D2.1 Learnings from the evaluation of climate services in other countries and in Austria
- Report on the results of WP2 of the project “Use.AT”

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Version 1.0, 22.01.2025

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Introduction

Use.AT is a research project funded by the Austrian Climate and Energy Fund as part of the ACRP funding program. It aims at systematically harvest learnings from Austria's current national climate scenarios, ÖKS15, and comparable international approaches. Thus, it contributes as an accompanying research project to the development of new Austrian climate scenarios as part of the Climate Scenarios.AT initiative (see www.klimaszenarien.at).

This report summarizes the results of the activities in WP2 of Use.AT. The aim was to learn as much as possible from the examples of existing Climate Services that could be relevant for the concrete implementation of a national Climate Service within the framework of Klimaszenarien.AT.

We applied four different approaches for the analysis and mapping of Climate Services, which were intended to complement each other in their statements. The general focus was on services at national levels that would roughly correspond to the objectives of the planned services of Klimaszenarien.AT:

Starting with an **overview of the existing market of services ("mapping")** via internet research and an analysis of the Austrian competency map for the areas climate change, sustainability and related disciplines, a **literature review** and **interviews** with representatives of (national) service providers were used to go into greater depth and shed light on a number of relevant aspects. The latter in particular provided new insights behind the scenes of existing climate services and an assessment of successful paths as well as challenges from the developers' perspective.

Among other things, the **strategy and intensity of involvement of future service users** and the role of the **actors and their legitimacy** emerged as aspects with a particularly large impact. Findings were not only summarized but we translated them to recommendations, particularly with respect to the current development of new Austrian Climate Scenarios, ÖKS26.

Objectives of the mapping of climate services

In the course of the mapping process, the landscape of providers and products of climate services (CS) in other countries as well as in Austria are compiled and learnings assessed. The assessment focuses on different aspects of the development and provision of a successful CS. Key questions for the CS mapping are defined.

The mapping of national and international climate services supports the main goal of the Use.AT project, namely to provides answers on how to improve climate services (and products). According to the preliminary target of the project application, climate services shall be demand-driven, user centric and usable. They shall further enable and support the inclusion of climate aspects within decision making processes. Hence, the outcomes and learnings derived from mapping climate services will be used to guide the process of developing new climate scenarios for Austria (ÖKS26), which are currently developed in the framework of the initiative "Klimaszenarien.AT".

In the course of the mapping process, the landscape of providers and products of climate services (CS) in other countries as well as in Austria are compiled and learnings assessed. The assessment aims to focus on e.g. what has already been learned when providing CS, on criteria for usable CS, on the specific demands, which services are already in place, how users have been involved, on the respective barriers and enablers of useful and actionable CS, on experiences with evaluation etc. Therefore, the landscaping tries to extend the work done in Cortekar et al. (2020) and Larosa & Mysiak (2019) towards the question “what defines useable climate services” (based on Jacobs & Street 2020). However, the aim of the conducted CS mapping is not to simply list existing Climate Services or data records. In particular, the study of Climate Services should make the following statements possible:

Key questions for the assessment of Climate Services in Austria and other countries

- What services exist in Austria and in other European countries based on climate scenarios (i.e. ÖKS15 in Austria)?
- How easy are they for users to use and what measures are used to achieve good usability?
- Which user groups are addressed and which areas and sectors do the users belong to?
- How is climate information made available? As raw data or as derived information (e.g. climate indicators such as “heat days” or “cooling degree days”)? What are the preferred data formats?

Definition of the term “Climate Service” in the context of Use.AT

In order to concretize the subject of the mapping, it was discussed what exactly is meant by the term “Climate Services” in the context of the “Use.AT” project. We defined aspects that should be included in “Climate Services” as well as the limitations of the term itself.

We first adopted and accepted the mainly general definitions provided by WMO, ClimateAdapt and ClimateEurope, that can be summarized as follows:

General definition of climate services

- Climate services help to understand current and future climate change and related impacts
- Climate services are the provision and use of climate data, information and knowledge to assist decision-making
- Climate services require appropriate engagement between the users and providers

For the question of how these points could be implemented, we based our strategy on the recommendations of Findlater et al. (2021), who expand on primary definitions above by emphasizing which concepts could be relevant in the development of climate services:

- Climate services should not only provide 'useful' information, but should be 'useable' and thus 'used'.
- A departure from the usual approach, according to which climate services want to make new findings from climate research usable for users instead of developing services in response to specific requests from users.
- A stronger focus on the Climate Service process than on the product.
- Involve not only climate research experts from the scientific side, but also social science expertise, for example social scientists.

According to Findlater et al. (2021) it is also important to define which groups are counted as 'users' for a specific services. In the framework of 'Use.AT' this question is explored in depth in WP 3.1 'Mapping of users'.

In addition to the positive definition of Climate Services, the delimitation of the term was also discussed, taking into account the objective of the 'Use.AT' project with reference to 'Klimaszenarien.AT'. In doing so, the project team decided that Climate Services in the current project should include information on both the climate past and the climate future, but not climate forecasts for seasonal or decadal periods. Furthermore, preference should be given to services that describe weather and climate phenomena relevant to users rather than pure data sets for individual meteorological parameters.

The latter led us to also ask about the level of implementation: Is a service mainly limited to the delivery and description of data sets (basic level), were user-oriented products derived from the data (intermediate level) or was the service developed with intensive user involvement in the sense of co-production (optimal level)? The various stages of implementation are outlined in Figure 1.

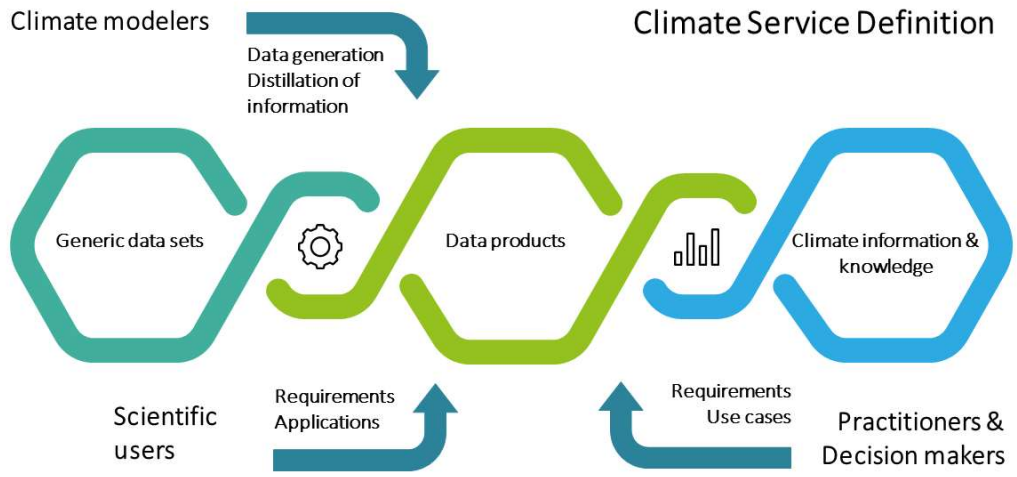


FIGURE 1: OUTLINE OF VARIOUS EXPANSION STAGES OF CLIMATE SERVICES, AS THEY ARE TO BE INVESTIGATED WITHIN THE FRAMEWORK OF USE.AT

Strategies for mapping climate services

Different approaches were chosen as a strategy for mapping and investigating climate services. Here, we provide a short overview on the approaches. See Figure 2 for a sketch of how these approaches should complement each other for a wholistic view.

