I-CISK

HUMAN CENTRED CLIMATE SERVICES

Milestone MS10

A prototype framework on co-creating end-user centred climate services

28 February 2022

Milestone MS10

Milestone Reported	Milestone Confirmed	Date
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This report presents the prototype framework to co-create human–centred Climate Services which distribute useful climate information through a usable climate product and which are used to assist sustainable, effective decision-making.

It is structured as follows: Chapter 1 situates the goal of this report and its context within the I-CISK project. Chapter 2 introduces the basic terminology and definitions regarding climate services (CS), and includes a list of criteria to make CS effective. Chapter 3 introduces the basic terminology and definitions regarding co-creation (inclusive of stakeholders), and includes a list of criteria to make the co-creation process effective. Chapter 4 elaborates the stakeholders of this co-creation process, and explains the Living Lab (LL) setup. Chapter 5 contains the I-CISK framework for co-creating CS in LL and consists of guidelines for each step of this process: (A) what needs to be achieved? (success measure), (B) which actions need to be taken? (expected outputs), (C) what are the requirements to make this step successful (enabling elements), and (D) which methods exist to perform these actions (the tools / techniques). Chapter 5 closes with a roadmap indicating timing, roles and responsibilities for each co-creation step, to be identified within the I-CISK LL.

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Acronyms

I-CISK	Innovating Climate services through Integrating Scientific and local knowledge
CS	Climate service(s)
CSIS	Climate service information system
DRR	Disaster Risk Reduction
ICT4D	ICT for Development
IP	Intellectual Property
LL	Living Lab(s)

1. Scope of this report

This report represents milestone 10 of the I-CISK project (A prototype framework on co-creating efficient Climate Services tailored to the end user needs and preferences), and will be a working document for deliverable 2.5 (A guideline that combines all best practices from the co-creation processes that have taken place in the I-CISK Living Labs (LL) for an end-user centred co-creation of climate services across Europe and beyond). The main objective of the I-CISK project is to develop next-generation climate services (CS) that address climate information needs of citizens, decision makers and other LL stakeholders at the spatial and temporal scale relevant to them, by integrating local knowledge, perceptions and concerns with research-based scientific knowledge; and by taking into account the behavioural factors and preferences that influence the uptake of climate information by end users.

This report presents a prototypical framework that proposes steps to support the following objectives:

- recognise end user's needs, perceptions, knowledge, capacity, and adaptive behaviours, as well as the climate adaptation strategies they are trying to implement; along with them;
- remove the barriers of end-users to use climate information effectively in order to instigate behavioural changes; together with these end users;
- advance 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, and,
- jointly foster 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-users needs.

to co-create CS with stakeholders in focussed LL, aiming to empower end-users to take the impacts of extreme climatic events and climate change into account in their decisions.

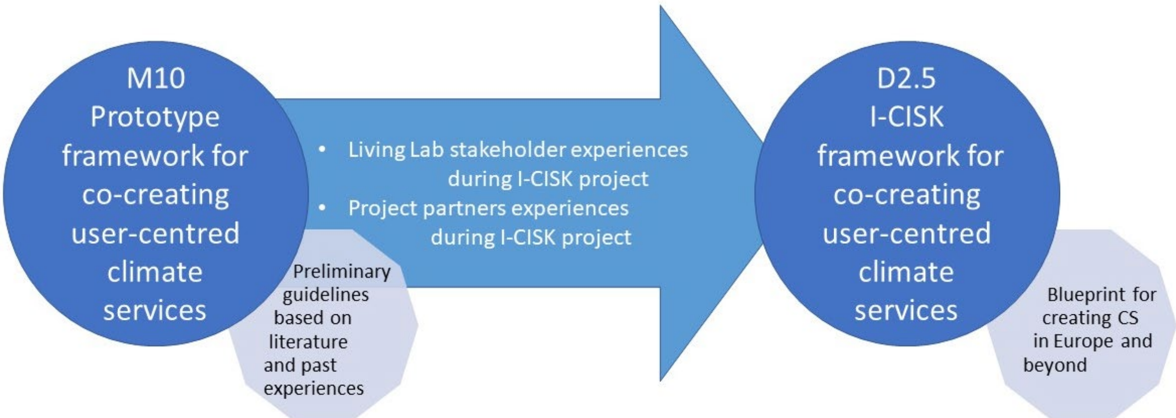


Figure 1: Schematic overview of the goal and development of this report (left blue circle) within the I-CISK project.

This prototype framework for end-user-driven co-creation of CS (left, Fig.1) was created with and will be discussed, contextualized, adapted and applied by the stakeholders of the seven LL of the I-CISK project (Chapter 3). In its current form, it can be seen as preliminary guideline, a generic starting point for setting goals and direction towards value addition and innovation to CS. This document establishes a common language with respect to CS (e.g. agree on definitions) and a common understanding of the co-creation process, including the steps, roles, and responsibilities associated with it. Ultimately, by evaluating the steps in the co-creation process throughout the I-CISK project cycle (arrow Fig.1), best practices and lessons learned will be identified and added to this framework. In addition, commonalities as well as divergence across LL will be acknowledged, and scalability of the framework will be analysed, so that this prototype framework will result in a blueprint for the participatory co-creation of other CS within Europe and beyond (right, Fig.1).

2. Introduction to climate services

2.1 What do we mean by "Climate Services"?

In the European Roadmap for research and innovation in CS, the term "climate services" is given a broad meaning: *"the transformation of climate-related data — together with other relevant knowledge — into customized products such as projections, forecasts, warnings, trends, economic analysis, and risk assessment, which allows to deliver information on best practices, to develop and evaluate solutions, and to provide any other service in relation to climate that may be of use for the society at large*"(Street et al., 2015). Over the last decade, efforts to produce and circulate CS have increased in scale, diversity, complexity, and spread (Webber, 2019). Multiple types of CS exist (Visscher et al., 2020); they all involve the provision of, and guidance for the use of, climate (impact) information for some form of decision-making to support adaptation, mitigation or disaster risk management (Bessembinder et al., 2019).

CS (Fig.2) consist of a *Climate Service Information System* (CSIS) which distribute climate information tailored to end users' needs to specific decision makers. This info is distributed through a *climate product* which consists of climate *data*, which are combined with (sectoral) climate *knowledge* 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). CSIS involve tools, products, websites, or bulletins which can support specific mitigation or adaptation decisions and disaster risk management in general (Global Framework for Climate Services; Bremer et al., 2019; Bruno Soares et al., 2018; Vaughan et al., 2018).

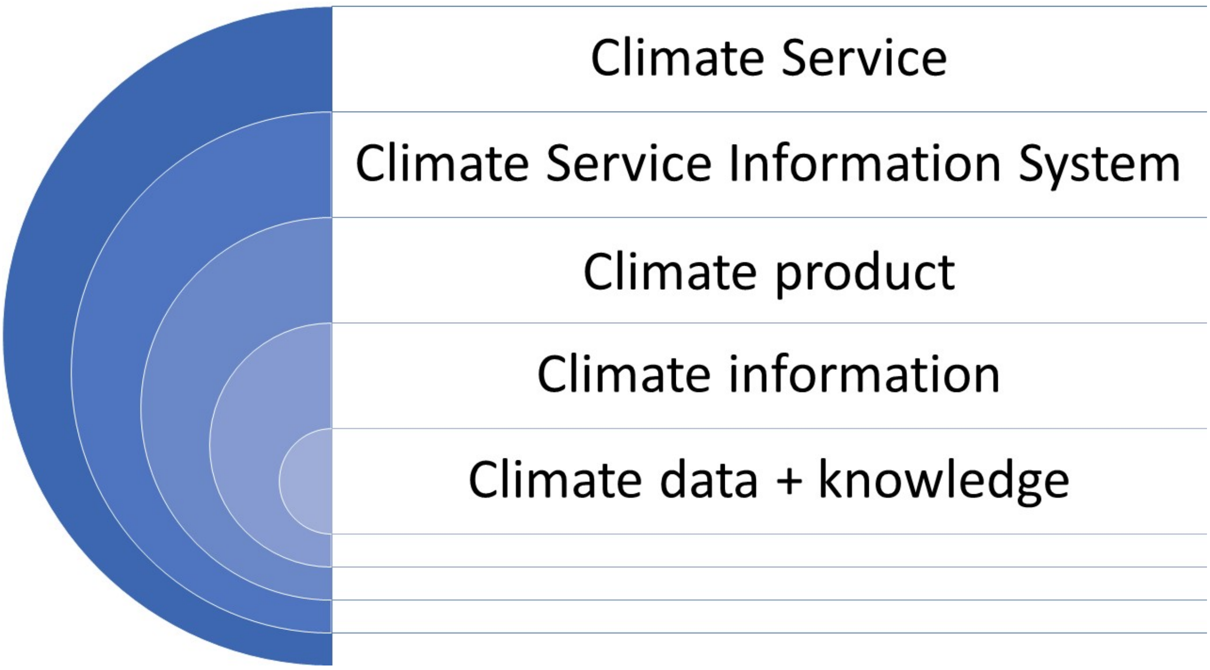


Figure 2: Climate services key terminology,

2.2 I-CISK criteria for effective climate services

The following product criteria (Fig.3) can be used to evaluate CS. Specific indicators to measure and monitor these criteria should be decided on with stakeholders in each co-creation context. *The assumption is that if all criteria are successfully achieved, the CS will be effectively used.*

