I-CISK

HUMAN CENTRED CLIMATE SERVICES

Deliverable D2.8

A guideline for end-user centred co-creation of Climate Services across Europe and beyond

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I-CISK

Innovating Climate services through Integrating Scientific and local Knowledge

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Author(s):	Marthe Wens, Marije Schaafsma
Contributing Authors(s):	Micha Werner, Lucia de Stefano, Megi Gamtkitsulashvili, Ilyas Masih, Sumiran Rastogi, Gyorgyi Bela, Paolo Mazzoli, Schalk Jan van Andel, Debora Dotta Correa, Alexandros Ziogas
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Executive Summary

The I-CISK (Innovating Climate Services through Integrating Scientific and Local Knowledge) project, funded by the European Commission (2020-2025), focused on developing a new generation of human-centred climate services (CS) that are socially and behaviourally informed. By placing end-users at the centre of the design, development, and evaluation, I-CISK aimed to promote climate change adaptation and disaster risk reduction through co-created, viable, accessible, clear, credible, useful, and usable CS.

Central to the project was the development, piloting, and refinement of a co-creation framework for CS (I-CISK Work package 2 Task 2.5). A prototype co-creation framework was devised at the beginning of the project and tailored to the composition and preferences of each LL. It was implemented in seven Living Labs (LLs) located in the Netherlands, Spain, Italy, Hungary, Greece, Georgia, and Lesotho. These LLs served as testbeds for participatory action research. The prototype co-creation phases were tested by Multi-Actor Platforms (MAPs) within the LLs, through iterative and inclusive collaboration between scientists, service providers, and end-users. LL leads were asked to regularly evaluate the product and process and participated in a final focus group discussion for a reflexive monitoring exercise towards the end of the project.

The co-creation process was widely appreciated for fostering mutual learning and trust, and for facilitating the integration of scientific data with local knowledge (LK) and user needs. However, its success varied across LLs. Key enabling factors included transparent communication, inclusivity fostering the integration of diverse climate risk experiences, and flexibility in adapting to new insights. However, challenges such as limited capacity and uneven responsiveness among stakeholders sometimes undermined legitimacy and ownership. Throughout the phases, co-evolution of knowledge regarding both CS product and co-creation process was observed among project partners, CS developers, CS providers, CS intermediaries, and CS consumers (the end-users). The final co-created pre-operational CSs, were generally scored high for usability, accessibility, and clarity. However, credibility, and particularly the effective communication of uncertainties, remained a concern for the CS in several LLs.

Based on this evaluation and other experiences communicated through project deliverables, an updated I-CISK co-creation framework is created and presented in this report. It offers a structured but adaptable roadmap for future CS development and comprises five phases:

- Phase 0: Build common ground and understanding
- Phase A: Co-ideate how CS can support decision-making and manage expectations
- Phase B: Co-develop climate product, bringing together local and global climate data and knowledge
- Phase C: Co-design climate service information system distributing the jointly produced climate information
- Phase D: Co-deliver and co-exploit the co-created pre-operational climate service

These phases are complemented by an iterative evaluation cycle, supporting flexibility and enabling contextual adjustment and refinement.

The final I-CISK co-creation framework supports climate change adaptation and disaster risk reduction decision-making by addressing barriers to the use of climate information and can be used by CS co-creation projects to contribute to the next generation of human-centred CS development.

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Glossary

Acronym	Definition
CCA	Climate Change Adaptation
CS	Climate service(s)
CSIS	Climate service information system
DRR	Disaster risk reduction
FGD	Focus group discussion
I-CISK	Innovating Climate services through Integrating Scientific and local knowledge
LK	Local knowledge
LL(s)	Living Lab(s)
MAP(s)	Multi-actor platform(s) – the collection of actors in the living lab
MEL	Monitoring, learning and evaluation
MS	Milestone – a project milestone as defined in the I-CISK proposal
ToC	Theory of Change
WP	Work Package – a combination of tasks as defined in the I-CISK proposal

1 Introduction

Central to the European Commission funded I-CISK (Innovating Climate services through Integrating Scientific and Local Knowledge) project (2020-2025)[1] was to develop next-generation climate services (CS), following a social and behaviourally informed approach for co-producing CS that meet the climate information needs of citizens, decision makers and stakeholders, at the spatial and temporal scale relevant to them. I-CISK recognized that to achieve behavioural change, the active use of climate information in informing decision-making toward climate change adaptation and mitigation requires that citizens, stakeholders and decision-makers are at the centre of value creation; of the design, production, delivery and evaluation of CS, and that they co-create the value of this CS for society.

A critical starting point for the I-CISK project was to develop a framework for co-creating human-centred CS by co-exploring user needs, incorporating social and behavioural factors and integrating LK with scientific data, tailoring climate information based on the adaptation options. Suhari et al. (2022) note that "the number of conceptual frameworks, methods and practical tools for the joint production of CS are continuously growing. It is a challenge to set up a consistent co-creation approach for a specific research context and being competent about its application as well as its theoretical and methodological underpinnings". Therefore, in I-CISK, we co-produced, piloted, and improved a framework (I-CISK MS10: Wens et al., 2022) on how to set up action research and ensure a holistic participatory process to co-create human-centred CS in and with the users of seven Living Labs (LLs) in diverse climatic and socioeconomic regions in Europe and Africa (Rijnland - Netherlands, Los Pedroches – Andalucia Spain, Italy, Hungary, Crete - Greece, Alazani Basin – Georgia, and Lesotho) (Masih et al., 2022).

This deliverable reports on the development and evaluation of the prototype user-centred co-creation framework, and then presents the final I-CISK framework for co-creating next-generation, human-centred CS. It contains a comprehensive assessment of the prototype co-creation framework developed at the start of the research project and builds upon the research practices and experiences with constructive interactions throughout the I-CISK project. The prototype framework supported a tailored co-creation process and was developed by combining best practices found in different strands of literature, including CS literature and design thinking, and building on relevant frameworks including Information and Communication Technology for Development (ICT4D; Heeks, 2017), and Weather and Climate Services for Africa (WISER; Carter et al., 2019). Several steps in the co-creation process were distinguished, all of which were executed by a diversity of stakeholders (scientists, producers, end-users, decision makers) in the seven I-CISK LLs. As such, the prototype served as a guideline to integrate existing physical and socio-economic datasets, global data sources and existing services (e.g. Copernicus, GEOSS, C3S, ESA), in-situ datasets and innovative new data sources identified during the project.

The updated co-creation framework, presented in this report, scrutinizes the context-specific best practices and varied experiences from the different LLs, based on iterative evaluations and reflection on the co-creation process of LLs and Multi-Actor Platforms (MAPs) members that were established in each of the LLs. The prototype co-creation framework is slightly revised and extended with tested methods and approaches that fit the contexts of our seven LLs best. The aim of the updated co-creation framework for user-centred CS is to serve as a guideline for the co-design and co-development of CS across Europe and beyond.

[1] Https://icisk.eu

1.1 Scope of this report within the context of the I-CISK project

The first of six main objectives of the I-CISK project (I-CISK, 2021) was "to develop a framework for co-producing next-generation, human-centred CS by co-exploring user needs, incorporating social and behavioural factors and integrating LK with scientific data, tailoring climate information based on the adaptation options." Within the I-CISK project, Work Package (WP) 2 was dedicated to the co-development of human-centred CS through setting up and executing a user-centred co-creation framework, including guidelines on how to identify user needs, integrate LK and behavioural factors. Task 2.5, to which this report pertains, included both the development and evaluation of the prototype co-creation framework and the development of a final, piloted guideline for co-creating CS (Fig. 1).

This report thus contains a comprehensive assessment of the prototype developed at the start of the research project. Building upon this evaluation as well as on the research practices and experiences throughout the I-CISK project (especially WP2, but also WP1 where the LLs and MAPs were established, and WP3 that focussed on data integration), improvements are suggested and implemented, resulting in the final I-CISK framework for co-creating next-generation, human-centred CS. It should be noted when interpreting the findings, that at the time of data collection for this evaluative analysis (summer 2025), many of the seven LLs were still refining their CS; this report therefore does not provide an assessment of the final I-CISK CS products. Whilst it is mentioned in the project proposal that Task 2.5 would also provide "guidelines for integrating existing physical and socio-economic datasets, global data sources and existing services", this aspect is described in WP3 Deliverables 3.3 (Pesquer et al., 2024) and 3.5 (Van Andel et al., 2025). The co-creation approach to co-developing the actual CS solutions takes place in WP5 through so-called "Climate Service Task Forces" and is detailed in D5.2 (Bagli et al., 2024).

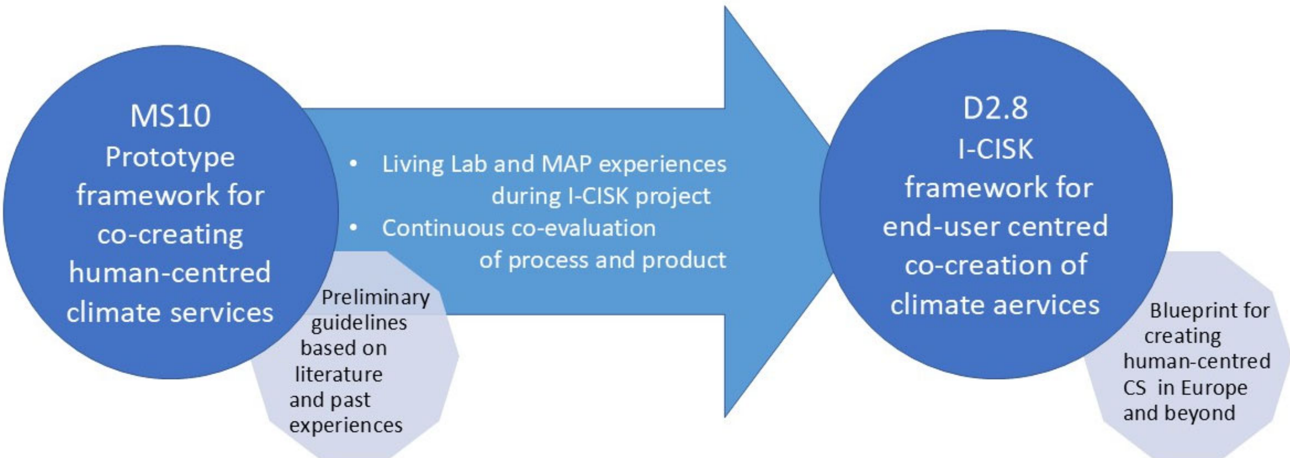


Figure 1: From a prototype to a tested user-centred co-creation framework for climate services

1.2 Reading guide

This deliverable includes an introduction to the concept of co-creation, encompassing the prototype developed in MS10 (Chapter 2), and an elaboration of the methodologies employed to critically evaluate the prototype (Chapter 3). Chapter 4 provides an assessment of the phases of co-creation, while Chapter 5 addresses the evaluation of the associated processes. Chapter 6 includes an evaluation of the pre-operational CS products created in the LLs following the co-creation phases, and Chapter 7 compiles all recommendations for enhancing the prototype framework. Finally, Chapter 8 outlines the revised framework for the co-creation of user-centred CS, and Chapter 9 offers the report's conclusion.

2 I-CISK‘s understanding of co-creation

The interdisciplinary, interactive and iterative process of co-creation has become a standard approach in developing CS, aiming to strengthen societal ownership, legitimacy and long-term sustainability of the CS (Vincent et al., 2018). It is a way to bridge the divide between climate science and decision makers (Buontempo et al., 2014) and increase CS usefulness (context-specific and fit for purpose), usability (easy access and handling), and usage (transfer and upscale) (Chiputwa et al., 2021; Clarkson et al., 2019; Conway & Vincent, 2021). Co-creation can be seen as the deliberate collaboration of science, technology and society, transforming inputs (e.g., data, knowledge, information, ideas) into products and services (Barnet et al., 2021), and influencing how scientists pursue science and how users understand the possibilities and limits of science, with the goal of creating innovative, useful and effective science and products (Bremer et al., 2019; Williams & Jacob, 2021). Co-creation and co-production, co-design or co-generation are often used interchangeably (Allison, 2015; Bremer & Meisch, 2017; Fdez-Arroyabe & Roye, 2017; Máñez Costa et al., 2021; Neukirch, 2014). In this report, and in the I-CISK project, we use the first term.

According to Voorberg et al. (2015), there is a difference between co-creation and co-production, which is manifested in this degree of collaboration. The term co-creation “has been built on the premise that service forms the foundation of value creation through which end users are intensely engaged in every stage of the value creation process” (Voorberg et al., 2015). In co-creation, reciprocity and mutuality are essential while co-production emphasizes a producers-centric view of stakeholder involvement during service production (Voorberg et al., 2015).

Other authors also find nuanced differences between the two terms (Brandsen et al., 2018): Mauser et al. (2013) see co-creation a combination of co-design (problem definition), co-creation (knowledge integration) and dissemination (delivery) (Fdez-Arroyabe & Roye, 2017; Mauser et al., 2013; Suhari et al., 2022; Terblanche, 2014); Larosa & Mysiak (2019) emphasize the importance of co-creation for delivering innovation (rather than only producing it (R.B. Street et al., 2019). Rubio-Martin et al. (2021) see in co-creation the opportunity to create CS using a business model perspective and Chathoth et al. (2013) see co-creation as giving stakeholders an active role, co-creator of value and innovation through continuous engagement; while co-production is more focussed on perceiving stakeholders as a resource to build economic value led by the producers.

Given the user-centred perspective of the I-CISK project, in which the joint production of value for both end users, stakeholders and the project alike are key, this inclusive rather than participative connotation of the co-creation process seemed more suitable. Therefore, in this I-CISK guideline, we choose to use the term co-creation over its synonyms, as the term to describe the collaborative process of co-designing, co-producing, co-evaluating and disseminating to achieve a prototype, user-centred climate service.

Co-creation in I-CISK thus consists of the entire process of joint knowledge and service creation between experts from different disciplines and the economic sectors (Brandsen et al., 2018; Máñez Costa et al., 2021). It includes active involvement of all stakeholders of a product/service at the different phases of the process; starting from problem formulation to mutual quality control of scientific rigor, social robustness and practical relevance of the tangible (CS system) and intangible (improved understanding, capacity) outcomes (Bremer et al., 2019). Stakeholders are considered creative partners, which also means they have to agree on the research outline and methodological approach itself. It is an “inclusive process, with the mutual construction of ‘good science’ not solely determined by the scientific community but also by interactions with internal and external stakeholders and with a wide end-user community” (Howarth et al., 2022).

In the ideal case, a co-creation process will lead to the co-evolution of knowledge and CS: both knowledge and CS are jointly formed step-by-step, and knowledge systems, capacities, practices and institutions change over time through joint and reciprocal learning. The bridging and strengthening of distinct knowledge system results in the generation of new understanding and an improved CS (Chapman & Scott, 2020). This co-evolution dynamic is steered by both by the project scientists and the LL stakeholders.

Different types of stakeholders are thus involved in the co-creation of the CS. “Stakeholders” is used here as a general term encompassing CS producers, CS providers, CS intermediaries, CS end-users and other actors (Wens et al., 2022). Actors are all stakeholders (people/entities) either affecting or being affected by the decisions informed by the CS (or current absence thereof). This includes project team, scientists, practitioners, decision makers, consumers etc. They should play an active role in the technology, institutional and investment readiness of the CS for the market and thus be an active part of the co-creation process. Service providers are public or private actors or institutes who supply data, investment, regulatory context for the CS to be sustained, and operate on (inter)national or local level. Intermediaries can be seen as service purveyors: actors serving as knowledge brokers providing guidance on ways that CS can address problems, bridging the gap between CS providers and end-users (the consumers) and ensuring that business opportunities are adequately communicated. They are critical for reaching the “last mile”.

According to Hirons et al. (2021), potential levels of stakeholder engagement lie on a spectrum between consultative and immersive (or as termed in Bremer et al., 2019, as descriptive and normative) (Fig. 4). On the consultative side, the process is quite fixed: the questions to be addressed and envisioned outputs are established before interaction with all the stakeholders. On the immersive side, the process of co-creation is more fluid: stakeholders are deeply involved in the process, which is established through discussion and agreement (Bremer et al., 2019; Hirons et al., 2021). This aligns more with the goal of the I-CISK project to create human-centred CS, where important stakeholders are at the centre of the design, innovation and implementation of the CS.

Figure 4: Different stakeholder engagement strategies. Source: FutureclimateAfrica project (Co-Production in African Weather and Climate Services, 2019)

2.1 The I-CISK prototype framework

The prototype framework (Fig. 2, Wens et al., 2022) comprised of six iterative phases, from building continuous engagement, to co-delivering pre-operational CS innovation systems that support climate change adaptation (CCA) and disaster risk reduction (DRR). These phases, described in detail in MS10 (Wens et al., 2022), were based on a literature review and inspired by the WISER approach (Carter et al., 2019), guided the I-CISK co-creation processes in the LLs. They were designed to tackle major challenges in human-centred climate change adaptation (Christel et al., 2018):

- **The Information Challenge**: This involves tailoring climate products to end-user needs, including probabilistic data and effective communication through design and visualization. Co-creation steps A to D focused on achieving information-fit and design-fit
- **The Domain Challenge**: This relates to deploying CS in complex user landscapes and emerging markets. Step F emphasized engaging purveyors and producers during dissemination to support uptake and sustainability
- **Co-learning of all actors across the CS value chain**: This refers to the opportunity for co-evolution of CS and knowledge through immersive collaboration between CS producers, providers, purveyors and consumers, between project partners and all other stakeholders.

In the I-CISK project, this framework was applied in a context-sensitive manner involving various actors across the CS value chain in MAPs (Masih et al., 2022). The I-CISK Deliverable 1.3 presents a critical, end-of-project reflection on the contributions of these MAPs to the I-CISK project, and in particular the co-creation processes in the seven LLs (Masih et al., 2025). The other phases of the prototype framework, taking place within the context of the LLs as operationalised in WP1, were designed and co-executed in other tasks in I-CISK WP2 as well as WP 3 (focused on integrating LK to transform scientific data), WP4 (assessing the human-climate feedbacks at different spatial-temporal scales), and WP5 (CS implementation and business development). The full I-CISK PERT diagram can be found in I-CISK (2021).