Literature research	The research of scientific literature reveals fewer climate services to be named, but rather various general aspects of climate services. These can be linked to the climate service providers found in the online research and incorporated into the evaluation of the categorized list.
Online search for (inter)national climate services and analysis by category	During the online research on climate services related to climate scenarios and future climate. The focus was naturally placed on services that have a highly visible website. This should enable classification into selected categories for Climate Services. Internationally, the search was primarily for services at national level, i.e. institutions or initiatives that are comparable in their role to the "Klimaszenarien.AT" initiative in the development of national climate scenarios and services derived from them. At the national level, we were primarily interested in providers that develop customized services for and with specific user groups. This includes consulting companies that are themselves users of climate data and information and offer advice on topics such as the EU Taxonomy Regulation

Evaluation of the CCCA's **Austrian competence map** of climate researchers	The map of competences (german: Kompetenzlandkarte) (CCCA, 2024) provides an overview of hundreds of people with different specializations and skills. Individuals can enter their expertise and fields of activity themselves and are represented in a network based on their competencies, which clearly shows connections to adjacent disciplines. In total, 544 individuals are listed on the map. To identify various climate services (CS), the data underlying the map were used and filtered according to selected categories. The aim was to determine whether the individuals were involved in the development of climate services.
Interviews with experts from major domestic and foreign climate service providers	While the other methods were intended to provide an overview of existing services, interviews with selected (inter)national experts offered a very detailed insight into individual climate services. In the approximately one-hour interviews, questions were not only asked about the current status of the services, but also about the development of the services, the strategies for user involvement and the learning effects of the providers from their own perspective.

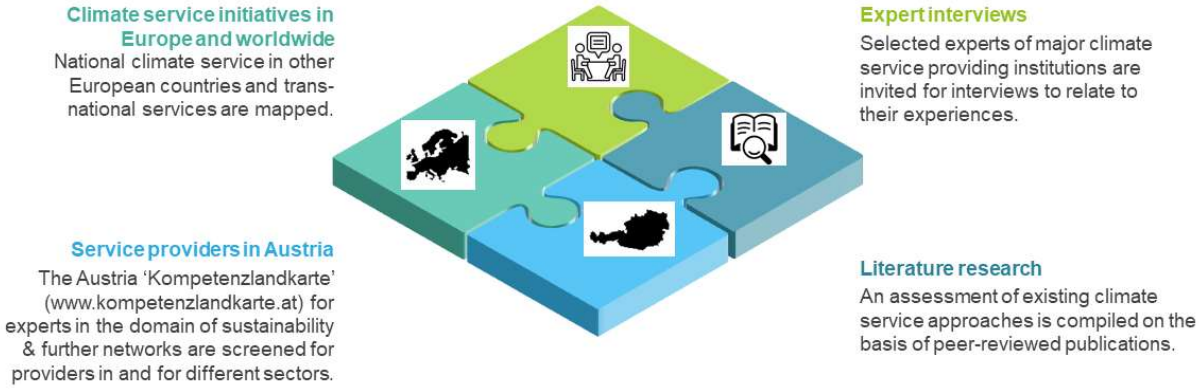


FIGURE 2: SELECTED METHODOLOGICAL APPROACHES USED TO CARRY OUT CLIMATE SERVICE MAPPING

Synthesis

The synthesis summarizes the main outcomes of the individual research approaches as described above. Here, we highlight the key findings, whereas we refer to section "Extended results of individual mapping procedures" for a more detailed insight.

Relevant aspects in literature

The literature analysis offers us the opportunity to map general aspects of the development of climate services.

One part of the current literature is dedicated to an inventory of existing services. It often deals with the investigation of observed undesirable developments and also the question of why often only part of the available information is used by users.

In this context, it is criticized that the concepts of many existing services underestimate the importance of user involvement. Due to the (justified) effort to create the best possible data basis, too little attention is paid to communication with relevant user groups and the development of services specifically for these groups. This creates a so-called “usability gap”, with, for example, classic climate research and impact research on the one hand and the socio-economic community and the real need for climate information on the part of users on the other. The lack of interaction between different scientific communities and the overall rather uniform groups of actors in the development of climate services contribute to this. Among other things, this is also related to the service providers' understanding of their role and the specific mandate and expectations of the clients.

These problems are addressed by another group of publications that present solutions in the form of recipes and guidelines.

The core aspects to be considered when developing useful climate services include the adaptation of the service to specific user groups. Contrary to what developers may often assume, the largest user group of climate services is not that of scientific users, but the group that needs climate information as a basis for their decisions. Further recommendations in the 'recipes' are therefore also the comprehensibility of data and analyses, the visualisation and communication of available information as well as the relevance for specific use cases. The trustworthiness of climate information is also a key aspect for users.

Specific guidelines for the development of climate services, particularly in the context of national climate scenarios, are provided by the WMO guidelines and large-scale projects such as Climateurope/Climateurope2. It is explained how national climate services could ‚ideally‘ look. At the same time, it is also emphasized that the services in each country differ due to the different framework conditions. Nonetheless, the guidelines can be seen as an invitation - not only for the implementers, but also for the clients, i.e. the governments - to substantially develop climate services at national levels.

CS Mapping via online research

87 climate services that mainly focus on the provision of future climate information were mapped and investigated in the course of the online research. The European climate service landscape paints a diverse picture:

The majority of the analysed CS offers data & products that typically focus on hazards. CS that focus on adaptation and/or risk rather offer consultancy & capacity building. Generally, the mapped CS have in common that they usually show a high readiness level, i.e. most of the services are already used by their specific target groups. However, the online research involved mainly services with internet presence. Therefore, we assume that the observed high readiness levels could be a bias due to the research method. The target area can range from an international level to a national, regional or local level.

