This approach builds trust, improves usability, and supports more confident, context-sensitive adaptation planning. An understanding of user requirements provides a foundation for evaluating the extent to which current climate information systems and modelling approaches meet these needs.

3. Current Approaches to Delivering Climate Information

Traditional climate information—particularly quantitative projections derived from physical climate models—remains a cornerstone of climate science and adaptation planning. These models provide essential insights into future climate conditions, including temperature, precipitation, and extreme events, under various emissions scenarios. Their scientific rigour and global comparability make them indispensable for informing long-term strategies, infrastructure design, and risk assessments. Climate information is traditionally delivered through quantitative projections derived from physical climate models. These outputs are often presented as long-term averages, statistical ranges, or ensemble simulations, reflecting the natural sciences’ emphasis on precision and objectivity (Bercht, 2021; Shepherd, 2021). These projections form the foundation upon which most climate scenarios are built. However, while technically robust, these quantitative approaches often fall short of meeting the practical needs of decision-makers. Understanding their strengths and constraints is therefore critical to developing complementary approaches that enhance decision-making under uncertainty.

3.1. Defining Climate Scenarios

The literature reveals two main interpretations of the term ‘scenario’ (Kelly et al., 2020). The narrow definition, which are, essentially, quantitative climate science scenarios, focusses on physical changes to the climate and their impacts, often using outputs from

GCMs combined with evidence from observed trends and attribution studies. These scenarios are valuable decision-support tools for governments, businesses, and investors, helping them understand quantified risks and opportunities at global to local scales, although uncertainties remain due to emissions, carbon cycle feedbacks, ecological tipping points, and regional modelling challenges.

The broader definition incorporates social, economic, and technological change, recognising their interdependence with climate. This broader approach ensures scenarios are plausible and coherent, and is essential for analysing socio-political uncertainties, such as transition risks, the geopolitical landscape and technological change. Shared socio-economic pathways (SSPs) (IPCC, 2023) are a prominent example of mixed method climate scenarios which include broader socio-economic factors. While SSPs do incorporate this nuanced qualitative information, they are most relevant to the global and national scale, and do not provide insight of the nuanced impact of project climate change on the sub-national or local scale. This leaves a gap in information for local decision-makers. The combination of qualitative science with additional qualitative factors allow exploration of a wide range of plausible futures, accounting for both physical and societal uncertainties.

3.2. Presentation and Interpretation of Climate Data – an Example

A clear example of how climate information is often communicated is in the following example from the IPCC's Sixth Assessment Report (AR6), Working Group 1. This [figure](#) shows the projected frequency of extreme precipitation events under different levels of global warming (1.5°C, 2°C, 3°C, and 4°C), relative to the late 19th-century baseline. Rather than providing a single number, the figure uses box plots to summarise the spread of results from multiple climate models: the central line shows the median, the shaded box covers the central 66% of model results, and the whiskers indicate the 90% range. This presentation style highlights not only the likely outcome but also the degree of uncertainty, which is crucial for decision making under different warming scenarios.

This is but one of various possible examples to illustrate how quantitative climate information is presented. These formats often prioritise scientific consensus over usability. As Weaver et al. (2013) argue, climate models should be used not just as prediction machines, but as tools to explore system behaviours and support robust decision-making.

3.3. Limitations of Quantitative Climate Information

Such quantitative climate data plays a vital role in informing policy and public understanding yet its utility by local decision makers faces challenges.

Uncertainty and model limitations remain central obstacles. Climate projections are typically derived from ensembles of models, each with differing assumptions and structures. Yet, there is no universally accepted method for evaluating or weighting these models, making it difficult to express confidence in specific outcomes (Knutti et al., 2010; Cox et al., 2012). This ambiguity can undermine trust and hinder the uptake of climate information.

Complexity and volume of data further complicate communication. High-resolution outputs and ensemble simulations generate vast amounts of information, which can overwhelm users and obscure actionable insights (Stephens et al., 2012; Overpeck et al., 2011). Decision-makers often struggle to extract relevant meaning from this technical detail, especially when time and capacity are limited.

Interpretation and visualisation present additional difficulties. Probabilistic information and uncertainty ranges are often poorly conveyed, and overly detailed graphics may hinder clarity or mislead non-expert audiences (Stephens et al., 2012; Stein, 2020). The challenge lies not only in presenting data accurately but in doing so in ways that are intuitive and decision-relevant.

