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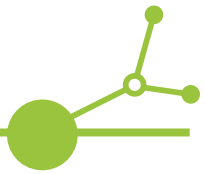
Climate_CRICES

Climate_CRICES PROJECT
O1.1 – Climate_CRICES Strategy

A roadmap for co-creating a climate change adaptation dashboard



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EXECUTIVE SUMMARY

This strategy document presents the Climate_CRICES framework for guiding the development of regional climate adaptation dashboards across Central Europe. The Climate_CRICES project was initiated to address the fragmented landscape of climate-relevant data and the need for tools that support integrated, cross-border decision-making. This document captures the lessons learned from that process and transforms them into a strategic roadmap designed to be replicated and adapted by other regions or institutions.

At its core, the Climate_CRICES strategy focuses on making climate information useful and accessible for regional authorities, particularly in the fields of heat and drought, flooding, and impacts of climate change on biodiversity. The strategy outlines a step-by-step approach for building a dashboard that is not only technically sound but also institutionally embedded and user-informed. It emphasizes the importance of co-creation with users and data providers, the use of structured metadata to improve data transparency and comparability, and the value of iterative development processes over linear planning models.

The strategy is built around three main phases: (1) preliminary analysis and preparation, (2) data collection and dashboard development, and (3) dashboard deployment and institutionalization. Within these phases, the document details specific tasks, such as stakeholder engagement, metadata structure design, data gap assessment, and training workshops. It also offers a set of reusable outputs including classification schemes, workshop designs, and evaluation templates.

The added value of the Climate_CRICES strategy lies in its ability to bridge the gap between complex climate data and actionable policy decisions. By centring user needs and institutional context, the strategy promotes durable solutions that can be sustained beyond the scope of individual projects. It also lays the groundwork for regional cooperation and knowledge exchange, making it a relevant tool for fostering climate resilience not only within but also beyond Central Europe.

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Introduction

The Climate_CRICES strategy was developed in response to the increasing demand for practical, data-informed tools that help regional governments and institutions manage the impacts of climate change. In particular, Central European regions are experiencing growing risks related to heat and drought, flooding, and biodiversity loss. Yet many of these regions lack cohesive, user-friendly platforms that enable them to visualize, compare, and act on the relevant data.

This document delivers a strategic roadmap for how such a platform—in the form of a regional climate adaptation dashboard—can be developed through a participatory, evidence-based process. The strategy reflects the hands-on experience of the Climate_CRICES project and translates that experience into guidance for others.

The structure of the document follows the three-phase approach adopted during the project:

1. **Preliminary Analysis**
    - Identification of relevant climate change impacts and indicators.
    - Mapping of existing climate information platforms and policy frameworks.
    - Early stakeholder and data provider engagement.
2. **Data Collection and Dashboard Development**
    - Construction of a metadata structure to enable data interoperability.
    - Collaborative identification of data gaps and priorities.
    - Design of user-friendly dashboard functionalities based on co-creation workshops.
3. **Dashboard Deployment and Institutionalization**
    - Launch of a prototype dashboard and initial testing.
    - Capacity-building for stakeholders.
    - Development of a sustainability model and forward-looking action plan.

Each of these sections combines methodological guidance with practical insights. Outputs such as glossary terms, metadata templates, and stakeholder analysis tools are also provided to ensure that users of the strategy can implement its recommendations directly.

The strategy is not a fixed blueprint but rather a living framework that can be adapted to different regional contexts. It recognizes the need for flexibility, iterative design, and above all, cooperation between data providers, users, and decision-makers. It aims to provide a foundation for data-driven climate resilience that is practical, inclusive, and scalable.

Climate_CRICES Strategy

Co-production of knowledge is a critical step in the development of effective climate adaptation measures and plans that help diverse stakeholders in the implementation of these (Jacob et al., 2025). In more general terms, climate services refer to: "*a complex combination of data, processes, products, actors, sources of knowledge, delivery modes, and organisations, that ensure climate knowledge is not only scientifically robust, but also 'fit for purpose' in a particular decision-making context*" (ibid). Co-production is needed for services to be fit-for-purpose, meaning that they are useful for the respective user communities, government entities, city officials, and other decision-makers. These groups, however, do not have the knowledge or capacities to fully understand and grasp the complexity of climate information, climate change impacts, or the effects of adaptation strategies on the reduction of climate impacts. 'Climate service providers', entities such as National Hydrological and Hydrological services, specialized research institutes and boundary organisations need to work together with users, their capacities, needs and constraints to find a way in which climate information can be conveyed and used in a manner that is appropriate but also relevant (Jacob et al. 2025). In Climate_CIRCES, the following three main learnings emerged:

1. Early and Continuous User Engagement Is Crucial

One of the most important lessons from the Climate_CRICES process is the necessity of engaging end-users—especially regional and local stakeholders, users as well as providers—from the earliest possible stage. The initial roadmap was primarily expert-driven, and only later validated through co-creation workshops. This delayed integration of user needs limited the project's ability to align data, indicators, and dashboard features with practical, on-the-ground adaptation requirements. Future processes should build in structured co-creation from the start, enabling more tailored outcomes and fostering stronger user ownership.

2. Iterative Design Over Rigid Roadmaps

The original linear roadmap was insufficient to accommodate the evolving understanding of regional data realities, policy contexts, and stakeholder needs. The process has to be adapted iteratively, especially after the user workshops and dashboard prototyping revealed gaps and new requirements. This highlights the importance of flexibility and iterative learning in the development of adaptation tools, allowing for real-time adjustments based on user feedback and regional constraints.

3. Integrated Structures Require Shared Understanding

Establishing a shared metadata structure, glossary, and classification system was essential to integrate multi-scale, cross-regional data and policy content. However, aligning on terminology and structure took significant effort and time—effort that could have been better streamlined with earlier stakeholder involvement. A common language and data framework must be co-developed early with users to ensure meaningful integration and usability of dashboard content across different regions and administrative levels.

Based on these lessons learned and findings, we present in this section an **idealised strategic roadmap** (Figure 1). This roadmap should allow defining the added value of integrated, compiled, and visualized multi-scalar data for a region's climate change adaptation and possibly integrating own or further data into the Climate_CRICES dashboard or to create a similar product. We hope that the process presented here can serve as an inspiration for others to implement a similar process, or to expand on what was achieved in Climate_CRICES. The following subsections provide an overview of an idealised process using methodologies and key insights from the Climate_CRICES results as examples that can be applied and used further. Examples of what was done in Climate_CRICES can be found in green sections, and boxes for the co-creation workshops in red.

The Climate_CRICES project focused on three topics of climate change impacts: heat and drought, flooding, and the impact of climate change on biodiversity. Thus, as a first step, the **scope** of any new project has to be determined. This includes not just a geographic scope, but also the description of the impact scope. Many other climate change effects not addressed in Climate_CRICES are also relevant for regional climate adaptation and could be included in future projects.

The strategic process starts with the **preliminary analysis** of climate change impacts and indicators for the geographic scope, e.g., Central Europe. The glossary, which is displayed as Annex 1.1, can be reused and refined to reflect the new project scope. Two elements should be integrated right at the beginning of the project: (1) Stakeholder Engagement that includes both users and data providers, and (2) the Information System and Data Pre-Analysis. These two elements are critical for selecting and defining the tools, meeting user and provider requirements, and determining the added value of integrated, compiled, and visualized multi-scalar data.

It is followed by the presentation of the necessary **data collection and dashboard development** that allows bringing the requirements of the dashboard users and the data providers of the dashboard together. This facilitates a better understanding of data gaps to design and implement climate change adaptation strategies and may also allow defining strategy to overcome these. A shared workshop between data users and providers fosters trust building for sustained collaborations across these entities also post-project.

Finally, the **dashboard deployment** that integrates climate change data on impacts, their indicators and the related policies that describe climate change adaptation strategies is wrapped up by launching the dashboard to the broader public.