Most of the CS that are offered are not restricted to a specific spatial context and can be used internationally, beyond a local, regional or national context. This includes CS that provide general

information on climate change and related hazards and impacts, often touching on water, agriculture and energy issues.

On the other hand, there are a lot of climate services offered for a specific spatial extent. This often includes reports and assessments of how the local or regional situation will change within a changing climate and typically addresses public decision makers and politicians. The providers often aim at providing a decision basis for the target group to take measures for adaptation and strengthening their resilience. However, they usually do not include suggestions for measures, but rather provide data & products, often as geodata, reports, images or interactive maps. This type of service is often offered by meteorological and hydrological services or research institutions, free of charge, as a product of their everyday work.

Furthermore, there are also those CS designed to support private businesses, often in the finance & insurance sector, in terms of helping them to assess their own risk and comply with guidelines and regulations such as the EU taxonomy or CSRD. Those services often reach beyond the sole provision of data and information, but rather include tool boxes, dashboards, consulting services and trainings. One very specific provider type is consulting companies, that offer climate risk analyses. Those services typically have to be paid for.

Interviews

Due to their different organisational setup and background, there are some differences that characterise the providers:

Typically, the NMHS have the legal mandate to develop climate scenarios or follow requests of the government to do so. They mostly provide data and information for actors from administration in the form of locally and regionally tailored information. They have made some changes to their climate services, often revolving around technical aspects such as improving the resolution, include new simulations and improve their CS based on new insights and scientific developments, or using local and regional examples to showcase local and regional impacts of climate change and meet users and their needs.

The research institutions are similarly set up like the NMHS in terms of what kind of services they provide. They often develop their CS within research projects and tend to also work on technical improvement of their CS, with a clear research focus.

NCSC on the other hand mostly see themselves at the intersection of research and practice. That is reflected in them often developing their CS in close cooperation with users and offering very tailored products for different user groups and needs. Still, they often act based on either a legal mandate or a request by public bodies and the government.

In comparison, consulting companies are mostly offering their CS to private businesses. One typical use case is supporting of those customers in terms of conducting risk assessments in order to comply with requirements such as the EU taxonomy or CSRD and adapting to climate change.

What unites the providers are for example the challenges that they are facing. All of the providers have to deal with shortage of resources. This can mean human resources such as time and knowledge, but also material and budget – on their side as well as on the customers' side.

Moreover, they all collect user feedback via various channels: A very popular approach are workshops as well as surveys, interviews or also indirect feedback that is collected e.g. through downloads. Co-production is an aspect which is highlighted as important by several of the providers.

In terms of future developments, the providers state they want to focus on language and visualisation aspects. Moreover, they want to improve their CS in terms of resolution, providing explanations, better and reliable data, but also improve the understand on the users' side as well as gaining a better understanding of what the users need. And last but not least, they want to integrate data and information on climate with other contextual data to make it more tangible.

The evaluation of the Austrian "Kompetenzlandkarte" of experts in the subjects of climate and sustainability (Kompetenzlandkarte.at) is not mentioned as the outcomes are not relevant for the learnings of WP2. For a detailed explanation we refer Evaluation of the CCCA's Austrian competence map of climate researchers. However, the investigation was not in vain, as results could be used for WP3.

Summary of learning effects

What learnings can we "harvest" for the development of climate services in general and for the next generation of Austrian Climate Scenarios in particular? This section we summarize our suggestions for the most relevant learning effects of the above described assessment of CS.

➔ **Strategies for climate services at national levels**:

- Strategies vary significantly from country to country: Decision on the specific national strategies depend, among other aspects, on framework conditions as the 1) (legal) requirements, 2) the expectations of clients and 3) purpose the of climate scenarios (mainly adaption to climate change). The set up of an **NFCS** („National Framework for Climate Services") according to WMO recommendations can effectively pool and structure the expertise available nationally (spread across institutions). Governments play an Important role of establishing an NFCS though a clear mandate. A supported framework also helps to

➔ **Identification of target groups & and their requirements** :

- Scientific users (e.g. impact modelers) require a different concept than practitioners or decision makers. The latter form comparably large groups compared to scientific users and each of the groups have their special needs concerning the use of data (formats, platforms, special products) and their prior knowledge on the interpretation of climate information. In any case, scientific "raw data" users are the smallest group of users; the majority of users consume information via media and reports.
- Although there is for most national climate services the attempt to create information that can be used by everyone, the 'general public' is NOT necessarily to be seen as a primary target group. It might be more expedient to consider which target groups are best

suited to reaching the general public, e.g. via administration and management at municipal and state level or via certain media.

➔ **Co-production and user involvement: "**

- **Co-production"** should not just be a fashionable term for the fact that users of climate information are involved in the creation of data sets in some way. If co-production is taken seriously, it means that users are genuinely involved in the conception of data products, from their generation to information processing and communication. In doing so, the communication and "usability" of climate infromation is at least as important as scientific aspects.
- The earlier user groups are involved in the process, the more likely they are to use the products later on. Moreover, a useful and usable climate service is one that overcomes a possible "usability gap" (Skelton et al., 2017). Hence, it does not only provide data and climate information, but comes with an explanation, an example or the possibility for users to ask questions about it.
- The intensive process of co-production also helps to identify different target groups at an early stage and prioritize products as user-tailored based on their specific requirements. Co-production involves actors of different scientific communities. That means that academic quality forms a necessary basis, but does not automatically prevail. Otherwise there might be insufficient focus on the needs of the market.

Learnings and related questions with a special focus on AUSTRIAN climate services:

➔ Clearify the status and the possibility of legal mandate(s) for future climate scenarios and services in Austria. **Who is/who are the main clients and sponsors of (future) Austrian Climate Scenarios? What could a general mandate look like and what is expected as a product?**

➔ **ÖKS26 as a main reference?** The ÖKS26 climate scenarios will be conceived as a main reference for scenario data in Austria and shall fulfill main requirements (useful, usable, scientifically sound). The required information should be **known and accessible to all official bodies** so that it is clear to which climate changes in the country the public discussion relates. However, “main reference” should **not exclude other data sources**, especially as continuous further development and international exchange are of great importance. To **assess the validity and usability of other data sets**, it would also be helpful to appoint a panel of experts who can make official recommendations on the data sets. In addition to reference data sets, it is also important that the climate research community **agrees on uniform positions** and communicates these.