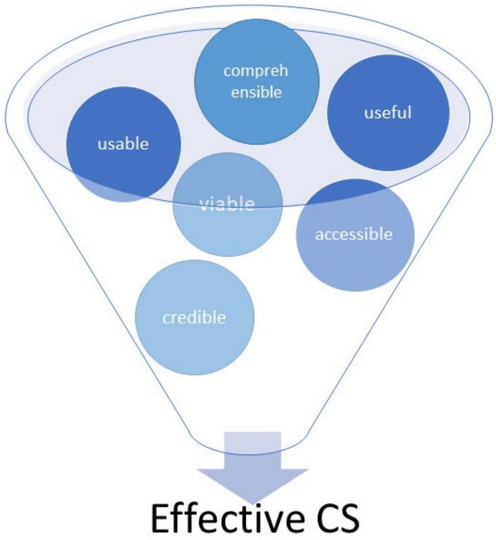


Figure 3: criteria for effective CS

- **Usefulness**

CS should account for the heterogeneity in content needs and decision framings over time and among different end users in order to be effective (Christel et al., 2018). They should be applicable for the geographical area, or sector (Barnet et al., 2021). They match the timing and spatial scale of the decisions to be supported. The CS should have a (perceived) information fit - purposeful to the decision (Vincent et al., 2020).

- **Usability**

CS are usable when they are designed in a way that considers the socio-economic conditions of the wide variety of users and should be built based on existing experience and requirements. They should be scalable and be delivered timely (Lemos et al., 2012; Vincent et al., 2020) and must be designed in a manner sensitive to existing decision-making logics of those users (Carr & Onzere, 2018).

- **Accessibility**

The communication mode of the CS should align with the end user preferences regarding media/channel; which should be open and inclusive. Moreover, it should be affordable for all, especially where equity considerations are subscribed to (SENAMHI & MeteoSwiss, 2018).

- **Clarity**

The climate information should be transformed into an understandable, comprehensive product aligned with users' understanding, and translated and visualized to support efficient use (SENAMHI & MeteoSwiss, 2018).

- **Credibility**

Climate information should be accurate, reliable and trustworthy, including clear communication about uncertainties and limitations (Lemos et al., 2012; Buontempo et al., 2014).

- **Viability**

CS should be economically and institutionally efficient in order to be sustainable in the long term (Lemos et al., 2012).

3. Introduction to the co-creation process

3.1 What do we mean by "co-creation"?

The interdisciplinary, interactive and iterative process of co-creation 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 overcome the divide between climate science and decision makers (Buontempo et al., 2014) and increase the uptake of CS (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 possibilities and limits of science, with the goal of creating innovative, 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), ***and this report uses the first term: co-creation***[1].

Co-creation consists of the entire process of joint knowledge and service creation between experts from different disciplines and the sectors (Brandsen et al., 2018; Máñez Costa et al., 2021). It includes active involvement of end-users of a product or 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 (CSIS) and intangible (improved understanding, capacity) outcomes (Bremer et al., 2019). Moreover, end-users 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).

According to Hirons et al. (2021), the type of stakeholder engagement lie on a spectrum between consultative and immersive (or 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 create human-centred CS, where important stakeholders are at the centre of the design, innovation and implementation of the CS.

Figure 4: Source (FutureclimateAfrica project (Co-Production in African Weather and Climate Services, 2019))

[1] 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) (Mauser et al., 2013; Suhari et al., 2022; Terblanche, 2014; Fdez-Arroyabe & Roye, 2017); Larosa & Mysiak (2019) emphasize the importance of co-creation for delivering innovation (rather than only producing it (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, <u>we chose to use the term co-creation</u> 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 CS.

3.2 I-CISK steps in the co-creation process

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's a challenge in its own right 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 this I-CISK guideline, a tailored co-creation process is developed by combining best practices found in different strands of literature, including CS literature, ICT4D (ICT for Development) and design thinking. Several steps in the co-creation process can be distinguished, all of which are executed by a diversity of stakeholders (scientists, producers, end users, decision makers). (Fig.5; adapted from (Botzen et al., 2020; Christel et al., 2018; Ecologic et al., 2018; European Commission, 2020; Hirons et al., 2021; Vaughan et al., 2018, 2019; WISER, 2017, CO3 project, 2022, Máñez Costa et al., 2021; the SEI tandem framework and designkit.org)

Figure 5: Co-creation of user-centred climate services: building blocks of the process that take place in a LL context

The co-creation process will lead to the **co-evolution of knowledge and service**: both knowledge and service will be created step by step, and this dynamics will be steered by both by the LL stakeholders and by the project scientists and producers who will learn from each other. The bridging and strengthening of distinct knowledge system results in the generation of new understanding and an improved service (Chapman & Schott, 2020).

0. Build continuous engagement in the Living Labs

*This step focuses on **empathy** and trust building: who are potential 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 the initiation phase, a variety of LL (see chapter 4) covering a range of relevant sectors and regions are assembled, and the engagement of a variety of end-users in these LL 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, 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, LL with representative stakeholders are the foundation of successful co-creation.

A. Co-explore climate information needs and climate service desires

*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 in order to match user requirements with technical possibilities, and make decisions on the within-scope and out-of-scope needs. In order 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 as a result of the co-creation process itself. This iterative nature makes it possible to change objectives and subsequent aligning expectations throughout the process.

B. Co-identify adaptation plans and disaster risk reduction strategies to be supported

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 climate adaptation (e.g. NAPAs) and disaster risk reduction (DRR) and potential new strategies / measures that can benefit from decision-support through CS, are mapped out. In this phase, these adaptation and risk reduction interventions are assessed, in order 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. Importantly, as part of this step, request regarding timing of information provision, the type of data and the level of spatial and temporal aggregation have to be identified.

C. Co-develop climate (impact) data and knowledge into a climate product

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 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 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.

D. Co-design the user-centred climate service providing climate information

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 transdisciplinary design approach involving the 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 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 taken into account so that the CS can be tailored to the local context (sector, region) in order to optimise it effectivity.

E. Co-evaluate the co-created climate service

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 timelines.*

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 (the 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.

F. Co-deliver pre-operational climate service information system

In the co-delivery phase, the CS information system 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 LL; the scientific and academic research and education community; policy makers; and the general 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.

These I-CISK co-creation steps address two key challenges for human-centred CA (Christel et al., 2018): the information challenge and the domain challenge. The ***information challenge*** is the requirement to address end-user needs and decision framings through a tailored climate product that contains probabilistic data; and the requirement to communicate the climate information (design, visualisation) addressing end-user desires and capabilities. Co-creation steps A to D focus on ensuring this information-fit and design-fit, supporting the interpretation and use of complex scientific data. The ***domain challenge*** is the requirement to make CS used in a complex landscape of user that are unknown or hard to access, and for a not yet established market. Co-creation steps F focusses on fully engaging with purveyors and producers during dissemination, supporting the uptake and sustainability of the CS.

3.3 Principles for a successful co-creation process

The assumption is that a well-designed co-creation process leads to effective CS design. The principles shown in Fig.6 allow for a successful co-creation process in the I-CISK project. (Adapted from (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; Steynor et al., 2020; Suhari et al., 2022; Vincent et al., 2018, 2020; WISER (Weather and Climate Information Services for Africa), 2017).

Figure 6: Principles for a successful co-creation process

These principles are interdependent and often difficult to attain all at once within the practical constraints (time, budget, capacity and other resources) of a project. It is important nonetheless to be cognisant and transparent about potential trade-offs between these principles. Any co-creation process is a balancing act between navigating time constraints, including stakeholders' different and changing demands and perspectives while retaining a high level of flexibility and reflexivity (EC 2020 climate resilient Europe). I-CISK will use these principles, as well as the criteria for success outlined in 1.2 to evaluate the co-creation processes that will take place over the course of the I-CISK project in each of the LLs.