An additional issue is relevance. Quantitative data can be misaligned with the temporal, spatial, and sectoral scales of local decisions, limiting its utility in adaptation contexts (Ye et al., 2021; Stephens et al., 2012). For example, long-term averages may not help a local council plan for short-term flood risks or infrastructure stress.

Ethical and epistemic concerns also arise when model-based uncertainties are communicated without acknowledging the normative assumptions embedded in model design (Winsberg, 2012). These assumptions—about emissions trajectories, socio-economic development, or system boundaries—can shape outcomes in ways that are not always transparent to users.

Accessibility and standardisation issues further constrain the dissemination and use of climate data. Despite growing emphasis on FAIR principles (Findable, Accessible, Interoperable, Reusable), many datasets remain difficult to locate, interpret, or integrate across platforms and user communities (Eggleton & Winfield, 2020; Overpeck et al., 2011).

Beyond these technical and epistemic barriers, climate information is often under-utilised due to broader systemic challenges. These include:

- **Physical limitations** in what the climate system allows us to monitor or predict,
- **Technical barriers** such as the timing, format, or availability of data when decisions need to be made,
- **Cognitive factors** like trust, perceived credibility, and user experience,
- **Institutional constraints**, including whether organisations have the procedures, capacity, or access needed to interpret and act on climate data effectively (Hidalgo, 2022).

Together, these limitations underscore the need for more integrative approaches that combine quantitative rigor with qualitative relevance, especially in the face of complex phenomena like compound events. Bridging these gaps will require not only improved modelling and data practices but also deeper engagement with the diverse contexts and capacities of climate decision-makers.

As Weaver et al. (2013) discuss, climate models should not be used solely as prediction machines within “predict-then-act” frameworks. Instead, they should serve as tools to generate scenarios, explore complex system behaviours, and support critical thinking within robust decision processes. Despite the technical robustness of quantitative climate projections, their limitations in addressing localised and compound risks have prompted increased interest in qualitative methods that offer greater contextual relevance.

4. The Role of Qualitative Climate Information in Local Decision-Making

There is growing recognition that qualitative methods can augment traditional climate information by providing context, uncovering hidden concerns, and making climate information more meaningful and actionable for diverse audiences (Bercht 2021, Shepherd 2021). Qualitative approaches, such as narrative scenarios, interviews, and storylines, help reveal contradictions in attitudes and behaviours that quantitative data alone may miss, and they contextualise numerical findings to enhance understanding, relevance and salience (Bercht 2021, Shepherd 2021). Despite this, qualitative information remains underrepresented in climate science publications and policy discussions, often

due to disciplinary biases and the perception that qualitative data is less rigorous (Bercht 2021, Bergh 2004). Some research advocates for integrating qualitative expressions of confidence and narratives alongside quantitative uncertainty to improve communication and decision-making (Padilla 2021, Shepherd 2021). In media coverage and public discourse, both qualitative and quantitative frames are used, but scientific reporting still tends to prioritise quantitative evidence (Antilla 2005).

Qualitative climate information—encompassing local observations, indigenous knowledge, and participatory assessments—plays a vital role in supporting context-specific decision-making, particularly in regions where quantitative data is scarce, uncertain, or not directly applicable (Soares 2018, Singh et al 2018, Briley 2015). Its value is significantly enhanced when it is co-produced with local stakeholders, tailored to specific socio-ecological contexts, and integrated with existing knowledge systems (Vincent 2018, Hill 2020, McClure 2024, Klenk 2017).

Such information, including indigenous indicators and historical analogs, helps translate complex climate data into formats that are more accessible and actionable for local communities. This is especially relevant for local governments, smallholder farmers and other actors engaged in climate-sensitive decision-making (Singh et al., 2018; Kniveton et al., 2015; Ubisi et al., 2023; Wilke & Morton, 2017). In practice, many local decision-making processes rely on daily, weekly, and seasonal qualitative insights to guide immediate actions and decisions, such as disaster preparedness or agricultural planning (Jones et al., 2017).

Participatory approaches—such as knowledge timelines, scenario planning, and co-production workshops—are instrumental in building trust and ensuring that climate information aligns with community priorities and lived experiences (Soares, Daly & Dessai, 2018; Kniveton et al., 2015; Ubisi et al., 2023). These methods can not only democratise the production of climate knowledge but also enhance its relevance and uptake, though as Parsons et al highlight, practitioners must still be careful to not sustain power imbalances (2025).