➔ Define main target groups and assure that they are involved continuously in the development of climate scenarios. **Who is supposed to use Austrian Climate Scenarios and for what purposes?** What technical requirements and know-how can be assumed? After many discussions with the Stakeholder Advisory Board of Klimaszenarien.AT, among others, decision-makers and (regional) authorities as well as experts from various sectors are emerging for the ÖKS26 climate scenarios. The group of purely scientific users is small compared to the aforementioned groups. But **how**

should the general public be addressed? There is much to be said for making core information accessible via the media or authorities. For those who want to actively inform themselves, access to essential data and information should generally be public.

➔ Quality and realiability is a precondition of successful CS: Important aspects are the provenance of the data as well as the reproducibility, which requires a functional infrastructure of tools. These measures are not of technical interest but are needed as an archive and reference option for the providers, if errors are noticed after publication and data is recalculated, or for fellow scientists as a reference for future projects. The comprehensibility of the results also forms the basis for effectively countering scepticism about science.

➔ **Consider linking the development of climate scenarios and climate-related scenarios:** One Suggestion is to prepare the ÖKS26 datasets for further modeling applications and establishing a stronger link to the results. Many further applications require the climate data as boundary conditions or input information. First and foremost, micrometeorological (**urban climate**) and **hydrological** simulations can be mentioned here. However, continuous calculations for the future are also made in the areas of **agriculture, forestry, health, etc.** One aim is to make calculations that use the Austrian climate scenarios as a reference more visible and to emphasize their reference to a uniform climate reference.

Extended results of individual mapping procedures

The secion „Extended results" contains a detailed description of outcomes for each research approach. Partially, we inserted comments where information could also be relevant for other WPs of Use.AT.

1. Literature research

Objectives

In the course of the literature analysis, scientific papers and reports dealing with the genesis of optimal climate services are examined. The main objective of the literature assessment is to identify general support for the development of climate services as well as support that applies to the specific situation in Austria and the framework of Klimaszenarien.AT. Ideas that may be of importance in the further course of the Use.AT project will also be noted as „internal remarks".

General aspects & typologies

Some papers address general aspects, including the types of activities, users and the focus on various target sectors.

For example, Cortekar et al. (2020) distinguish between private vs. public providers and in particular between 1) downstream (e.g. publications, consulting), 2) upstream activities (e.g. data collection)

and 3) different target sectors. All three parameters are fundamental for a mapping of climate services, as carried out in the course of Use.AT.

Jacobs et al. (2005) explicate six core questions that are considered central to ensuring the benefits of CS. These are: (I) “answering the right questions”, (II) “comprehensibility of data and analysis”, (III) “trustworthiness of information”, (IV) “spatial resolution”, (V) “temporal fit with decision cycles” and (VI) “realistically achievable benefits”.

Roughly comparable to the questions from Jacobs et al. (2005) is the approach proposed by Vaughan and Dessai (2014), which identifies 4 main components for the evaluation of climate services: (I) “Problem identification and decision context”, (II) “Characteristics, design and communication of available information”, (III) “Governance, process and structure of CS”, and (IV) “Socio-economic value of CS”. Each of the four components is multidimensional, which means that a focus on sub-aspects is necessary for concrete operationalization a CS. The framework represents the conceptual breadth with which a holistic and user-oriented development would ideally take place.

➔ **Use.AT internal remark: The six questions/four aspects appear to be helpful for the development of the guidelines for interviews with CS providers.**

Jacobs and Street (2020) emphasize the potential of interdisciplinary interface roles that act as bridge builders between the production and user sides of CS.

➔ **Use.AT internal remark: The question of whether such “translators” have been installed/are available in the context of concrete CS could enrich the mapping with regard to the functional assessment of the science-to-service-to-practice claim.**

Skelton et al. (2019), on the other hand, present a kind of typology of CS users. They distinguish between the user types “Observer”, “Sailor” and “Diver”, combined with the metaphor of an iceberg. In their assessment they found all three types almost regardless of the respective target sector: According to the study, the majority of CS users are classified as “sailors”: They are interested in the (smaller) part of the iceberg that can be seen above the surface of the water, i.e. they mainly read summaries of reports. “Divers”, on the other hand, who deal in depth with the entire (raw) data basis, form a much smaller group. Just like the “Observers”, who might be interested in climate scenarios but do not make use of this potential.

➔ **Use.AT internal remark: This typology represents an interesting and helpful parallel to the user typology defined in Use.AT (WP3 - Name), which also distinguishes potential users from non-users. It could also support a classification of the target group for which a CS is designed, or by which a CS is primarily used.**

The ongoing Horizon Europe project Climateurope2 (2022-2027, coordinated by the Barcelona Supercomputing Centre), together with its predecessor Climateeurope, meets the enormous demand for high-quality climate services by developing standardized procedures for climate services. Standardization, as it is meant in the context of the project, does not contradict the statement in Skelton et al. (2017) that the implementation of climate services varies from country to country due to different framework conditions. Rather, it is about experiencing climate service as a process. The individual interdependent process steps must be perceived as indispensable for the process and implemented to a high standard - under the given framework conditions.

Quality and reliability of climate data is not only a precondition for a successful CS. Also for the users the credibility and accuracy of the climate information must be replicable in order to make well-informed decisions (Spinuso et al., 2024). In order to describe the provenance of the data, an infrastructure of tools, software repos and computer infrastructure that allows reproducibility is needed in addition to literal knowledge.

Challenges

Other writings focus on the discrepancy between the wish and the implementation and describe where the problem usually lies.

Findlater et al. (2021) criticize that CS usually do not optimize the service aspect in the sense of better decision support, but focus too much on providing better data.

Räsänen et al. (2017) identify a number of reasons why CS can fail to have the desired effect. Specifically, these include: limited usability, lack of information, lack of resources and restrictive institutional arrangements. Analytically, the focus is therefore on the (non-)user side. In CS mapping, however, the results can provide guidance on the question of whether feedback loops have taken place in the development of the respective CS with regard to these problem areas.

Bremer et al. (2019) emphasize that the paradigm of "co-production" runs quite consistently through the climate services literature and should be understood as multifaceted process beyond the attirbutes ‚interative and interactive': They suggest applying a co-production „prism" with 8 characteristic lenses, including ‚constitutiv', ‚interactional', ‚institutional', ‚joint services', empowerment', ‚pedagogical', ‚interactive research', and ‚extended science'. In this concept, each lense is assigned to a specific context, a process of co-production and concrete measurable values fort he evaluation of the co-production process.