- **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 capability of all stakeholders: scientists and practitioners who participate in co-creation should have time, money, support, etc. to actively participate. 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, monitoring and learning, there may be a need to refine product and process" - the integration of multiple perspectives. Moreover, during 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, monitoring and learning between the different stakeholders, there may be a need to refine product and process. This requires and agile process, adaptability of the product, 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)**

Linked with I-CISK gender guidelines

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, and jointly owned by these stakeholders. Besides, it should be customized to different people with different needs, experiences, perspectives and “knowledge systems”; be aware of stakeholders’ differentiated demands and contextual circumstances. Indeed, diversity should be embraced. The project should ensure fair representation of these stakeholders throughout the process, and their partnership in the process of producing a service. There should be space for multiple stakeholders to share expertise and challenge each other's views and contributions. Indeed, collaboration involves changing each other’s perspectives 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. 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 (Porter & Dessai, 2017).

- **Trust (requires transparency and respect)**

Linked to I-CISK ethical + GDPR guidelines

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 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 more legitimate if independent from political or commercial interests (Reinecke, 2015). It 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. Introduction to Living Labs

4.1 What do we mean by "Living Labs"

Living Labs[2] (LL) are places for innovation, multidisciplinary ecosystems in which the I-CISK co-creation process will place. They are experimental setting and a safe space for stakeholder involvement (Fuglsang et al., 2019); real-life environments in which multiple heterogeneous stakeholders are connected through public-private-people partnerships and in which innovation-development activities can be conducted (Hossain et al., 2019). LL can be distinguished from test beds, in which users are involved as passive participants providing feedback on producer activities rather than co-creators, both object and subject in the innovation-development activities (Hossain et al., 2019). LL explore the feasibility of a business models of complex solutions in real-life contexts.

Indeed, for LL, co-creating CS is a method to tackle the "real-life" problems, drawn from everyday experiences and actors' interests and perspectives, surrounding climate adaptation by connecting knowledge from science and society in a transdisciplinary learning process (Hagy et al., 2017). The values of societal and academic partners in the LLs shape and create the design of the LL, its processes and workings, and its outputs. A LL indeed comprises the ecosystem within which the co-creation process happens; and in that sense is very much central to co-creation process.

I-CISK LLs facilitate the process to co-create the CS, but does not have the ambition to exist beyond the timespan of the ICISK project. It is important that through the LL, a sustainable product (i.e. a CS) is co-created, which needs to be embedded in a viable ecosystem of users, purveyors, providers and wider stakeholders (e.g. decision makers) for its long-term use.

I-CISK LL stakeholders can use this guide as a starting point and modify the suggested processes, methods and tools to fit their needs and context, while adhering to the process and output principles. In the development of the framework, each LL may hence shape their own framework.

The role of I-CISK project members vis-a-vis others involved (LL stakeholders) needs to be specified at the start of the collaboration. While I-CISK project members should ideally stand on equal footing, with their funding they may have a larger capacity to take on certain roles/responsibilities.

In I-CISK's LL:

- A guiding principle for I-CISK is inclusiveness and meeting the needs of the end-users including vulnerable groups, as well as addressing unintended consequences. Special efforts are needed to ensure that vulnerable groups are involved to ensure equal responsibilities, rights and outcomes.
- Relevant stakeholder groups will be identified, and each of the stakeholder groups has to agree on their assigned roles and responsibilities in each of the co-creation steps. This information is shared across LLs to facilitate cross-learning.
    - Some activities require the involvement of particular stakeholders while others would not be desirable. For example, purveyors should not determine end-users' needs. Once the list of stakeholders is identified - different for each LL, further guidance on their desirable/required level of involvement and roles and responsibilities will be discussed.
    - Some stakeholders may prefer a role of reactive informers (Harvey et al., 2019);
    - This identification and listing is different from a full stakeholder analysis in which for example influence/power are considered.

[2] Living lab is a conceptualisation of multi-contextual and cross-sectorial experimental user-centric innovation processes with the aim of developing and/or improving welfare products, democratic engagement, services or processes based on the application of co-creation methodologies depicted by transdisciplinarity (Jargalsaikhan et al., 2019).

4.2 Who is involved?

Different types of stakeholders will be involved at different stages of the co-creation of the CS and with different intensity. "Stakeholders" is the general term encompassing *CS producers, CS intermediaries, CS consumers or other people/entities either affecting or being affected by the decisions informed by the climate service (or current absence thereof)* [3].

The categorisation of stakeholders within a LL (Fig.8) is important in order to identify who to involve and whom to target with different project activities in the LL.

Very generically, we can define following categories of stakeholders;

- **actors**: those stakeholders that play an active role in the technology, institutional and investment readiness of the CS for the market - these are the stakeholders affecting the decisions, by creating either drivers or barriers for the regulatory and broader institutional context, technological context or market context (includes project team, scientists, practitioners, decision makers, private sector, public authorities, enabling institutions, providers and end-users, etc.);
- **providers**: some actors will provide the necessary data, investment, regulatory context for the CS to be sustained; CS providers supply climate information and knowledge. CS providers may operate on international, national, regional, or local levels and in a range of different sectors; they may be public or private, or some mixture of both (Cortekar et al., 2020; Vaughan and Dessai 2014).
- **purveyors**: Service purveyors act as knowledge brokers providing guidance on ways that climate services can address regional problems. They also ensure that products, scientific results and business opportunities are adequately communicated to end-users
- **end-users**: those actors that will use the CS at different levels of the decision chain. CS users employ climate information and knowledge for decision making; they may or may not participate in developing the service itself. In some cases, climate information users may also pass information along to others, making them both users and providers (Vaughan and Dessai, 2014). Users can be civilians, companies, developers, private organisations, local communities, civic organisations, governments and more (Barnet et al., 2021)

[3] The video in this link[3] gives an introduction to the methods to identify and categorize stakeholders in the living labs. Based on this identification/categorization, each LL can then fill in its own typology of stakeholders. In addition, the video highlights some common pitfalls in stakeholder engagement as well as key conditions to avoid them, which need to be considered in crafting the agreements and aligning expectations with stakeholders (see section VI).

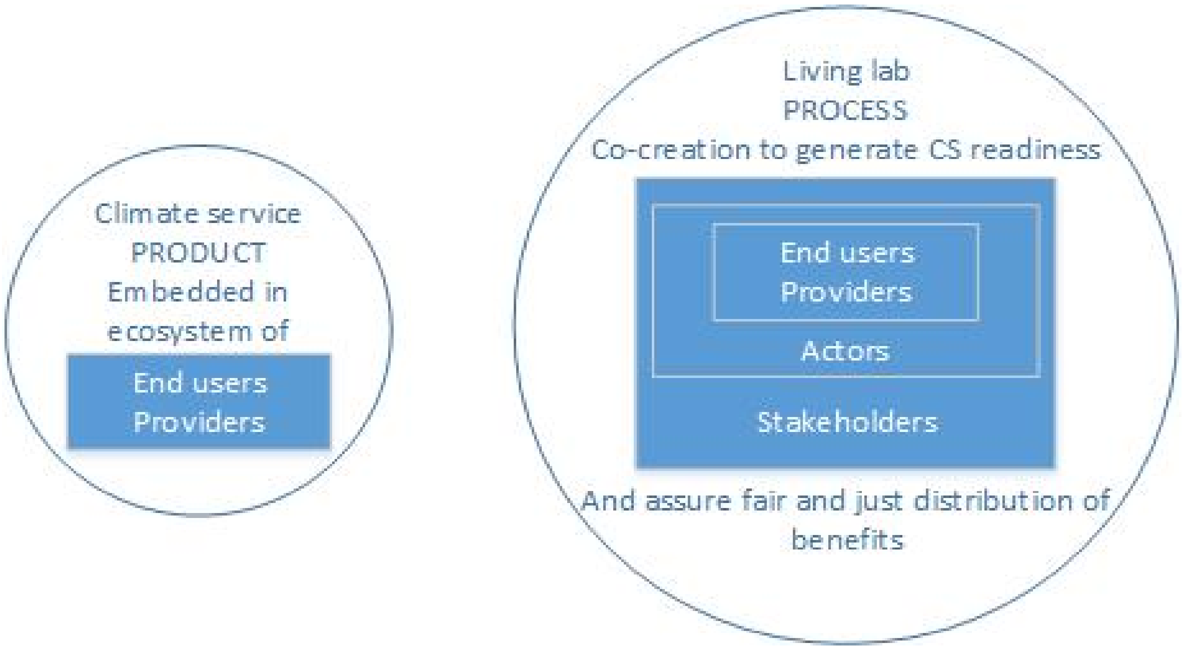


Figure 7: Typology of stakeholders and different stages of involvement in the co-creation and co-delivery of the climate service (Draft - please comment)