Integrating scientific climate data with local and indigenous knowledge systems has been shown to improve the effectiveness of adaptation strategies, particularly in rural and resource-constrained settings. Tools such as participatory downscaling and decision-tree analysis further support this integration by translating broad-scale projections into locally meaningful insights (Nidumolu et al., 2020).

4.1. Narrative Scenario Approaches

Narrative climate scenarios are a form of qualitative foresight that describe plausible future developments across climate, society, technology, and policy domains. These scenarios often integrate both qualitative and quantitative elements to explore the complex interactions and uncertainties inherent in climate change (Ansari, 2019; Jack, 2020; Mallampalli, 2016; Baulenas, 2023). Constructed through expert analysis, stakeholder engagement, and, in some cases, numerical modelling, narrative scenarios offer multidimensional perspectives on how climate risks may evolve and interact with socio-economic systems.

As tools for decision support, narrative scenarios translate abstract climate risks into tangible and relatable storylines, making them more accessible to diverse audiences—including policymakers, communities, and businesses (Fløttum, 2017; Jack, 2020; Baulenas, 2023). When co-produced with stakeholders, these scenarios reflect local values, priorities, and contexts, thereby enhancing their relevance, legitimacy, and uptake in adaptation planning and climate services (Mallampalli, 2016; Kraus, 2020).

A key strength of narrative approaches lies in their ability to represent different types of uncertainty and incorporate alternative perspectives that are often excluded from conventional modelling frameworks (Ansari, 2019; Jack, 2020). In practice, narrative scenarios are frequently translated into quantitative assessments to evaluate potential impacts on land use, energy systems, or economic outcomes (Zenios, 2021; Mallampalli, 2016). This hybridisation supports inclusive planning processes and enables more adaptive responses to climate change (Jack, 2020; Baulenas, 2023; Kraus, 2020).

Narrative scenarios are particularly valuable in contexts where compound climate events challenge traditional predictive models. By embedding stakeholder knowledge and systemic thinking, these approaches offer a flexible and context-sensitive framework for exploring plausible futures and informing robust decision-making.

4.2. Event-Based and Impact-Orientated Scenario Planning

Qualitative scenarios can also frame climate information in local climate events and their impacts, which is critical for adaptation decision-making. Unlike traditional projections that emphasise long-term averages or broad regional trends, event-based approaches focus on specific, localised scenarios that reflect the real-world complexity and on-the-ground impacts of climate hazards. A key feature of this approach is the reversed flow of

information—where decision-makers provide contextual insights to climate experts, enabling tailored analyses that enhance relevance and usability.

By translating abstract risks into tangible, actionable insights, event-based information supports timely, context-sensitive decisions and strengthens preparedness. This approach is particularly valuable for diverse stakeholders—governments, businesses, and communities—by fostering a grounded understanding of potential impacts and response strategies (Sillmann et al 2020). For example, local ecological tipping points, which may trigger irreversible changes, are often missed in broad-scale models but can be addressed through event-based assessments, enabling more precise and proactive risk management (Dakos et al 2024).

4.3. Challenges in Applying Qualitative Climate Information

While qualitative information, may help to overcome some of the challenges with quantitative climate information, there remain limitations. Uncertainty and trust can be problematic, as qualitative expressions of confidence are frequently misunderstood or inconsistently interpreted, potentially leading to poor risk judgments (Padilla et al., 2021; Singh et al., 2018). Qualitative information tends to be more effective for short-term decisions, such as seasonal responses, but is rarely used to justify long-term planning or investments due to its perceived subjectivity and lack of precision (Singh et al., 2018; Jones et al., 2017). Communication barriers further limit its impact: technical language, inconsistent terminology, and divergent expectations between scientists and users can hinder comprehension and application (Briley et al., 2015). Moreover, limited stakeholder involvement in the development and validation of qualitative products often results in reduced uptake and relevance (Soares et al., 2018). Institutional and structural barriers—including rigid protocols, access constraints, and weak coordination between researchers and decision-makers—can compound these challenges and restrict the integration of qualitative insights into formal decision-making processes (Hidalgo, 2022).