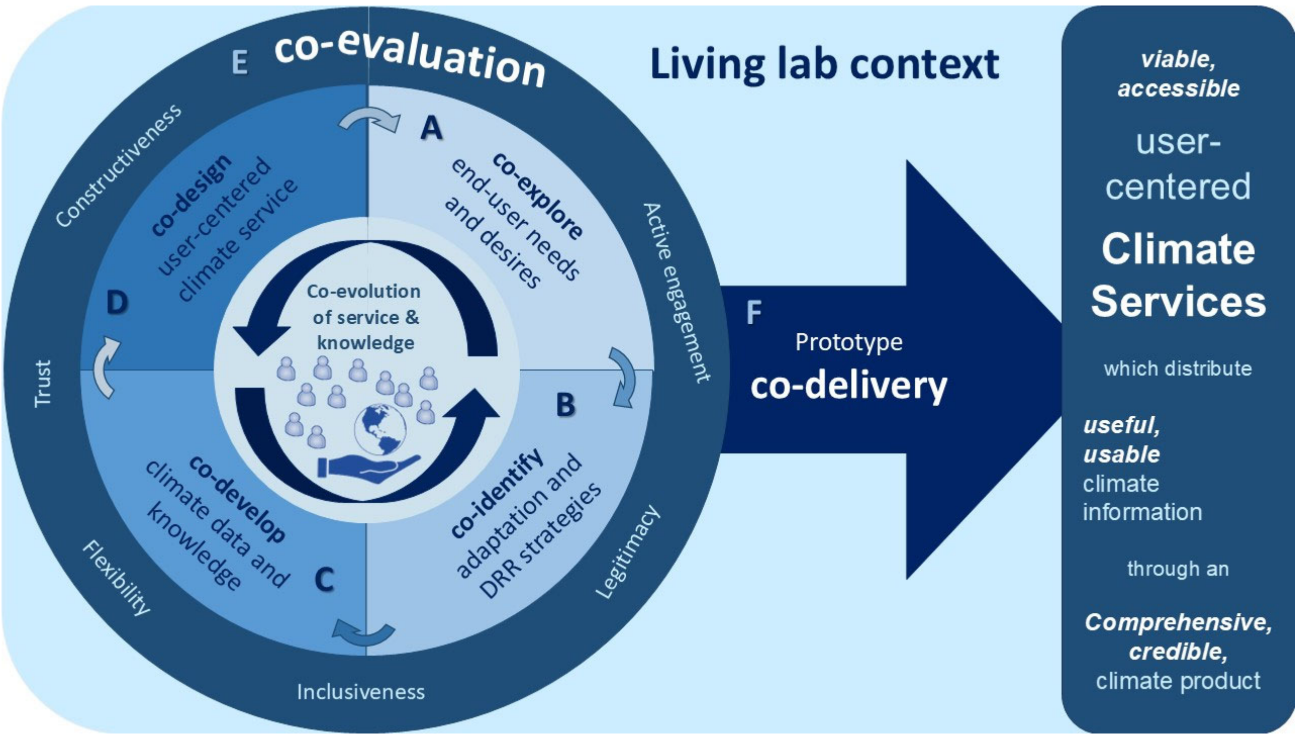


Figure 2: The protype I-CISK co-creation framework. (Source: I-CISK MS10, Wens et al., 2022)

3 Method used in this deliverable

3.1 Data collection methods for the evaluation

Throughout the project and thus during in the piloting of the prototype co-creation framework, **iterative monitoring surveys** were filled in by all the LL leads **after each co-creation phase**, collecting best practices, challenges encountered and tips regarding the co-creation phase. The surveys collected information on the methods, tools and techniques used in each step and assessed for each phase whether the LL leads believed that the main 'enablers' (i.e. requirements and tips to make a step a success) were applied. The survey encouraged reflection on whether the 'key questions' for completion of every co-creation step could be answered based on the interactions with relevant stakeholders. A total of four surveys were completed by at least seven respondents, with representation of all LLs.

In the last quarter of the project, a **reflexive questionnaire** using specific evaluation criteria **to assess the success of the co-created CS** (product, Ch. 3.3) **and the co-creation process** (practices, principles, Ch. 3.4), was distributed among the LLs. The questionnaire was developed in collaboration with WP1, evaluating the role of the LLs and their MAPs, and consisted of a set of over 50 questions. It was completed in the summer of 2025 by 11 members of the LLs (at least one member from each LL).

At the end of the project, a **reflexive focus group discussion** (FGD) was held, facilitated by a project member that was not part of any of the case studies nor closely involved in developing methods for the WPs, with six out of seven LL leads (LL lead Lesotho was contacted individually afterwards). This discussion focused mainly on validating the interpretations of the iterative monitoring survey results, and on perception of the LL leads **on the co-evolution of knowledge and CS** throughout the project. The notes reflecting the key results of the discussion were shared with the participants to check for accurate representation of the shared experiences.

Through this co-evaluation, practical experiences of regarding the co-creation of CS were obtained. They, together with the phase-specific surveys and with project deliverables linked to tasks that fall within each co-creation phase, informed ng suggestions for the final co-creation framework.

3.2 Ongoing developments in the Living Labs

At the time of data collection for this evaluative analysis (summer 2025), many of the seven LLs were still refining their CS through usability testing (LL Hungary) and user evaluations (LL Rijnland). Accuracy and reliability testing was also still ongoing. LL Italy was working on replicating the CS in other regions, while LL Hungary was planning a follow-up project to enhance comprehensiveness.

3.3 Product evaluation criteria

The criteria below (Fig. 3) were used to evaluate the final prototype framework of the project, as established in I-CISK MS10 (Wens et al., 2022). The criteria were compiled based on a review of several existing co-creation frameworks, tested in applied in CS projects across the world: Barnet et al. (2021); Buontempo et al. (2014); Carr and Onzere (2018); Christel et al. (2018); Lemos et al. (2012); SENAMHI & MeteoSwiss (2018); Vincent et al. (2020). Together, these criteria determine the effectiveness of the CS, i.e., the extent to which the CS can produce the desired information. In the evaluation, each of these six criteria was assessed using supporting indicators, which are put in bold in the following descriptions of the criteria:

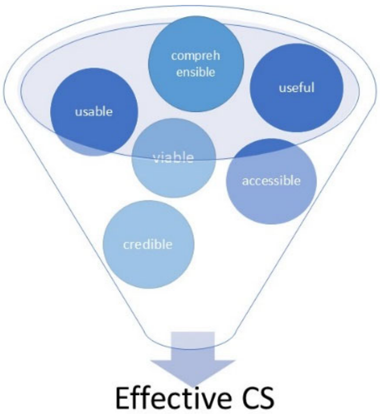


Figure 3: Product criteria for successful co-creation (I-CISK MS10)

● *Usefulness* - CS should account for the heterogeneity in content needs and decision framings over time and among different end-users to be effective. Climate information to decision making bodies or publics (salience) and applicable to the geographical area, or sector, which can be obtained by including local expertise and data on climate variability, adaptation and risk reduction into the climate product. CS should match the timing and spatial scale of the decisions to be supported. The CS should have a (perceived) information fit, i.e., be purposeful to the decision.

● *Accessibility* - The communication mode of the CS should align with the end-user preferences regarding media and channels used, which should be open and inclusive. Moreover, it should be affordable for all, especially where equity considerations are subscribed to.

● *Viability* - CS should be economically and institutionally efficient to be sustainable in the long term.

● *Clarity* - The climate information should be transformed into an understandable, comprehensive product aligned with users' understanding and translated and visualized to support efficient use.

● *Credibility* - Climate information should be authoritative, believable, and trusted. This means in needs to be accurate and reliable, including clear communication about uncertainties and limitations. Credibility can be strengthened by building on both global and local data, on traditional scientific information and more informal or local knowledge, while building the CS. Moreover, credibility stems from jointly validating the CS product (van den Homberg et al., 2024)

● *Usability* - CS are usable when they are designed in a way that considers the socio-economic conditions of the wide variety of users. Thus, CS should be built based on existing local experience and requirements, grounded in understanding of the local (political) context (van den Homberg et al., 2024). CS should also be scalable and be delivered timely; and must be designed in a manner sensitive to existing decision-making logics of those users (mediate goals and interests).

3.4 Process evaluation criteria

The criteria below (Fig. 4) build on several existing co-creation frameworks and their evaluative approaches (Adams et al., 2015; Christel et al., 2018; Hegger et al., 2012; Hegger & Dieperink, 2014; Hirons et al., 2021; Hof et al., 2018; Howarth et al., 2022; Lemos et al., 2012; Neset et al., 2021; Porter & Dessai, 2017; Reinecke, 2015; Steynor et al., 2020; Suhari et al., 2022; Vincent et al., 2018, 2020). The WISER framework (Carter et al., 2017) formed a particularly important point of departure.

Figure 4: Process criteria for effective Climate Services (I-CISK MS10)

●*Active engagement (requires capacity, accountability)* - Active involvement in co-creation means that stakeholders go beyond a role as (passive) recipients of research knowledge and play an active role in commissioning, overseeing and assessing research (two-way interaction). This requires capacity of all stakeholders: scientists and practitioners who participate in co-creation should have time, money, support, etc. to actively participate, and to deliver on the roles and responsibilities that they have taken on. Together, all stakeholders are accountable for the co-creation process. Stakeholders can hold each other accountable for executing the different steps conforming to the principles below and for the products they deliver.

● *Constructive interaction, coordination, direction (requires relevance)* - Collaboration is solutions-focussed and decision-driven, objective and outcome led, with clearly identified roles and responsibilities. Discussions happen targeted and iteratively (where reflexivity is important). Engagement therein should be relevant for all stakeholders: it should be tailored to the context, recognise interests of participants; addressing their needs and expectations and ensuring value added for all involved. It needs to be clear that the process works towards a jointly agreed upon product which has value-added for all involved, meets user needs and produces information of relevance for decisions. Therefore, clear goals regarding the process and product should be set and stakeholders should be committed to this shared end-goal of co-creating user-centred CS.

●*Flexibility (requires openness and adaptability)* - Flexibility of the co-creation process is required because “as a result of continuous knowledge exchange and monitoring, evaluation and learning (MEL), there may be a need to refine product and process”, the integration of multiple perspectives. Moreover, during the first Iterations, there will be many unknowns and uncertainties, and openness to testing and experimentation is required to better understand what is needed for effective CS. Both top-down and bottom-up approaches should be applied. As a result of continuous knowledge exchange and MEL between the different stakeholders, there may be a need to refine both the product and the process. This requires an agile process, adaptability of the product, and responsiveness to feedback of all stakeholders. The process should facilitate collaborative learning and allow for the inclusion of new stakeholders and perspectives.

● *Inclusiveness (requires fairness, equitability)* - I-CISK focuses on recognising and including non-scientific knowledge from the start of the co-creation journey. Thus, the process (mode, method, intensity, timing) should be built upon inclusion of a heterogeneous (age, gender, regional background, educational background, experience with CS, vulnerability) set of users, producers, policy makers and scientists, embracing diversity. The process should be jointly owned by these stakeholders and be customized to stakeholders with different needs, experiences, perspectives and “knowledge systems”; being aware of stakeholders’ differentiated demands and contextual circumstances. The project should ensure fair representation of these stakeholders throughout the process, and their partnership in the process of producing a CS. There should be space for multiple stakeholders to share expertise and challenge each other's views and contributions through negotiations, so aiming for an equitable distribution of power and influence between different stakeholders is critical. This requires logistics, including project communication, to happen in an accessible way and through equitable negotiation and compromises.

Given the emphasis in the transdisciplinary co-creation processes of I-CISK, which aims to bring local and scientific knowledge together, it is important for I-CISK researchers to be aware of epistemological approaches and reflect on the role of academic science. It involves changing each other's perspectives through negotiations and dialogue. When scientists and users try to deliberately co-produce knowledge, they can have very different, if not irreconcilable, ideas about what constitutes credible, relevant, and usable science, which hampers dialogues and real inclusiveness.

●*Trust (requires transparency and respect) -* The process should ensure that all stakeholders are involved in all parts of the co-creation process, and can understand, share and contribute to details of the process and the outcomes. This means that information is open and shared (when desirable, e.g. sensitive information or Intellectual Property (IP) protected data are excluded from this sharing), and that decisions are clearly explained to parties involved. A common ground (shared understanding) regarding languages and terminologies should be created. Moreover, the process should be respectful towards participants' divergent values and beliefs, unbiased in its conduct, and fair in its treatment of opposing views and interests. This way, trust can be built.

● *Legitimacy (required fairness) -* The core stakeholders and the final CS should also be seen as legitimate by the end-users, based on their integrity, their performance over time, persistence and effectiveness. For example, knowledge production may be seen as fairer if it takes place independent from political or commercial interests while appropriately considering the values, concerns, and perspectives of the different actors. This criterion also involves whether the process is seen as legitimate, where the core actors have a clear mandate and are committed to delivering a valuable product, and different stakeholder groups feel that their values and interests are represented, making the end-product acceptable.

4 Evaluation of the co-creation steps

In this section, we evaluate the different steps (phase 0 to phase E) as defined in the I-CISK prototype co-creation framework (Wens et al., 2022), focusing on the process as it evolved within the LLs and the overall I-CISK project. It also presents the evaluation of the co-evolution of knowledge and CS product.

4.1 Phase 0 – Building continuous engagement in the Living Labs

Prototype framework description of phase 0 (MS10, Wens et al., 2022)

In the initiation phase, different LLs covering a range of relevant sectors and regions are assembled, and the engagement of a variety of end-users in these LLs is identified. This is a collaborative effort supported by snowballing to reach a diverse group of stakeholders. Once a group of engaged stakeholders has been established in a MAP, a roadmap for the process should be established, with a set of envisioned activities, outputs and goals. Common definitions must be agreed upon. Moreover, roles and responsibilities should be shared, and a point of contact should be designated. In I-CISK, LLs with their MAPs form the foundation of successful co-creation. This step focuses on **empathy** and trust building: who are potential end-users; what is important to them? It cements the relationships and understanding between actors and creates a space where jointly defined issues can emerge.

In this phase, the LLs and their MAPs were established, either from scratch or based on existing networks, and initial meetings with the MAP were held to gain insight into the decision-making context, primarily through dialogues and small-scale meetings. On average, eight meetings were devoted to this phase. Most LLs reported successfully completing the inception phase (Fig. 5); they reported successfully clarifying decision-making processes and establishing agreed-upon communication channels. This phase was concluded for all LLs by developing a draft roadmap (with a tailored action plan and contact points) for implementing the co-creation framework (Werner et al., 2022). However, contextual changes in LLs Alazani Basin (Georgia) and Los Pedroches (Andalucia, Spain) hindered follow-up activities. These changes affected both citizen-level translation and regional integration of CS in the LL Alazani Basin and requiring concerted collaborative efforts with MAP members to ensure the long-term sustainability of the CS in LL Los Pedroches.

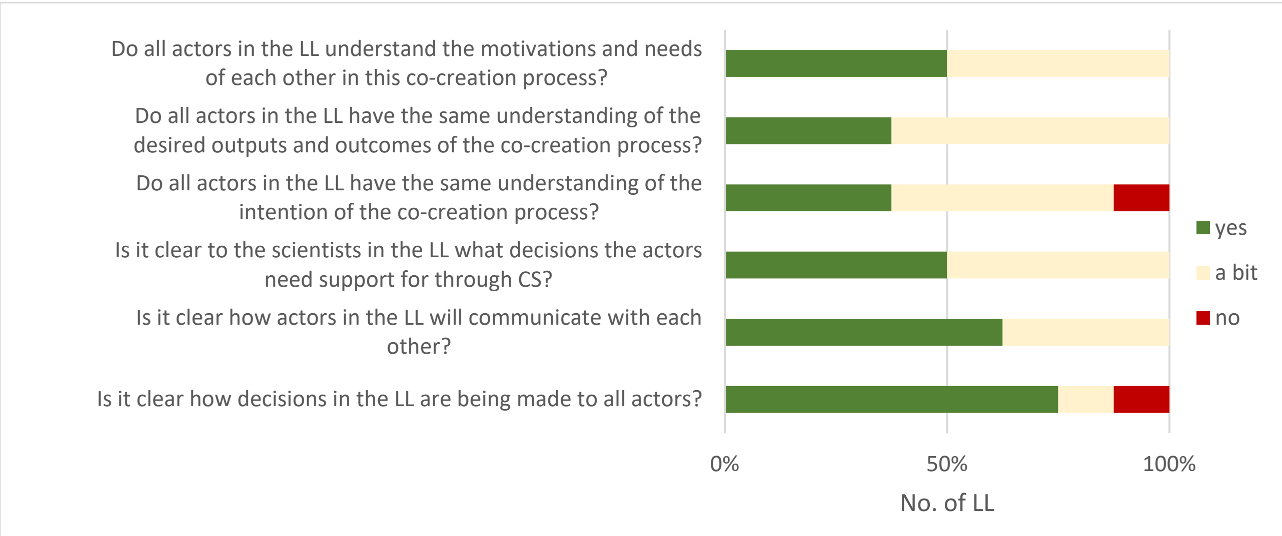


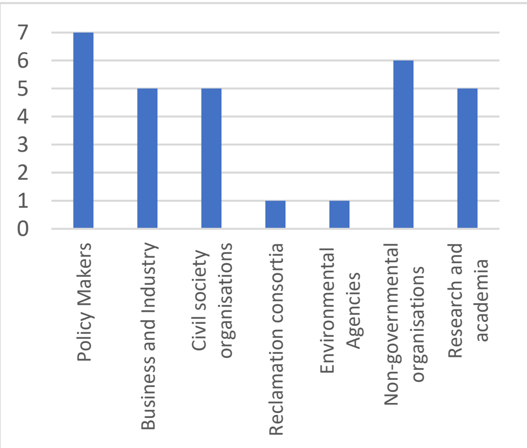
Figure 5: Perception of successful completion of the initiation phase (own survey)

Enablers and methods used

To promote *inclusivity*, as a factor enabling successful co-creation, LLs invested time in identifying key stakeholders through stakeholder mapping and literature research (Fig. 7), resulting in a diverse range of stakeholder groups involved (Fig. 6). Ensuring that all stakeholders were directly or indirectly involved was achieved within the first year of the project (except in one LL that was still being established at the time of reporting). LL leads reported including a diversity of voices regarding gender, sectors, and hierarchy, although in some MAPs (notably Rijnland and Lesotho), gender balance could not be achieved (Ch 6.4).

To foster *constructive interaction*, coordination, and direction, the LLs also made significant efforts to manage expectations (e.g., regarding the number of CS to be developed). The evaluation revealed that many LLs followed an iterative process, first meeting individually with stakeholders to establish common ground, and then holding general meetings with stakeholders to discuss shared goals and foster mutual understanding of the challenges they faced (Fig. 7). Both approaches contributed to understanding the demand for novel CS in the LLs and demonstrated a clear interest among stakeholders to participate. It also helped in gaining insight into competing priorities and the broader decision-making context.

Understanding and agreement on the outcomes of a co-creation process was essential for transparent communication with stakeholders and for adequately managing expectations, which in turn contributes to *building trust*. The communication methods used consisted of balanced involvement, giving everyone a voice, and providing clarity about the actions taken. A mailing list and periodic informative emails were mentioned as a functional horizontal communication channel, and a Miro board was considered an effective way to summarize expectations and desired outcomes in LL Lesotho. To foster understanding of each other's needs and motivations, LL Rijnland successfully implemented a user story writing workshop with mixed groups of stakeholders.



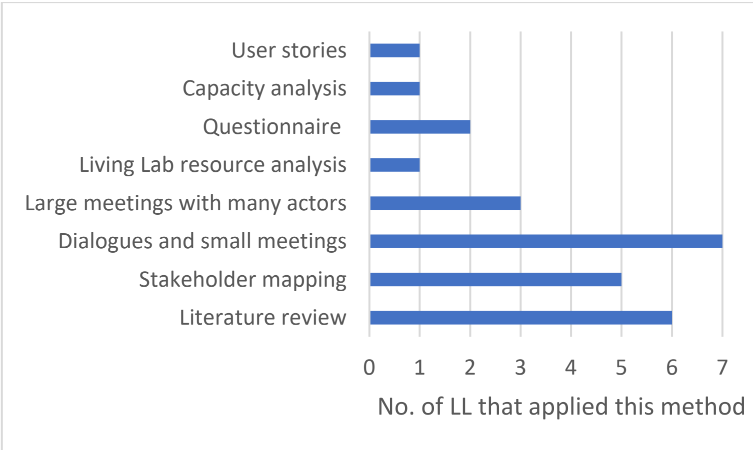


Figure 6 (left): Stakeholder groups included in the MAP
Figure 7 (right): Frequency of methods used in phase 0 (own survey)

To build *trust* and promote transparency, efforts were also made to translate and simplify terminology (for example, in the LLs Hungary and Alazani Basin, where the word CS does not exist in the local languages). Time (at least six months of ongoing dialogues) and resources were key factors in the success of this. At the same time, however, it was observed that in most LLs, complete mutual understanding between all MAP partners had not yet been achieved before moving to the next step of the co-creation phase, and that creating a common ground was an ongoing process (Fig. 8).

Regarding *active engagement*, the evaluation suggests that more attention should have been paid to the capacities of actors and their limited resources (Fig. 8: only in half of the MAPs was the available capacity assessed positively, and no LL conducted a full resource analysis). Time and resources remained a constraint, and it was important to acknowledge that experts are busy and have to balance participation in LL MAP meetings with other work, and that there is diversity among actors and therefore diversity in capacity and resources (some have resources available and are more reactive and flexible). A suggestion for future projects would be to develop a table with information on end-users, producers, intermediaries, final end-users and their role in adaptation decision-making processes, as well as the resources of each of these actors. This could be a starting point for a discussion about who should be involved in the MAP and when (and what) each MAP member could contribute during the co-creation process. Such an overview of capacities and resources can be used for accountability in subsequent steps of the process.