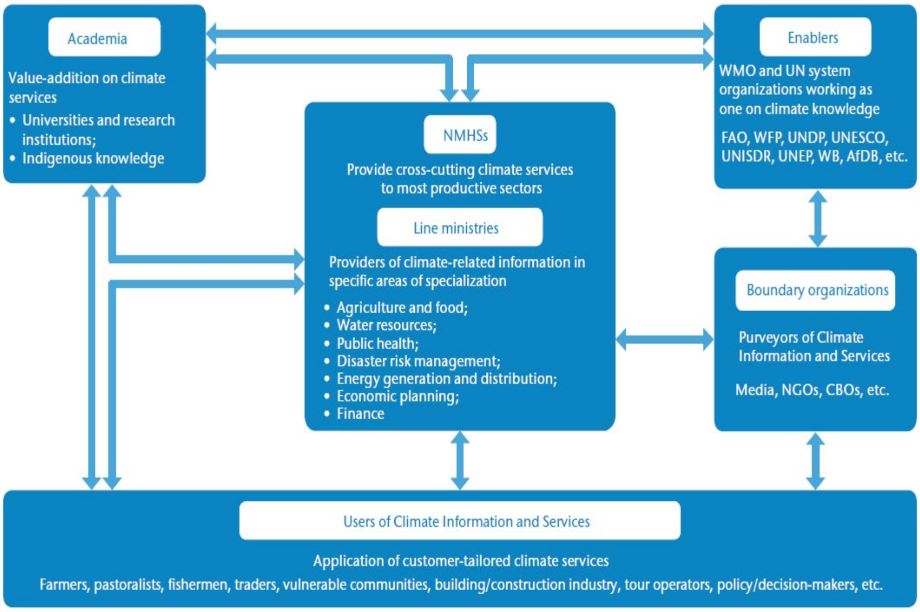
It is essential to cast a broad net of stakeholders early in the co-creation process to identify people being affected. Which stakeholders to involve in which stage of the co-creation process can be linked to efficiency and equity arguments and should be linked to the qualifiers of the process (see section 3.2) and product/service (see section 2.2).

- **efficiency argument**: stakeholders that will be part of the ecosystem that makes the final product sustainable (providers, end-users) + those that help us understand the readiness for CS from institutional, investment and technology perspectives (what is the regulatory framework, willingness to pay, what is current level of data/CS and how can it be upscaled).
- **equity argument**: those stakeholders that will be impacted by the decisions informed by the CS (or the absence thereof) - these stakeholders are generally low on the influence scale, but high on importance (i.e. the changes in climate and responses to it highly affect them) and need to be at least identified and involved in early stages of the co-creation process.

More specifically, the relevant stakeholders are likely to vary across LL contexts. An example of the type of stakeholders that may be involved in an CS arrangement at national level is provided in the figure below (Fig.7). Indeed, academic institutions and purveyors (as boundary organisations) often are involved as well.

Sometimes a distinction is made between LL stakeholders (including end users, citizens, policy makers) and project team stakeholders (including scientific partners, production partners). Both groups are stakeholders to the CS co-creation and ideally work on equal footing.

Beyond ‘involvement’ in different stages, it is also important to assign **roles** and **responsibilities** that come with this involvement, and determine **ownership** of different processes. For example, in many cases it is an National Meteorological and Hydrological Service, an Non-Governmental Organisation, or a commercial provider that is the purveyor of an operational CS. That purveyor needs to own the process. Experience with LL in various context has suggested that appointing LL Champions or Leads may help to maintain momentum during the lifetime of a LL – and sometimes beyond.



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- *Figure 8 : National level stakeholders for the co-creation of CS Source:*(WMO-GFCS, 2018)

5. I-CISK framework for co-creating user-centred climate services in designated Living Labs

5.1 Guidelines

I-CISK recognizes that to achieve behavioural change, the active use of climate information in informing decision-making toward climate 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. The I-CISK co-creation approach (Fig.9) 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 (Blane et al., 2017; Harvey et al., 2019; Hirons et al., 2021). It is **crucial to discuss and agree on the co-creation steps in every LL**, at the start of the actual process.

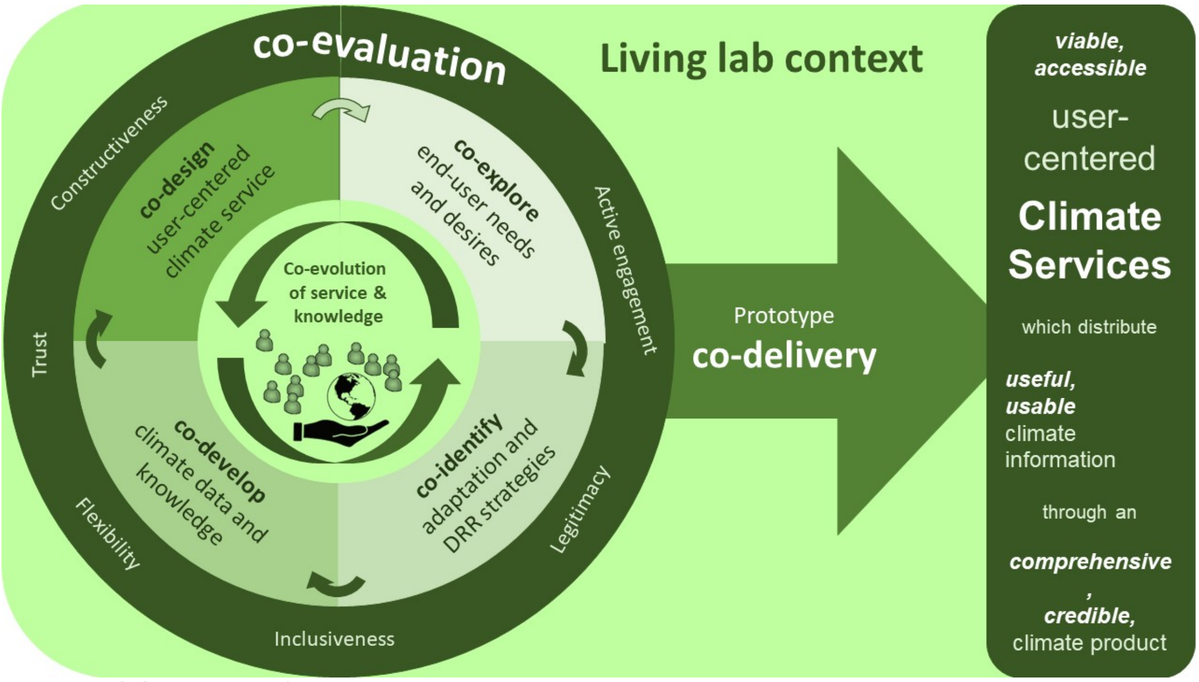

Figure 9 I-CISK prototype framework to co-create user-centred climate services

The **following section elaborates per co-creation step** which enablers and success factors can be used and which possible barriers will need to be overcome in order 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: these relate to the ICISK project objectives
- Key Performance Indicators: these are indicators for success for the ICISK project
- Components: actions that need to be taken, led by project consortium
- Method/tools: techniques to execute these components
- Enablers: tips to execute the step successfully
- Questions: questions that LL actors should be able to answer at the end of each step.

It is important to emphasize the **flexibility** (rather than prescriptive nature) of these guidelines. As I-CISK operates in a wide variety of LLs, the process can be modified during the project, responding to needs or changing circumstances, for instance. I-CISK searches for an optimal **balance** between standardization of the co-creation process across LLs, which enables comparisons, and customization of the co-creation process, which ensures relevancy in each LL (EC 2020 climate resilient Europe).

I. Initiate Living Labs covering broad diversity in sectors

Objective (success factor)

Understanding decision-making contexts (Vincent et al., 2020) to create CS aware of (together with) knowledge, skills and perceptions of users and their socio-political context: the systematic inclusion of local, contextualized, and experiential resources of knowledge is a key component for the co-creation of CS.