5. Scenario Development Approaches Beyond Climate Modelling

Climate science is not the only domain that engages with future uncertainty. Disciplines such as strategic foresight, futures thinking, systems thinking, and indigenous knowledges offer valuable conceptual and methodological tools for developing climate scenarios that are more inclusive, adaptive, and context-sensitive.

5.1. Strategic Foresight and Futures Thinking in Climate Planning

Strategic foresight is defined as “a systematic, participatory, future-intelligence-gathering and medium-to-long-term vision-building process aimed at enabling present-day decisions and mobilising joint actions” (European Commission, 2002). It provides structured approaches to scenario development, helping users explore a range of plausible futures and align scenario outputs with specific decision-making needs (Hines & Bishop, 2015).

Futures thinking complements this by emphasising the cognitive and imaginative dimensions of anticipating change. It encourages decision-makers to challenge assumptions, consider emerging risks, and expand the horizon of what is considered possible or desirable (Miller, 2007; Inayatullah, 2008). These approaches support the integration of diverse knowledge systems and help navigate the social, political, and behavioural dimensions of climate uncertainty (Bengston, 2012; Lacroix, 2019).

Useful heuristics such as Muner-Roldan’s (2025) framework distinguish between predictive, anticipatory, and speculative futures. While traditional climate science tends to focus on predictive, trend-based projections, narrative scenarios—especially those developed collaboratively—enable exploration of more anticipatory and speculative possibilities. Similarly, tools like the Cone of Possibilities (Voros, 2003) help visualise the expanding range of plausible futures and encourage preparedness beyond most-likely outcomes.

5.2. Systems Thinking for Integrated Climate Adaptation

Systems thinking offers a critical lens for understanding the interconnected and dynamic nature of climate adaptation. It emphasises feedback loops, interdependencies, and

unintended consequences—elements often overlooked in conventional climate scenarios (Germond-Duret et al., 2023; Blokland, 2019), but important for all decision-making.

Evidence suggests that individuals and institutions with strong systems thinking capacity are more likely to perceive climate risks accurately, endorse effective adaptation policies, and adopt pro-environmental behaviours (Burato et al., 2023; Lezak & Thibodeau, 2016). Systems-based models and decision support tools allow users to simulate trade-offs, explore adaptation pathways, and co-create innovative responses to complex problems (Loucks, 2022; Dissanayake et al., 2024).

Embedding systems thinking into governance structures can help break down institutional silos, align competing interests, and foster transformative change—particularly in cross-sectoral planning contexts such as sustainable land use (Ison & Straw, 2020; Rickards, 2010).

5.3. Indigenous Knowledge and Scenario Development

First Nations and other Indigenous peoples offer vital perspectives on climate futures, grounded in long-standing relationships with land, holistic knowledge systems, and lived experiences of environmental and social disruption. Indigenous worldviews emphasise the interconnectedness of humans, nature, and climate, integrating ecological, cultural, and spiritual dimensions of knowledge and practice (Datta et al., 2025; Cameron et al., 2021; Mazzocchi, 2024).

Climate change is often understood within Indigenous communities not as a standalone issue, but as a continuation of colonial processes—marked by land dispossession, resource extraction, and cultural erosion (Whyte, 2018; Golden et al., 2015). This perspective challenges dominant climate narratives and highlights the need for culturally grounded responses that prioritise continuity, stewardship, and relational ethics.

Calls for Indigenous leadership and self-determination in climate policy reflect broader demands for inclusion, sovereignty, and respect for Indigenous law and governance systems (Etchart, 2017; Bedford et al., 2021). Integrating Indigenous perspectives into scenario development enriches the process by introducing deep-time knowledge and alternative conceptions of resilience and adaptation.

6. Communicating and Co-Producing Qualitative Scenarios for Compound Climate Events

The increasing complexity of climate risks—particularly compound events—has prompted a shift in how climate information is conceptualised, developed, and communicated. Traditional climate science, grounded in physical modelling frameworks established in the 1970s, has made significant advances in simulating climate dynamics. However, these models often fall short in capturing the social, political, and economic dimensions of climate change, which are increasingly recognised as critical sources of uncertainty (Shepherd, 2018; Pacchetti et al., 2024). As such, the most pressing uncertainties in climate adaptation planning now lie not solely within the climate system itself, but in how societies will respond to change.