Brasseur & Gallardo (2016) distinguish between ‚top-down' and ‚bottom-up' initiatives. Systemically, they see two parallel strands from which CS emerge: On the one hand the classical climate research community and on the other hand the Socio-Ecological Systems (SES) community with stronger interdisciplinarity. In this context, 'top down' means that, e.g., (national) weather services develop develop climate services based on their knowledge in forecasting and assessment of climate risks. In contrast, 'bottom-up' means that questions of social vulnerability and the need for adaptation to climate change are taken as a starting point. This requires knowledge of social processes and concepts for the transformation of society in the face of climate change. The actors involved in 'top-down' and 'bottom-up' approaches usually come from different scientific communities. The authors criticize a largely insufficient focus on the needs of the market and the assumption that (academic) quality automatically prevails. As a linked problem, they identify too homogeneous constellations of actors with too little fit between the academic milieu and what users would need in terms of short-term and clear answers.

➔ **Use.AT internal remark: How the discrepancy between target formulation and implementation comes about is also a topic in Use.AT in the interviews with representatives of (national) climate service providers (see subsection 4 - Interviews with experts from major domestic and foreign climate service providers). It is also an important task for Klimaszenarien.AT to focus on the "co-production" of national climate scenarios in its full meaning and to involve also scientific expertise from other scientific communities than the classical climate research community.**

CSs in national frameworks

Skelton et al. (2017) compare the 3 national climate scenarios of KNMI, UKMO, MCH including their service character in order to work out which factors are decisive for differences in the resulting climate services. These factors include social and scientific values, institutional arrangements, but also the political culture of the countries. They can be understood as general national framework conditions for climate services and have an influence on key aspects of the services. Examples of this are the roles of government and NGOs, for example in the question of commissioning and financing CS projects. Also the roles in which science sees itself and its view of the roles of users are also decisive. In many cases, co-production as the goal of the implementation path fails / or is only implemented in partial aspects because scientists fail to listen to the users in first place. They need to know their problems, their need for climate information and their options for processing it. Otherwise, a "usability gap" occurs because the information provided is too complex.

Golding (2023), present a concrete guideline for recommended development stages of an NFCS ("National Framework for Climate Services"). It is illustrated by the examples of the same three countries as in Skelton et al. (2017), namely UK, Netherlands and Switzerland. According to the WMO guidance document (WMO,2018), "for Establishing a National Framework for Climate Services", an NFCS can effectively pool and structure the expertise available nationally, which is often spread across a wide range of institutions such as universities, as well as regional and state research institutions. Golding et al., (2023) emphasize, among other things, the role of government authorities in supporting the establishment of an NFCS through a clear mandate to implement national climate scenarios and services. Actors should also pay attention to the precise definition and delimitation of the tasks of the NFCS. It is also important to ensure government support in order to plan development for future challenges. Another essential pillar is the involvement of (key) stakeholders from the outset and for continuous cooperation, which has a significant impact on the design of the services.

➔ **Use.AT internal remark: In the Austrian context, the definition of roles is not yet clear. On the one hand, the impetus for Klimaszenarien.AT was provided by the provincial governments of the federal states. On the other hand, the consortium of partner institutions involved in Klimaszenarien.AT has constituted itself, defined its objectives and looked for ways of funding. The transition to an NFCS as recommended by the WMO is not the task of the Use.AT project. However, communicating the relevance of this topic is.**

Orientation to markets / Business models

Larosia and Mysiak (2020) analyze the 32 European CS providers in a business models framework. The analysis used a business model „Canvas" in relation to the three macro categories „value proposition", „value network" and „fincancial structure". Further, the model was expanded to include the "Barriers and Opportunities" component. The analysis revealed a strong focus on the question of sustainable financing and the creation of added value.

➔ **Use.AT internal remark: As part of the CS mapping, it is possible to identify if there are conflicting objectives in this area of tension.**

2. Online search for climate services

An important part of climate services mapping is also a look at national and international climate services. A focus was placed on Europe and on services and initiatives at a national level that provide information not only for the past and present, but also for the future climate conditions. For example, services that have a status comparable to the "Klimaszenarien.AT" initiative in the respective country, albeit under country-specific framework conditions.

Selected categories for mapping climate services

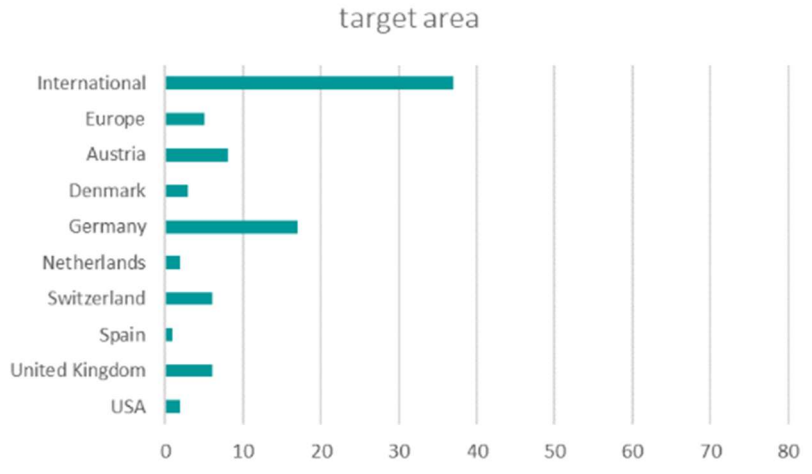
1. Target area: Countries, EU/Europe, international
2. Target groups: Public decision makers/politicians, general public & media, researcher and (scientific) experts, private businesses
3. Public and private target sectors
4. Readiness level: research level, demo level, service in use
5. Type of service: data & products, consultancy & capacity building
6. Focus in terms of climate risk assessments: definition of hazards, definition of hazards & risks, development of adaptation measures
7. Subordinate categories such as: time scale, data format, Costs for service users

In total, we took a look at 87 climate services that build on or provide information and services on **climate scenarios**. The services were identified via desktop research, based on insights of preceding projects such as the ACRP project CRiSDA and a literature review (Cortekar et al. 2020, Larosa & Mysiak 2019, Jacobs and Street 2020, Brasseur and Gallardo 2016), following a snowball sample approach.