Successfully initiating the LL ensures achieving I-CISK objective #1: *Integrating social and behavioural factors to produce context and sector-tailored CS*

Successfully collaborating on the co-design process ensures achieving I-CISK objective #8:
Increase resilience of society, organization (private and public), and individuals to multiple risks

Key Performance indicators (I-CISK project proposal)

- Number of the LL CS co-design roadmaps defined
- Gender Balance in stakeholder representation and participatory research in LL (Percentage Women)
- Number of citizen groups, stakeholders and decision makers in LL collaborating in the process (at least 3 per LL)
- Number of workshops held in LL (at least 5 per LL)

Components (outputs / actions to be done - WP1 to lead)

- Identify key actors and create partnerships:
    - Identify relevant actors, involve actors at key entry points, develop new networks and strengthen existing partnerships, enable open interaction among actors, recognise all partners roles, strengths and limitations, recognise gender and cultural differences, prioritise listening, create a space for regular interaction and exchange;
- Build common ground:
    - Make clear impact/benefit requirements from all stakeholders, reach a shared vision and common goal, develop agreed principles and ways of working together (agree on co-creation process), strengthen understanding of key concepts (WISER project coproduction manual)
- Develop operational co-creation action plans
    - These serve as a memorandum of understanding formalising the relationships for continued co-creation, and clearly map out roles and responsibilities
- Manage expectations by identifying clear scope
- Context mapping
- Capacity analysis and identification of resource constraints
    - secure adequate resources for all partners, factor in time to support (WISER project coproduction manual)

Methods / tools / techniques

- Talanoa Dialogue (UNFCCC, 2018)

    - building consensus and decision-making through storytelling
- action research approach
- roadshow
- literature review (Bon et al. 2016)
- Co-creation of a 'glossary'
    - to understand varying perspectives of different terminology & ensure effective communication across partners, sectors, regions etc.
- discussion group
    - to set expectations and co-explore roles in the co-creation process (Hirons et al., 2021).

Enablers (requirements / tips to make this step a success)

- ☐ **Time and resources**: The full process in the LL should be managed with enough time, resources and facilities to deliver the quality and guarantee continued *active engagement.* Providing enough time to clarify key concepts, definitions and terminology can foster mutual understanding between heterogeneous project partners (Suhari et al., 2022). All actors in the co-creation process require capacity building to effectively work in new knowledge systems. (Hirons et al., 2021). Participation should be facilitated and every relevant stakeholder should be part of decision making to ensure *active engagement and transparency.*
- ☐ **Inclusiveness**: It is important to have a diverse, transdisciplinary set of stakeholders so that different types of knowledge and experiences, different viewpoints and paradigms can be included in the co-creation process to ensure *inclusivity*.
- ☐ **Trust**: understanding among the stakeholders should be built through working *transparently* in order to guarantee *legitimacy* of the co-creation process, and will allow to create a trustable product. This relationship building requires time and effort, as well as effective communication strategies.
- ☐ **Understanding the decision making context** will support the creation of usable CS. Scientists are required to understand the realities (exposed to complex real world problems, have to decide timely and efficiently) of stakeholders in order to improve the societal impact of climate knowledge (Suhari et al., 2022).
- ☐ **Consider competing priorities** (Hirons et al., 2021): right at the start, it is necessary to develop a shared understanding, across actors, of the intention and desired outcomes of the co-creation process. This includes identifying and discussing any competing priorities, interests and motivations across the group. This is critical for managing expectations across all the actors (Tröltzsch et al., 2018) and important for legitimacy.

Key questions

During this co-creation step, the following questions should be discussed (and documented) with each actor (Watkiss, 2008)

- Who makes decisions that are influenced by climate?
- Who can provide information?
- Who do we include to ensure that all decision-makers are included?).
- To what extent does the climate affect their planning and decisions?
- What interest do they have in climate?
- What information do they want from you?
- Who else might be influenced by their opinions?
- Who else do they think should be play a role in co-creation?
- What are the embedded assumptions and motivations of initiating the co-creation process?
- Are we including/planning to include all potential users and decision-makers?
- Are all parties willing to work in a collaborative manner?
- How do stakeholders see the process of co-creation?
- What other actions do we need to take to continue a process of co-creation?).
- What is a realistic expectation of working together, within the available time-scale of the project?
- What level of engagement level can you provide (workshops, bi-lateral, joint work, joint dissemination)?
- What is a realistic expectation for delivering results that meet your needs, within the description of work (bounded)?
- Are there joint knowledge products that we can develop together?
- Are there case studies that are of particular interest that we could focus on (DES)? If so, then understand the decision context, information needs, etc. (see above sections).
- Who else is important to engage within the organisation? Who else do they think should be playing a role in co-producing knowledge (outside the organisation)?

A. Co-explore climate information needs and climate service desires

Objective (success factor)

Understanding users' climate information needs (Vincent et al., 2020) so that the CS created addresses jointly defined issues and following desires of (together with) users.

Successfully exploring needs and desires ensures achieving I-CISK objective #1:
Co-creating the next-generation, human-centred CS.

Key Performance indicators (I-CISK project proposal)

- Number of decision processes requiring tailored climate information identified within the specific contexts of the LL (at least 2 decision processes per LL)
- Number of participatory activities and sessions (e.g. meetings, workshops, focus group discussions, interviews) held to co-explore end-user needs, knowledge, adaptation needs and behaviour (at least 5 per LL).

Components (outputs / actions to be done – WP2T2.1 to lead)

- A detailed needs assessment and dedicated priorities analysis
    - synthesize the state of knowledge, the strengths and weaknesses of available products, and end-user desires regarding adaptation and DRR policies and resilience (WP2T1).
    - a detailed assessment of existing use of CS and the context in which they are implemented;
    - develop deeper understanding of the envisioned end product (Bon et al., 2016)
- Iterative process
    - regularly revisit needs and priorities and co-explore strengths and weaknesses of co-produced tailored CS.

Methods / tools / techniques

- Field research
- participatory appraisal study
- use case modelling (requirements analysis)
- Participative documents that can be iteratively completed and adjusted throughout the co-creation process
- User questionnaires, interviews, quizzes
    - to understand decision-making requirements of a range of stakeholders;
        - open questions with space to listen to perspectives and stories of each stakeholder
    - to evaluate stakeholder & user understanding and perspective of climate information, uncertainties, probabilities etc.
    - to identify how climate information could potentially influence decision-making in their sector and specific decision-making context (Hirons et al., 2021)
- User stories
- Collaborative, iterative workshops,

- to update stakeholders on the work being done to address their needs & the identified gaps in CS; do the variables, designs, skill/performance information etc address their needs? regular check-ins to ensure research is in the right direction and moving towards useful, usable, accessible etc.
- to manage expectations - e.g. if feedback is 'we need x / x would be really useful', but we cannot produce 'x', what other alternatives are possible that would satisfy the user needs? Focus on both understanding of user needs and on user understanding of possibilities and limitations.

- sector-themed discussion groups to co-explore sector specific needs and to discuss misunderstood terminology which they had encountered (Hirons et al., 2021)
- Decision-making activities on use of CS for local decisions & actions, e.g. Neumann et al. (2018).

Enablers (requirements / tips to make this step a success)

- ☐ This step requires an *active engagement* with multiple stakeholders to outline criteria that are relevant for the local context and sector-of-importance, ensuring a widely useful service. It is important to involve stakeholders with different needs and perspectives to avoid reinforcing power balances (Vincent et al., 2020).
- ☐ Generate discussion around what types of information the heterogeneous stakeholders want by describing the inputs that are necessary for their problem in their own terms (rather than scientific language or constrained by technological or scientific interests) (Briley et al., 2015).
- ☐ The needs assessment should be focussed on **added value** of a new CS application (actors believe that the right questions have been asked concerning the right problem) to increase *legitimacy* (Hegger et al., 2012; Hegger & Dieperink, 2014). A strong focus on the demand side and on the provider/user interface is important.
- ☐ Sufficient interactions with an open agenda
    - to overcome perception gaps, build **trust**, create mutual understanding and awareness of CS context, needs and limitations, interests and assumptions
    - to provide space for bi-directional learning and communication.
- ☐ Jointly identify issues to work on, to address a concern prioritised by the end users / stakeholders (WISER (Weather and Climate Information Services for Africa), 2017).