Outcomes

Evaluating the whole inception phase, the results show that the stakeholders involved in the LLs were not yet familiar with co-creation processes at the end of the phase. Figure 8 shows that in most MAPs, stakeholders still did not fully understand the purpose of co-creation, and that this understanding was not achieved, particularly in LL Alazani Basin. There was also some uncertainty among the LL stakeholders regarding the desired outputs and results of the co-creation process, partly due to a further lack of clarity about each other's needs. This emphasized the importance of focusing on direction in subsequent phases to ensure continued active involvement.

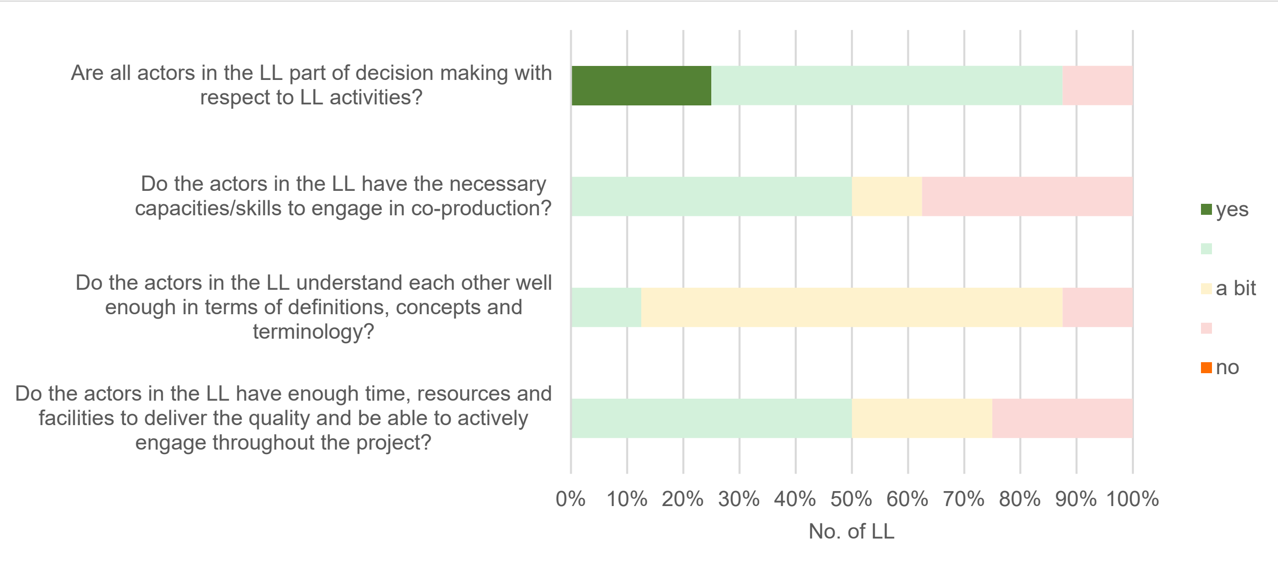


Figure 8: Perception of achieving the enablers in the initiation phase (own survey)

4.2 Phase A - Co-explore climate information needs and climate service desires

Prototype framework description of phase A (Source: MS10, Wens et al., 2022)

This step aims to **define** the user needs through identifying gaps in climate information to support decisions and barriers to using existing CS. In the co-exploration phase, a set of data and information needs, including CS-related sources, formats and modes of dissemination that are relevant for the local context are collected. This is done to match user requirements with technical possibilities and make decisions on the within-scope and out-of-scope needs. To highlight the interplay between new knowledge added by the CS and existing user knowledge, it is necessary to conduct a detailed context mapping, needs assessment and an evaluation of the existing available products together with all stakeholders. This is an iterative, interactive step, as needs can alter because of the co-creation process itself. This iterative nature makes it possible to change objectives and subsequent aligning expectations throughout the process

In this step, all LLs prepared detailed needs and priority assessments through context-specific iterative processes. Seven to ten different types of meetings were held with MAP members per LL to assess the state of knowledge, strengths, and weaknesses of available CS, as well as the context in which they are being implemented. A good description of what end-users currently do and how they do it was part of this phase and aided in this process. This iterative process was incorporated into the I-CISK project in task 2.1 and synthesized end-user desires regarding climate information, CCA and DRR options, and resilience (elaborated in Egan et al., 2025, and Baugh al., 2025).

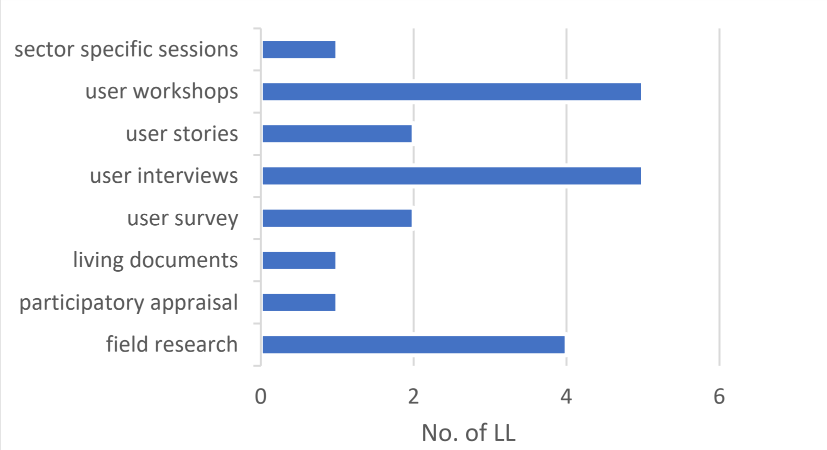
Enablers and methods used

This phase required *active engagement* and took approximately seven to ten collective and bi-lateral meetings in each LL. In one LL, this phase lasted about a year, which some MAP members considered quite long. However, this time also allowed the LLs to ensure that all voices were heard, even in the presence of more involved, dominant stakeholders, and to cautiously go beyond conventional practice. To further support *inclusiveness*, many LL meetings were held with all MAP members. However, in two LLs, collaboration took only place with actors who were the intended end-users.

Supporting *trust*, all but one LL reported that meetings had an open agenda, which facilitated the creation of mutual understanding and awareness. Considerable effort was made to make the materials accessible (in understandable local language) and to collaboratively develop communication materials, such as fact sheets, to facilitate this phase, especially where MAP members lacked technical expertise. Interactive tools such as Miro boards and other online platforms were used to support collaboration and *transparency* throughout the process. Communication efforts, including a webpage and Facebook campaigns, were also implemented to encourage broader engagement.

To promote mutual learning among diverse stakeholder groups, including scientists, several well-considered approaches were employed (Fig. 9): interactive formats such as plenary sessions, workshops with mixed sectoral breakout groups, and open online forums where stakeholders could exchange views on needs, priorities, and intended deliverables. One LL asked end-users to give short presentations on their needs, presenting a specific set of questions and answers. These discussions allowed for the necessary input and priorities of diverse stakeholders to be further described in their own words.

Moreover, most MAPs used user-narratives and interviews to map information needs, detailing variables, time, and spatial scale and resolution. This helped make these needs highly specific. In the I-CISK project, LLs were trained in creating user narratives by one of the project partners during a general meeting and through online training sessions. Field research was also frequently conducted, often to gain insight into the extreme weather challenges faced by the LLs.



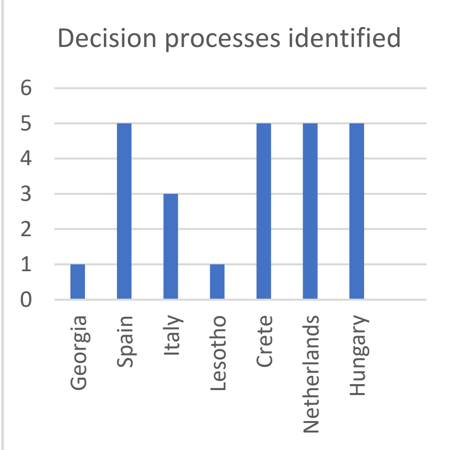


Figure 9: Frequency of methods used in phase A (own survey) (left)
Figure 10: Decision processes that require tailored climate information identified in each MAP (own survey) (right)

Outcomes

On average, more than three decision-making processes requiring tailored climate information were identified in each LL (Fig. 10). These identified needs included a water runoff forecasting system, medium- and long-term climate forecasts, and the relationship between phenology and climate. In two of the seven LLs, the needs of the various end-users were not consistent, resulting in multiple use cases. Some LLs reported that it was difficult for MAP members to articulate their needs. A good description of what end-users currently do and how they do it (e.g., through decision timelines) facilitated a deeper understanding of desires and preferences.

In the evaluation survey, most LLs indicated that discussions were conducted in an understandable manner (Fig. 11). Ensuring active involvement worked well in half of the MAPs. However, at the end of this phase, differences across LLs could be observed in terms of their ability to define goals. Some LLs already had a prototype CS that could be used as a starting point or were able to define concrete objectives. Other LLs started the I-CISK project with abstract goals, and at the end of this phase, the intended CS remained too vague. This result can in part be attributed to the approach followed in the I-CISK project, where the emphasis in this step was on identifying and articulating needs without having a specific CS in mind. This approach aimed to avoid specifying CS options at this stage, to prevent CS developers from rushing into proposing CS solutions to end-users without carefully listening to the needs and decision-making processes that required CS support.

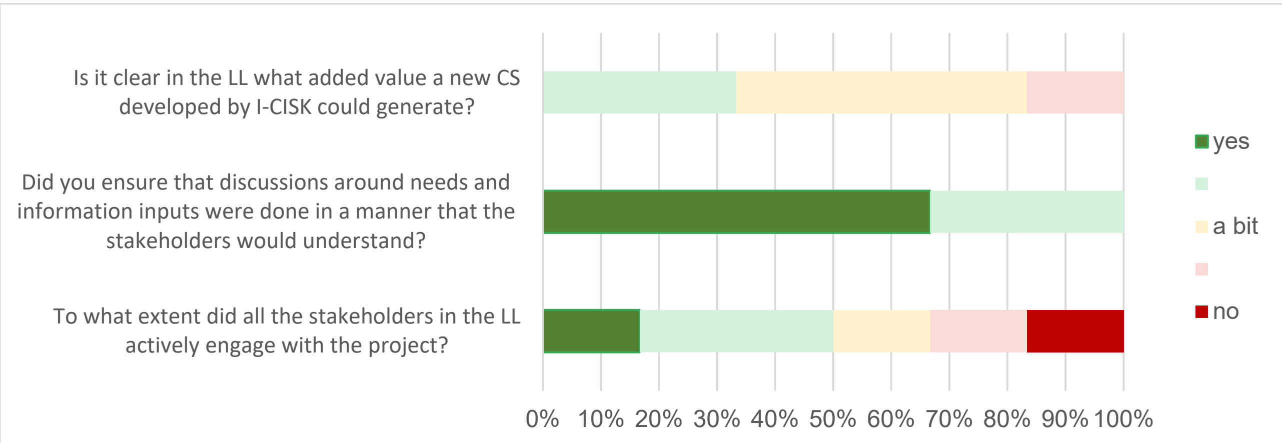


Figure 11: Self-evaluation of phase A activities (own survey)

4.3 Phase B - Co-identify adaptation pathways and disaster risk reduction strategies to be supported by the CS

Prototype framework description of phase A (MS10, Wens et al., 2022)

After the context-specific climate challenges have been identified and building further on the gap analysis of step A, this step provides an opportunity for stakeholders to **ideate.** Collective brainstorming should result in a multitude of decisions (on policies, actions, and measures) that can be supported by the CS. In the co-identification phase, existing plans for CCA and DRR and potential new strategies or specific measures that can benefit from decision-support through CS, are mapped out. In this phase, these adaptation and risk reduction interventions are assessed, to prioritize and rank them. This is critical to ensure that the final CS supports climate decisions relevant to user objectives. In addition, it is important to establish the time scales of these adaptation or risk reduction objectives and to develop approaches that help achieve these objectives, tailored to the needs of the stakeholders. This step involves collaborative knowledge exchanges with a variety of stakeholders to include local experiences, perceptions and concerns regarding climate and risk management decisions. Importantly, as part of this step, requests regarding timing of information provision, the type of data and the level of spatial and temporal aggregation must be identified.

To map the mitigation and adaptation measures, plans, policies, and strategies to be supported by the I-CISK CS, adaptation pathways were jointly defined within the LLs using a variety of methods (Hernández-Mora et al., 2023; De Stefano et al., 2024). It was recognized by multiple LLs, e.g., in LL Italy, that translating the CS into more practical decisions was also a topic in previous and subsequent phases. This ensured the relevance and applicability of the CS to be developed within the local context.

Enablers and methods used

Involving local expertise in the process provided greater insight into user preferences for CCA and DRR to be supported by the CS and helped identify additional needs of various stakeholders. However, end-users were not always willing to answer questions about specific plans (making this a time-consuming process). By emphasizing understanding institutional mandates and responsibilities (making it clear who is responsible for what), more targeted and *active engagement* was possible and facilitated.

Moreover, MAP participants were open to the *flexible* aspects of phase B. The iterative approach allowed the co-creation framework to evolve in response to new insights, ensuring strategies remain relevant as circumstances change, fostering *constructive interaction*. However, this phase showed challenges with respect to *transparency*, as most LLs reported that not all materials were available in non-technical language (Fig. 14).

While literature research was primarily used to review local adaptation studies and map relevant policies and frameworks, this identification phase was informed by both scientific data and LK (Fig. 12). Impact studies, combined with their professional mandates, enabled some stakeholders to easily identify adaptation needs and plans, while for others, further development was required in LL Crete. In some LLs, the concepts of DRR and CCA were insufficiently explored in academic research (E.g. LL Alazani-Lori), making the inclusion of LK crucial to validate climate information at a larger scale. In such cases, a larger data collection effort, including iterations between interviews, field visits, FGD and workshops provided a wealth of information regarding CCA and DRR measures adopted.

Through individual user interviews (Fig. 12) with each stakeholder, adaptation goals, plans, and strategies were established, which were used to validate data from the literature and emerged from both individual (bilateral) and collective stakeholder interactions. Interviews were primarily used to gather detailed, individual perspectives and gain a better understanding of specific adaptation options, while FGD were used to explore decision-making processes and collaboratively characterize adaptation pathways, comparing perspectives.

Workshops were used to introduce tools and validate previous findings, but also (like FGD and bilateral meetings) to verify previous findings and refine interpretations.

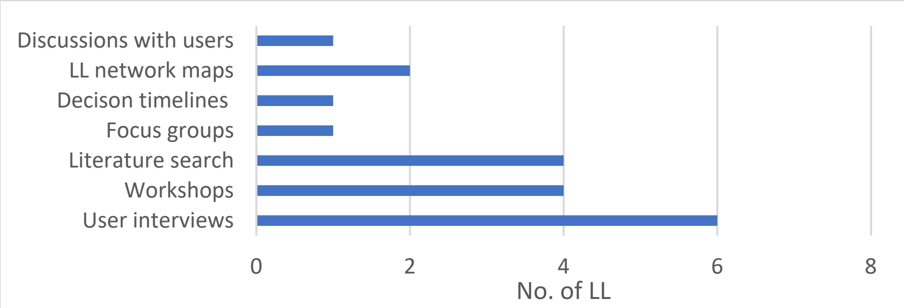


Figure 12: Frequency of methods used in phase B (own survey)

Outcomes

In all LLs, the phase concluded successfully with the identification of sector- and context-specific adaptation pathways. On average, six different adaptation options were discussed in each LL (Fig. 13), sometimes categorized into overarching clusters by sector or timeframe. Sectors covered included the water sector itself (with water pricing, desalinisation and maintenance plans), agriculture (with crop choices, livestock and feed management, irrigation plans), transport (with heat and de-icing management plans), and tourism (with water (re-)use and coastal protection plans to be supported by prototype CS). Overall, these pathways are judged to be sector-specific, reflecting local and/or sectoral visions, and tailored to the context-specific challenges and risks (Fig. 14)

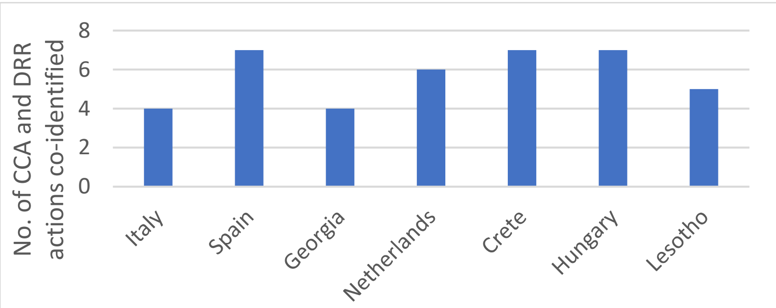


Figure 13: Climate adaptation options and disaster risk reduction actions co-identified in each LL (own survey)

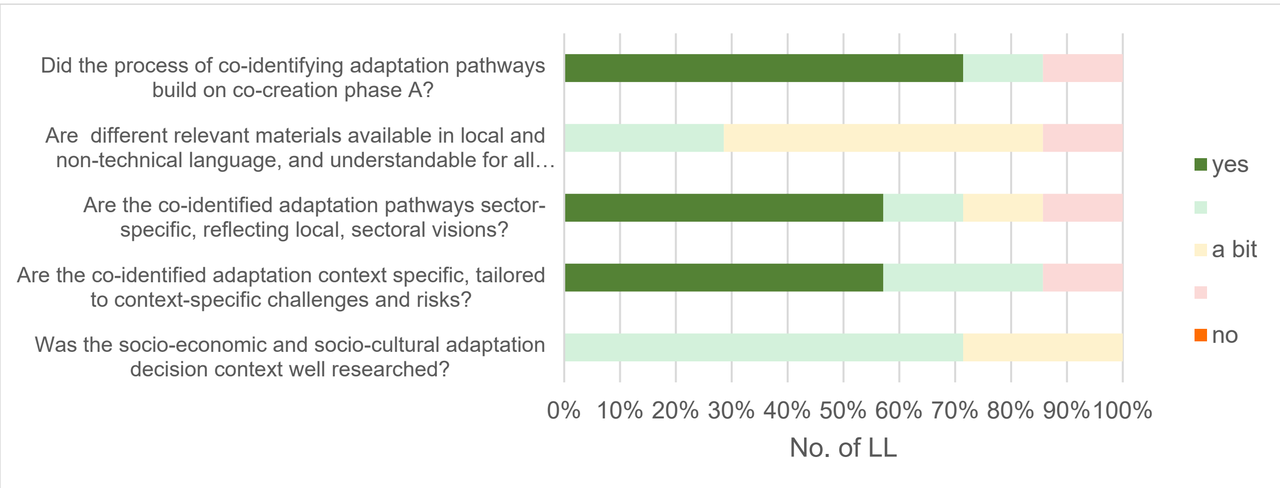


Figure 14: Perception of achieving the enablers in phase B (own survey)

4.4 Phase C - Co-develop climate product containing tailored local and state-of-the-art regional climate data and knowledge

Prototype framework description (MS10, Wens et al., 2022)

After the context-specific climate challenges have been and building further on the strategies to be supported of step B, this step too allows stakeholders to **ideate**. Collective brainstorming should result in a multitude of climatic parameters, thresholds, and climate knowledge, to be integrated into the climate product. In the co-development phase, interests (strategies to be supported) are translated into a climate product (with relevant scenarios, time scales, triggers, etc.). It is a process in which providers and end-users work together (often with the help of intermediaries) to combine different knowledge, skills and practices to create new, relevant knowledge that meets the needs of end-users, and that addresses a shared concern. This step thus involves the integration of stakeholder knowledge and experiences (joint combination of the diverse knowledges of the stakeholders) and matching local observations (e.g. through citizen science) with scientific climate data (modelled, projected, e.g. from Copernicus, S2S Prediction project, EMODnet, GEO, ESA Actions) which will enhance the accuracy and acceptance of the CS.