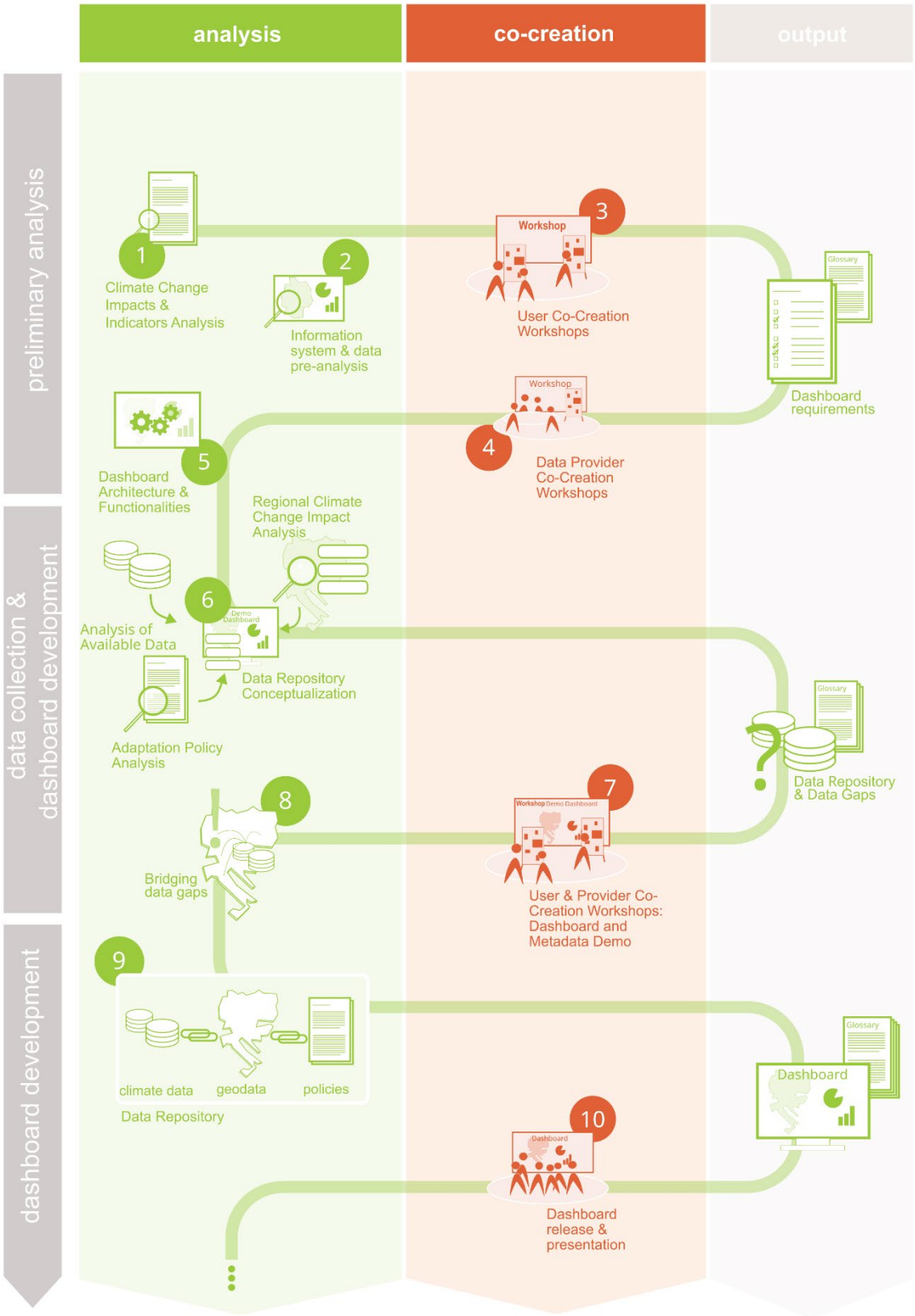

Figure 1: Roadmap for the dashboard co-creation process (© Eric Neuber @ IOER)

Preliminary Analysis

This section presents the **foundational process** for defining the technical and stakeholder-informed requirements for an adaptation dashboard (see Figure 2). It outlines how project partners identified key climate impacts and indicators, analysed existing climate information systems, and conducted an initial assessment of available datasets. The section then highlights how these preparatory analyses, alongside structured co-creation workshops with users and data providers, inform the strategy for dashboard development. It details both methodological steps and expected outputs, such as interoperability criteria, user-specific functionalities, and institutional coordination needs. Finally, it introduces the architectural choices and lessons learned, emphasizing the importance of usability, accessibility, and long-term sustainability for a dashboard intended to support regional adaptation planning across Central Europe.

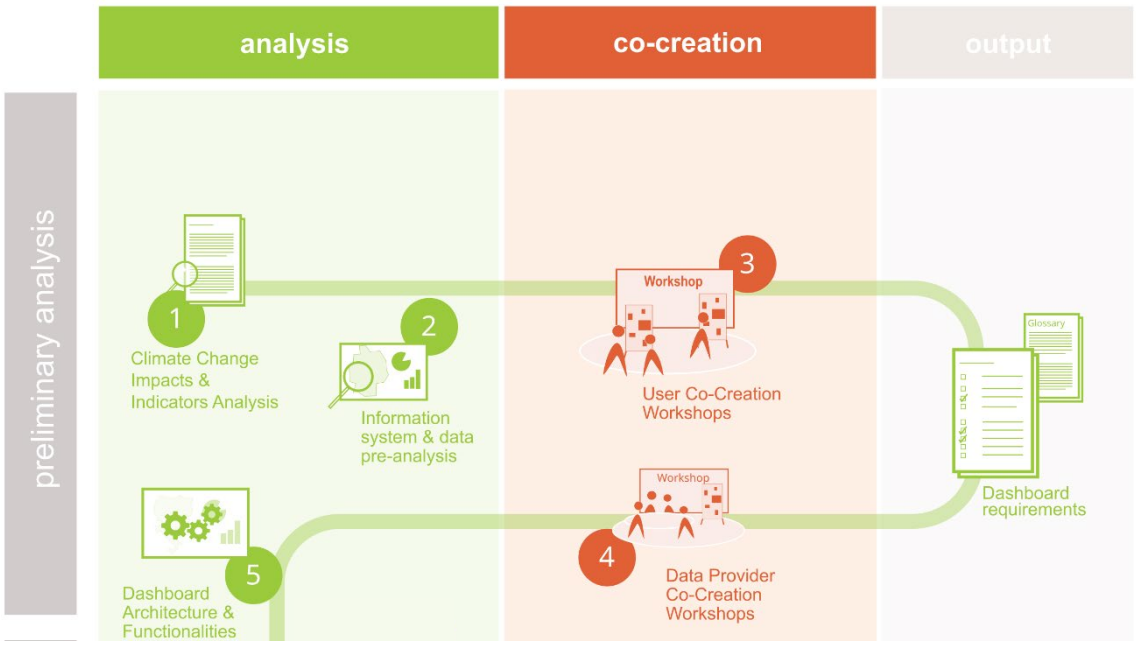

Figure 2: Preliminary Analysis of the roadmap for the dashboard co-creation process (© Eric Neuber @ IOER)

It is critical to spend time and effort on this foundational process to facilitate:

- **User-Centered Design:** Early engagement with stakeholders ensures that the dashboard is tailored to real-world needs, increasing its relevance, usability, and likelihood of long-term uptake.
- **Efficient Data Integration:** By mapping available datasets and identifying technical barriers upfront, the process allows for targeted integration efforts, reducing duplication and streamlining future data updates.
- **Enhanced Interoperability:** Defining data standards, metadata structures, and cross-sector linkages early on supports seamless interoperability across regions, sectors, and platforms.

- **Institutional Buy-In and Trust:** Involving data providers and end-users from the beginning builds mutual understanding and trust, laying the groundwork for sustained cooperation and shared data governance.
- **Scalability and Replicability**: The clearly documented methodology and outputs (e.g. indicator lists, glossary, metadata framework) serve as ready-to-use components that facilitate scaling the dashboard to new regions or adapting it to other policy contexts.

These benefits help ensure that future steps—such as dashboard testing, pilot implementation, and post-project scaling—are more efficient, effective, and grounded in stakeholder realities.

1 Climate Change Impacts and Indicators Analysis

To define the most important **climate change impacts and climate-related indicators** 1, working groups for the project foci (i.e. for Climate_CRICES heat and drought, flooding, impact on biodiversity) can be established to derive lists of impacts and indicators, which are relevant for the project regions.

The initial phase focuses on compiling a **broad set of climate change impacts and corresponding indicators**. Working groups systematically select key impacts and indicators relevant for the project's impact scope. Sources can include major scientific references, particularly the current IPCC Assessment Report, and in European regions the EU Adaptation Strategy, as well as the indicator sets from the European Environment Agency. These initial lists should be circulated among all project partners for feedback and the possibility to add more impacts/indicators.

In the Climate_CRICES project, this analysis resulted in a list of 25 impacts and 44 indicators, each described with additional information such as definition, calculation methods, units, and the appropriate monitoring scale (local, regional, or national).

2 Information system and data pre-analysis

Analysing **existing information systems** 2 gives key insights into the capabilities, strengths, and limitations of these platforms and enables the identification of gaps that are relevant to the goals of the project. The analysis can be done via fact sheets collected by the partners in their respective regions, considering regional, national, and global platforms. For each system reviewed, the partners provide key information, such as a representative image, web link, the institutions responsible for its implementation, a brief system overview, and an assessment of its key strengths and limitations. Key variables for the assessment of strengths and limitations can be: User friendliness, spatial resolution, comparability functions and trends analysis and options for data import and export.

The data pre-analysis enables an overview of existing datasets relevant for climate change adaptation and gives a first impression of what kind of data needs to be included. Starting from the information system analysis datasets included in these information systems can be analyzed by:

- **Topic:** which of the project foci is addressed by the dataset
- **Receptor or Impact dataset:** Does the dataset contain data on meteorological impacts (e.g. temperature, precipitation, …) or receptors (e.g. nature conservation areas, species data, water bodies, …)
- **Coordination system and data format:** Determining for dashboard architecture requirements.
- **Projections:** Gives an overview if historical and/or future time periods are covered.
- **Covered time periods**: Clearly stating which time periods are covered.
- **License:** Important for the integration of data into a new product.
- **Data source**: Findability, to later integrate data into the dashboard.

In the Climate_CRICES project, 31 information systems on regional, national and European/international level were analysed. These platforms were selected based on their relevance to climate risk management, data accessibility, institutional credibility, and alignment with policy frameworks. Together, these systems illustrate the range of institutional approaches, data integration capabilities, and policy alignment mechanisms informing evidence-based decision-making in climate adaptation. The initial data collection for 8 regions, already showcasing a huge quantity of available data but with limited overlap. These dataset collections were later reused and refined to match the impacts and indicators lists. This process is described under Dashboard architecture and functionalities.