Key questions

During this co-creation step, the following questions should be addressed (discussed and documented) together with all relevant stakeholders (based on COACCH, Beier et al., 2016):

- What are the biggest challenges that you face? What role does the climate play in these?
- How does/has weather and climate affect(ed) your activities (in the past)?
- How do you anticipate climate change will affect your future activities?
- What analysis have you undertaken (if any) to look at future risks?
- Do you have any particular priorities or key concerns (risks)?
- Do you already use climate research or climate information? If so, how?
- What is the issue at hand? What questions are being addressed? What topics are included or excluded from consideration?
- What decisions are being made? Are they flexible or limited in scope? What is the timing of decisions? What problem or decision can we address with the research? Or if information was available, what decisions could it inform?
- What is the context in which the research (outputs) could be used? Who will use the scientific information (including downstream uses) and how will they use it?
- What data would help make better decisions or be most useful? In what form, process, or product will the data be most useful to the users?
- Given that decisions must be made before the science can be “settled,” what is a realistic expectation of what is possible and useful within the available time and budget? How quickly would you need results in order for them to be useful?
- What is necessary to make data accessible to all projected users? Who will own the data or other products? Where will the products reside?
- What would success look like for all parties?
- What alternatives are available to achieve success? What is gained or lost by pursuing one alternative over another?
- What variables does the decision maker care about? What resolution of data? What spatial extent? What level of precision is realistic, achievable, and adequate for the decision? If such precision is not feasible, should the project be abandoned or modified?
- What is the planning time horizon? Is this horizon appropriate for the purposes agreed on by the stakeholders?
- How will uncertainty be addressed? To what extent can multiple projections (e.g., emission scenarios, general circulation models) bracket uncertainty?
- Which dissemination/knowledge products would be interesting/needed? Are there issues with data availability and publication? Can data and results be accessible publicly or not?
- How regularly should we review progress, and update direction?

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

Objective (success factor)

CS designed to support existing mitigation and adaptation measures, plans, policies and strategies already implemented by LL users to deal with disaster risk and climate change. User-identified potential (additional) adaptation pathways and DRR strategies will contribute to the usefulness of the created CS, supporting the increase of end-users' resilience to climate-related hazards.

Successfully co-identifying adaptation pathways contributes to achieving I-CISK objective #2: *providing actionable information across timescales: sub-seasonal, seasonal, decadal*

Successfully co-identifying adaptation pathways ensures achieving I-CISK impact #1, 6 & 7: *Enabling citizens, stakeholders and decision-makers to factor climate change and climate action into the decisions that will affect our lives for decades to come & Improve European capacity regarding availability of solutions to adapt to and mitigate climate change, including by tackling sector and/or geographical gap & Provide appropriate responses to European and international climate policies we commit to.*

Key Performance indicators (I-CISK project proposal)

- Number of climate adaptation options and disaster risk reduction actions co-identified (at least 3 options and actions per LL)

Components (outputs / actions to be done – lead by WP2T2.3)

- co-explore the expertise on and the desires regarding climate risk management options, and cultivate social learning among the end-users within the LL
- co-create an evidence base for implementing and monitoring climate adaptation and disaster risk reduction strategies (mitigating water risks, adapting to climate change and preparing for water related disasters)
- co-create an agreed upon output (tangible or intangible) that aims to improve previous approaches and better enables the uptake and use of weather and climate information.
- Identify solutions (climate adaptation, risk reduction) by enabling knowledge exchange amongst LL users and between users and project partners

Methods / tools / techniques

- Meetings and semi structured interviews:
    - CS users should explain to project partners how risk is evaluated and managed in their sector and how informed decisions are made despite uncertainties. This includes the characterization of the cultural and socioeconomic context in which decisions are made (Beier et al., 2016)
    - to co-explore the timing context into which climate information would be added, based on the identification and analysis of key sector activities, key user decisions, and current available forecast information (Hirons et al., 2021)

- LL network maps:
  - to co-explore the organizational governance context into which climate information would be communicated (Hirons et al., 2021)
  - to map with the support of users and documental analysis the LL institutional context, including accountabilities and constraints on authorities for each agency or actor separately (Beier et al., 2016)
- Literature search and cross seeding:
  - Project partners should seek in the existing institutional frameworks and in similar socioeconomic contexts additional DRR strategies potentially relevant to the LL and share them with the LL users.

Enablers (requirements / tips to make this step a success)

- ☐ CS are useful when they are prepared in a way that considers the socio-economic conditions of the wide variety of users. Understanding needs and capacities is key to ensuring the effectiveness of a CS. (WMO-GFCS, 2016; GFCS 2011)
- ☐ Design process following desires regarding actual climate change adaptation; disaster risk mitigation; EWS questions of (together with) users
- ☐ context - and sector-specific: local, sectoral visions on climate and disaster resilience included; tailored to context-specific challenges and risks
- ☐ translated (language and local knowledge perspective)
- ☐ Having the stakeholder describe a particular concern or describe existing vulnerabilities that they face (to avoid disordered integration of when stakeholders want to bring climate information into decision-making processes (Briley et al., 2015))
- ☐ Need to broaden the context of the CS and products to those required to inform action consistent with that foreseen in the Paris Agreement and the UN Agenda 2030 SDGs (Jacobs & Street, 2020) Here, a large focus should be placed on *relevancy* for the stakeholders

Key questions

During this co-creation step, the following questions should be addressed (discussed and documented) together with all relevant stakeholders (Beier et al., 2016; Watkiss, 2018):

- What approaches and methods do you currently use to make decisions?
- Do you use economic tools for decisions (economic appraisal, investment IRR, CBA etc.) and if so what methods, inputs, assumptions (e.g. DR, threshold IRR), etc.?
- What other tools and information do you use to support your decisions? Please include both formal and informal sources of information.
- Where do you seek source of inspiration or advise in the design of your adaptation pathways and DRR strategies?
- How and by whom do you get support (of any kind) to implement your adaptation pathways and DRR strategies?
- What are the main obstacles (of any kind) in the implementation of your adaptation pathways and DRR strategies?
- What time frame do these decisions get made in? What is the planning time horizon? What is the lifetime of decisions?
- Who makes decisions (that are influenced by climate change)?
- To what extent does the climate affect their planning and decisions already? What decisions are they making that are relevant to climate now (if any)?

- Do you use climate research or information to inform decisions and if so what sources?
- How do you currently factor uncertainty into decisions?
- What would be an acceptable level of uncertainty in order to include new climate-related information in your decision-making process?
- What information would you like to be available? How could you use it?
- What is the context in which the research (outputs) could be used? Do we know enough about the context in which the research (outputs) will be used?
- What problem or decision can we address with the research? Or if information was available, what decisions could it inform? Do we know enough about user needs?
- Who will use the information (including downstream uses) and how will they use it?
- How quickly would you need results in order for them to be useful?

C. Co-develop climate product containing tailored local and SOTA climate data and knowledge

Objective (success factor)

Creating climate metrics inclusive of local experiences, data and knowledge, so that the created CS is trusted and addresses users' needs (Vincent et al., 2020).

Successfully co-producing climate data ensures achieving I-CISK objective #1:
Integrating local knowledge with scientific data, tailored climate information linked to adaptation needs

Successfully co-producing climate data ensures achieving I-CISK impact #2 & #3:
Contributing to the exploitation of information and data from the Copernicus programme and GEO initiative & Improving robustness and predictive quality of data, and information and knowledge on climate adaptation and mitigation

Key Performance indicators (I-CISK project proposal)

- Number of multi-model climate forecasting systems from existing services and datasets (Copernicus, EMODnet, GEOSS) co-identified to meet user needs in each LL)
- Number of tailored CS variables and indicators evaluated from a user oriented perspective)

Components (outputs / actions to be done – lead by WP2T2.2, WP3)

- Co-explore the different types of knowledge on and experience with the current climate system and its threat, present among the end-users within the LL
- Jointly put together climate data to add value and so that useful climate information based on past present and future climate and its impact on natural and human systems can be co-produced. (GFCS, 2011)
  - a derived synthesis of observations and model outputs; ST and LT data (indicators, thresholds, timing) missing to support needed information regarding actual climate change adaptation; disaster risk mitigation; EWS questions and challenges)
  - combined with (sectoral) climate knowledge
  - Incorporate local knowledge and data, including citizen science
  - transform scientific datasets to a spatial and temporal scale appropriate to user needs
  - seamlessly integrate climate data across timescales from sub-seasonal to seasonal, to decadal and climate change

Methods / tools / techniques

- questionnaire on the role of weather in decision making (Hirons et al., 2021)
- Participatory processes, discussions
  - to provide space for bi-directional communication,
  - to conveying content and uncertainty of climate projections
  - to discuss forecast reliability and limitations

- user-driven evaluation of existing & tailored CS; understand user needs for information on forecast skill/performance, and tailor evaluation to these needs
- literature on integrating local knowledge

Enablers (requirements / tips to make this step a success)