End-users within the LLs actively participated in exploring various types of knowledge and experiences related to the current climate system and its associated risks, as elaborated D2.4 (Van den Homberg et al., 2024). The objective is to link expertise from the consortium scientists and LK from the LLs and complement climate data from Copernicus and GEOSS and research with local data, within the particular social, economic, and sectoral contexts of the LLs. Data collection methods, elaborated in D2.2 (Van den Homberg et al., 2022, Ch. 3) were employed to understand the requirements for climate products in relation to decision-making. Based on these insights, climate metrics were co-developed to incorporate local experiences (e.g., habits regarding thresholds) which were consecutively validated (Van den Homberg et al., 2024).

Enablers and methods used

Decision timelines were employed as a structured framework to understand the sequence and timing of decisions within a community. By mapping out when and why certain decisions were made, insight into the contextual factors that influence choices was gained. The presentation of available climate data and services—sometimes through serious games, other times through dialogues—and the co-testing of forecast reliability and uncertainty visualization (conducted in six LLs) stimulated discussions on useful and potentially useful climate parameters, their limitations, and how uncertainty can be communicated to support decision-making (Fig. 15). This approach was reported to build *trust* and reduce unrealistic expectations. The decision-time-line exercise was a valuable tool for identifying actual climate data needs between end-users and decision-makers, and for demonstrating potential uses of available climate data. However, maintaining *active engagement* among MAP members in this phase proved challenging in some cases (e.g., LL Crete).

Additionally, a literature review was conducted to explore effective methods for integrating LK into CS, ensuring contextual relevance. This led to a well-defined dataset of integrated information, including its limitations (Fig. 16). While this specificity is a strength, it also poses challenges for mainstreaming the results of the co-creation process beyond the LL area, as they are highly tailored to the LL needs.

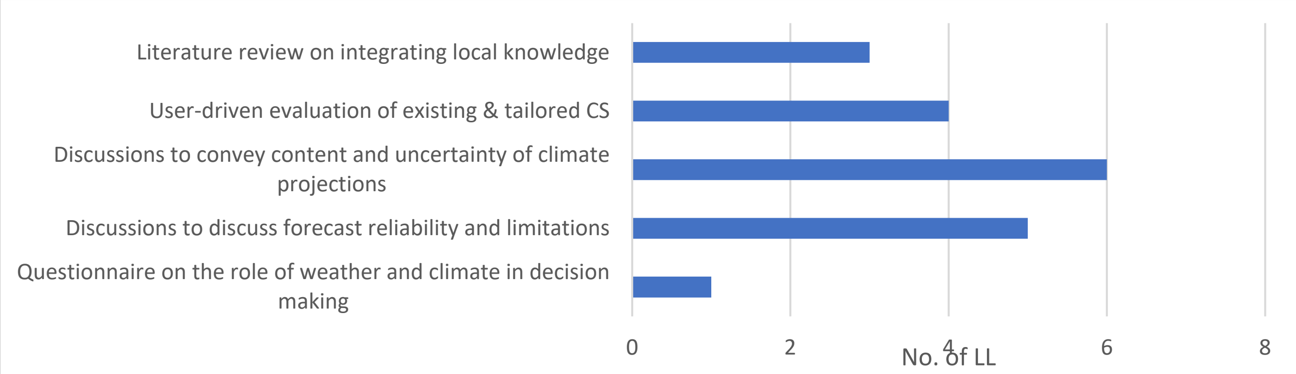


Figure 15: Frequency of methods used in phase C (own survey)

Outcomes

On average, seven meetings were held during this phase. These meetings led to a clear understanding among end-users of how to adapt the CS to their needs. Overall, this phase was considered the easier part of the process, building on the foundations laid in Phases A and B. Collaboration with technically skilled MAP members proceeded smoothly (e.g., LL Italy), but asymmetries in skills, and consequently in decision-making power, posed risks. In LL Alazani Basin, the differences in capacity affected the extent of participation, for example, more technical institutional users led the agenda-setting for the CS development process. However, through the co-creation process, I-CISK LL leads tried to bridge this gap by providing space to other members of the MAP to provide input and feedback. In one case (LL Lesotho), the I-CISK CS was integrated into an existing CCA protocol, meaning that certain data decisions had already been established.

LK informed the prototype CS development in multiple ways, from a deeper understanding of climate information needs (building on Phase A), decisions to be supported by prototype CS and local capacities for adaptation (building on phase B), but also provided data and knowledge on local perceptions and knowledge of climate and weather, risks and impacts. The activities focused on LK also helped validate scientific data, but the inclusion of LK was not overall reported to be incorporated to the extent initially aimed for.

However, a challenge emerged in some LLs in maintaining the promises made during Phases A and B. Integrating L or data into climate models was not always straightforward due to inaccuracies, lack of standardization, and differing subjective perceptions. For example, in LL Los Pedroches, although local data existed, it often lacked the necessary functional characteristics (e.g., length, reliability) for integration, which lead to some disappointment among MAP members. In LL Hungary, relevant data was generally scarce, particularly because much of it was not open source. As a result (Fig. 16), combining local and global data, models, and knowledge remained difficult. To cope with this, qualitative data was recognized as a critical source of information for developing CS when local quantitative data was unavailable.

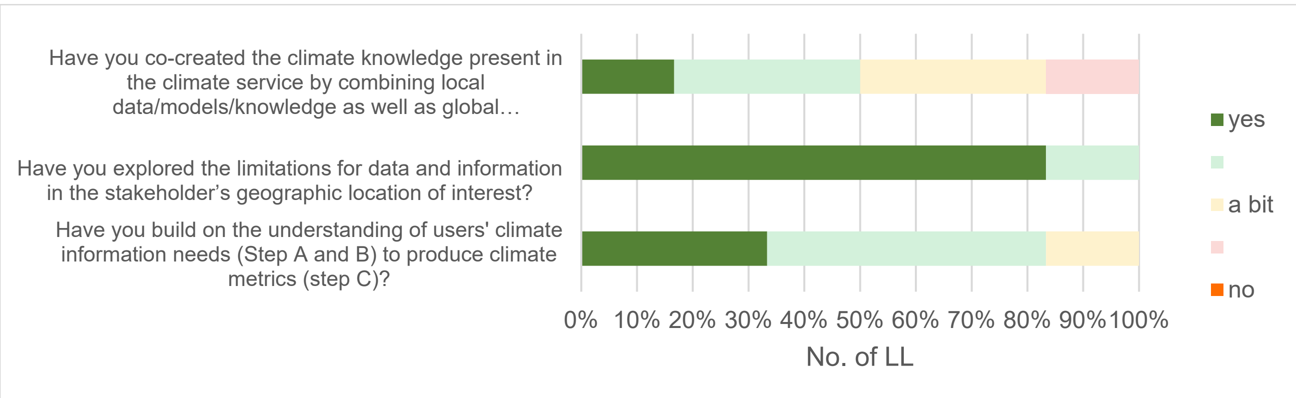


Figure 16: Perception of achieving the enablers in phase C (own survey)

4.5 Phase D - Co-design user-centred climate service system providing tailored climate information

Prototype framework description of phase E (MS10, Wens et al., 2022)

The climate product, and adaptation and DRR strategies are combined into a comprehensive, actionable climate information. The output of this step is a **prototype** of a user-centred CS that communicates this climate information to end-users. In the co-design phase, the climate product is visualized in such a way that its information can be easily interpreted and that it efficiently supports decision making. Through a participatory interdisciplinary design approach involving end-users, a representation of this product and information that corresponds with the needs, is constructed. This requires the use of existing or complementary, new platforms and tools for the transformation, visualization and distribution of the climate information. Providers, intermediaries and end-users work together to design a CS based on a shared understanding of complexity of decision-making, and of individual and institutional capacities. Here, the behavioural factors, drivers, and barriers that influence the uptake and effective use of climate information are assessed and considered so that the CS can be tailored to the local context (sector, region) to optimise it reflectivity.

To ensure that CS were developed in a way that resonated with end-users, the delivery of climate information was carefully tailored through an average of five meetings with the MAPs which includes meetings on design and visualization (Bagli et al., 2024; Egan et al., 2024; Van Andel et al., 2025). This process was grounded in co-identified needs from the MAPs, where end-users helped shape not only the content and metrics of the information, but also how and when it was communicated, and through which channels it could be accessed. A detailed reflection on the co-design process and resulting visualisation prototypes of CS information in the I-CISK LLs can be found in Van Andel et al. (2025) (I-CISK Deliverable 3.5).

Enablers and Methods used

Scientific information developed in earlier steps was translated into accessible formats and delivered using optimized visualization and communication tools such as interactive maps. A key part of this was the preparation of multiple visualisation examples for each information component for each living-lab. These were successfully used in MAP workshops and bilateral meetings for feedback, refinement, and selection for implementation, supporting *constructive interaction and the inclusion of local knowledge* as well as data interoperability in the back-end design (Bagli et al., 2024). This also included feedback climate information components already in operational testing, supporting *flexibility* and evidenced by the resulting highly customised applications. A balance had to be found between scientific best practices (including detailed uncertainty information or colour-blind accessibility) and user preferences (Van Andel et al., 2025).

Five LLs conducted requirement elicitation dialogues to identify design needs, including visualization options (Fig. 17). These insights were then used for rapid prototyping (via FGD) and collective interpretation of the CS information (five LLs) through iterative sprint sessions (bi-weekly co-development sessions) involving MAP members, information providers, and service developers in so-called “Climate Service Task Forces” (Bagli et al., 2024) (Fig. 17). For this, a workshop format was found to work best to support *active engagement*. Bilateral meetings/FGD and/or individual interviews were found to be more effective and efficient when gathering specific information from stakeholders. This ensured that the final outputs (an agreed upon set of visualisation maps and graphs in the form of scripts) were not only scientifically robust but also practical and relevant to end-users’ everyday decision-making. Understanding how end-users adapt to climate challenges was central to this effort.

Additionally, two LLs jointly analysed adaptive behaviours through serious games, allowing the CS to be designed in a way that removed barriers and built on existing motivations for adoption. This approach was used to test whether “provided new knowledge shall be targeted to practical decisions improving over current business-as-usual alternatives.” Other LLs reported difficulty in assessing whether the product was being used as envisioned or whether the CS would lead to improved decision-making. Both the FGDs and serious games enabled meaningful integration of feedback on different designs of the I-CISK CS. For example, one LL reported: "At an early stage of the project, a prototype of the CS was ready based on end-user needs, as interpreted by the CS development team. Then, hands-on experience with the prototype was provided to stakeholders, and feedback was taken into consideration for further development. The new prototype has been available for end-user feedback since September 2024." In two LLs, discussions on making the CS usable—particularly in overcoming cognitive, institutional, and financial barriers—remain ongoing.

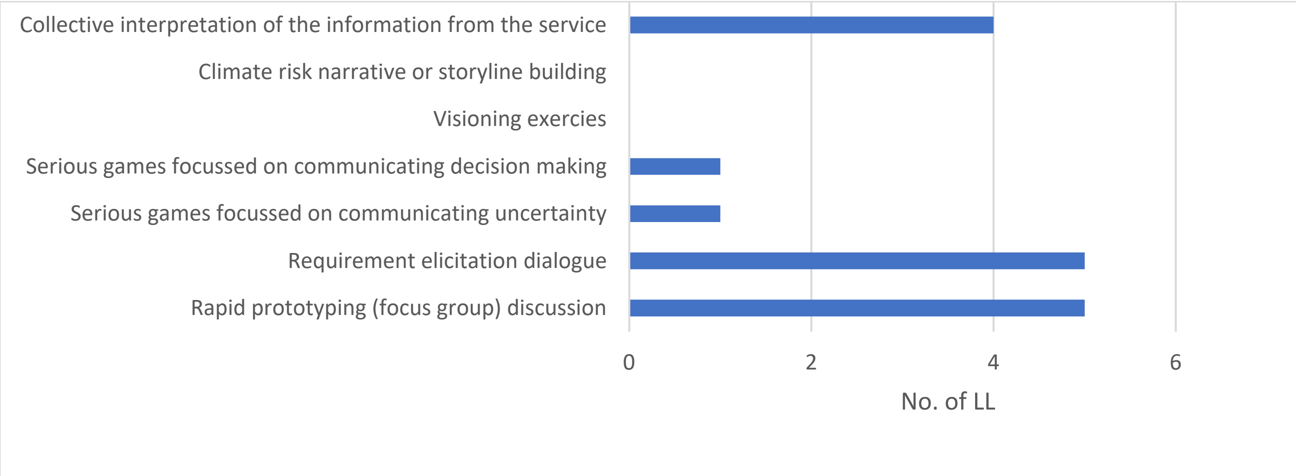


Figure 17: Frequency of methods used in phase D (own survey)

Outcomes

At the time of reporting, all seven LLs have CS in development with prototypes available (including data processing scripts that can allow the operationalisation of the visualisation, in LL pilot CS applications scripts). Four prototypes are available on https://i-cisk.dev.52north.org/ (Alazani Basin, Italy, Spain, Rijnland). The LL Crete prototype is located on the EmvisWater platform and is, for now, password protected. The LL Hungary prototype is available at https://city.zcan.eu/osm-orto-heat-layers.html. They are build following the co-creation steps and reported to visualise the co-created climate information in a human-centred way (Fig. 18). However, in multiple LLs, the discussion on cognitive, institutional and financial barriers to make the CS widely usable are not yet held.

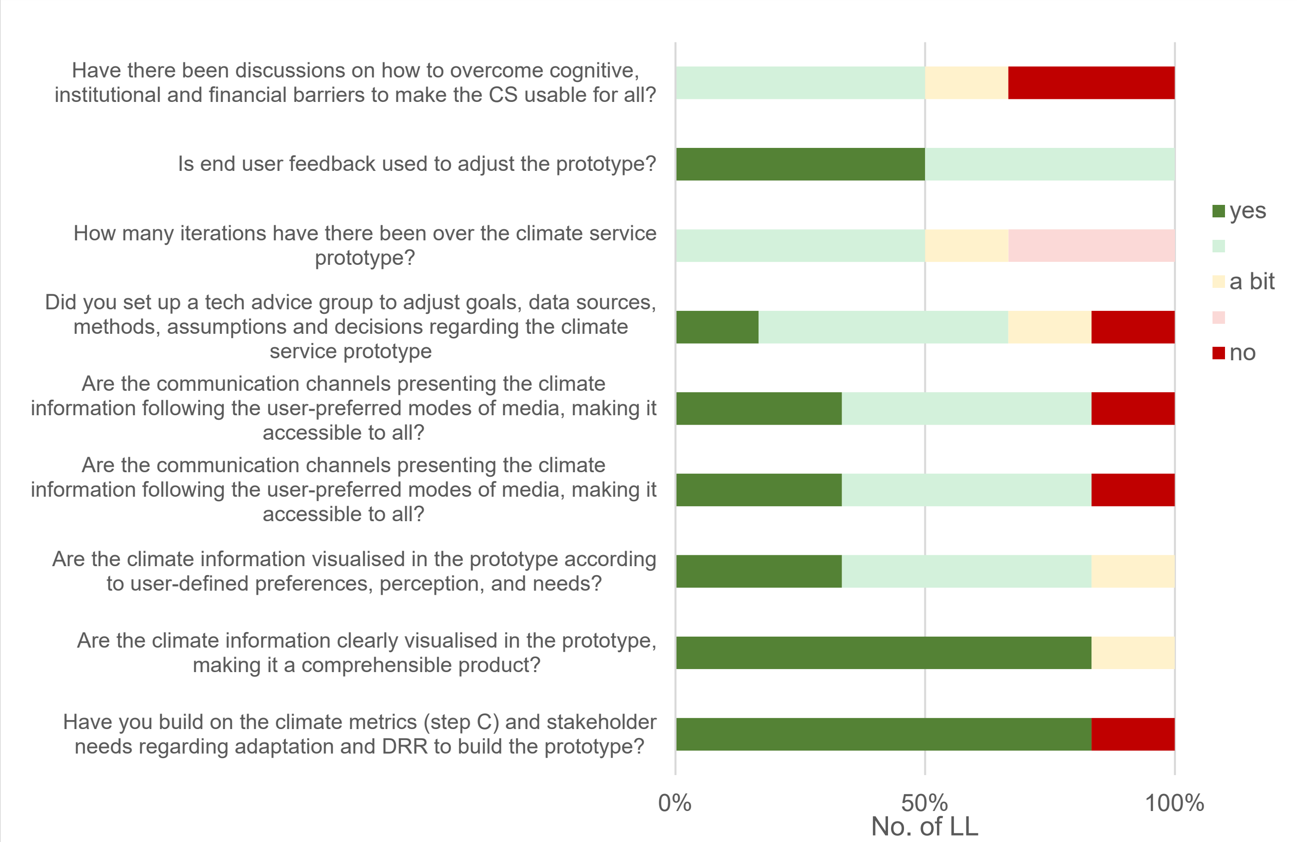


Figure 18: Perception of achieving the enablers in phase D (own survey)

4.6 Phase E - Co-evaluate co-created, user-centred climate service information system

Prototype framework description of phase E (MS10, Wens et al., 2022)

The prototype service (the product developed in step D and the layout of its communication medium) is collaboratively **test**ed after which improvements are suggested. This will lead to **an iteration of steps A, B, C and D**, where LL stakeholders need to agree on the number of iterations and timeliness. In the co-evaluation phase, testing is done through regular reflection and monitoring moments whereby each co-creation building block is reviewed. Ongoing feedback from all stakeholders regarding usefulness, usability, accessibility, credibility, clarity and viability, and match with expectation of the co-created CS allows to improve the project output. In a final stage, the progress of the co-creation process is assessed and the final outcomes (CS) evaluated: feedback on transformation and target accomplished from all stakeholders should be collected. As such, intangible innovation (IP, knowledge) and a broader diversity of innovation can be assessed (Hossain 2019). Moreover, new knowledge and innovation gaps emerging from the use of the CS should be identified, and lessons learned should be summarized into best practices for the future.

To move from merely useful to truly usable climate information, the co-creation process focused on ensuring a strong perception of information fit, interplay, and interaction. By actively addressing perception gaps, building trust, and creating mutual understanding of needs and limitations in every constructive interaction with MAP members and other LL stakeholders, the CS became more than just a technical product; it evolved into a shared tool for informed decision-making, grounded in both science and local realities. LL Los Pedroches reported “Co-evaluation was very useful and gained new insights in forecast quality assessment and presentation of quality assessment results (which metrics to show, and which not because difficult to interpret, and notably also which aspects of a forecast a user finds important)”. However, sometimes it was not clear how feedback was considered, how flexible (responsive to feedback) the process was (LL Alazani Basin).

Attention was given to the quality of the product and the quality of interactions throughout the process. Product quality monitoring was done more informally, organically throughout each productive interaction. Co-creation activities were mainly evaluated by the MAPs in the LLs, but feedback from individual end-users was also obtained through FGD, a Facebook campaign, and household interviews. Sometimes product evaluation was a bit too technical and less accessible to all end-users. Process evaluation, with exception from the surveys, did not always receive structural attention in the LLs.

4.7 Phase F – Co-deliver pre-operational climate service information system

Prototype framework description (MS10, Wens et al., 2022)

In the co-delivery phase, the CS information system (CSIS) is co-exploited and co-disseminated. This participatory implementation of strategies for the appropriate use of the CS thus includes the creation and update of an exploitation plan and decision regarding the procedure of dissemination. It is crucial to incorporate CS providers as active members of the co-creation process. Indeed, a coordinated delivery of data, info, expertise and training improves the uptake of CS (Cavelier et al., 2017) Collaborative business development is aimed at future commercial exploitation, while capacity building and policy outreach can strengthen the dissemination of the CS. Different channels relevant to the target audiences will be used to ensure a broad outreach of developed CS, e.g., through common portals that build on the existing ones (Cavelier et al., 2017). Audience groups include the CS community; end-users of CS beyond the stakeholders in the MAP; the scientific and academic research and education community; policy makers; and the public and civil society organisations, and media. Embedding CS in existing institutions ensures that they are used in practice and that mechanisms exist to maintain, evaluate and update the CS, as necessary.