Together the information system and data pre-analysis reveal first requirements for the dashboard architecture by showcasing best practices that can be implemented, limitations that can be targeted and data visualisation needs that have to be considered.

3+4 Co-Creation of Knowledge

Best practices in the field of co-production for climate services are still emerging and developing. Spaces such as the WMO Regional and National Climate Outlook Fora have been providing valuable insight into the challenges of sharing climate information that is relevant to a heterogeneous user group in the past 10 years (Hewitt et al., 2020). Boon et al. (2024) showed in a Delphi study with climate services experts that twelve elements are critical for successful climate services for adaptation (see Figure 3). These relate largely to elements that define the quality of the climate service, such as the communication of uncertainty, and a suitable communication format of the information to users (e.g. in the choice of language). These also relate to the results that follow from the production and use of the climate service, such as the increased understanding of a particular issue, e.g. the impacts of climate change, or better decision-making abilities for adaptation. Lastly, the Delphi study showed that elements describing the production process of the climate service itself are less relevant and only pertain to the need that the information provided is relevant to the user needs, problems, or decision-making.

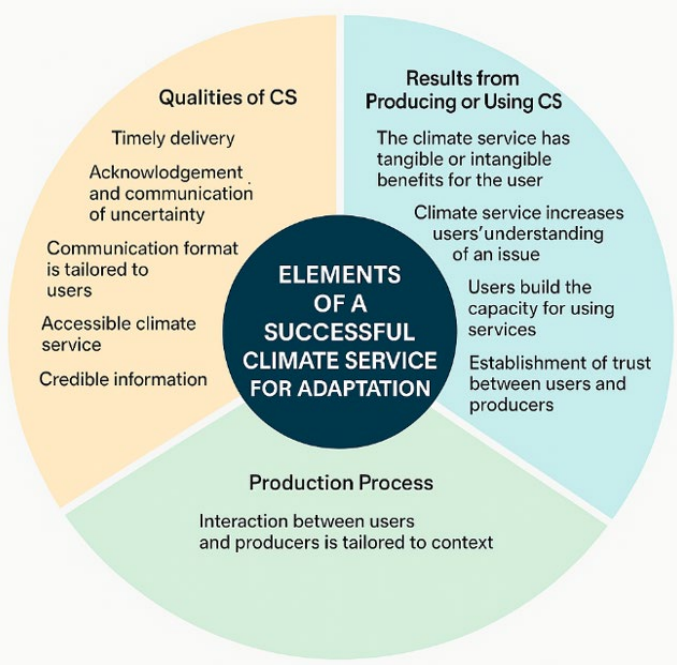

Figure 3: Elements that are relevant for successful climate services (CS) for adaptation (redrawn from table 2 of Boon et al. 2024)

In addition, Daniels et al. (2020) came up with an ideal process for climate services development (see Figure 4). The respective online guidance tool can also be used to help work through guiding questions in the different stages (https://weadapt.org/tandem/) and is added here as an alternative source of inspiration to guide co-creation processes for the development of climate services.

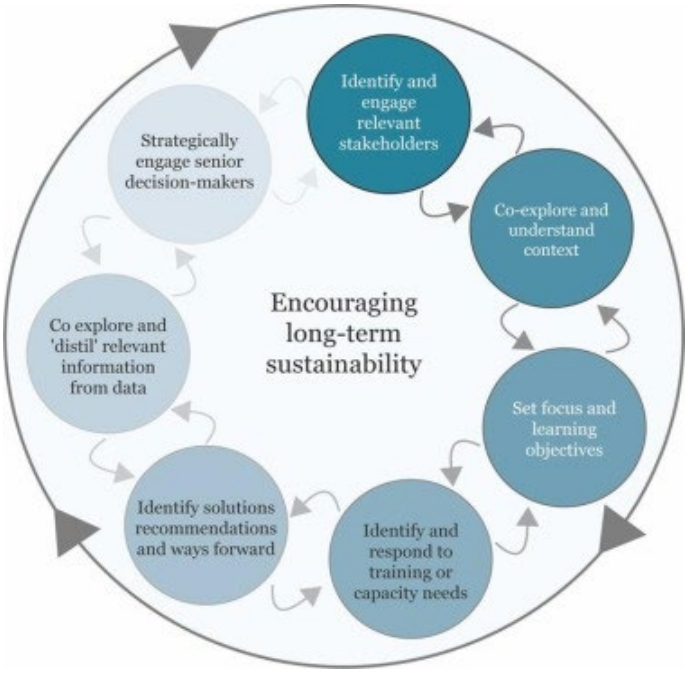

Figure 4: Ideal co-production process for climate services development that ensures long-term use of information, source: https://weadapt.org/tandem/

Identification of relevant stakeholders

One effective way to systematically identify relevant stakeholders is to combine an ex-ante approach with a more flexible, ad-hoc method. The process often begins with the project team mapping stakeholders across a set of predefined categories, providing a structured starting point. This initial list can then be expanded through the snowball method, in which existing stakeholders suggest others who may be relevant. This blended approach helps ensure that no significant actors are overlooked. The five stakeholder categories used to guide the initial identification are outlined in Table 1.

Table 1: Overview of stakeholder groups relevant for the dashboard development

GROUPS	GROUP EXPLANATION	STAKEHOLDER CATEGORIES	PRACTICAL EXAMPLES
1) DEVELOPERS AND IMPLEMENTERS	Officials or other stakeholders who work with the adaptation plans and are responsible for its realisation	• Local authorities • Regional authorities • Others from public administration	Official River basin manager
2) POLICY MAKERS	Stakeholders who, at the final level, decide on the implementation of specific measures and approve the adoption of strategies	• Elected representatives of local/regional governments	(Deputy) Mayor (Deputy) Governor
3) LOCAL USERS	Stakeholders who benefit from the climate change adaptation	• NGOs • Local businesses and industries • Environmental organisations • Private enterprises • Other potential users	Local company director Farmer
4) EDUCATIONAL AND RESEARCH INSTITUTIONS	Researchers connected to climate change	• Universities • Schools • Research institutions	Researchers
5) OTHERS	Mainly added by snowball method		

It is advisable to make a list of stakeholders with contact information. Efforts should be made to invite stakeholders from groups 1-4 (1-3 is the minimum). Although stakeholders may have varying interests or levels of influence, the goal is to engage all of them in the discussion. It is essential to

navigate the entire engagement process and aim to involve them across all four levels: informing, consulting, involving, and collaborating[1].

a) **Inform**: Share clear and accessible information about the project's goals, activities, and expected outcomes to ensure stakeholders understand its purpose and relevance.
b) **Consult**: Gather feedback from stakeholders through discussions to identify their needs, concerns, and priorities.
c) **Involve**: Actively engage stakeholders in shaping strategies and solutions, ensuring their perspectives are integrated into decision-making processes.
d) **Collaborate**: Work closely with stakeholders to co-develop and implement solutions. Maintain long term relationships with stakeholders.

Development and organisation of co-creation workshops

For this strategy, we suggest at least four rounds of workshops:

(1) an early engagement workshop with the potential users of the platform, primarily aimed at introducing the project and identifying user needs 3.
(2) an early engagement workshop with potential data providers to the platform, focused on exploring issues related to data availability, format, scale and interoperability 4.
(3) once the initial platform is available, a joint workshop, bringing users and providers together to clarify the platform's functionalities, and to address potential data gaps 7.
(4) lastly, the final workshop in this project phase will introduce the dashboard to a wider audience and assess further capacity development needs to enhance the usability and usefulness of the tools 10.

The aims and ideas for the individual 4 workshops are represented in this document through red boxes, as can be seen below. Annex A.2 shows an overview of how workshops were carried out in the Climate_CRICES project and what requirements were drawn from these for the dashboard development.

[1] Note that stakeholder engagement usually entails five levels - the fifth one being often empowerment (Arnstein, 1969). In Climate_CRICES empowerment will follow in the second and third phase of the project, which is why it is not represented here.

3 1st Co-Creation Workshop for Users

These initial workshops serve as a platform to effectively involve local communities, governmental bodies, and other relevant stakeholders in the revision of regional adaptation strategies.

The objectives are threefold:

Stakeholder Engagement: Understanding the diverse needs, barriers, and feedback of stakeholders to ensure that adaptation strategies are inclusive and effective. By actively involving a range of voices in the discussion, solutions that are tailored to the unique challenges faced by each region can be created.

Dashboard Design and Data Needs: A significant focus of the workshops will be on the design of an interactive dashboard that will facilitate informed decision-making. Participants will discuss the types of data required and the ideal indicators that should be included to enhance the dashboard's utility. This includes also the identification of climate change impacts and their indicators. This collaborative approach will ensure that the dashboard meets the practical needs of users and supports ongoing adaptation efforts.

SWOT Analysis Contributions: The workshops will also offer valuable insights for developing a comprehensive SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis of the current and potential use of climate data in creating and updating adaptation policies within pilot areas. This analysis will serve as a foundational tool for understanding the existing state of regional adaptation initiatives and identifying opportunities for enhancement.