- ☐ Understanding users climate information needs (Step A and B) allows to produce useful and comprehensible and clear climate metrics (step C) to improve transparency
- ☐ Explore limitations for data and information in the stakeholder's geographic location of interest to avoid unrealistic expectations regarding the development of climate information products for problem solving (Briley et al., 2015)
- ☐ Through the co-creation of climate knowledge using local data as well as global models, the credibility of the CS will be improved. The perceived adequacy of the knowledge produced and the robustness of the process of data collection and analysis also contribute to this.
- ☐ Ensure familiarity with data of (together with) users. The inclusion of place-based knowledge and the integration of climate information with multiple data sources increases credibility (Hegger et al., 2012; Hegger & Dieperink, 2014; Street, 2016)
- ☐ Create a space for discussing, challenging and providing meaning to scientific data. Scientists should honestly convey the meaning of uncertainty in their results, as well as the main implications for appropriate use of the information provided.
- ☐ A continued and broad-minded dialogue between the ESM developers and CS providers' communities is needed to improve both the optimal use and direction of ESM development and CS development (van den Hurk et al., 2018)

Key questions

During this co-creation step, the following questions should be addressed (discussed and documented) together with all relevant stakeholders (based on COACCH):

- o What is the timescale of interest (General and specific, i.e. defined years or time periods).
- o Are they specific scenarios of interest? temperature thresholds, etc.
- o What resolution of data you are interested in?
- o What spatial extent?
- o What climate variables does the decision maker care about?
- o What output variables and metrics are most useful?
- o What level of precision is realistic, achievable, and adequate for the decision or problem?
- o How do they want uncertainty to be considered/presented?
- o To what extent can multiple projections and uncertainty (e.g., emission scenarios, general circulation models) be considered (in general, in specific decisions)?
- o Do you understand existing data fully; does it provide the information that you need to make decisions? Would additional explanations or information be useful?

+Questions on local knowledge and local data to be developed

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

Objective (success factor)

The ability to deliver identified climate information in a comprehensive way (Vincent et al., 2020) so that the created CS is developed according to (communication) preferences of (together with) users.

Successfully co-developing CS ensures achieving I-CISK objective #3:
Advancing science and technology integrating and visualizing scientific data and local knowledge

Successfully co-developing CS ensures achieving I-CISK impact #5:
Make high-level information on climate change more accessible to people's lives and to provide data in a format that makes it useful for its user;

Key Performance indicators (I-CISK project proposal)

- Number of new datasets and actionable information products generated by integrating local information with large scale climate information (at least one per LL))
- Number of open source tools, front and back end, integrated to Copernicus and GEOSS, and adaptable to create new CS)

Components (outputs / actions to be done – lead by WP2T2.4 and WP5)

- take into account the co-identified needs of the end-users within the LL, with regard to the content of the information and metrics, its communication medium and timing, and its access mechanism to most effectively inform user decisions;
- take into account co-analysed adaptive behaviour of end-users within the LL, ensuring the CS to take away barriers, while capitalizing on drivers for the adoption of CS and ensuring feedbacks of adaptation options are included in decision making
- Science-based information (based on step B and C) is prepared (summarized and interpreted to be accessible by users) and delivered to meet (respond to) users' needs (GFCS, 2011) through an optimized visualization and communication medium (step D).

Methods / tools / techniques

- rapid prototyping, focus group (Bon et al., 2016)
- requirement elicitation (Bon et al., 2016)
- 'Serious games' focussed on communicating uncertain and probabilistic information (e.g. HEPEX resources), or decision-making, or enhancing understanding of others' responsibilities, knowledge and perspectives (e.g. Red Cross decision-making games)
- visuals ~perceptions, interpretability;
- Climate risk narratives and storylines to frame risk relative to events;
- Interpretations of the scientific information as scenarios or advisories (Vincent et al., 2020)

Enablers (requirements / tips to make this step a success)

- ☐ Useful information should be effectively visualized, based on user-defined metrics and preferences, its interpretation translated aware of risk perception and aligned with local capacities, end users' understanding and needs, in order to create a **clear**, comprehensible product (Vincent et al., 2020)
- ☐ Significant attention should be paid to the communication channels based on preferred modes and media, tailored to user logistics and capacities; in order to create an **accessible** CS (Vincent et al., 2020)
- ☐ Timeliness of the service delivery and the communication are of key importance to the **usability** of the CS
- ☐ Engage a subset of key people to serve on a tech advice group that will adjust goals, review method decisions and coproduce interferences. Over the course or the project, iteratively discuss key assumptions, models, approaches, data sources and criteria (Beier et al.,2016). Allow for this design process to be flexible and match stakeholders requests and limitations (Vincent et al., 2020), and involve new stakeholders over time with new iterations
- ☐ Ensure user feedback is used by, and learning on the part of, the science community. Do not assume "perfect knowledge" of the users' needs, and willingness to use any information and tools (Jacobs and Street 2020)
- ☐ In the development of the service, one needs to overcome cognitive, institutional and financial barriers that exist in the context and sector targeted, ensure that communities have the necessary knowledge and skills (GFCS 2011), in order to generate **usable** CS.

Questions to address

[To be developed in I-CISK]

D. Co-evaluate co-created, user-centred climate service information system

Objective (success factor)

CS that has a good perception of information fit (applies to needed purpose, available at right place/time, accurate, credible, translated), and good interplay (existing knowledge, context, stakeholder capacities, experiences, flexibility and knowledge-seeking efforts) . A good perception of fit (applies to needed purpose, available at right place/time, accurate, credible, translated), interplay (existing knowledge, context, stakeholder capacities, experiences, flexibility and knowledge-seeking efforts) and interactions (to overcome perception gaps, build trust, create understanding and awareness of context, needs and limitations) are needed to go from useful to usable information. (Briley et al.,2015)

Successfully co-evaluating CS contributes to achieving I-CISK objective #3: *Insight into the feedbacks and causal mechanisms between CS, adaptation and climate risk*

Key Performance indicators (I-CISK project proposal)

- Change in the use of CS in the LLs compared to baseline in particular understanding of CS use barriers and incentives)
- Number of decision making processes of stakeholders demonstrably changed due to the outcomes and improved capacities on climate information from the project)

Components (outputs / actions to be done – lead by WP2T2.5, WP4)

- Impact analysis
- LT usability/usefulness assessment
- Sustainability assessment
- evaluation of the tangible innovation (new CS prototype), intangible innovation (IP, knowledge), diversity innovation (market related, maybe e.g. open weather) created through the project (Hossain et al., 2019)
- continue to monitor and reassess the *solution* after prototype completion, ensure continuous feedback loops;
- Regularly review and co-evaluate the *process*;
    - Document successes and failures in the process,
    - ensure continuous feedback loops;

Methods / tools / techniques

- Collaborative, iterative workshops,
    - to co-explore mock-ups of different CS designs and visualisations e.g. decision-making activities to understand how decisions may be influenced depending on the design of the information
- functional evaluation, technology assessment, scenarios,... (Bon et al., 2016)

- system dynamics modelling (Bon et al., 2016)
- Bi-annual producer and user questionnaires to understand if and how the new testbed products are being incorporated into operational procedure, as well as capture how they have been iterated based on user feedback (Hirons et al., 2021)
- Operational co-creation action plans to serve as a memorandum of understanding formalizing the relationships for continued co-creation during the two-year testbed (Hirons et al., 2021)
- Extensive note taking by the testbed facilitating team, including making observations of the co-creation process and having informal discussions with participants (Hirons et al., 2021)
- Existing evaluation frameworks (Hossain et al., 2019; Wall et al., 2017; Wutich et al., 2022)

Enablers

- ☐ the product should be purposeful to the adaptation decisions envisioned (time & space) in order to render a **usable** and **trustworthy** product
- ☐ Importance of scheduling regular time for reflection and monitoring to increase *transparency* and keep *active engagement*
- ☐ *Flexibility* is required: evaluation can lead to repeating previous steps.
- ☐ Cyclic!
- ☐ Rigorous
- ☐ Important to experimentally designing CS programs for evaluation based on an impact pathway, rather than leaving evaluation as an after-thought.(Tall et al., 2018)
- ☐ methods for evaluating CS span qualitative context-based and quantitative methodological approaches.(Tall et al., 2018)
- ☐ iterative feedback process is more effective when sufficient resource has been invested in relationship-building (Hirons et al., 2021)

Key questions

During this co-creation step, the following questions should be addressed (discussed and documented) together with all relevant stakeholders (Beier et al., 2016; Tröltzsch et al., 2018; Vincent et al., 2018):

- How well did scientists and managers specify the problem statement at the outset?
- In retrospect, would different scientific information and processes have been more useful? What steps could have better set up the project at the outset?
- Did the project give appropriate priority to process and products? Was the process collaborative, communicative, and positive for both scientists and managers?
- If scientists provided post contract advice on the appropriate use of the information, was this continuing engagement properly budgeted for?
- What practical steps could have been taken to provide better guidance on appropriate use of the scientific products?
- Did the scientific information and process lead to better decisions (or was it capable of doing so, even if constraints precluded a better decision)? How should future projects be managed to better meet this goal?
- What obstacles to collaboration were encountered in shaping the goals and final results?
- Is the product being used in the way it was envisioned? If not, why not?