To enhance both the availability and economic relevance of the CS, co-dissemination and co-exploitation strategies were actively pursued within each LL.

Enablers and methods used

Network mapping helped identify existing communication channels and contact networks accessible to both partners and stakeholders, forming the basis for a targeted dissemination strategy. This was further supported by a structured exploitation plan, which guided the communication of key outputs such as CCA and DRR plans.

Dissemination activities were embedded in stakeholder-led events, including workshops and fairs, ensuring that the CS reached relevant audiences in meaningful ways. However, it was noted that this phase should have started earlier, with technician-led trainings illustrating how to use the CS to change adaptation decisions, which would have allowed for one more iteration of feedback, before the final dissemination workshops.

In LLs Crete and Italy, much work was done to adapt business model storylines to the specific contexts of the LLs, clearly demonstrating the added value of human-centred CS and supporting commercial exploitation. More details on the development of business model storylines for the sustainable exploitation of CS developed within the seven LLs can be found in Ziogas et al. (2025) (I-CISK Deliverable 5.5). These models were supported by business case evaluations and the deployment of pre-operational CS, which were tested directly with stakeholders to assess usability and impact. These LLs pointed out the importance of the business part of the co-creation of CS; finding economic feasible ways (e.g. by involving public funding and embedding it in existing public processes and policies) to make everything work rather than only looking at technical capabilities ensured sustainability. Opportunities for replication and upscaling were also explored, targeting similar regions and sectors where the CS could be effectively applied (LL Italy) or building further to operational CS with new hosts (LL Hungary).

Outcomes

Not all LLs reached the end of this phase. In LL Crete, all five CS co-identified with MAP members were under development at the time of this evaluation. Only two CS—sub seasonal to seasonal predictions and historical data—were fully developed and implemented in the platform. The remaining three—climate projections, agroclimatic indicators, and hydrogeological characterisation—were still under development. Similarly, in LLs Los Pedroches and Rijnland, the prototype CS were not yet fully deployed, so their use over a full season could not be evaluated. In LL Rijnland, the pilot was being kept active to build up testing experience and further refine the application: “The drought alert CS system pilot application is up and running, but there is still ongoing development work to complete it and enhance it based on MAP feedback.”

LLs that reached this phase generally found it manageable and effective, particularly when end-users were clearly defined. For example, LL Los Pedroches worked mainly with intermediaries, which made engagement more complex, while Italy adopted a more top-down approach, offering options and examples that facilitated decision-making. Some LLs also engaged in more elaborate sustainability discussions. In Italy, the impact of the new service on regional sectoral policies was reviewed and discussed, and potential public funding channels were identified. For most LLs, however, ensuring the sustainability of the product, particularly regarding automated updates based on new scientific results and learning beyond the project's lifetime, remained a challenge.

4.8 Co-evolution of knowledge and CS prototypes

The co-creation approach within the I-CISK project was observed to contribute to the co-evolution of CS product and knowledge among both scientific and societal actors convened in the MAPs in each of the seven LLs. Across all LLs, there was general agreement that the CS prototypes were developed through mutual learning, as evidenced by a year 3 evaluation on how LK informed the CS development (Fig. 19). Scientific partners reported gaining innovative insights through dialogue with other MAP participants. LK informed the CS development process and product through creating a better understanding of user capacities, preferences and complementary needs, even if LL leads would have wanted LK to be integrated even more (Ch. 6). Including LK also contributed to stronger validation of traditional scientific data.

Furthermore, the reflexive monitoring exercise concluded that co-creation, through discussion and presentation of show cases, contributed to achieving increased awareness and understanding among intermediaries and end users regarding the concepts of CCA and DDR within the LLs. Through the period of engagement, responses of MAP members changed, showing time and interaction contributed to the co-evolution of knowledge of all stakeholders.

In some LLs, co-evolution was mostly observed in the choice of methods of co-creation, particularly in engagement strategies such as from more online meeting and workshops to more in the field and in-person interactions. For instance, LL Alazani Basin transitioned from a consultative, one-way format to a more dialogical approach, fostering open discussions and enabling diverse feedback that enriched the process. In other LLs, such as in LLs Los Pedroches and Hungary, co-evolution was more evident in the development of relationships among participants, especially in how collaboration and communication facilitated a shared vision of user-centred CS.

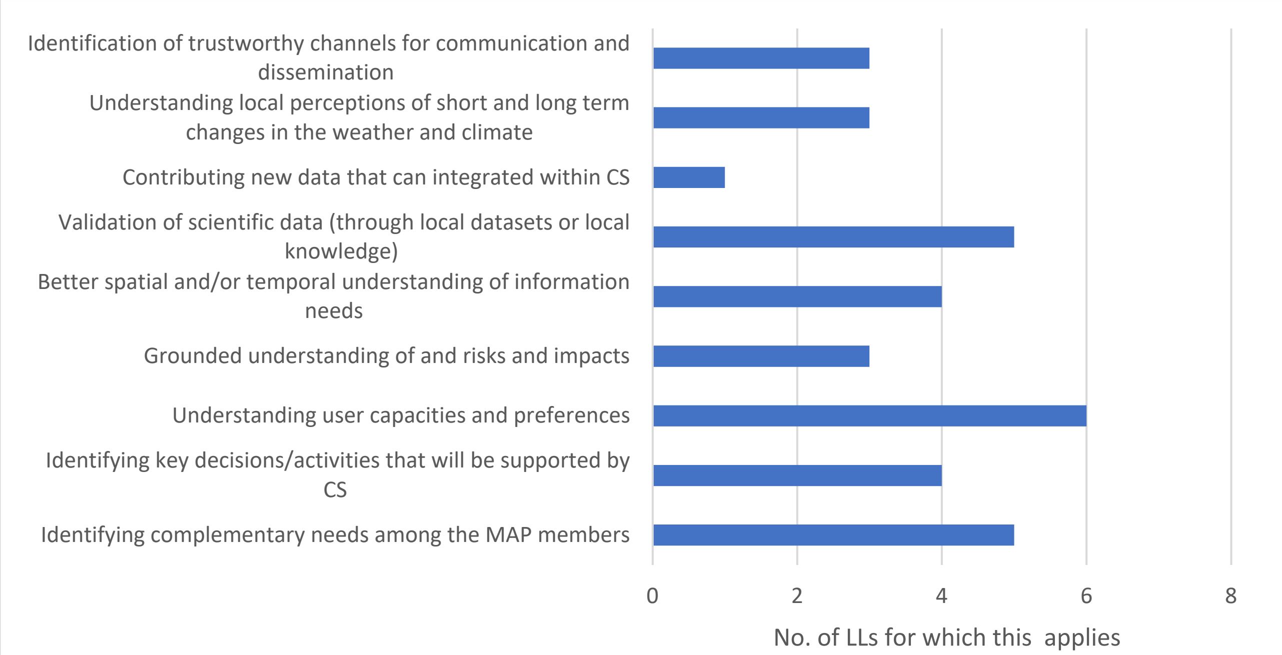


Figure 19: Ways how the consideration of local knowledge has informed the CS development process (own survey)

5 Evaluation following the co-creation process evaluation criteria

In this section, we evaluate the co-creation process as it evolved within the LLs and the overall I-CISK project using the process evaluation criteria (Ch. 3.4). It is important to note that the evaluation reflects a generalisation across LLs of the overall results, but that the LLs showed considerable variation in their development and performance.

5.1 Active engagement (requires capacity, accountability)

In the overall I-CISK project, members of the MAP were active in all phases, with over half of the LLs reporting constant or frequent presence of all stakeholders (Fig. 20). Only in the co-delivery phase, this was significantly lower, mainly because this phase had at the time of writing not been concluded in some LLs. It was reported that intermediaries could hamper active engagement of end-users, as it limited more direct contact with these end-users (LL Lesotho). Closer physical distance to the LLs by project partners enabled active engagement.

Looking at the availability of resources (Fig. 21), for the capacity to actively engage, time was seen as a large bottleneck that was managed as well as possible ("fairly sufficient"), while resources were not or barely sufficient in two LLs (Hungary, Lesotho). All LLs succeeded in creating clarity on roles and responsibilities. However, this did not always translate into accountability towards the process and end product (Fig. 22): LLs Hungary and Alazani Basin reported that this was not (yet) achieved. It may be, however, that accountability will be created when the CS become operational, for instance in Georgia when the product is transferred to the National Environmental Agency.

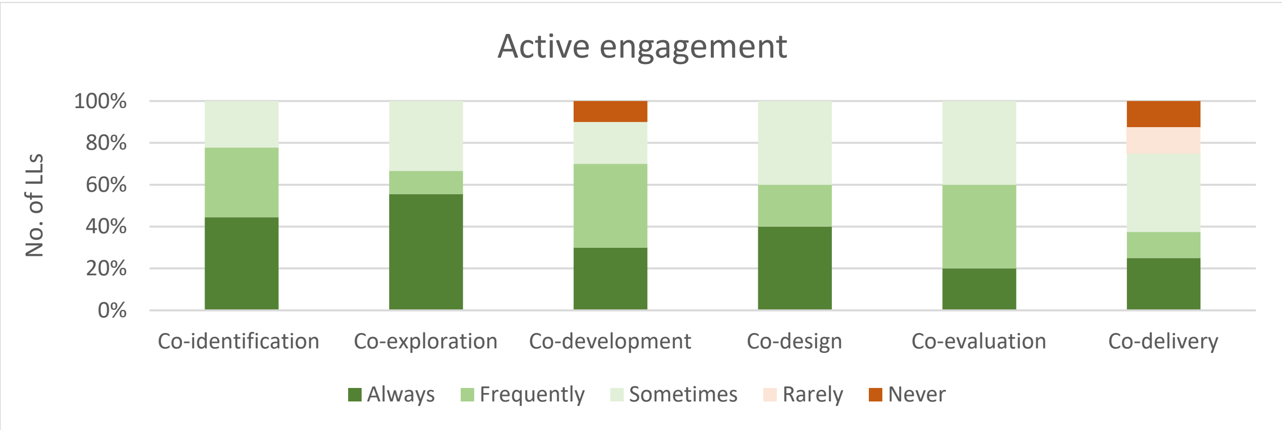


Figure 20: Perception regarding active engagement of MAP members during the co-creation phases (own survey)

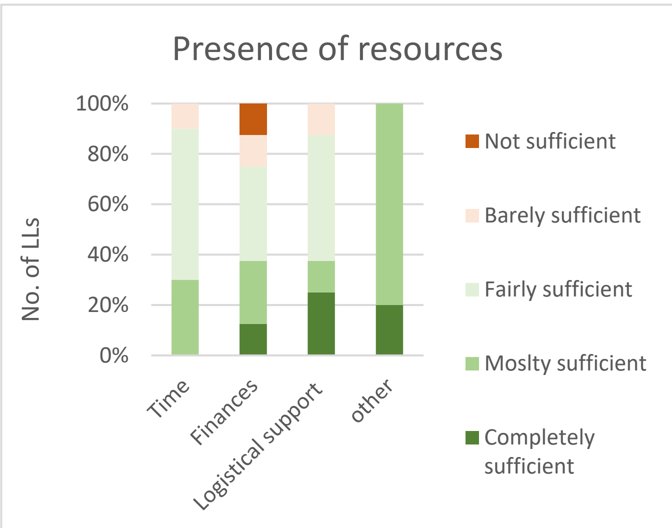


Figure 21 (left): Perception regarding presence of resources for active engagement of MAP members (own survey)
Figure 22 (right): Perception regarding accountability over the co-creation process and product (own survey)

5.2 Inclusiveness (requires fairness, equitability)

In most LLs, a fair to good diversity in MAP members was achieved (Fig. 23). Creating a balance in gender was not always achieved, while a variety of stakeholder experiences with climate risks was included in all MAP, except in LL Hungary. All reported that the diverse values and interests were considered throughout the project by creating equal opportunities to contribute (only LL Hungary faced some barriers here) (Fig. 24). However, it remained a challenge to ensure an equitable distribution of power and influence, especially in LL Lesotho.

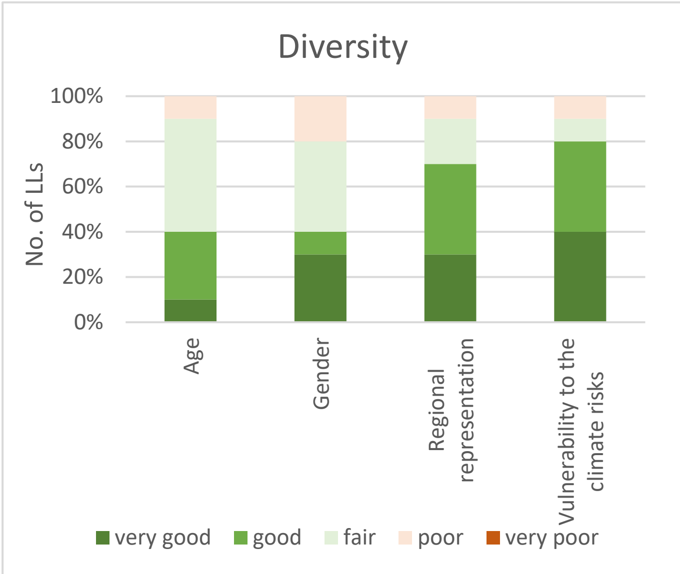
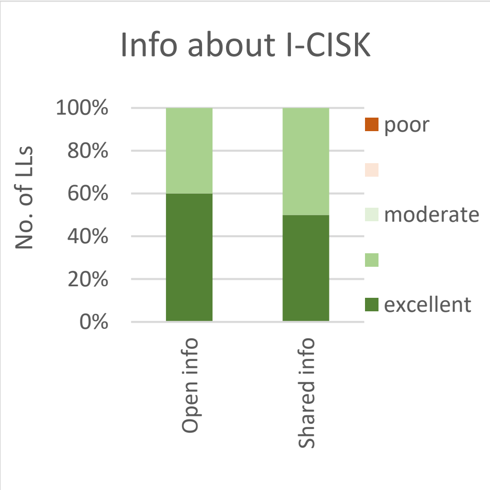


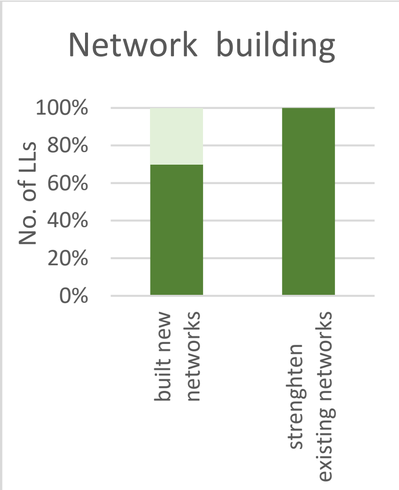
Figure 23 (left): Perception regarding inclusivity of the MAPs (own survey)
Figure 24 (right): Perception regarding diversity within the MAPs (own survey)

While this diversity in representation adhered to the intended inclusiveness of the co-creation approach (see Ch. 3.4. Process evaluation criteria), it was felt that this inclusive representation resulted in concerns around institutional and economic efficiency, thus viability, for some LLs. When only one decision-making level was involved, co-creation could be managed more tightly, potentially accelerating progress toward effective CS. The LL Lesotho included the Lesotho Red Cross Society as the main end-user, which provided focus in the co-creation process focused. In contrast, tailoring services to multiple governance levels proved to introduce complexity, stemming from challenges in aligning diverse stakeholder needs and navigating institutional structures. LLs involving multiple user levels (e.g., LLs Alazani Basin and Los Pedroches) faced greater complexity in developing effective, end-user-centred CS. In LL Los Pedroches, for instance, it remained uncertain whether the CS will reach farmers, considered the most distant end-user level. Similarly, in LL Rijnland, the diversity of stakeholders made it difficult to meet all needs. In LL Alazani Basin, the CS was at the time of evaluation still too technical for citizens but served the National Meteorological Services well. To address this, LLs Los Pedroches and Crete created ‘Umbrella services’ that bring together multiple bespoke indices for different users or sectors. LLs Alazani Basin, Italy, and Rijnland targeted one, or a small number, of main CS users, the co-creation could be managed more tightly potentially accelerating progress towards effective CS.

5.3 Trust (requires transparency and respect)

In I-CISK, information about the project was shared openly with all MAP members (Fig. 25) and the project was able to strengthen existing networks and build new ones (Fig. 26). This led to moderate to excellent trust building in all LLs (Fig. 27), with attention to the full comprehension of the process and product among all MAP members. Overall, this enabler was evaluated very positively. A key learning is to account for cultural differences, for example regarding the right way of approaching partners and how to organise dialogues.





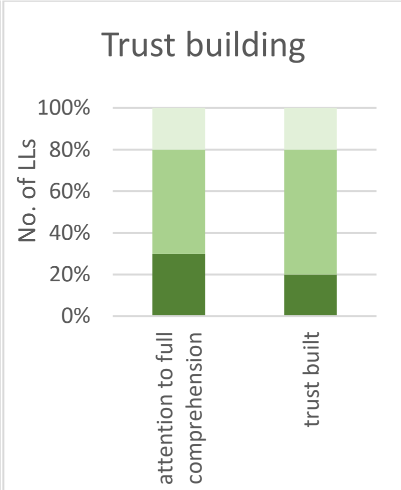


Figure 25 (left): Perception regarding information sharing about the I-CISK project within the LL (own survey)
Figure 26 (middle): Perception regarding the network building character of the MAPs (own survey) (legend left)
Figure 27 (right): Perception regarding trust building within the MAPs (own survey) (legend left).

5.4 Constructive interaction, coordination, direction (requires relevance)

In I-CISK, constructive interaction was on average considered excellent or very good (Fig. 28). Only in LL Lesotho, it was mentioned that working towards a joined CS goal, meeting all LL needs, was not fully achieved – the iterative nature can be a challenge and requires efficiency. Moreover, in LL Lesotho, both a pre-defined feasibility study and a delineated Early Action protocol existed, serving as basis for the I-CISK CS. This situation, while ensuring relevancy, might have prevented newer MAP members (such as the Lesotho Metereological Service (LMS) offices) from feeling fully involved, and might have resulted in a challenge of keeping them engaged.

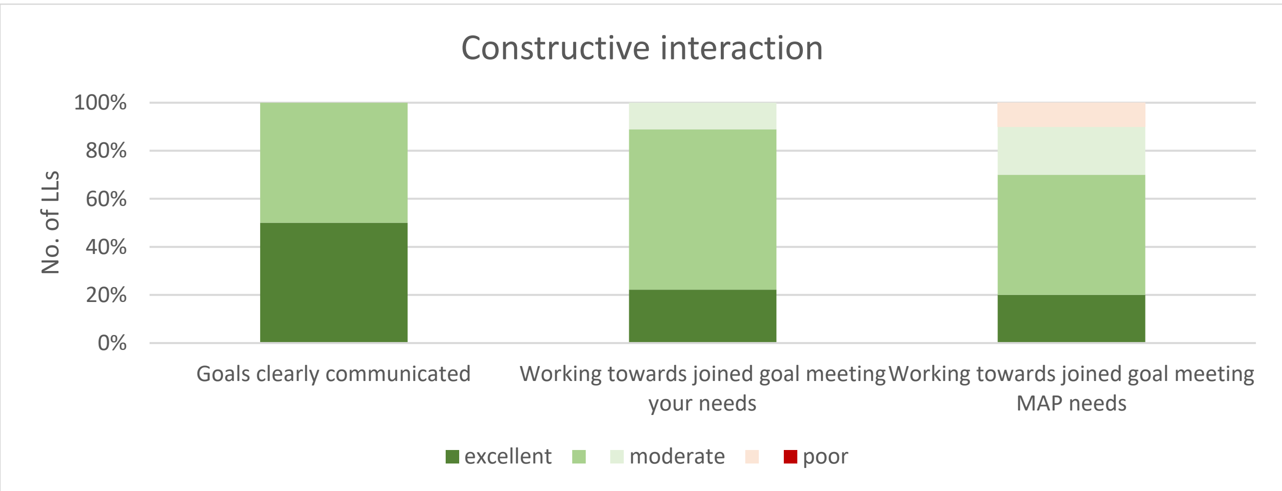


Figure 28: Perception of LL leads regarding the experiences and atmosphere during constructive interactions (own survey)

5.5 Flexibility (requires openness and adaptability)

In I-CISK, all LLs succeeded in performing a co-creation process that was open for new perspectives and seemed to have found a moderate balance between time and flexibility (Fig. 29). It was reported that the applied iterative approach allowed the co-creation framework to evolve in response to new insights, ensuring that the strategies remained relevant as conditions changed. However, LLs Hungary and Lesotho experienced a poor responsiveness to feedback, which, compounded with reported lower capacity (Ch. 5.1), lead to lower reported accountability and less constructive interactions (Ch. 5.4).