The following questions can be used to guide the workshop
(from https://weadapt.org/tandem/)**:**

- What local organisations and initiatives are already working on issues of climate resilience and related issues? Are there partnership opportunities?
- Which institutional actors are critical to engage in this process? E.g. the local meteorological department or NHMS; national government; local government decision-makers and councillors; private sector; civil society, etc.
- What data needs are there beyond climate impact indicator data?
- Do all participants understand climate change and the differences between weather and climate and the terms that are used by climate providers? Exploring the basics of climate change and the terminology used in climate change and adaptation can provide a strong foundation for discussing participants' understanding and experience of weather and climate impacts and agreeing on use of shared language.

Expected Outputs from the 1st Co-Creation Workshop for Users:

1. **User-Centered Functional Requirements for the Dashboard**

   A prioritized list of functionalities and features drawn from direct input by user groups. This includes the types of climate change impacts they wish to track, key indicators needed for decision-making, preferred data formats and visualization methods (e.g. maps, reports, graphs), and platform usability features. These requirements will directly inform dashboard design and development to ensure fitness for purpose.

2. **Identification of Practical Data Needs and Gaps**

   A consolidated overview of specific data needs from users at different governance levels (e.g. local governments, civil protection, planning authorities), including information on spatial and temporal resolution, thematic coverage (e.g. water stress, land use change), and interoperability concerns. This will guide dialogue with data providers and the technical specifications for dashboard integration.

3. **Stakeholder Mapping as a Snowballing Exercise**

   A dynamic and participatory process to identify key actors already involved in adaptation efforts, complemented by a mapping of currently absent but necessary stakeholders for robust and inclusive implementation (e.g. utilities, private sector, local meteorological services). This snowballing approach will support the expansion of the stakeholder network over time and guide future engagement activities.

4. **Institutional-Level Understanding of Vulnerabilities and Adaptation Barriers**

   Insights into the institutional drivers of vulnerability and adaptation challenges—such as governance fragmentation, lack of mandates for climate planning, insufficient technical capacity, or gaps in vertical coordination between national and local levels. These findings will inform the adaptation strategy refinement process and help align dashboard outputs with institutional planning realities.

O1 Dashboard Requirements

Determining the requirements for the dashboard is crucial to choose a fitting architecture with the functionalities. The requirements can be derived from the previous steps:

- Key lessons learned, inspiration and limitations to be targeted from the information system analysis;
- Data format requirements from the data pre-analysis to ensure that the architecture can handle the most formats and is OGC-conform;
- First data visualization and resolution requirements based on available data resolutions, the data format, the geographical projection and available time periods;
- User requirements regarding for example (open) accessibility, usability, import/export functionalities, comparability features, data scope (e.g. which indicators are (regionally) mandatory) and visualization needs from the first co-creation workshops;
- Keeping track of license information right from the beginning.

As such, key requirements derived from the **analysis of existing information systems** and the **stakeholder workshops** resulted in the following dashboard requirements in Climate_CRICES:

1. Interoperability and Multi-Scale Data Integration

The dashboard must support the seamless integration of local, regional, national, and international datasets, with the ability to import/export and compare data across administrative borders. It should be interoperable with existing platforms to promote transboundary planning and reduce duplication.

2. User-Centric Design and Accessibility

The interface must be intuitive, multilingual, and open-access, ensuring usability by non-specialists, including local authorities, civil society, and the general public. It should feature clear visualizations, contextual explanations, and guided navigation, with attention to accessibility across devices (e.g., mobile-friendly).

3. Real-Time and Regularly Updated Data

The dashboard should integrate real-time or near-real-time climate data streams where possible, along with a system for structured, periodic updates. This ensures timely and relevant information for decision-making, with clear metadata and source transparency.

4. Customizability and Sectoral/Geographical Coverage

Users should be able to tailor data visualizations, compare regions or sectors, and explore multi-sectoral data (e.g., water, biodiversity, infrastructure) at various spatial scales. This supports targeted adaptation planning and cross-sectoral analysis.

5. Sustainability, Training, and Iterative Improvement

A clear long-term maintenance and funding strategy is essential, along with institutional responsibility for updates. The platform should be rolled out with training workshops, include practical testing, and incorporate a feedback loop for continuous improvement based on user experience.

Not all of the above-mentioned requirements could be met within the project, as for example features such as real-time data integration, dynamic map overlays, and advanced user customization were identified as desirable but currently out of scope.

At this point in time, it becomes critical to better align user needs with available data and sources. We saw in Climate_CRICES, that it would have helped bringing in data providers early on to help overcome apparent data gaps, interoperability and scalar integration issues. This can also help in building connections that are based in trustworthy relationships across users and providers, with the research project acting as a bridge (see also 3rd workshop bringing users and providers together). Hence, we suggest to include here a workshop with data providers (see box below).

4 2nd Co-Creation Workshop for Data-Providers

A critical component of climate services and their information is climate related data, and those underpinning impacts assessments as well as adaptation measures. We thus consider it to be critical for 'data providers' to also provide their perspective on the dashboard requirements.

The following objectives are of relevance:

Setting up cooperation with data providers: Data providers are essential to feed the dashboard with credible and curated data and information. Creating an active and trustful setting for cooperation between users and providers is crucial to the effective use of the platform for climate adaptation.

Dashboard Design and Data Availability: A significant focus of the workshops will be on the design of an interactive dashboard that will facilitate informed decision-making. Data providers play an active part in making the dashboard useful. Understanding how available data can be integrated into the dashboard needs to happen early on to address issues of scale and interoperability. This includes also the identification of climate change impacts and their indicators.

The following questions can be used to guide the workshop
(from https://weadapt.org/tandem/)**:**

- How can activities be designed to communicate to and engage participants on various approaches to climate risk assessment, global climate modelling and projections and

downscaling of data? The use of graphics, maps or narratives may assist in communicating medium to long-term climate patterns and change with different stakeholders.

- Can specific information needs at relevant time and spatial scales now be articulated for particular decision-making processes or the development of plans, processes or tools? These information needs may be weather and climate-related but also wider e.g. groundwater abstraction and recharge rates, rates of population growth and projected water demand.
- How is data and information being communicated, shared and disseminated? How does this need to vary and be tailored to different groups e.g. technical staff, senior decision-makers, media etc?

Expected Outputs from the Co-Creation Workshop for Data Providers:

1. **Inventory of Available and Relevant Datasets**
   A compiled list of existing datasets held by regional, national, or sectoral data providers, including metadata on spatial/temporal resolution, data formats, update frequency, and licensing. This output will identify what data can realistically be integrated into the dashboard in the short- and medium-term and highlight any critical data gaps.
2. **Data Interoperability and Standardization Requirements**
   A shared understanding of the technical and institutional requirements for data integration, including preferred standards (e.g. INSPIRE, ISO), APIs or data portals in use, and protocols for ensuring interoperability between heterogeneous data sources (e.g. between hydrological, biodiversity, and climate projections).
3. **Initial Set of Climate Impact Indicators**
   A shortlist of climate change impacts and corresponding indicators (e.g. temperature anomalies, flood frequency, soil moisture deficits) that data providers can supply or co-develop. This includes agreement on calculation methods and the feasibility of disaggregating indicators at local/regional scales.
4. **User-Specific Data Delivery and Visualization Preferences**
   Insights into how different audiences (e.g. municipal planners, national agencies, NGOs) should receive and interpret climate data. This includes preferred visualization formats (e.g. interactive maps, graphs, narrative summaries), update frequency, and levels of technical complexity suitable for diverse users.
5. **Framework for Long-Term Cooperation and Data Sharing**
   A preliminary roadmap or agreement on how to sustain cooperation beyond the workshop, including roles and responsibilities, data governance protocols, and potential mechanisms for regular updates and co-maintenance of the dashboard's data streams.

5 Dashboard architecture and functionalities

As the final step in the preliminary analysis which allows selecting a fitting **dashboard architecture and functionalities** 5, all requirements derived from the previous steps should be considered, including the specifications from the second workshop with data-providers. The dashboard architecture selection should follow an open, transparent, and structured decision-making process. The objective is to identify an architecture that best meets the dashboard's functional and strategic requirements — derived from the previous steps.

All relevant inputs must be consolidated and translated into **architectural priorities**. These priorities should cover critical aspects such as:

- Spatial data handling
- System scalability
- Export and reporting capabilities
- Interoperability with existing systems
- Accessibility and usability standards
- Use of open-source technologies, where appropriate

These priorities guide the evaluation of both backend and frontend components:

- **Backend architecture** should be evaluated in terms of spatial database efficiency, robustness of data pipelines, API architecture, adherence to open standards, and the ease of integration with external systems.
- **Frontend architecture** should prioritize dynamic and responsive map rendering, tools for data comparison and analysis, user-friendly export functionality, and the ability to extend or customize features using open-source libraries.

Throughout the process, teams should ideally remain open to alternative technical approaches—balancing innovation with feasibility and long-term maintainability. Often, project and funding contexts, however, restrict the possibilities of free platform choices.

Data Collection and Dashboard Development

Having arrived at initial user requirements, this section now outlines the process of **developing the data repository and dashboard** (see Figure 5), emphasizing how regional climate impacts, adaptation policies, and available datasets can be systematically analysed and structured. It explains how a metadata-based repository can be developed further to support integration and comparison of cross-regional data, and how entities such as impacts, policies, objectives, measures, indicators, and datasets can be defined and classified. The section also describes the third co-creation workshop, where users and providers jointly address unresolved technical and governance issues. It concludes by detailing how European and global datasets can be used to bridge regional data gaps, ensuring consistency and completeness for the dashboard across e.g. Central Europe.