To address these challenges, a growing body of literature advocates for the integration of qualitative, participatory approaches that complement quantitative modelling. These include narrative scenarios (Jack et al., 2020), storyline methods (Shepherd, 2018), adaptive learning frameworks (Watkiss, 2015; Kim, 2017), and anticipatory governance models (Quay, 2010). Such approaches enable decision-makers to engage with climate information in ways that are more intuitive, context-sensitive, and responsive to local priorities. They also support the exploration of non-linear impacts and cascading effects—features that are difficult to simulate using conventional predictive models but are central to understanding compound events (Zscheischler et al., 2018; Bevacqua et al., 2021).

Central to these alternative approaches is the practice of co-design and co-production. These processes involve iterative, two-way engagement between researchers and stakeholders, ensuring that climate scenarios are not only scientifically credible but also socially legitimate and practically usable (Soares et al., 2018; Gerlak et al., 2023). When local knowledge, community priorities, and lived experiences are embedded into scenario development, the resulting outputs are more likely to be acted upon and sustained over time (Munenzon, 2024; Singh et al., 2021; Kalsnes et al., 2023).

Co-production also plays a vital role in building trust—an essential component of decision-making under uncertainty. Early and consistent stakeholder engagement fosters relationships across sectors and governance levels, enhancing the credibility and longevity of adaptation strategies (Sartorius et al., 2024; Dannevig et al., 2022). Moreover, the integration of diverse knowledge systems—including scientific, local, and Indigenous

perspectives—enriches the scenario development process by introducing alternative conceptions of resilience, adaptation, and risk (Wamsler, 2017; Cameron et al., 2021; Mazzocchi, 2024).

Participatory approaches have the added benefit of promoting equity and environmental justice. By actively involving historically marginalised groups, co-production can help rebalance power dynamics and ensure that adaptation efforts do not reinforce existing vulnerabilities. This is particularly important in the context of compound events, which often magnify systemic inequalities and expose gaps in institutional capacity (Munenzon, 2024; Dannevig et al., 2022).

For co-production to be effective, it must go beyond one-off consultations. Successful initiatives are typically iterative, flexible, and responsive to evolving needs. They involve continuous feedback loops, capacity-building, and the development of shared understanding among participants (Singletary et al., 2022; Nalau & Cobb, 2022). Narrative scenarios have proven especially useful in these settings. By allowing stakeholders to collaboratively explore plausible futures, they create a shared space for dialogue, learning, and strategic foresight. Case studies from Fæhn (2023), Cairns (2013), Baba (2021), Cradock-Henry (2021), Iwaniec (2020), and Mora (2020) demonstrate how narrative approaches can foster deeper engagement and generate locally relevant insights that inform real-world decisions.

Implications for practice – How the co-design narrative approach can best represent compound events

The increasing complexity and interconnectedness of climate risks—particularly compound events—necessitate a shift in how future scenarios are conceptualised, developed, and communicated. Traditional modelling approaches, while scientifically rigorous, often fall short in capturing the cascading impacts and multi-hazard dynamics that characterise compound events. These limitations underscore the need for more adaptive, inclusive, and context-sensitive methods of scenario development.

Co-design and narrative approaches offer a promising pathway for addressing these challenges. By engaging stakeholders throughout the scenario-building process, co-design ensures that climate information reflects local priorities, lived experiences, and

institutional realities. This participatory model fosters trust, enhances relevance, and improves the usability of climate scenarios in decision-making contexts. When applied to compound events, co-design enables the integration of diverse knowledge systems—including scientific, local, and Indigenous perspectives—thereby enriching the understanding of risk and resilience across sectors and scales.

Narrative scenarios, in particular, provide a flexible and intuitive framework for representing complex climate futures. Unlike purely quantitative projections, narrative approaches allow for the exploration of plausible storylines that incorporate uncertainty, social dynamics, and systemic interactions. These scenarios can be tailored to specific decision contexts, making them especially valuable for planning under conditions of deep uncertainty. When co-produced with stakeholders, narrative scenarios become powerful tools for dialogue, learning, and strategic foresight, helping communities and institutions prepare for compound events that are difficult to model but critical to anticipate.

In summary, the co-design of narrative scenarios represents a methodological advance in climate risk communication. It bridges the gap between scientific knowledge and decision-making needs, offering a more holistic and actionable approach to understanding and preparing for compound climate events. As climate risks continue to evolve, embedding these approaches into climate services and adaptation planning will be essential for fostering resilience and equity in a rapidly changing world.

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