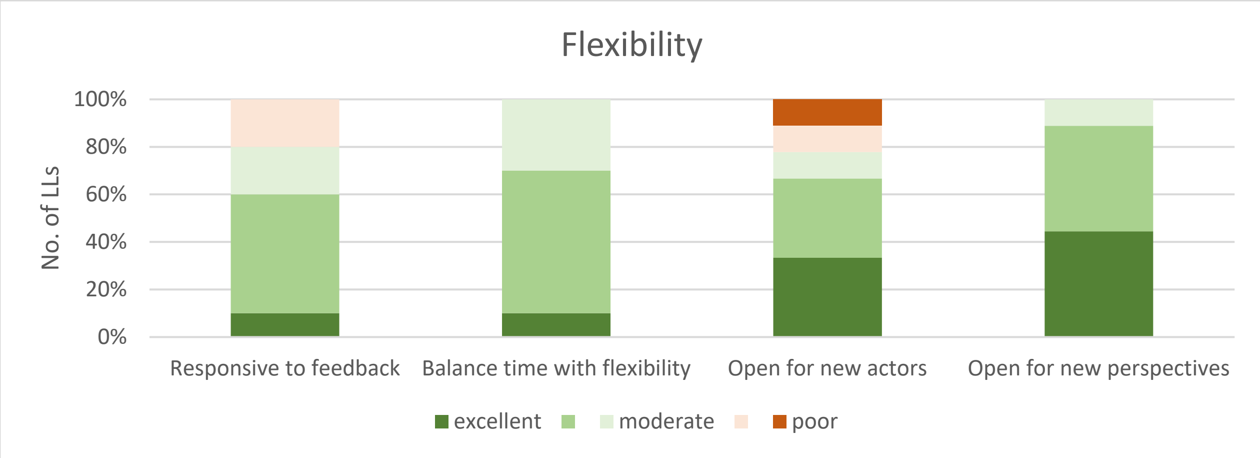


Figure 29: Perception regarding trust flexibility within the MAPs (own survey)

5.6 Legitimacy (requires fairness)

Given the reasonable diversity of the MAPs (except in LL Lesotho), a fair representation of end-users throughout the whole I-CISK project was achieved in most LLs; only LL Lesotho reported that fairness was poorly achieved (Fig. 30). Still, all LLs could co-create an end product that was widely deemed relevant by MAP members, as reported by the LL leads. A key lesson for this is the importance of understanding institutional mandates and responsibilities. Identifying roles and responsibilities allows for more targeted engagement, ensuring that specific actors receive the information and support they need.

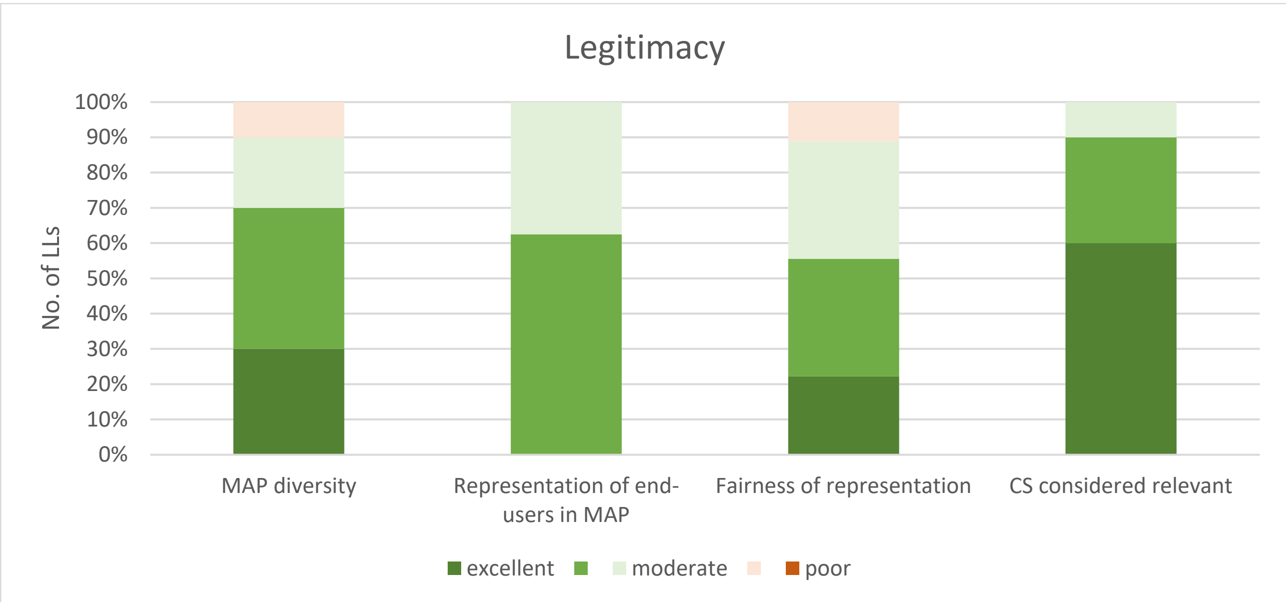


Figure 30: Perception regarding the legitimacy of the co-creation process within the MAPs of the LLs (own survey).

6 Evaluation following the product evaluation criteria

In this section, we report the results of the evaluation of the prototype CS themselves. The primary goal of the I-CISK co-creation process was to develop viable, accessible, clear, credible, useful, and usable prototype CS in each of the LLs (see Ch.3.1). As such, we evaluate whether co-creation can indeed contribute to the next generation CS, overcoming the information and domain challenges described in Chapter 2.1.

The evaluation suggest that the product goals were largely met in most LLs, with high scores on the indicators applicability (usefulness), affordability for areas and sectors (accessibility), and understandability (comprehensiveness) (Fig. 31). However, the integration of LK and local data (LK in Fig. 31) on climate change and variability (credibility), a key objective of the I-CISK project, was only moderately successful, and identified as an area for improvement in some LLs. Successful integration of LK was achieved in the LL Los Pedroches, where historical data inclusion enabled users to contextualise events based on their own experiences, and in LL Crete where user-defined thresholds and user-suggested data were integrated (Egan et al., 2025). The use of decision timelines was reported to be a successful tool to unpack and understand how local decisions are made and which LK, and local wisdom and experience is used in the triangulation of information supporting CCA and DRR decision (van den Homberg et al., 2024). In LL Rijnland, while the co-delivered prototype CS received positive feedback, some scepticism among MAP members persisted, particularly regarding credibility. Credibility was also flagged as a challenge in LL Crete.

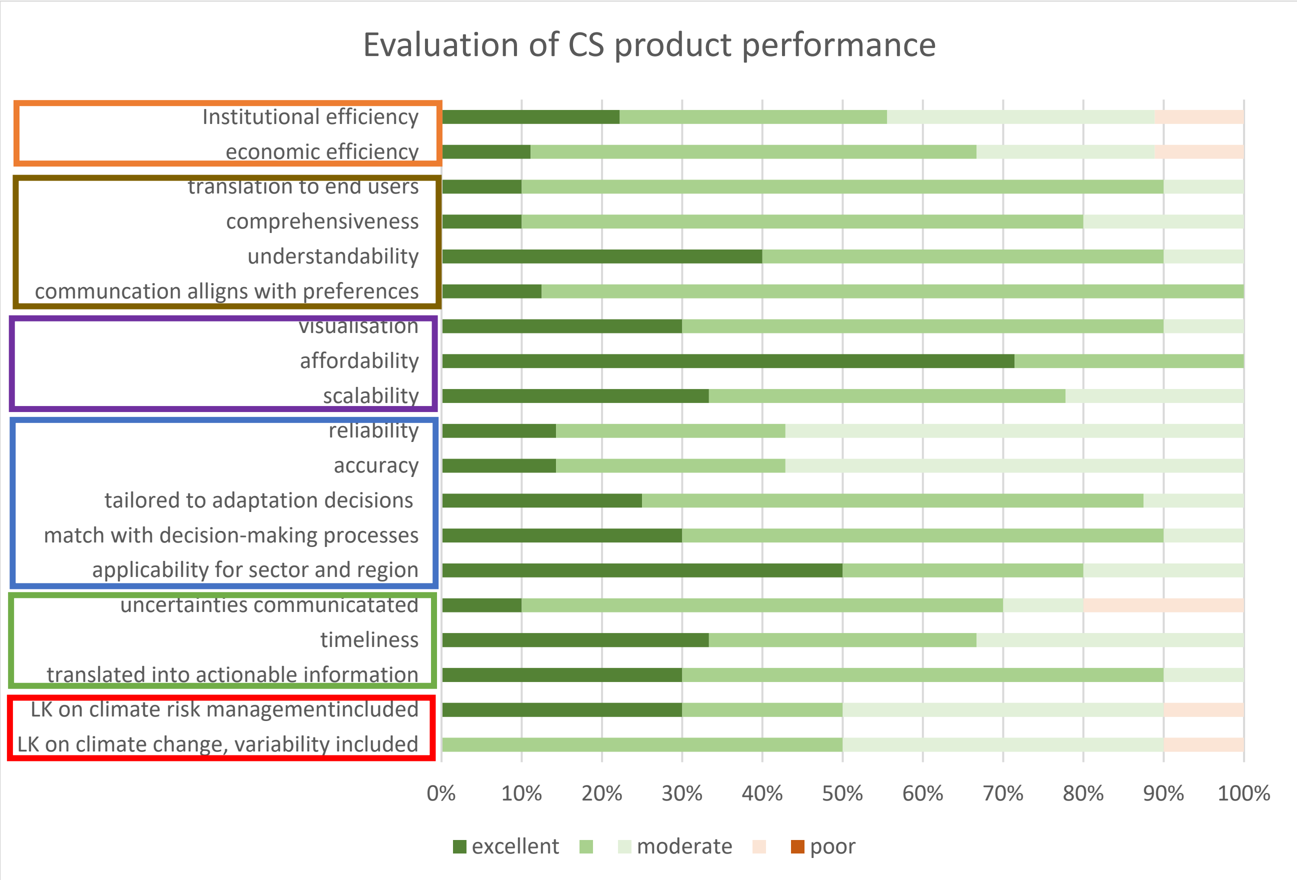


Figure 31: Overall performance of the co-delivered prototype climate services in the Living Labs (own survey)

Note: based on the evaluative qualitative scores on the indicators for the product evaluation criteria. The red box refers to credibility, the green box to usability, the blue box to usefulness, the purple box to accessibility, the brown box to comprehensiveness, and the orange box to viability.

7 Overall suggestions for improving the co-creation framework

Based on lessons learned throughout the I-CISK project, several improvements to the prototype co-creation framework emerged to enhance the co-creation process in all phases. These are summarised here and implemented in the final co-creation framework in Chapter 8.

Phase 0: Include resource inventory and monitoring criteria

To strengthen co-creation processes, LL leads recommended to include a comprehensive stakeholder inventory. This exercise can map the roles of end-users, producers, and intermediaries in adaptation decision-making, as well as their capacities, interests, and other resources. This can support more strategic engagement and ensure that all relevant perspectives are considered. Furthermore, the framework could strengthen its focus on equality strategies by integrating targeted metrics to address gender gaps. While changing inequalities in stakeholders' institutions is largely beyond the reach of single co-creation projects, targeted approaches can still promote more inclusive participation.

Phases A & B: Merge co-exploration and co-design and make this merge step follow a highly iterative process

To better reflect the dynamic nature of co-creation, LL Leads recommended to combine phases A and B into a single, iterative phase that supports continuous learning and adaptation. This joint phase should, among other things, clarify the current state of adaptation behaviour and define desired shifts in adaptive practices. A structured timeline for decision-making proved to be very useful for identifying key adaptation decisions, formulating desired changes, and exploring future possibilities. It can also foster more reciprocity in this phase, for example, by providing examples that challenge habitual thinking, while still allowing end-users to identify and articulate their own needs. The evaluation also suggested that expectations should be managed from the outset, e.g., regarding achievable lead times, which is crucial for maintaining trust and momentum. To prevent stakeholder fatigue, activities should be streamlined to ensure that participation remains meaningful, manageable, and sustainable throughout the iterative process. Furthermore, integrating value chain thinking through the development of a draft business case should be added, to help anchor the process in practical and economic reality. The phase should conclude with the joint development of an impact trajectory, such as a Theory of Change (ToC) (Castellana et al., 2025), to create a shared vision and logic for change.

Phase E: Integrate evaluation across all co-creation phases

To ensure robust monitoring, evaluation, and learning (MEL) throughout the co-creation process, the reflexive FGD at the end of the project showed that it is essential to embed MEL into the workflow by designating explicit moments, such as the end of each phase, to ensure this step is not overlooked. It was recommended to tailor the process MEL criteria for collaboration early in the process, ideally in Phase 0, to the specific objectives of each phase; for example: during the initial co-exploration phase, inclusivity may be more important than active engagement. The criteria should be adopted by the MAP to enable systematic process MEL, ensuring the quality of stakeholder engagement throughout the project. The end-of-project FGD also underscored the importance of developing product evaluation criteria in Phase A to effectively track progress; these can be expressed as Key Performance Indicators (KPIs). Furthermore, it was suggested to incorporate reflection on behavioural changes in CS use throughout the project to ensure the creation of CS that are behaviourally informed as well as to track impact. It is expected that new evaluation approaches will strengthen systemic MEL, fostering continuous improvement and deeper understanding of the effectiveness of co-creation efforts.

Phase F: Add capacity building training and support

The main suggestion was to strengthen the focus on training and capacity building to empower stakeholders and increase long-term impact.

Cross-cutting Recommendations

To increase the effectiveness of co-creation, it was deemed important to move beyond one-way participation and promote multidirectional interaction between project partners and MAP members to fosters richer, two-way exchanges of knowledge and perspectives. This approach supports deeper mutual understanding and more meaningful collaboration. Furthermore, LL leads recommended that the design of the co-creation process should remain iterative and flexible, allowing methods and content to evolve in response to stakeholders' evolving insights. This flexibility, however, must be balanced with a clear path toward a final, collaborative decision to prevent fatigue and ensure closure. Lastly, the final co-creation framework should consider the varied starting levels, requiring additional data collection in some instances or skipping a phase in others.

8 Final I-CISK co-creation framework

8.1 Co-creation framework overview

The I-CISK co-creation approach (Fig. 32) combines principles for successful CS with principles for successful co-creation and supports the development of an effective and sustainable end-user centred CS that responds to the knowledge needs of decision-makers. It builds on the prototype (Wens et al., 2022), the evaluation (this deliverable) and other project experiences (all summarized in deliverables, accessible at i-cisk.eu/resources).

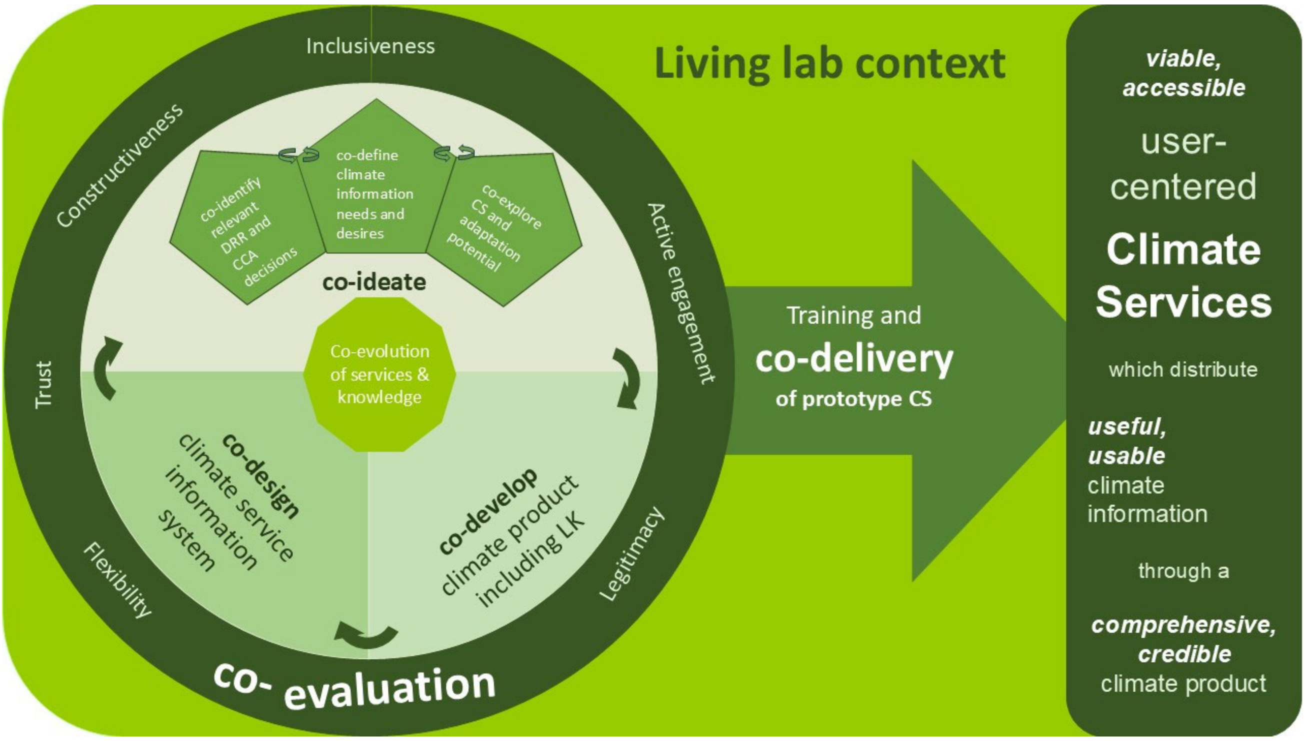


Figure 32: Piloted co-creation framework for user-centred climate services, based on I-CISK experiences

The tested-and-improved framework to co-create CS with stakeholders in focussed LLs consists of one initiation phase (0), four main phases (A-D), and a constant iterative evaluation phase (Fig. 32). Application of the identified phases of the framework, leads to:

- recognising end-user's needs, perceptions, knowledge, capacity, and adaptive behaviours, as well as the CCA and DRR strategies they wish to implement
- removing the barriers of end-users to use climate information effectively to instigate behavioural changes
- advancing the data science and technology base necessary for the development and implantation of tailored CS that respond to the needs, perceptions, knowledge and capacities of end-users, in collaboration with end-users and other stakeholders
- jointly fostering a sustainable CS market sector and capacities of CS developers, service providers and purveyors, both in the public and private sector, through tools, platforms and mobile applications that best meet end-user's needs
- initiating the co-evolution of knowledge and CS within the LLs
- enabling end-users to develop more effective CC adaptation strategies based on improved CC knowledge provided by the CS.