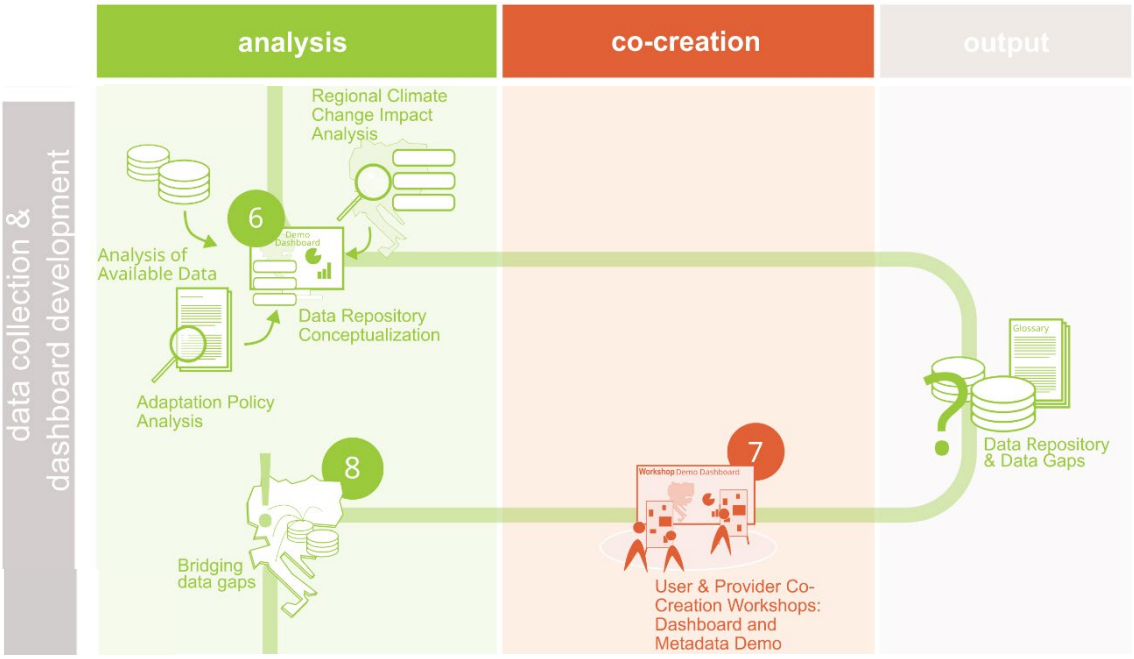

Figure 5: Data Collection and Dashboard Development of the roadmap for the dashboard co-creation process (© Eric Neuber @ IOER)

6 Data Repository Conceptualization

The **data repository conceptualization** 6 is based on two things: (a) the dashboard architecture and (b) the data that drives the dashboard. The following three steps can be undertaken here:

1. Analysis of regional climate change impacts
2. Analysis of climate change adaptation policies
3. Collection of available data (referring here to: impacts, indicators and their descriptions in policy documents, and indicator values)

The following three subsections describe each step with regard to their influence on the repository conceptualization, whereas key takeaways for the repository are outlined in the last subsection.

1. Analysis of Regional Climate Change Impacts

The relevance of selected climate impacts can be further assessed through a systematic review of strategic and adaptation policy documents from the pilot regions. The analysis focuses on identifying which impacts are explicitly mentioned in these documents. These findings are then compared with the initial list of climate impacts to evaluate their regional relevance.

This comparison can result in three possible outcomes:

1. The impact is mentioned in both the policy documents and the initial list.
2. The impact appears only in the adaptation strategy.
3. The impact is included only in the initial list.

For impacts mentioned only in adaptation strategies, it is important to assess their relevance in other regions. If they are found to be significant elsewhere, they can be added to the revised list. Even if they are specific to one region, they may still be included, depending on the project's scope. Impacts that appear only in the initial list but are not relevant to any pilot region may be removed. However, since the initial list is based on established scientific literature, such exclusions should be made cautiously. The absence of certain impacts in all reviewed strategies could point to gaps in those policies rather than irrelevance. Therefore, an additional literature review is recommended to validate any such decision.

Impacts are the first entity in the metadata structure, which is the basis for the data repository. The associated metadata components are listed in Figure 6. A second entity describes the analysed policies by the components listed ibid.

2. Analysis of Climate Change Adaptation Policies

Climate change adaptation policies can be further analysed in terms of the objectives, measures and indicators contained. Starting from the analysis of regional climate change impacts and their inclusion in policies, also the presence of corresponding objectives and measures can be analysed. For this analysis both the analytical sections and action plans within the documents would be subject to derive objectives and particularly the action plans are relevant to identify corresponding measures.

Objectives and measures can be linked with each other and with the impacts they are counteracting as well.

Additionally, the presence of impact indicators in the policies can be analysed. The indicator analysis can focus on three levels: Relevance of indicators in the regions, definition of the indicators in the policies and the availability of data to represent the indicators or of an option to calculate them. Based on this analysis a detailed record can be created, listing missing indicators and highlighting where potentials for the data collection lie. Analogous to the revision of the impacts list, additions and dismissions to/from the indicators list can stem from this analysis.

3. Analysis of Available Data

The key element for the repository conceptualization is the initialization of the **structured collection of available datasets**, representing the selected indicators. Based on the data pre-analysis from **Information system and data pre-analysis** 2, the data collection can be refined and focused on the selected indicators from the revised indicators list. The actual indicator dataset collection can start from the definition of the data repository, enabling findability of the datasets and links to the indicator's entity. Therefore, the entity datasets can be determined by the metadata components listed in Figure 6.

This collection and analysis of available datasets enables the assessment of the coverage of the indicators list in the individual regions and paves the way for future dataset integration into the dashboard.

O2 Data Repository

Three things can be determined from the previous analysis: **(1) regional data gaps, (2) data visualization needs** and **(3) data provision needs**. Data provision is especially relevant for datasets that are not openly available and therefore their integration possibility depends on the support from data providers. The data repository can initially be built by the following metadata entities (definitions of terms as per the Climate_CRICES GLOSSARY):

- Impacts – The consequences of realized risks on natural and human systems, where risks result from the interactions of climate-related hazards (including extreme weather/climate events), exposure, and vulnerability.
- Policies – In the context of the Climate_CRICES project policy refers to the analysed climate change adaptation strategies of the pilot regions. These are documents managing the expected impacts of climate change, grounded on projections and expected impacts of climate change.
- Objectives – In the context of the Climate_CRICES project objectives are the specific goals for adaptation derived from the analysed policies.
- Measures – In the context of the Climate_CRICES project measures refer to the specific interventions for mitigation and adaptation that are specified in the analysed policies.
- Impact-Indicators – Impact-indicators describe the effects of climate change.
- Response-Indicators – Response-indicators describe adaptation measures or activities and conditions that support the adaptation process.
- Data – Quantitative data and information that describe the indicators; often hydro-meteorological and/or socio-economic data.

If necessary more entities, based on the project's scope can be added or the entities can be described by additional metadata components. The metadata structure enables cross-border analysis and visualisation. Due to the diversity of climate adaptation policies and indicators across countries and regions comparison depends on a common framework.

Figure 6 presents links between the here described entities. This promotes comparability of policies in the dashboard and the findability of objectives, measures and indicator datasets to support climate change adaptation. This can be supported by the implementation of a classification system for the entities. The classification enables to filter, compare and link the different entities and is an important step on the way to the provision of integrated multi-scalar climate change adaptation data.