Results according to the above categories:

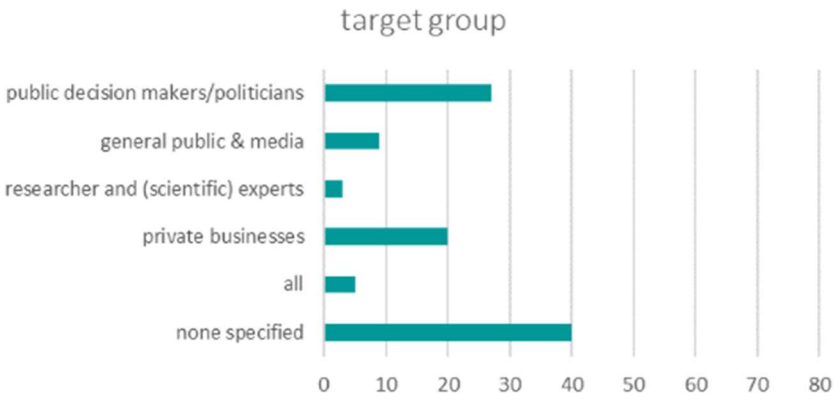
Target area

Out of the 87 CS, more than one third targets an international area. In this context, international signifies a target area that goes beyond one country and also beyond the remits of Europe. Such CS include climate data, tool boxes and dashboards, fact sheets and risk assessment solutions for private businesses. On the other hand, there are CS that have a country as designated target area. These typically include national climate scenarios and derived products, often adapted to a regional and/or local scale. A large number of such CS can be found in Germany, followed by Austria, Switzerland and the United Kingdom. A few CS focus on Europe as a target area, while a few are offered in Denmark, the Netherlands, the USA and Spain.



Target group

Most CS target public decision makers and politicians, followed by private businesses, the general public & media. CS that target public decision makers and politicians usually provide them with local/regional/national climate information or tools and planning instruments. CS targeting private businesses often revolve around providing them with data, information, tools and services to conduct climate risk analyses as well as identify adaptation measures. CS for the general public & media tend to provide images, reports, interactive maps, and dashboards, mostly in order to provide and illustrate information on climate scenarios. Researchers and (scientific) experts are the least prominent group. CS for this target group include technical reports, data and tools for hazard and risk assessments. Some CS focus on all those target groups. However, in the majority of cases, no specific target group is indicated.



Public and private target sectors

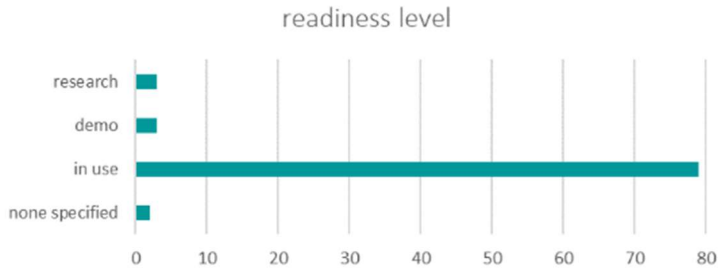
The absolute majority of CS does not indicate a target sector. The ones that do indicate one mostly focus on water, energy, agriculture, forestry & timber, and finance & insurance. A handful of services also covers transportation & logistics, industry & trade, tourism & leisure, health, (critical) infrastructures, urban/spatial planning, food & drink, and social structures & governance. Single services focus waste management, education, building & construction, or all sectors at once, while two services focus on other target sectors (wildfire and climate).

Sectors like water, energy, agriculture, and forestry & timber are often directly affected by climate change impacts, whereas other sectors might be affected further down along the line. This might explain the focus of CS tending to those needs. Moreover, the CS focusing on finance & insurance typically offer climate risk analyses, which in turn reflect on the growing demand due to the EU taxonomy regulation.

Readiness level

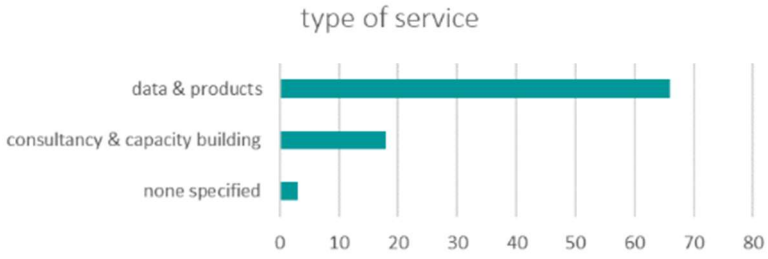
In terms of the readiness level, most of the analysed CS are “in use”, which means that they are already provided to and used by their specific target groups. Only very few categorise as a demo service or product or a research project. For two services, no readiness level could be determined. Since most providers are likely to only publicly present CS that are ready to use for service reasons, it is likely that there are a lot more CS existing that are still in earlier phases. We therefor assume that the observed high readiness levels could be a biased due to the research method.

This shows a strong aim of the providers to offer CS that should be applied. However, this does not necessarily indicate, whether the services in use are actually used by many users or whether they are considered useful and/or usable or not.



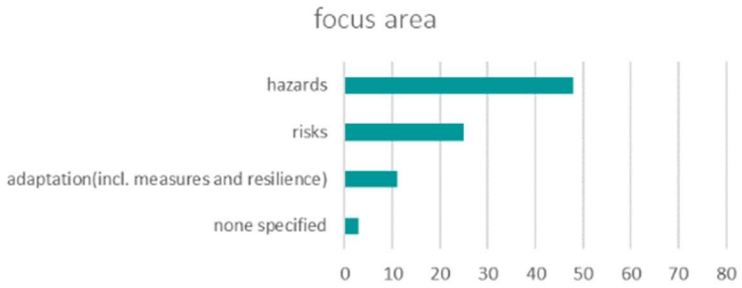
Type of service

The majority of services rather focuses on the provision of data & products (around three quarters) than on consultancy & capacity building (around one quarter). In few cases the CS cannot be clearly allocated to one category. Data & products typically include reports, datasets, tools and information material and can be mostly situated within the climate research community. They mostly focus on hazards. CS focusing on consultancy & capacity building on the other hand tend to address rather be associated with the social-ecological systems community, tending to private businesses and targeting the finance & insurance sector. They also have a clear focus on risk and adaptation, often offering workshops, trainings and interactive WebGIS tools and dashboards.



Focus area

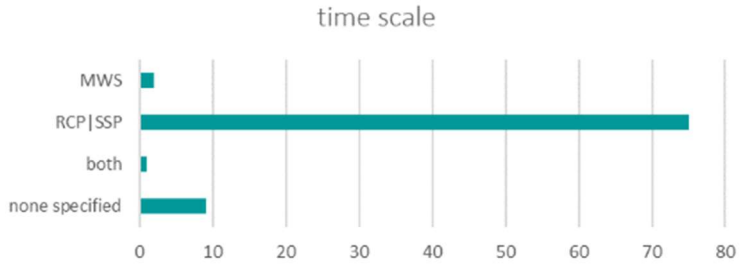
More than half of the services we investigated have a hazard focus, followed by around one quarter that focuses on risk. Some services focus on adaptation including the development or provision of measures and a focus on resilience. Only in few cases no focus area can be specified. As outlined in the category type of service, there is a correlation between type of service and focus area, with data & products often focusing on hazards, and consultancy & capacity building mostly focusing on risks and adaptation. CS that focus on risk often target private businesses and support them in conducting climate risk analyses, while CS focusing on adaptation typically target public decision makers/politicians and businesses to support them in identifying and implementing adaptation measures. There is no typical CS focusing on hazard, as they cover a wide variety of target groups, target sectors and data formats.