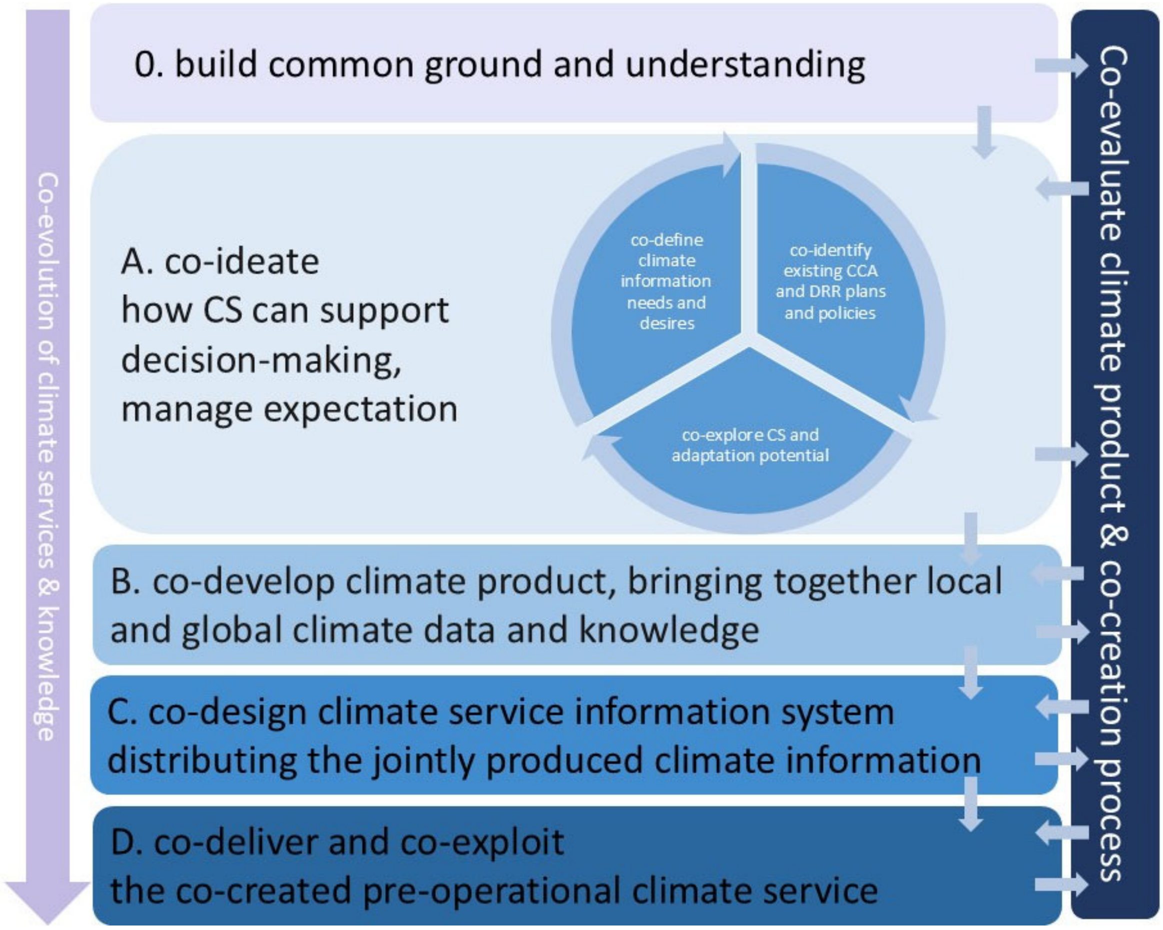


Figure 33: Phases in the piloted (tested, evaluated, updated) I-CISK co-creation framework

Figure 33 shows how going through each of the co-creation phases, builds the co-evolution of CS and knowledge, especially if each phase is structurally co-evaluated with attention to both the CS and the co-creation process. While Figure 33 shows a rather linear process, one has to imagine it very much iterative (like Fig. 32), and depending on the context, phase 0 and A can be skipped if a LL and MAP already exists, and if a clear demand and feasibility study has already been executed, respectively.

The following sections elaborate per co-creation phase which enablers and success factors can be used, and which possible barriers will need to be overcome, to produce such CS. Each step is complemented by an overview of methods and tools that can be applied. For each step, there are:

- Objectives/scope: these relate to the project objectives
- Core activities: actions can need to be taken (tailored to the needs of the LL) and tools to execute them
- Practical considerations: tips to execute the step successfully
- Relevant process evaluation criteria: critical points to evaluate during each phase.

It is important to emphasize the flexibility (rather than prescriptive nature) of these guidelines: the process can be modified, responding to needs or changing circumstances. We recommend searching for an optimal balance between standardization of and customization of the co-creation process (EC 2020 climate resilient Europe), and the roadmap in phase 0 is a first point to discuss tailoring the co-creation process with all stakeholders.

8.2 Phase 0 – Build common ground and understanding

The establishment of LLs and MAPs is a crucial starting point for the co-creation of CS. This phase focuses on **building empathy, trust, and mutual understanding among a diverse group of stakeholders** in the MAP and serves as the foundation for inclusive collaboration. Here, potential end-users are identified, and, through dialogue and resource analysis, an understanding is developed of what is important to them and how their perspectives can influence the development of effective and context-sensitive CS.

Phase objectives and scope

This phase focuses on creating a safe environment for discussion and collaboration within the LL, where trust can be built and shared challenges can be identified. Central to this process is the formation of a MAP and an agreement regarding the principles of interaction. It is essential to ensure the inclusion of all relevant actors, producers, intermediaries, and end-users, as exclusion can invalidate or undermine the co-creation process (WISER, 2019). By building partnerships among stakeholders from different sectors, regions, and backgrounds, the LL becomes a space for open dialogue, mutual learning, and joint agenda-setting. This facilitates structured collaboration and ensures that all voices—decision-makers, knowledge holders, and involved communities—are heard throughout the co-creation process.

Stakeholders are engaged through strategic outreach and snowballing techniques to ensure broad representation. Once a committed group is formed, the collaboration is formalized through a jointly developed roadmap outlining shared goals, roles and responsibilities, and principles for engagement. Context mapping and capacity analysis help anchor the process in the realities and capabilities of each group, while attention to gender, cultural diversity, and power dynamics ensures inclusive representation of diverse stakeholder groups. This phase sets the tone for the rest of the collaboration process, creating common ground as the starting point for meaningful co-creation of CS (WISER, 2019). Importantly, it sets the basis for active involvement in, and commitment to, the co-creation process, where stakeholders go beyond a role as (passive) recipients of research knowledge and play an active role in commissioning, overseeing and assessing research (two-way interaction) throughout the project.

Core activities of this phase

A variety of methods and activities can be employed to effectively initiate LLs:

- **Stakeholder (network) Mapping**: Identifying key actors, their interests and their roles within both the CS and the project itself. This involves identifying who makes decisions that are influenced by climate—across sectors, scales, and communities—and understanding the contexts in which these decisions are made. It also involves identifying how influential different decision-makers are in shaping the climate risks policies and actions. The aim is to include not only those who make climate-related decisions, but also those who are affected by these decisions, those who hold relevant knowledge, and those who can contribute to innovative solutions.

- **Capacity analysis of stakeholders**. Resource mapping of all stakeholder profiles, including their potential roles in the project, their knowledge and expertise, their technical capabilities, their human and financial resources and time availabilities. Identification of barriers for full participation and support needs is helpful, so that the final engagement strategy can be tailored to it.

- **Context mapping**: Small bilateral meetings, among other techniques, foster empathy and help build common ground early in the process. They help uncover who can provide relevant information, who is affected by climate-related decisions, and who should be involved to ensure that all relevant perspectives are represented. It is crucial to explore the **extent to which climate affects end-user planning**, what interests they have in CS, and what kind of information they expect from the co-creation process.

- **Broader dialogues for expectation management**: Clearly defining the scope and acknowledging the iterative nature of co-creation helps manage stakeholder expectations. Competing priorities across the MAP should be discussed. This requires an open and trust-based setting and includes asking participants to reflect on who might be influenced by their opinions and what assumptions and motivations underlie their participation. These conversations help surface embedded power dynamics, knowledge gaps, and differing expectations.

- **MAP expansion (where necessary)**: Based on the insights from the dialogues, the MAP can be expanded ensuring diversity in experience, gender, and representation of end-users. Initially selected stakeholders can be asked to reflect on **who else within and outside their organisations** should be engaged, also to address power dynamics and underlying assumptions and biases of initial MAP members. If this is done in all next co-creation phases too, this activity ensures that the co-creation process remains open, adaptive, and inclusive, and that it continues to evolve in response to emerging insights and needs.

- **Roadmap Development**: The roadmap serves as a blueprint for the collaborations between stakeholders in the LL and the project partners. It is co-designed not only with the intermediaries but also with the end-users and other MAP members. It outlines envisioned activities, outputs, and goals, and includes:

  - Agreement on common definitions and principles
  - Designation of points of contact
  - Identification of resource constraints and capacity needs
  - Development of operational co-creation action plans
  - Clarification of roles and responsibilities across each phase/action
  - Establishment of mechanisms for regular interaction and exchange.

  Scenario-based example roadmaps (for different starting points of a MAP) can help facilitate this process.

- **Developing a shared understanding or clarification of terms, concepts and goal**: Creating a shared glossary helps bridge differences in terminology and understanding across stakeholders. **Discussion groups** can help to clarify terminology misunderstandings and align the understanding of climate concepts among all stakeholders. This helps in later steps ensure that all stakeholders interpret climate data and projections in a consistent and useful way.

- **Monitoring metrics**: Establishing indicators to evaluate collaboration and progress facilitates agreement within the MAP on mechanisms for ongoing collaboration. This sets the basis for the iterative and continuous evaluation of the CS and co-creation process and should thus contain assessment criteria for each phase.

Practical considerations

- **Project partners:** it is helpful to have, within the project team, both a practical partner (e.g. Met office, consultancy) and a process-oriented partner (e.g. university, research institute) that are situated within the LL and part of the MAP.

- **Diversity:** Stakeholders (see Ch.2) must be engaged not only for their formal roles but also for their lived experiences, informal influence, and capacity to shape outcomes. Relevant stakeholder groups include public authorities, private sector actors, civil society, and community representatives. It also includes CS producers, providers, purveyors and end-users. The roadmap should be customized to different people with diverse needs, experiences, perspectives and "knowledge systems", considering stakeholders' differentiated demands and contextual circumstances.

- **Proximity and presence**: Researchers, consortium partners, and stakeholders are encouraged to meet in person on a regular basis as this helps reduce barriers to engagement. Also, the use of trusted intermediaries (bridging the gap between developers and consumers) and building on existing networks or projects is recommended.
- **Structured online engagement**: Using agendas, collaborative documents (e.g., Excel sheets to characterize CS needs, interactive MIRO boards to build user profiles) adapted to users' abilities and resources, and translation tools facilitates inclusive and effective communication.
- **Time Allocation**: Approximately six months is typically needed to complete this phase thoroughly. Developing equitable, trust-based relationships should not be rushed and requires a series of interact (WISER, 2019).

Relevant process evaluation criteria

Accountability: The capacity of all stakeholders, including scientists and practitioners who participate in co-creation, in terms of time, money, support, etc., enables them to actively participate and fulfil the roles and responsibilities assigned to them.

Inclusivity: The established MAPs reflect the diversity in stakeholders and built upon inclusion of a heterogeneous (age, gender, regional background, educational background, experience with CS, vulnerability) set of end-users, producers, policy makers and scientists, and the roadmap is tailored to each MAP member and jointly owned by these stakeholders.

Flexibility: The co-creation process is open to add new actors and new perspectives to the MAP.

Legitimacy: The process of creating the roadmap is perceived to be legitimate by all end-users, meaning all voices are heard and perspectives respected, hence equitable representation was ensured.

8.3 Phase A – Co-ideate how CS can support decision-making

This phase focuses on ideation and iterative dialogue to jointly explore how CS can meaningfully contribute to decision-making in DRR and CCA. Through three interlinked activities (identifying relevant decisions and plans, identifying climate information needs, and exploring adaptation options while managing expectations) stakeholders and researchers jointly generate creative ideas and shape an impact trajectory, the backbone of the collaborative process. This ensures that real challenges are addressed that reflect user-defined priorities. This first phase helps to further define realistic goals, aligning ambitions with the available resources and timelines of all actors.

It is possible to skip this phase when merely updating existing CS technically or when a clear feasibility study already has been conducted.

Phase objectives and scope

To make the co-cocreation process more efficient, avoiding barriers, a clear and joint understanding of the envisaged end product should be agreed upon (Jacob et al., 2025). This happens in three steps:

- "Co-identification of adaptation plans and disaster risk reduction strategies to be supported" involves mapping context-specific, existing and potential CCA and DRR strategies. Stakeholders jointly identify key decisions, policies, and measures, assess their relevance, and link these to the timing, scale, and information needs of CS.
- "Co-definition of climate information needs" involves finding gaps in climate information for achieving adaptation potential as well as barriers to using existing CS. Stakeholders inventorise existing CS and assess which data, formats, and delivery methods are most useful and which are missing, formulating the problem.
- "Co-exploration of adaptation potential" involves a creative visioning exercise to ideate how CS could enable transformative adaptation. It is a collaborative, imaginative process where stakeholders formulate a wide range of desired futures that can go beyond business-as-usual approaches.

Building on the previous ideation steps, which can go through multiple iterations (exemplified in I-CISK D2.1., Egan et al., 2024), the end goal of this phase is to decide on priorities regarding the development of a CSIS. After this brainstorming, stakeholders reflect on the feasibility of these possibilities, helping to align ambitions with project scope and resources. These are tailored to the technical capabilities of the project team. All of this is summarized in an impact trajectory that links identified problems to actions, outputs, outcomes, and long-term impact on the system. This can include co-developing a "theory of change” (ToC) which can guide the development of the product as well as MEL in the co-creation process and ensures that stakeholder needs and project goals are aligned.

Core activities of this phase

Activities of each of these four steps can be combined in time (e.g. in the same survey, same workshop) but iteration is paramount. It is recommended to conduct these steps in deeply interactive formats with varying styles (such as plenary meetings, FGD, online boards) rather than only consultative formats (surveys, interviews). It is important to create accessible documents (language wise) and be aware that this phase needs a significant communication effort (e.g. web page, Facebook).

1. Co-identify climate change adaptation plans and disaster risk reduction strategies

- **Document analysis** to examine the institutional and governance context, including responsibilities, constraints, and decision-making authority of the stakeholders identified in phase 0. This contributes to understanding who makes decisions (institutional mandates), how they are supported (responsibilities), and which institutional factors influence implementation of CS-based decisions. Attention to economic tools (e.g., cost-benefit analysis, internal rate of return) used in decision-making, and assumptions or thresholds are applied, is needed.
- **Interviews or surveys** to understand the timing and scale of key sector activities and decisions to determine when and how climate information can be most effectively integrated. This includes identifying planning horizons, the lifespan of decisions, and the urgency of information needs.
- Participatory **mapping of existing and potential CCA and DRR strategies**, (e.g., through FGD) identifying which decisions, policies, and measures could benefit from CS. This includes examining the timing, scope, and flexibility of decisions, and understanding which issues or decisions could be supported by new CS.

2. Co-ideate adaptation potentials, desires, and preferences

- **User stories and user profiles** to capture evolving ideas and expectations during the co-creation process. This supports the refinement of priorities and helps track how stakeholder needs change over time. Attention to the institutional and regulatory framework is needed as this is often considered a barrier to successful adaptation decisions.
- **Knowledge sharing between different MAPs** (or a more structured training or overview of CS in other regions) to identify innovative solutions (moving beyond business-as-usual) and foster social learning. This reciprocal activity serves as inspiration and support.
- **Visioning exercises and storytelling** sessions to explore transformative adaptation options (beyond "business-as-usual + 1") and how CS can support these. This includes sketching alternative decision timelines. These activities help stakeholders articulate their desired futures and adaptation options and consider the trade-offs between different strategies. It also helps uncover barriers to CS use across multiple contexts.

3. Co-explore climate information needs and climate service preferences

- Semi-structured interviews or workshops to create **decision timelines** in which CS users explain how risks are evaluated and managed in their sector, including how decisions are made under uncertainty and which formal or informal tools are currently used. Decision timelines (Hernández-Mora et al., 2023) provide a framework to understand the decision-making process in time and LK cues that underpin it. This temporal mapping is crucial for identifying patterns and trends that might not be apparent through other data collection methods, such as surveys or interviews. Decision timelines, complemented with in-depth interviews or storytelling, help uncover both the technical and cultural dimensions of decision-making.
- Joint **evaluation of existing CS products** through **dialogue between producers and users**. Consider starting with **questionnaires** to provide a good starting point of the dialogue. A SWOT (strengths, weaknesses, opportunities, threats) evaluation can provide insight into which data are useful and in what format, as well as what is missing (such as sector-specific tailoring, spatial and temporal resolution, interpretability, fragmentation); additional information that could be important for decision-making. The role different sources of information play in the decision-making process, and a clearer understanding of what these sources of information are, for instance, clearly identifying what is understood as LK, past experiences or traditional knowledge, on which adaptation decisions are based, should be uncovered. This also includes investigating preferred dissemination formats, how quickly results are needed, and any accessibility or ownership issues that may arise.
- **Field visits** with full MAP presence to build trust and to create opportunities for direct interaction, as well as informal conversations (akin to storytelling and transect walk methods) to understand key challenges, assets, experiences, etc. Where direct engagement with end users is limited, consider working through

trusted intermediaries (such as extension officers, community leaders, or local NGOs) who can facilitate access, build trust, and help translate technical content.

- **Interviews, quizzes, and serious games** to gain insight into stakeholders' views on climate information, including acceptable levels of uncertainties and skill (performance and accuracy). They can help understand how to deal with probabilistic information when thresholds for triggering action are required. They can also be used to identify barriers to adoption and gaps in the available information, which in turn can be translated into needs.

4. After co-identification co-exploration and co-ideation, focus on expectation management

- **Needs-possibilities workshop** where the identified user needs are linked to the project team's technical capabilities, distinguishing between feasible and out-of-scope CS elements. In a workshop, preferences and focus for improved CS form the starting point, which can then develop into a discussion about **realistic expectations** for what a new CS can deliver within the available time and budget. To manage expectations for next steps, it is important to define and agree on (concrete or abstract) outputs that improve previous CS and increase the acceptance and usability of climate information. This includes exploring issues related to data accessibility, ownership, and publication to ensure that products are usable and sustainable.
- A **forward-looking** exercise including co-constructing an **impact pathway**. This includes mapping the progression from problem statement (step 1-3 of this phase), project inputs and activities to outputs, outcomes, and long-term impacts, while making clarifying the context in the final CS will be used (actual end-users, core actors for the MAP, versus stakeholders who need to be consulted occasionally, versus the rest of society who will perceive the impacts). An example of such impact pathway is a **ToC,** which can be co-developed during online or live participatory workshops and makes explicit the assumptions and external factors influencing success. To support systematic monitoring of the impact pathway, a set of Key Performance Indicators (KPIs) can be designed (Castellana et al., 2025). Evaluate and validate the impact pathways regularly, so it remains responsive to changing priorities and new insights.
- Open **dialogue to surface assumptions, motivations, and expectations**. This expectation management exercise also includes discussing what success would mean for different actors and a discussion to align ambitions with the project's scope and resources. Co-define what impact means and collaboratively create an evidence base (baseline, KPI) for monitoring progress to the impact.
- A dedicated **session to explore data governance**: who will own the data and outputs, where they will be hosted, how will access be managed (e.g., open access, restricted, institutional platforms), and how will we ensure the final CS product is economically and technically sustainable (start thinking about the **value chain, business plan**): who will maintain or update it, how will ongoing costs be covered, and which institutional or financial models (e.g., government funding, partnerships, subscription models) can support its long-term viability.