- Was a mechanism created to insert new scientific results and learning that occurred by observing the outcomes of decisions made using the products? - Did the project team have the right mix of individuals across disciplines and with the needed experience, expertise, and skills to develop a usable CS? - Are adequate resources earmarked to enable collaboration (e.g. for engagement activities, such as meetings, workshops, as well as programme management)? - Are mechanisms in place to ensure effective inclusion (e.g. translation/language, support for those with disabilities (e.g. non-visual materials, sign language) transport availability, ensuring time of meetings that fits with gender roles)? - Do the various parties feel joint ownerships of the process? - Was the role of researchers and stakeholders, and their respective knowledges, clear and adhered to? - Is the process putting in place/developing the networks and capacity necessary to ensure sustainability of collaboration post-project? - Have periodic opportunities to revisit the goals, activities, and timelines been built in to the programme? - Is there scope for adjustment and flexibility based on ongoing monitoring, evaluation and learning? - Have key decision points been identified within the programme at the outset, where course corrections or adjustments could be made? - Has an ethic of 'learning-by-doing' been fostered among all actors to better incorporate evolving priorities and interests? - Has ongoing monitoring, evaluation, and learning been build included in the design to inform programming, both at the beginning and throughout the project? - Have opportunities for joint reflection and dialogue among partners been built in to the programme? - Were there appropriate incentives and rewards structures in place for scientists and stakeholders to participate in co-creation, and by the satisfaction of contributing to better decisions?

F. Co-delivery (dissemination, exploitation) of the preoperational climate service information systems

Objective (success factor)

Co-disseminating and co-exploiting improves availability and economic relevance of the CS

Successfully delivering the CS ensures achieving I-CISK objective #4 & #6:
Work with citizens, decision makers and stakeholders demonstrating the value-proposition of human-centred CS; to multiply the stories of the demonstrator CS beyond the LL

Successfully delivering the CS ensures achieving I-CISK objective #5:
Upscale use of climate information in risk management and planning across sectors

Successfully delivering the CS ensures achieving I-CISK impact #4 & #9: *Bring a step change in the use of knowledge and information and allow users to become active players in climate action; & Support the development of the European Service sector regarding end-user CS*

Key Performance indicators (I-CISK project proposal)

- ➢ Number of next generation pre-operational CS co-designed and demonstrated in the LL (at least one per LL)
- ➢ Number of business models developed to upscale the next generation of CS (at least one per LL)
- ➢ Number of pre-operational CS launched (at least one per LL)
- ➢ Number of citizens, decision makers and stakeholders involved in the demonstration of pre-operational CS (at least 10 per LL)

Components (outputs / actions to be done – lead by WP5 and WP6)

- Business model storylines adapted to the context of each LL, to clearly show the added value deriving from Human Centred CS (commercial exploitation)
- business case evaluation
- pre-operational CS deployed tested with Stakeholders inside LL
- possibly to be replicated/upscaled to similar regions and other sectors deploying the CS
- network mapping, identifying the network of contacts and communication channels (e.g. press releases) that the partners and the involved stakeholders can access
- communication structure and strategy (Exploitation plan)
- disseminating developed adaptation plans, and other relevant outputs, including DRR plans,
- Identify opportunities to disseminate developed CS (e.g., workshops of fair events) directly organized by stakeholders
- ”I-CISK ambassadors” concept.

Methods / tools / techniques

- ▪ Agile development methods; demos and focus groups (Bon et al., 2016)

- Serious gaming during stakeholders sessions/webinars/ workshops to test adaptation options through CS in a decision-making like context (Crochemore et al., 2021)
- Organizing joint events with stakeholders to showcase results to other users belonging to the same group.
- Co-evaluate during meetings with stakeholders, during development, dissemination material (brochure, leaflets, videos, posters)
- CS Web tutorial with a specific YouTube Channel
- Live-demo of the CS with Q&A session with the end-users and stakeholders
- Rely on previous H2020 specific guidelines on co-creation and exploitation of CS are available from CLARA project.
- Success Stories or Story Maps focused on the added value of the CS with feedbacks reported by end-users
- Citizen Outreach specific events and tools
- Pitch-Deck presentation and video
- Social Media Channels
- Participation to scientific conferences
- Scientific Papers
- Press Release on Human Centred CS
- e-Newsletters conveying project related news (disseminated through social media & email)
- Dissemination of scientific results at key targeted conferences (e.g. EGU General Assembly, AGU meeting, European Climate Change Adaption Conference, ESA Living Planet Symposium), including convening of specials sessions to brand I-CISK
- Press releases and outreach to general media through partnership with local and national TV, radio and printed media, as well as accompanied media tours (these media events are focused on LL, and may vary per LL, depending on what is appropriate to the local situation)
- Educational products, such as courses, guidelines and videos to be used during events with Stakeholders and passed to external contacts

Enablers (requirements / tips to make this step a success)

- ☐ Very important is communication of the developed products with the decision makers at different levels to ensure that developed products are considered during the decision making process.
- ☐ requires close engagement of citizens, businesses and industries, governments, entrepreneurs and investors as well as scientists.
- ☐ requires agreement about how to communicate the collaborative outputs to ensure they are accessible and considered during the decision making process; that cultural considerations have been taken into account; and that all contributors are appropriately acknowledged. (Hirons et al., 2021)
- ☐ integration with existing long term climate adaptation process contacts and networks (Vincent et al., 2020)
- ☐ integration with existing climate warning systems and with relevant national policy and strategic documents

Key questions

During this co-creation step, the following questions should be addressed (discussed and documented) together with all relevant stakeholders (Beier et al., 2016; Ecologic et al., 2018; Vincent et al., 2018):

- Which outputs do we want to disseminate?
- Who are our target audiences and what are we offer
- Who in the group is best placed to carry out this particular dissemination activity?
- When do we disseminate?
- Which formats should we use to reach these different audiences?
- Which multipliers, channels could give us additional support?
- How will we know if we have been successful?

5.2 Roadmap

Template to be filled in / completed / agreed upon within each LL (contextualised) and which can be revisited - prone to change - throughout the project based on needs or desires from the LL stakeholders or project stakeholders. Such changes should be approved unanimously .

Note that it currently looks like a linear list, but that multiple actions will happen iteratively and/or simultaneously (as indicated in the time horizon column).

Components	Specific actions	Methods / tools	Task lead (project side)	Stakeholders (LL side)	Time horizon
Initiate Living Labs					
Identify key actors and create partnerships	Contact	Snowballing	IHE		Dec-Jan 2022
Context mapping	Survey	Document	LL leads		Jan-Mar 2022
Co-explore climate information needs and CS desires					
needs assessment	Survey	Stakeholder questionnaire	ECMWF	end users, citizens, decision makers	Jan-Mar 2022 Jan-Mar 2023 Jan-Mar 2024
Extreme impact indicators	Workshop and survey	Stakeholder questionnaire	ECMWF / SMHI	End users	May-Aug 2022
User-drive evaluation metrics	Workshop and survey	Stakeholder questionnaire	ECMWF / SMHI	End users	May-Aug 2022
Co-identify climate adaptation pathways and DRR strategies to be supported by the CS					
Co-develop climate product containing local and academic data and knowledge					
Skill assessment and model robustness	Scientific assessment	Using user-specified metrics for assessments	ECMWF / SMHI	LL partners	Jan 2025
Fit for purpose enhancement of local CS information	Scientific assessment	1-downscaling of meteo data 2- multi-modelling 3-subsampling	CREAF	LL partners	April 2024
Co-design user-centred CS providing tailored climate information					
Visualisation practices	Scientific assessments and survey in workshop	Stakeholder questionnaires	ECMWF / SMHI	End users	Jun 2023 Apr 2024 Mar 2025
Co-evaluate co-created, user-centred CS information system					
Scripts for visualisation	Scientific assessments	Scripts in R and python	WP3 partners		Dec 2024
Co-delivery (dissemination, exploitation) of the CS information system					

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