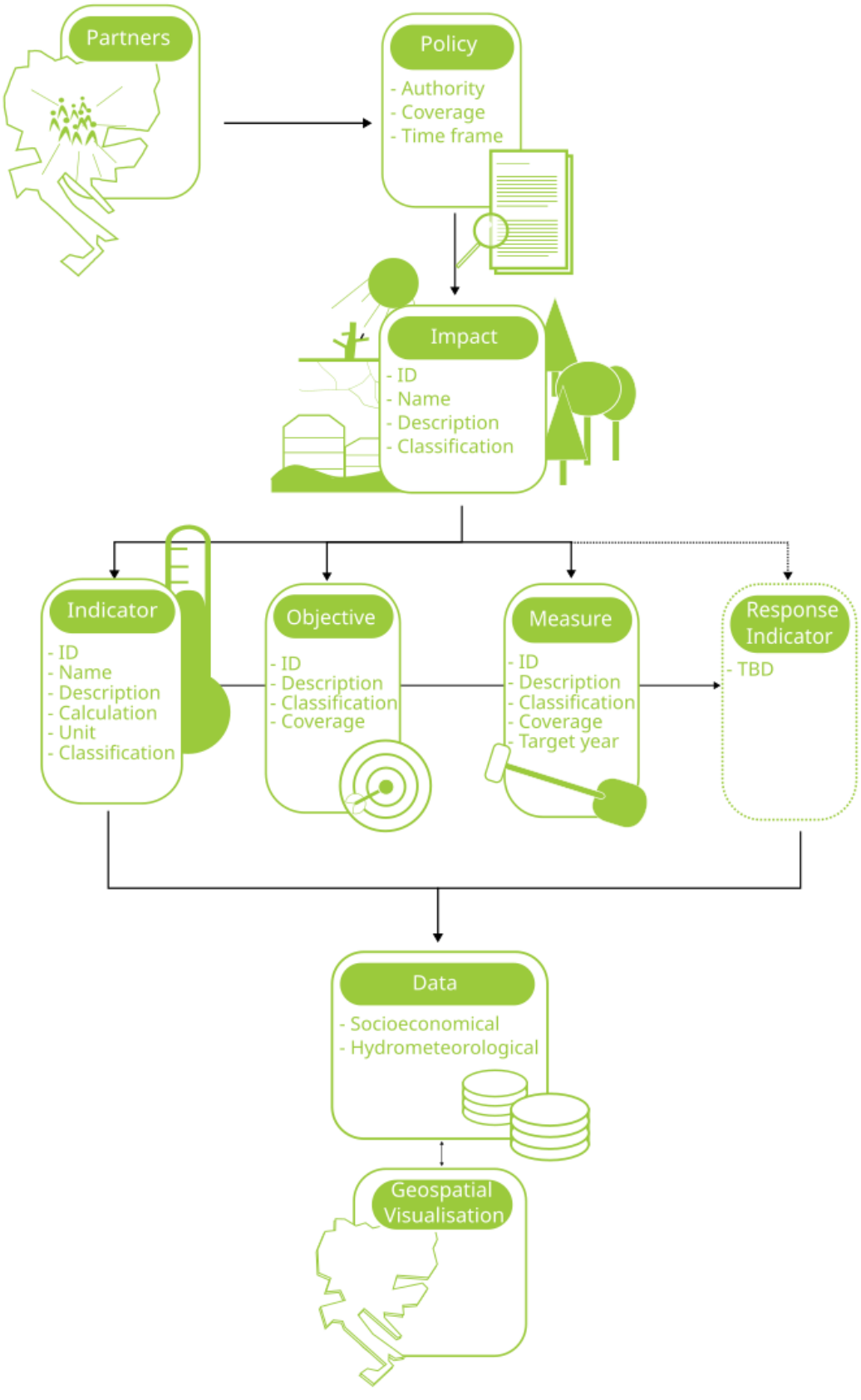

Figure 6: Entities metadata structure of the Climate_CRICES project (© Eric Neuber @ IOER)

The classification is a powerful tool to link entities with each other apart from directly connecting single elements. Together with the entities metadata structure it allows regional datasets and policies to be compared — even if the underlying data stems from different models or methodologies.

7 Promoting trust through continuous stakeholder engagement

At this stage, a preliminary dashboard is available and requirements have been assessed and contrasted against functionalities. The logic of how data and information are connected is available in the entities metadata structure and needs to be explained and made transparent to users and providers alike. Bringing stakeholders back and explaining to them what parts of their feedback was taken up and which ones fall out of scope is critical to sustain trust in the process. Bringing both users and providers together in this third workshop 7 further fosters trust and allows for learning from each other.

7 3rd Co-Creation Workshop for Users and Providers

The primary objectives of these workshops are:

Feedback and expectation management: Not all requirements could be fulfilled. This needs to be communicated in a transparent manner and explained. A discussion on the implications of a lack of fulfilment needs to ensure to be able to fully grasp the impacts the tool can then have or not for users but also for providers.

Overcoming data gaps: As was seen in the project, data gaps but also issues of interoperability across scales and datasets exists. These data gaps and mismatches need to be discussed and their implications assessed. Ideally, the workshop would result in a common decision of how to deal with data gaps, potentially aiming at closing some that might be deemed critical for policy fulfilment.

Fostering direct connections: Bringing users and providers together in the same room also intends to foster trust across these communities. Often language (jargon) and capacity issues hinder a fluid and sustained communication between these groups (e.g. use of the glossary created in the project). Research projects often allow for neutral, non-political spaces that foster trust building.

The following questions can be used to guide the workshop
(from https://weadapt.org/tandem/)**:**

- How can activities and engagements be designed to co-explore and recognise different perspectives and priorities and address the complexity of system-wide multi-sector issues in a collaborative and simple/accessible way?

- Have specific needs emerged from the co-exploration 'phase'? This may be particular needs or requests for training, further exploration and unpacking of a particular aspect of the adaptation issue or engagement of additional stakeholder groups identified as critical to decision-making processes.
- What solutions and recommendations can be identified? These may be the design and delivery of particular outputs, projects, policies, the strengthening of capacities through particular training or support, innovations in data sharing or the development of new partnerships or increased collaboration between institutions. Are these at appropriate temporal and spatial scales to address the adaptation issue(s) identified?
- Can examples from other cities or contexts help to spur possible adaptation measures?
- Where have 'windows of opportunity' been identified or created? E.g. a new political cycle, issues that are high on current political or social agendas, new initiatives, tools or processes that are under development or on the horizon. How can solutions build on existing efforts and initiatives or leverage existing partnerships to limit replication of work?

Expected Outputs from the 3rd Co-Creation Workshop for Users and Providers include:

1. **Consolidated List of Prioritized Technical Requirements**

   This includes confirmation of functionalities already implemented, identification of technically feasible next steps, and documentation of deferred or out-of-scope features. This list forms the basis for the platform's next development iteration and informs its sustainability roadmap.

2. **Technical Recommendations to Address Data Gaps and Interoperability**

   This includes addressing unresolved data issues, including standard formats and metadata for better interoperability, identification of critical data gaps, provisional solutions such as proxies or scenario ranges, and workflows for integrating decentralised or partner-specific data feeds.

3. **Preliminary Data Governance and Maintenance Need**

   This part provides insights into the governance structures needed to ensure ongoing data integration and dashboard updates, including defined roles for data maintenance, requirements for regular data refreshes, and proposals for inter-institutional cooperation such as data-sharing protocols or memoranda of understanding.

4. **Training and Capacity-Building Needs for Platform Use**

   This includes priority topics for upcoming workshops, suggestions for user support materials like manuals or video guides, and capacity-building measures for stakeholders with limited technical expertise.

8 Bridging data gaps

Based on the regional data gaps derived from step 6 **Data Repository Conceptualization**, possibly reduced by inputs from the workshop in step 7 **Promoting trust through continuous stakeholder engagement**, **Bridging data gaps** 8 is a challenge in any similar project. Data gaps can be closed by developing the respected data sets for the regions where they are missing. This is an undertaking with great outlay, depending on how many data gaps are apparent and on the complexity of the missing datasets. Nevertheless, this approach can ensure high consistency with data requirements, such as data format, spatial resolution, availability of future projections, and covered time periods.

In the Climate_CRICES project a different approach was followed, ensuring time efficiency and data availability across all of Central Europe: European and global data sources were included into the data collection to bridge data gaps. The partnership of the Climate_CRICES project selected in total 64 European/ global data sets by May 2025, including the following sources:

- Copernicus and Euro Cordex for data on e.g. temperature and precipitation, flow and ecological status of rivers, air and soil humidity, change in land cover (CORINE land cover), …
- Eurostat for data on the species related indicators
- National Aeronautics and Space Administration (NASA) for data on hail risk
- European Environmental Agency for data on forests and landscape fragmentation

To clarify the sources used in the Climate_CRICES dashboard, information shows how each indicator is linked to detailed metadata — including data origin, methodology, and geographic/ temporal resolution. This helps users understand the context and limitations of the information they are viewing. Where gaps or inconsistencies exist, they are not hidden but made visible.

Dashboard Deployment

This third and last section describes the final phase of the dashboard development, focusing on the **deployment and public presentation** of the tool (see Figure 7). It outlines how the dashboard integrates climate data and policy information via a structured metadata framework, resulting in a comprehensive and user-oriented platform for regional adaptation planning. The section explains how two core pillars — climate data (impacts and indicators) and adaptation strategies (objectives and measures) — are interlinked in the dashboard, offering multiple entry points for users. It also introduces the launch strategy, emphasizing stakeholder recognition, capacity-building needs, and communication plans to support the dashboard's use and outreach.

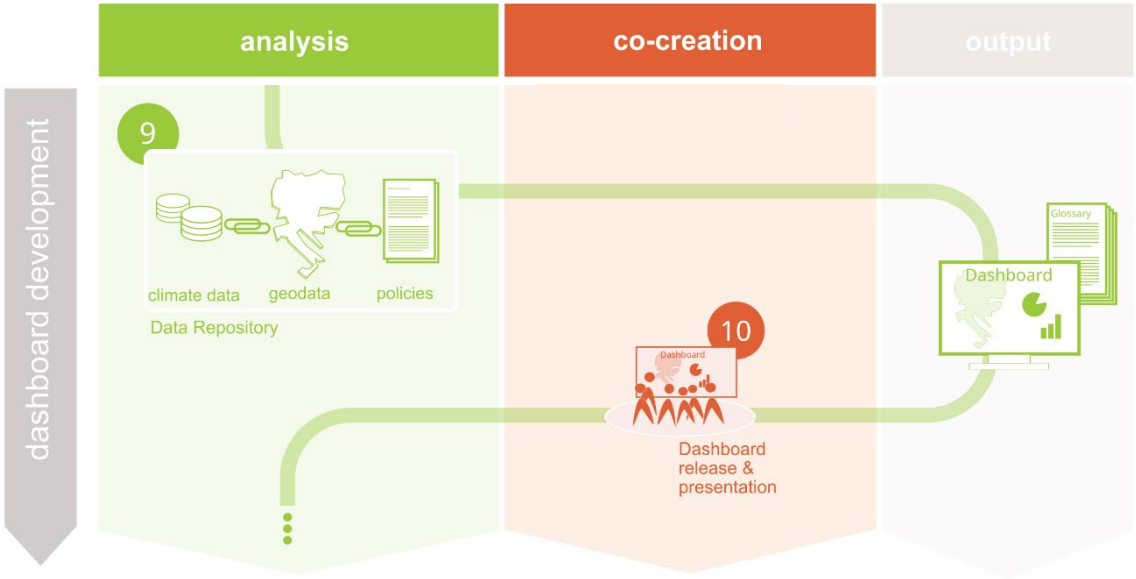

Figure 7: Dashboard Deployment of the roadmap for the dashboard co-creation process (© Eric Neuber @ IOER)