Practical considerations

- Organise meetings with clear agendas and goals that combine multiple activities. To reduce stakeholder fatigue and ensure sustained engagement, plan for shorter, well-paced sessions with clear objectives, and consider alternating between intensive and lighter-touch activities across the phase.
- Add reciprocity in each activity: The MAP should not be seen as only a source of information for the CS developers. Thought should be given to how researchers can contribute to the MAP.
- To overcome low awareness levels of the business-as-usual situation, which makes it difficult for stakeholders to identify and express their preferences and desires, iteration of the three first activities is a key solution.
- Facilitators could use varied examples of CS or adaptation strategies as prompts for discussion rather than templates, encouraging stakeholders to critique, adapt, or reject them to ensure the process remains

grounded in local needs and creativity. While sharing examples can help clarify, inspire, a good balance is needed to avoid steering the LL too much towards an example CS.

Relevant process evaluation criteria

Inclusiveness and legitimacy: The representation of stakeholders throughout the phase is fair, and the process provides a safe space for multiple stakeholders to share expertise and challenge each other's views and contributions.

Trust: The activities in this phase are performed recognising participants' divergent values and beliefs, unbiased in their conduct, and fair in the treatment of opposing views and interests.

Constructive interaction: the impact pathway will ensure that collaboration is solutions-focussed and decision-driven, objective and outcome led, with clearly identified roles and responsibilities. It needs to be clear that the process works towards a jointly agreed upon product which has value-added for all involved, meets user needs and produces information of relevance for decisions.

Flexibility: The process is agile and responsive to feedback of stakeholders.

8.4 Phase B - Co-develop climate product, bringing together local and global climate data and knowledge

After the context-specific climate challenges have been identified and building on the strategies to be supported, this step aims to develop a trusted climate product tailored to end users' needs regarding decision-making. It consists of global to local climate and weather data, projections and predictions, which are combined with (sectoral) climate knowledge and experiences from conventional scientific sources as well as from local partners into understandable climate metrics.

Phase objectives and scope

In this co-development phase, the CS needs are translated into an interpreted climate product (if so desired, with relevant scenarios, time scales, triggers, etc). It is a process in which providers and end-users work together (often with the help of intermediaries) to combine different knowledges, skills, and practices and to create new, relevant information that meets the needs of end-users and that addresses a shared concern. Collective brainstorming results in a multitude of climatic parameters, thresholds, and climate knowledge, metrics inclusive of local experiences, data, and knowledge and is integrated into a climate product so that the co-created CS is trusted and addresses users' needs. This step thus involves the integration of the diverse stakeholder knowledges and experiences, and matching local observations (e.g. through citizen science) with scientific climate data (modelled, projected, e.g., from Copernicus, S2S Prediction project, EMODnet, GEO, ESA Actions), with the aim to enhance the accuracy and acceptance of the CS. Including LK and data may require using qualitative data when quantitative data are unavailable.

Core activities of this phase

- **In-depth (structured and semi-structured) interviews and FGD** are useful to jointly explore diverse climate knowledges and experiences. It can also be useful to organise participatory dialogues and quizzes to discover how different stakeholders perceive and experience the current climate system and its threats. This will create an overview of LK, local expertise and citizen science (including data) to build a shared understanding of climate change-related risks and responses.
- **Collaboratively collect and synthesise climate data**. Interpret and combine local, sectoral and local knowledge, and project partners' expertise (conventional science) to jointly analyse climate data from observations and model outputs, both short- and long-term. The regional, modelled, and local datasets can then be adapted to the spatial and temporal scales required by the end-users; data interoperability is organised in the back-end to serve end-user needs in the front-end. Ensure that the climate information and models used are not only scientifically robust but also accessible to stakeholders, considering licensing, language, and technical barriers.
- **Workshop to co-transform climate data to information,** tailoring it to end-user needs. This exercise will result in a set of metrics (including indicators, indices, thresholds, and timing) relevant for CCA and DRR. This includes integrating data across sub seasonal, seasonal, decadal, and long-term climate change timescales, and ensuring that the format and resolution are appropriate for the decision-making context. It is also useful to co-explore accuracy and uncertainty of climate information.
- **Co-evaluation of the jointly developed climate metrics**. Dialogues can be used to verify whether these climate metrics reflect local experiences, such as thresholds and practices, whether the climate information derived from the metrics is understandable, whether different data sources are adequately integrated and differences are clear, and whether this information can adequately support the targeted CCA and DRR policies.
- Structured **reflection** on acceptable levels of performance (uncertainty and skill). This helps define thresholds for usability and informs how CS should communicate confidence levels and what constraints may

affect implementation. CS performance can be communicated in the form of Relative Operating Characteristics (ROC) curves, heatmaps of the skill metric at different forecast lead times, bar charts summarising the number of hits, misses and false alarms, and plots produced for specific past events. It might be a technical discussion that is only for providers and intermediaries, when end users prefer not using probabilistic information, rather thresholds or 'worst case-best case' predictions or projections. In that case, the CS interface should accommodate both.
- An elaborate overview of additional participatory methods to support this phase can be found in Van den Homberg et al. (2023).

Practical considerations

- Integrate local and scientific knowledge through mutual jargon understanding, common theoretical understanding, using different models and by joining the diverse interests in the end product.
- Remember to manage expectations regarding the possibilities of a climate product with respect to its sustainability (economic and institutional viability, options to keep updating it).
- When selecting datasets for the climate product, consider long-term accessibility and affordability to avoid lock-ins caused by discontinued or prohibitively expensive data sources.
- Provide enough space in data collection involving LK to participants to share their lived experiences, and, as researchers leading the data collection process, be aware of own biases and respect the knowledge of local communities.
- Take time (and if necessary, organise capacity building sessions) to clarify concepts of accuracy and uncertainty before evaluating them. For instance, hit rate ant threat score are easier to understand than Mean Absolute Error.
- Use the possibility to link the climate product and information to existing CCA and DRR protocols. Test user-defined thresholds for action with hindcasting of past events and communicate their consistency.
- Use a broad framing of LK, including a range of different knowledges derived either through traditional or cultural norms, personal observations, lived or occupational experiences (van den Homberg et al., 2024).

Relevant process evaluation criteria

Accountability: MAP members feel accountable for the product they co-developed.

Inclusivity: collaboration happens in an accessible way and through equitable negotiation and compromises. The distribution of power and influence is equitable between different stakeholders during this phase.

Trust, **transparency**: Information is open and shared *(when desirable, e.g. sensitive information or IP-protected data are excluded from this sharing)*, and decisions are clearly explained to all CS stakeholders involved.

Constructive interaction: reflexive discussions regarding the ToC happen targeted and iteratively. Engagement therein should be relevant for all stakeholders: it should be tailored to the context, recognise interests of participants; addressing their changing needs and expectations and ensuring value added for all involved.

Flexibility: there is openness to adapt the product and add new perspectives to the MAP and co-creation process, as well as responsiveness to feedback of all stakeholders.

Legitimacy: the process of combining local and conventional science and knowledge is seen as legitimate by the end-users.

8.5 Phase C - Co-design climate service information system distributing the jointly produced climate product

Once the CS solution has been agreed upon, the climate product developed in Phase B can be combined into summarized, interpreted climate information to add value (a derived synthesis of short- and long-term observations and model outputs on past and future climate and its impact on natural and human systems). The output of this step is a prototype medium to communicate this comprehensive, actionable climate information (the CSIS) to end-users.

Phase objectives and scope

In this co-design phase, the climate product is visualized in such a way that its information can be easily interpreted and that it efficiently supports decision making. Through a participatory interdisciplinary design approach involving the end-users, a representation of this product and information (interfaces, dashboards etc.) that corresponds with the needs is constructed. This requires the use of existing or complementary, new platforms and tools for the transformation, visualization and communication of the climate information. Providers, intermediaries and end-users work together to design a CS based on a shared understanding of complexity of decision-making, and of individual and institutional capacities. Behavioural factors, drivers, and barriers that influence the uptake and effective use of climate information are assessed and considered so that the CS can be tailored to the local context (sector, region) to optimise it reflectivity.

Core activities of this phase

- **Rapid prototyping dialogues** to collaboratively design CS interfaces (including visualisation such as map-based visualisations, time series graphs and boxplot ranges, icons and infographics, traffic-light alert systems, and summary dashboards), building on previously identified user needs regarding content, timing, access, and communication formats, ensuring the prototypes align with the decision-making context.
- **Sprint workshops** to collaboratively review (define, test and refine) mock-ups of the CS and gather targeted feedback on structure, accessibility, inclusivity, and usability, which feeds into the development of a functional prototype.
- **Bilateral meetings, FGD and interviews** to gather specific information and feedback, especially where user needs are diverse, and to assess behavioural factors, barriers and drivers for uptake.
- **Climate risk narratives** to explore how users interpret uncertainty and probabilistic information. Use visuals, narratives, and scenario-based advice to test the interpretability and relevance of scientific information. These activities support the translation of complex data into accessible formats tailored to user preferences.
- **Serious games** (supplemented with semi-structured interviews) to test how CS use influences adaptation behaviour (Rastogi et al., 2025). This fosters mutual understanding of roles, responsibilities, and perspectives in climate-related decision-making. It also helps identify drivers for adoption and understand feedback loops between adaptation options and decision-making.

Practical considerations

- Facilitate a longer testing period of mock-ups, including training on their use, for end-users to interact with the CS prototype. This allows trust to be built, feedback to be gathered, and expectations to be adjusted. This strengthens the iterative nature of the co-design process
- A LL with many end-users of the CS creates a challenge in targeting the CS visualisation and tailoring the medium. Set clear boundaries and provide a set of options (not fully open possibilities) to let the process go smoothly

- Provision of definitions e.g. of skill and uncertainty would be beneficial to ensure common understanding when evaluating content and design
- Reliability and uncertainty of CS projections are common barriers to adoption. It is crucial to discuss what can be expected from CS information and how to use uncertain data in decision-making
- Visual tools also serve an educational role. Through serious games, end-users can be supported in understanding probabilistic forecasts and projections
- Long-term sustainability of CS depends on both local engagement and the availability and accessibility of climate information and models and needs considering in this phase.

Relevant process evaluation criteria

Accountability: All MAP members feel accountable for the CS they co-designed.

Inclusivity: The distribution of power and influence between different stakeholders is equitable during this phase.

Legitimacy: There is a fair representation of all relevant stakeholder voices in the co-design process.

Trust, **transparency**: information is open and shared *(when desirable, e.g. sensitive information or IP-protected data are excluded from this sharing)*, and decisions are clearly explained to parties involved.

Constructive interaction: Reflexive discussions regarding CS development are targeted and iterative. Engagement in this phase should be relevant for all stakeholders: it should be tailored to the context, recognise interests of participants; addressing their changing needs and expectations and ensuring value added for all involved.

Flexibility: There is openness to testing and experimentation to better understand what is needed for creating climate information and a climate product tailored to end user needs. There is openness to adapt the product and add new perspectives to the MAP and co-creation process. There is responsiveness to feedback of all stakeholders. Both top-down and bottom-up approaches should be applied for this.

8.6 Phase D - Co-deliver and co-exploit the co-created pre-operational climate service

In this phase, the co-created CS is co-exploited and co-disseminated. The participatory implementation of strategies for the appropriate use of the CS includes the creation and update of an exploitation plan, a (train-the-trainer) training, and agreements regarding the procedure of dissemination and sustainability.

Phase objectives and scope

In the co-delivery phase, a coordinated delivery of data, info, expertise is done. It is crucial to incorporate CS providers as active members of the co-creation process, especially in this phase, as this improves the uptake of CS. Mandates and platform hosts are defined, and business plans are collaboratively developed, ensuring future commercial exploitation.

This phase also contains capacity building and policy outreach to strengthen the dissemination of the CS. Different channels relevant to the target audiences are to be used. Audience groups include the CS community, end-users of CS beyond the stakeholders in the MAP, scientific and academic research and education communities, policy makers, public and civil society organisations, and media.

Core activities of this phase

- **Co-evaluation workshops (including scenario-based evaluations)** to conduct impact and sustainability assessments. Scenario-based evaluations refer to specific test-cases such as evaluating recent events and the CS information that was given, decision made based on the. The product criteria established in Phase A (e.g. KPIs) can be used to guide the analysis. This reflective practice also supports learning and capacity building regarding CS use, and increases the effectiveness of the CS.
- **Iterative (e.g., biannual or seasonal) monitoring questionnaires** for producers and users to monitor how testbed products (after prototype implementation) are integrated into operational procedures and cultures. These continuous feedback loops provide insight into usability, relevance, and adaptation, and document how services evolve based on user input. It also ensures that the CS remains responsive to changing user needs and scientific developments.
- **Business model** development (building on the discussions in phase A) to assess economic feasibility and support commercial exploitation. These activities will explore financing options, integration into government policies, and potential for replication in similar regions and sectors.
- **Operational action plans** to support the long-term integration of CS into institutional workflows. These will also include formalizations of producer-user relationships to ensure ongoing collaboration.
- **Training, train-the-trainer activities,** and other structured capacity building, guidance, communications, dissemination and exploitation activities embedded in **stakeholder-led events**. These activities, if involving broad networks and with tailored language and formats, contribute to capabilities development of users and providers of CS and will ensure that CS reach relevant target groups and empower these target groups to effectively use/maintain the CS.

Practical considerations

- Embedding CS in existing institutions ensures that they are used in practice and that mechanisms exist to maintain, evaluate and update the CS, as necessary
- Continue capacity building and support for providers and users to foster effective use and trust in CS
- Build on the business plan developed at the start (in Phase A)
- Establish strong links between CS and policy or action frameworks at local and national levels
- Take enough time for this phase, preferably one year (but depending on the type of CS).

Relevant process evaluation criteria

Accountability: all MAP members feel accountable for the prototype that is co-delivered.

Fairness: negotiation and compromises are made in an equitable way.

Constructive interaction: reflexive discussions regarding the prototype happen targeted and iteratively.

Flexibility: there is responsiveness to feedback of all stakeholders.

Legitimacy: the co-delivered prototype CS is seen as legitimate by end-users.

8.7 Co-evaluate climate product and co-creation process

It is important to evaluate the tangible (e.g., new prototypes for CS), intangible (e.g., knowledge, intellectual property), and diversity innovations (e.g., market relevance) generated by the co-creation process, throughout the co-creation process. Ongoing feedback, learning and adjusting based on experiences creates a flexible process that is responsive to changing preferences and needs.

The co-creation phases should each have an explicit moment of evaluating the process. This can be done through an iterative dialogue in the MAPs and using the pre-defined product evaluation criteria (Ch. 3.3, tailored during phase 0). Furthermore, a moment of evaluating the co-creation product, collecting data about the KPIs developed during the first phase, should be planned after each consecutive phase. For this, the process evaluation criteria (Ch. 3.4) can be used. The evaluation moments should not be too technical but accessible to all end-users. The MEL process, including how feedback will be considered in upcoming activities, should be always made clear.

Evaluation can also be done through system dynamics and behavioural economics modelling to assess the long-term usability and utility of the CS. These methods will help determine how the service influences decision-making and adaptation planning over time and provide insights into how to avoid maladaptation.

9 Conclusions

The I-CISK project aimed to develop a framework for co-producing the next-generation human-centred CS based on LK, behavioural insights, and user needs. This report reflects on the co-creation process that took place in MAPs within seven LLs and evaluates the prototype co-creation framework developed at the start of the project, which served as a guide throughout the project. Based on this evaluation, it then presents the final I-CISK guidelines for co-creating viable, accessible, user-centred CS that distribute useful, usable climate information through a comprehensive, credible climate product.

Evaluating the I-CISK co-creation process and product

Overall, the co-creation process was evaluated very positively and largely deemed to be very useful. The process in the MAPs was characterised by strong active involvement, inclusivity, and constructive interaction, although not uniformly. Trust and legitimacy were obtained through transparent communication and iterative design, while flexibility allowed for adapting to new insights. These co-creation characteristics showed to be closely intertwined: weak performance on one criterium often impacted others. For example, where limited responsiveness and capacity hampered the process, less legitimacy and ownership were also observed.

Throughout I-CISK, the co-creation process was widely appreciated by both MAP participants and scientific partners. It supported mutual learning and contributed to the co-evolution of knowledge and services, as evidenced by both scientific and societal actors adapting their insights and practices along the way. Although time-consuming, co-creation proved valuable in building trust, validating LK, and increasing the relevance of climate information. In several LLs, the transition from a consultative approach to a more immersive approach led to richer collaborations and more inclusive and responsive CS products.

The effectiveness of the co-created pre-operational CSs in the LLs was generally rated as high. Most of the LLs reported that the services were useful, usable, accessible, and comprehensive. However, credibility, particularly the integration of LK and the communication of uncertainties, remained a challenge in some contexts. Further CS skill and usability validation exercises are recommended. Moreover, the viability of the CS beyond the project lifetime remained uncertain in some LLs due to political changes and/or late attention to business plans.

Although broader system changes beyond the LLs were not yet visible, the project laid the foundations for long-term impacts: relationships with policymakers and intermediaries, as well as the integration of the pre-operational CS into regional planning, point to the potential for long-term impact. Smaller but meaningful changes, such as increased awareness, improved use of seasonal data, and new connections, were reported in several LLs, suggesting that the co-creation process influenced adaptive thinking and behaviour.

It is important to note that this evaluation is based on the MAP leads in a final FGD as well as through self-reporting throughout the co-creation phases. It does not capture the full array of perspectives of all MAP members or LL stakeholders or project partners and might be influenced by the positionality and character of the reporters. An evaluation in two years by all CS value chain actors involved in the I-CISK co-creation process might have strengthened the evaluation presented in this deliverable. A structured end-user evaluation would be valuable to further evaluate the co-creation process and product. Moreover, a reflexive evaluation by the CS developers, providers and purveyors would add new perspectives on the co-creation process and successes of I-CISK.

A piloted and improved I-CISK co-creation framework

Based on insights from the reflexive exercises and evaluations, Chapter 8 of this report presents the piloted and improved I-CISK co-creation framework. This framework combines principles for successful CS development with principles for effective co-creation. It aims to guide future development of sustainable, end-user-focused CS that address the knowledge needs of decision-makers, covering the 'last mile' through tailored and actionable information, thus supporting CCA and DRR efforts of end-users. The framework consists of one foundational phase (Phase 0), four main phases (A–D), and a continuous evaluation phase. Each phase follows a structured, yet flexible process for collaboration, knowledge integration, and product development. Clear objectives, key activities, practical considerations, and evaluation criteria are developed for all phases.

- Phase 0 focuses on the establishment of a LL and the formation of a diverse and inclusive MAP. This phase builds trust, identifies end-users, and develops a joint roadmap for collaboration.
- Phase A focuses on co-ideation. MAP members identify relevant CCA and DRR strategies, clarify information needs and preferences, and agree on goals and realistic expectations. These can be summarized in an impact pathway, in the form of a ToC or other format, to guide the further development of CS.
- Phase B focuses on the co-development of the climate product. Local knowledge and data, global scientific data, and user experiences are integrated into a customised climate product that meets the identified needs.
- Phase C focuses on the co-design of a user-centred CSIS. Through participatory design, the climate product and information are translated into usable and accessible information tailored to the LL's decision-making contexts and presented in a way and through a medium that optimally supports the end-users' adaptation behaviour.
- Phase D focuses on co-delivery and implementation. The CS is embedded in decision-making processes, and stakeholders are supported to use climate information effectively. Capacity building and market development are encouraged to ensure that the final CS has a sustainable life.
- A continuous evaluation phase supports monitoring, evaluation and learning throughout the project iteratively, guided by product and process evaluation criteria. These criteria are adopted by the MAP and adjusted to the LL context.

The I-CISK project has demonstrated that co-creation is not a linear or uniform process, but a dynamic and evolving practice. By embracing complexity and fostering true collaboration, CS can be developed that are scientifically robust, socially relevant, and usable. The final framework provides a structured yet adaptable roadmap for future projects to strengthen climate resilience through user-driven, inclusive CS.

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I-CISK

HUMAN CENTRED CLIMATE SERVICES

Colophon:

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