Time scale

The vast majority of CS found build on or uses RCP respectively SSP scenarios, hence with a time horizont until 2100 or beyond. However, to display the background correctly, we had focused the search particularly on such services. Only 2 focus on macro weather situations, one service specifies to focus on both. In some cases, no clear time scale is indicated.

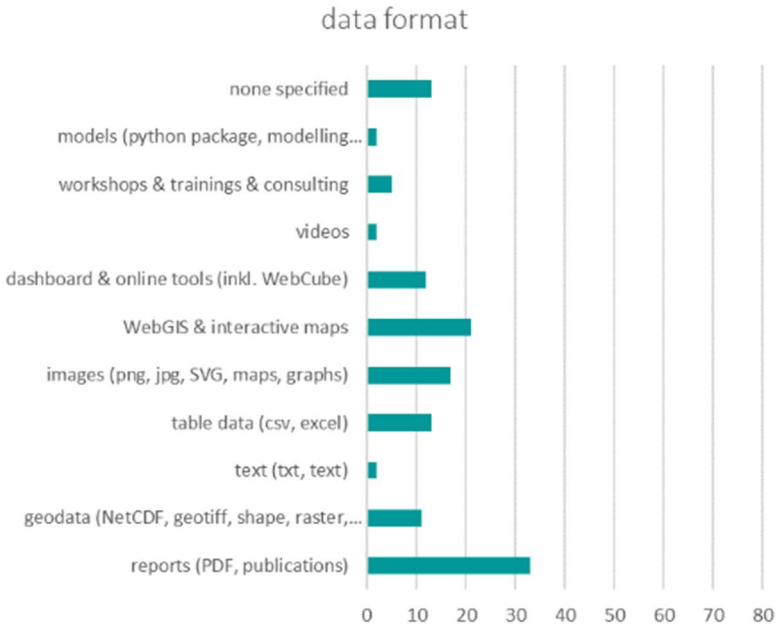
This is most likely due to the definition of CS within this project, where we focus on CS that have a clear reference to climate scenarios.



Data format

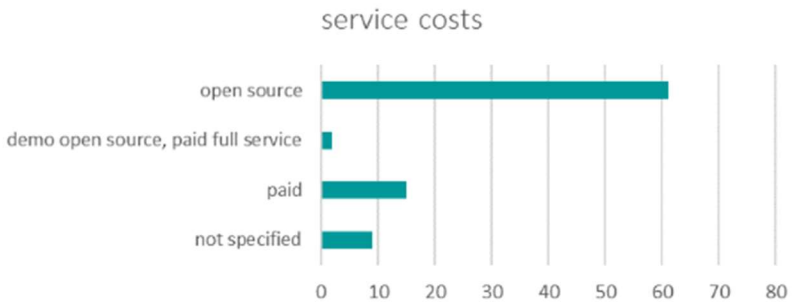
The most common data format of the investigated climate services are reports, mostly as PDFs or as publications. They are followed by WebGIS applications and interactive maps, images (which include maps, graphs, and various image file formats), table data, geodata, as well as dashboards and online tools. Much less prominent are workshops and trainings, text files, models and videos. In some cases, the data format is not specified. Reports can be found across all other categories, mostly falling into downstream activities as they explain information. Most WebGIS applications and interactive maps fall into the category of data & products and focus on hazards or risk. They can often be attributed to the climate research community, provide downstream insights and are typically open source. Images can be both an upstream or downstream product, as they explain and illustrate information. Usually, they come as data & product, from a climate research community, addressing hazards and risk. Both table data and geodata tend to focus on hazards and risk, being provided by a climate research community and falling into upstream activities. These are typical data & products, open source and provided by weather services, research institutions and data hubs. Trainings and workshops often correlate with a focus on risk and adaptation as well as consulting & capacity building activities. They tend to be allocated within the social-ecological systems community, and around half of them are paid services.

Data is the first and foremost product that can be directly derived from research. Therefore, this is what is often easily provided to users without much of a service aspect. The same often goes for reports and images. However, the more the CS take a user perspective into account, the more work has to be put in. That is reflected in CS such as dashboards, WebGIS platforms and finally workshops and trainings.



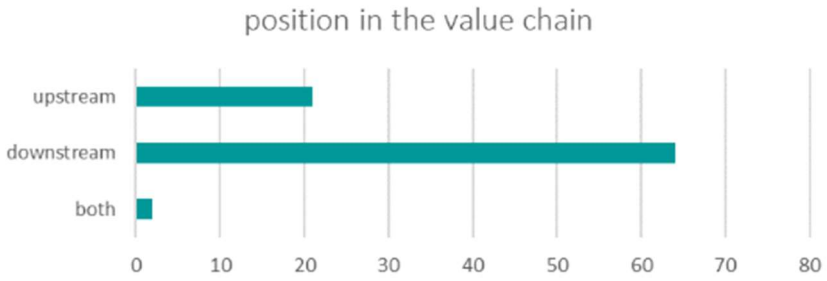
Service costs

Most of the CS are offered as open source products. Some have to be paid for (this includes mostly consulting services and risk analyses tailored to a specific region or user). Few providers offer CS that come with an open source demo, and later on with a paid full service. In some cases it is not clearly identifiable, whether the CS is open source or paid. Most of the CS that have to be paid for are services offered by consulting companies that conduct climate risk analyses for private businesses in the finance & insurance sector. They typically are downstream services, falling into the category of consulting & capacity building and being attributed to a socio-ecological systems background. Other services that are paid for include locally and regionally tailored climate information for public decision makers and politicians. The variety within open source CS is very wide, covering mostly data & products that come in manifold data formats, focusing on hazards as well as risk and adaptation, targeting different groups and sectors.