9 Data repository

The last analytical step is the compilation of the **Data repository** 9 interlinking climate data, geographic data and policy content, based on the metadata structure and visualising this content in the dashboard. This step is the compilation of all previous steps and has a two-pillar approach:

- **Data pillar**: The data pillar focuses on **climate change impacts and indicators** (1), which are representable by datasets (2 and 6). Arising data gaps can possibly be bridged in cooperation with data providers or need to be made visible as a minimum requirement (8). The representation is realised via a user-oriented (3/4) data-driven dashboard (5).
- **Adaptation pillar**: The climate impact information in the data pillar is supplemented with structured and accessible adaptation information. This pillar is based on the analysis of a broad collection of **climate adaptation strategies** (1 and 6). The objectives and measures

of these strategies, aiming at the selected impacts, are portrayed in a user-oriented way in the data-driven dashboard (5), enabling **findability, comparability and inspiration**. Through the integration with the data pillar cross-validation with the regional intensity of the climate change impacts is enabled.

The two pillars are linked on several levels: Impacts are represented by indicators and their inclusion in adaptation strategies in the whole project area can be mapped. Objectives and measures in those policies are linked with the impacts, making them findable and accessible for interested users.

O3 Dashboard

In Climate_CRICES, the data repository supported by the metadata structure (Figure 6) enables accessing integrated, compiled and visualized multi-scale data on many different levels, which become the entry points for the dashboard landing page (see Figure 8):

1. Starting from impacts to browse possible adaptation options or compare regional intensities;
2. Starting from policies to compare them supported by knowing the intensities of regional climate change impacts, uncovering adaptation gaps and best practices;
3. Starting from objectives and measures to find solutions for specific adaptation challenges.

By these means the dashboard based on this data repository guides future climate change adaptation in an increasingly complex and interconnected world.

Figure 8: View of the dashboard landing page

10 Launch and presentation of the dashboard

Once this revised and revisited version is ready and launched, a respective communication campaign acknowledging the stakeholders that supported its co-development is needed ⑩. This is also the point at which capacity development needs beyond videos and handbooks can be assessed and integrated into the subsequent activities of the project to allow for sustained and effective use of the product. We suggest thus in the box below a dashboard release strategy.

⑩ Launch and presentation of the dashboard

At this advanced stage, it is important to get back to the engaged stakeholders and show them what has been done with all the input they provided and show the demo version to them. This marks the time where the dashboard goes live and is accessible for the wider public.

The primary objectives of these workshops are thus:

Show gratitude to stakeholders for their feedback: It's critical to acknowledge stakeholder's time and efforts in the co-creation process. Showing gratitude and clearly presenting how the stakeholders' feedback was taken up and included in the tool development is critical to sustain trust and stakeholder engagement in the future use of the tool.

Building capacity: Using the tool may come with its own challenges. While handbooks and tutorials may not be sufficient for effective use, further capacity building activities may be needed. Assessing the stakeholders needs for further capacity development for the sustained use of the tool is essential for its success.

Communicating to the wider audience: The dashboard will go live with this event. The timing and communication strategy around this event may need to be chosen in a manner as to maximize its impact.

The following questions can be used to guide the workshop:
(from https://weadapt.org/tandem/)

- Have specific needs emerged from the co-exploration 'phase'? This may be particular needs or requests for training, further exploration and unpacking of a particular aspect of the adaptation issue or engagement of additional stakeholder groups identified as critical to decision-making processes.
- What key messages and new information emerging from the process need to be communicated to key influencers and senior decision-makers?

Conclusions

The Climate_CRICES strategy represents an important step toward more coordinated, inclusive, and evidence-based climate adaptation planning in Central Europe. By drawing on the collective experience of project partners and stakeholders across diverse regions, the strategy distils both the challenges and solutions associated with developing an integrated climate adaptation dashboard.

One of the key findings is that technical data alone is not sufficient to support effective adaptation. Instead, data must be embedded in a process that is responsive to user needs, grounded in institutional realities, and capable of evolving over time. The strategy therefore emphasizes the importance of co-creation, iterative development, and transparency—not only to ensure usability but also to foster trust among stakeholders.

In terms of lasting impact, the strategy helps build institutional capacity to manage, interpret, and act on climate data. It strengthens the link between policy goals and data collection practices, making it easier for regional authorities to track progress, report outcomes, and adjust measures as needed. It also offers a model for cooperation across borders, disciplines, and governance levels, supporting the broader aim of climate resilience in line with EU frameworks and international best practices.

Ultimately, the Climate_CRICES strategy is a call to action. It provides a roadmap that others can use or adapt to develop similar tools tailored to their local needs and challenges. By investing in co-production, capacity building, and structured data integration, regions across Central Europe—and beyond—can move closer to delivering climate policies that are both science-based and people-focused. This document is intended to help guide that journey.

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Annexes

A.1. Climate_CRICES GLOSSARY

Term	Definition	Source
Adaptation Strategy / Plan	The terms might be used interchangeably, but developing a climate change adaptation strategy or plan involves different processes. • A **strategy** serves as an overarching element in the early stages of policy formulation, which is key to implementation. It's a flexible, medium- to long-term, non-binding document that outlines your organisation's vision, adaptation objectives, processes and recommendations for enhancing adaptive capacity in your area. • A **plan** is developed subsequently, focusing on practical execution of the strategy. It outlines the adaptation actions prioritised for the short term (e.g. 5 years), along with the resources allocated and the designated actors. It requires broad involvement from the community and other stakeholders, which may pose challenges for adoption, compared to the strategy. Some local or regional authorities may develop these as a single document.	https://climate-adapt.eea.europa.eu/en/mission/knowledge-and-data/regional-adaptation-support-tool/step-5-implementing-adaptation/step-5-1-1
Biodiversity	Biodiversity or biological diversity means the variability among living organisms from all sources including, among other things, terrestrial, marine and other aquatic *ecosystems*, and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems (UN, 1992).	https://apps.ipcc.ch/glossary/
Capacity	The combination of all the strengths, attributes and resources available within an organization, community or society to manage and reduce *disaster risks* and strengthen *resilience*.	https://www.undrr.org/drr-glossary/terminology#R

Dashboard	A dashboard is a visual display of important information and key performance indicators (KPIs) that can be captured at a glance. It uses diagrams, graphs and tables to present data in a clear and understandable way. Dashboards are interactive and allow users to gain deeper insights into the data by using filters and drill-down functions. They are a key tool for monitoring and decision-making as they present complex data in an easy-to-understand form, helping to quickly recognise trends and problems.	https://www.haufe-x360.de/blog/erp-wissen/dashboard
Disaster Risk	The potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of *hazard*, *exposure*, *vulnerability* and *capacity*.	https://www.undrr.org/drr-glossary/terminology#R
Drought	An exceptional period of water shortage for existing *ecosystems* and the human population (due to low rainfall, high temperature and/or wind).	https://apps.ipcc.ch/glossary/
Meteorolo-gical drought	A period with an abnormal precipitation deficit.	https://apps.ipcc.ch/glossary/
Agricultural and ecological drought	Depending on the affected *biome*: a period with abnormal *soil moisture* deficit, which results from combined shortage of precipitation and excess *evapotranspiration*, and during the growing season impinges on crop production or *ecosystem* function in general.	https://apps.ipcc.ch/glossary/
Hydrologi-cal drought	A period with large *runoff* and water deficits in rivers, lakes and reservoirs.	https://apps.ipcc.ch/glossary/
Mega-drought	A very lengthy and pervasive drought, lasting much longer than normal, usually a decade or more.	https://apps.ipcc.ch/glossary/

Ecosystem	A functional unit consisting of living organisms, their non-living environment and the interactions within and between them. The components included in a given ecosystem and its spatial boundaries depend on the purpose for which the ecosystem is defined: in some cases they are relatively sharp, while in others they are diffuse. Ecosystem boundaries can change over time. Ecosystems are nested within other ecosystems, and their scale can range from very small to the entire biosphere. In the current era, most ecosystems either contain people as key organisms or are influenced by the effects of human activities in their environment.	https://apps.ipcc.ch/glossary/
Exposure	The situation of people, infrastructure, housing, production capacities and other tangible human assets located in *hazard*-prone areas.	https://www.undrr.org/drr-glossary/terminology#R
Flood	The overflowing of the normal confines of a stream or other water body, or the accumulation of water over areas that are not normally submerged. Floods can be caused by unusually heavy rain, for example, during storms and cyclones. Floods include river (fluvial) floods, flash floods, urban floods, rain (pluvial) floods, sewer floods, coastal floods, and glacial lake outburst floods (GLOFs).	https://apps.ipcc.ch/glossary/
Coastal Flood	Coastal flooding is most frequently the result of storm surges and high winds coinciding with high tides. The surge itself is the result of the raising of sea levels due to low atmospheric pressure. In particular configurations, such as major estuaries or confined sea areas, the piling up of water is amplified by a combination of the shallowing of the seabed and retarding of return flow (WMO, 2011).	https://www.preventionweb.net/drr-glossary/hips
Flash Flood	A flash flood is a flood of short duration with a relatively high peak discharge in which the time interval between the observable causative event and the flood is less than four to six hours (WMO, 2006).	https://www.preventionweb.net/drr-glossary/hips

Fluvial Flood/ River Flood	A fluvial flood is a rise, usually brief, in the water level of a stream or water body to a peak from which the water level recedes at a slower rate (WMO, 2012).	https://www.preventionweb.net/drr-glossary/hips
Pluvial Flood/ Rain Flood	The accumulation of water over areas that are not normally submerged and not necessarily in the vicinity of water bodies caused by heavy rainfall.	Internal definition
Hazard	A process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation.	https://www.undrr.org/drr-glossary/terminology#R
Heatwave	A heatwave is a marked warming of the air, or the invasion of very warm air, over a large area; it usually lasts from a few days to a few weeks (WMO, 1992). Alternative definition: A heatwave is a marked unusual period of hot weather over a region persisting for at least two consecutive days during the hot period of the year based on local climatological conditions, with thermal conditions recorded above given thresholds (WMO, 2020).	https://www.preventionweb.net/drr-glossary/hips
	A period of abnormally hot weather, often defined with reference to a relative temperature threshold, lasting from two days to months.	https://apps.ipcc.ch/glossary/
	Specific thresholds within the Climate_CRICES project: Heatwaves are defined here as periods of at least 3 consecutive days during summer (June to August) with a maximum apparent temperature and a minimum air temperature equals or exceeds 30 °C.	Internal definition
Heavy Precipitation Event	An extreme/heavy precipitation event is an event that is of very high magnitude with a very rare occurrence at a particular place. Types of extreme precipitation may vary depending on its duration, hourly, daily or multi-days (e.g., 5 days), though all of them qualitatively represent high magnitude. The intensity of such events may be defined with block maxima approach such as annual maxima or with peak over threshold approach, such as rainfall above 95^{th} or 99^{th} percentile at a particular space.	https://apps.ipcc.ch/glossary/

Impact	The consequences of realized *risk*s on natural and human systems, where risks result from the interactions of climate-related *hazard*s (including extreme weather/climate events), *exposure*, and *vulnerability*. Impacts generally refer to effects on lives, livelihoods, health and well-being, *ecosystem*s and species, economic, social and cultural assets, services (including ecosystem services), and infrastructure. Impacts may be referred to as consequences or outcomes and can be adverse or beneficial.	https://apps.ipcc.ch/glossary/
Indicator	Indicators are observable and measurable characteristics that can be used to simplify information to help understand the state of a concept or phenomenon, and/or to monitor it over time to show changes or progress towards achieving a specific change.	(Gill et al., 2022)
Impact Indicator	Impact indicators describe the effects of climate change.	(Umweltbundesamt, 2023)
Response Indicator	Response indicators describe adaptation measures or activities and conditions that support the adaptation process.	(Umweltbundesamt, 2023)
Measure	In the context of the Climate_CRICES project measure refers to the specific interventions for mitigation and adaptation that are specified in the analysed policies.	Internal definition
Metadata	Information describing the characteristics of data including, for example, structural metadata describing data structures (e.g., data format, syntax, and semantics) and descriptive metadata describing data contents (e.g., information security labels).	https://csrc.nist.gov/glossary/term/metadata
Policy	In the context of the Climate_CRICES project policy refers to the analysed climate change adaptation strategies of the pilot regions. These are documents managing the expected *impact*s of climate change, grounded on *projection*s and expected impacts of climate change.	Internal definition

Projection	A potential future evolution of a quantity or set of quantities, often computed with the aid of a model. Unlike predictions, projections are conditional on assumptions concerning, for example, future socio-economic and technological developments that may or may not be realised.	https://apps.ipcc.ch/glossary/
Receptor	An individual, a community, assets or systems that are impacted by *hazard*s. For example: The topic impacts on *biodiversity* within the Climate_CRICES project refers to the specific impacts on the receptor *ecosystem*s, having an influence on the diversity within species, between species and of ecosystems.	Internal definition based on *vulnerability* definition
Resilience	The ability of a system, community or society exposed to *hazard*s to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through *risk management*.	https://www.undrr.org/drr-glossary/terminology#R
Response	Actions taken directly before, during or immediately after a disaster in order to save lives, reduce health impacts, ensure public safety and meet the basic subsistence needs of the people affected.	https://www.undrr.org/drr-glossary/terminology#R
Risk	*See Disaster Risk*	
Risk Management	Plans, actions, strategies or *policies* to reduce the likelihood and/or magnitude of adverse potential consequences, based on assessed or perceived *risk*s.	https://apps.ipcc.ch/glossary/
Vulnerability	The conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the *impact*s of *hazard*s.	https://www.undrr.org/drr-glossary/terminology#R

A.2. Development and organisation of co-creation workshops

In the Climate_CRICES project, we followed five distinct steps in the preparation, organisation and evaluation of the workshop, as illustrated in Figure 9. We show these here as an example of how to organize co-creation workshops in a generalized manner.

Figure 9: Steps undertaken in Climate_CRICES for stakeholder co-creation workshops

1. Identifying Stakeholders

Before engagement begins, it's essential to map relevant stakeholders involved in climate adaptation — ranging from public authorities and data providers to researchers, practitioners, and community representatives. Involving these groups ensures that the dashboard and adaptation strategies reflect real regional needs and capacities.

2. Preparing for Engagement

Clear communication is key to motivating stakeholder participation. Invitations should be sent at least one month in advance, including logistical details, workshop goals, and translated materials like brochures. Promotion through media and professional networks helps raise awareness. Materials must be tailored to the regional context, summarizing local adaptation policies, climate impacts, and proposed indicators. Selecting appropriate engagement methods — such as interactive mapping or breakout groups — ensures inclusive dialogue.

3. Organizing the Regional Workshop

Workshops are designed around a shared agenda to ensure comparability across regions. They serve to inform stakeholders about the project, consult on their current practices and challenges, and actively involve them in identifying data and policy gaps. Hybrid participation options (e.g. via Zoom) and interactive methods (e.g. World Café, SWOT groups, digital tools like Slido) support dynamic engagement.

4. Creating Uniform Outputs

After each workshop, partners complete standardised templates capturing stakeholder input, including data needs, policy alignment, and potential barriers. A workshop report documents the discussion and collaboration, while a self-assessment reflects on successes, gaps, and stakeholder readiness to engage.

5. Maintaining Relationships

The engagement process does not end with the workshop. Maintaining contact with participants, sharing follow-up results, and integrating their feedback into future dashboard enhancements reinforces trust and cooperation. These relationships lay the groundwork for continued collaboration in cross-border climate adaptation planning.

For Climate_CRICES the result from the co-creation workshop carried out with dashboard users showed the following needs (based on the results of the SWOT analysis):

1. Requirements for the Dashboard Development

The dashboard must be user-friendly and open-access, ensuring that non-specialists—from small municipalities to civil society organizations—can navigate and use it effectively. A centralized and interoperable structure is key, enabling fragmented datasets to be consolidated in one place while allowing for import/export to support regional comparisons and policy coordination. To serve varied users, the platform should offer customizable visualizations, including regional overlays, sectoral breakdowns, or mobile-access features. Long-term sustainability is also critical; this means defining clear funding and maintenance responsibilities from the outset. Finally, stakeholder training and iterative testing are essential to ensure the dashboard meets real-world needs and builds user confidence.

2. Practical Data Needs and Gaps

Current climate data is often fragmented and inconsistently formatted, making integration and harmonization a major challenge. Much of the existing data is stored in overly technical formats that are inaccessible to many end-users, especially local planners and municipal staff. Additionally, data is not always updated regularly, which reduces trust and weakens its value for decision-making. There is also a clear lack of localized or disaggregated data, leaving smaller jurisdictions without actionable insights. Furthermore, the absence of proper metadata and unclear data provenance makes it difficult for users to understand how and why data may have changed, further limiting usability.

3. Stakeholders to be Further Involved

The dashboard's development and implementation require deeper engagement from local and regional authorities, particularly smaller municipalities that are often left out of digital planning processes. Universities and research institutions can support with both methodological rigor and training delivery. Environmental and public health agencies hold critical data on climate-related risks and must be involved to ensure sectoral relevance. National-level data providers and planning agencies are also needed for strategic alignment and to guarantee data access. Finally, EU and national funding bodies play an indispensable role in supporting the platform's long-term financial sustainability and wider deployment.

4. Institutional Vulnerabilities and Barriers

A lack of technical capacity, especially within small municipalities, remains a major barrier—many local administrations lack the staff or expertise to work effectively with climate data. Institutional fragmentation compounds the problem, with unclear roles and poor communication between relevant bodies. Overreliance on a few key experts makes ongoing projects vulnerable to disruption through staff turnover. Moreover, many platforms lack a stable funding or maintenance plan, undermining their long-term usefulness. Finally, in some regions, political or administrative leadership still fails to prioritize climate data use, limiting institutional support and slowing progress toward adaptation goals.

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