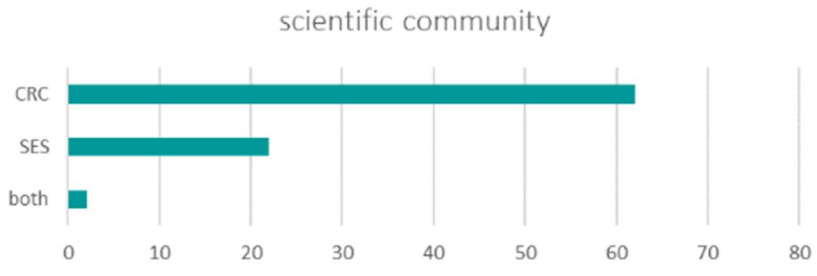
Upstream vs. Downstream

Typically, the CS focus rather on downstream activities than on upstream activities. Only few cover both aspects. Downstream CS typically come as information and data that is edited in order to be more useful and usable for the users. However, this does not necessarily mean that those CS have been designed and developed by integrating users' opinions. Upstream CS typically include data & products, often geodata, tables and images, that are open source and provided by a climate research community to various target groups.



Community

In terms of the scientific community which the CS can be attributed to, most originate from the climate research community (CRC) rather than from the socio-ecological systems community (SES). A few seem to cover aspects of both communities. CS that can rather be attributed to the SES community often focus on risk and adaptation, and almost always focus on downstream activities. Most CS that cover consulting & capacity building can be found in the SES community. In the climate research community, CS mostly cover data & products, including both upstream and downstream activities.



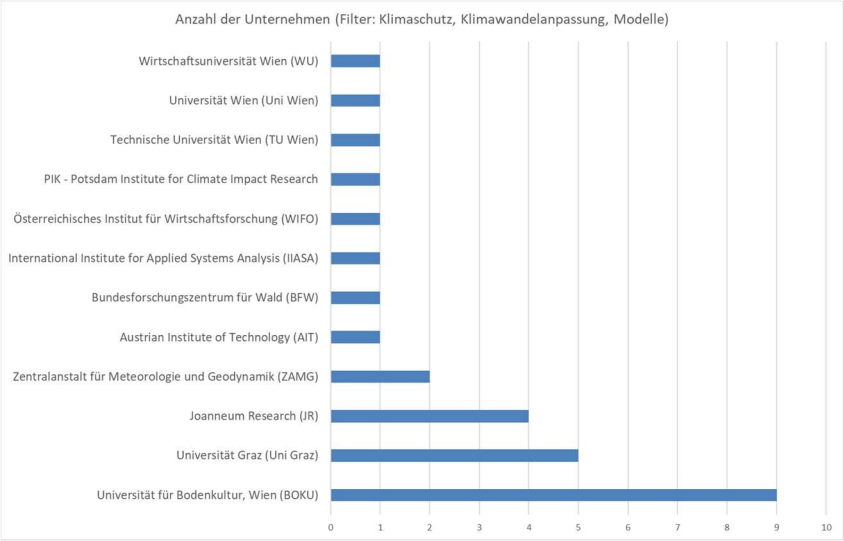
3. Evaluation of the CCCA's Austrian competence map of climate researchers

A detailed analysis of the activities of individuals listed in the competence map in recent years was carried out through internet research. However, no specific indications could be found that anyone was specifically involved in the development of Climate Services.

The assessment of national initiatives and services via the CCCA map of competences began with an initial list of services and a categorization according to the "Climate Services" definition developed in "Use.AT" (see Definition of the term "Climate Service" in the context of Use.AT).

The list of categories was the same as described in the "Online search for climate services" (subsection 2).

After filtering the research fields "climate protection" and "climate change adaptation," as well as "models," 5% (28) of the total experts (544 entries) remained. The experts come from the following companies:



Here it can be seen that the majority of individuals dealing with models and climate-related topics work at BOKU, followed by the University of Graz. Furthermore, it is noteworthy that the university, with seven representatives, is the predominant institutional type here, followed by four non-university research institutions and the PIK (Potsdam Institute for Climate Impact Research), which is organized as an association.

A detailed analysis of the activities of individuals in recent years was carried out through internet research. Although no specific indications could be found that anyone was specifically involved in the development of Climate Services, this approach could help identify companies dealing with the CS thematic area.

For the purpose of mapping climate services via the competence map, we can state that although the map is suitable for finding specific people for areas of work, the categorization alone offers little information about the development and provision of services. Many entries in the

"Advice/Consulting" area, for example, come from people who are primarily associated with universities and research institutions. It is also questionable to what extent the competence map is known outside of these institutions.

However, in a later step in WP3, where user mapping (instead of provider mapping) is conducted (Task 3.1), individuals and companies are identified and classified into "non-users", "users", or "potential users".

4. Interviews with experts from major domestic and foreign climate service providers

From the list of service providers, a number were selected that have many years of experience in developing climate services and from which selected representatives were willing to support the Use.AT project team with their expertise. The representatives were invited to report on the objectives and development of their service in interviews and to report on lessons learned in the course of service development. The interviewees were all among the main developers of the CS they described. Some of them more on the modeling side, others as experts in climate communication and consulting. Interviews were conducted with experts from the following Climate Service Institutions:

List of interviewed institutions

- Deloitte Austria, consulting company
- EY Denkstatt , consulting company
- Deutscher Wetterdienst (DWD), national meteorological and hydrological service
- Climate Service Center Germany (GERICS), national climate service centre
- Koninklijk Nederlands Meteorologisch Instituut (KNMI), national meteorological and hydrological service
- Meteo France, national meteorological and hydrological service
- Norwegian Centre for Environment-friendly Energy Research (NCCS Norway), research institution
- National Centre for Climate Services, Switzerland (NCCS CH), national climate service centre
- Potsdam Institute for climate Impact Research (PIK), research institution
- UK Met Office (UKMO), national meteorological and hydrological service

Content of the interviews

We conducted semi-guided online interviews with representatives of those institutions (each about 60 min – 90 min duration with one central representative). A list of key questions for selected aspects were tackled in the interviews to cover the subject area of backgrounds and experiences with the specific Climate Service (see

Annex for detailed questions): 1) Official aspects, 2) Target groups, 3) User involvement, 4) User Feedback, 5) Technical (Data) Aspects, 6) Visualization & language, 7) Internal strategic aspects, 8) Future developments.

Transcription

The transcription of the interviews was carried out with aTrain (Microsoft 2023) in line with EU-GDPR guidelines. The analysis of the interviews was conducted with ATLAS.ti (2024):

First, topics (in ATLAS.ti: code groups) were set up based on the core questions of the interview guideline. Within these, categories (in ATLAS.ti: codes) were established based on the input of the interviews. That allows us to identify, which category is mentioned by which interviewee, how often, in which context and also in combination with which other topics and categories. That way, cross references and patterns can be identified and made visible.

Limitations of that approach include the dependence on the perspective of the interviewee: If a person mentions one topic more than others, that does not necessarily mean it is more important. If a topic does not come up during the course of the interview, it will not be visible in the analysis. And if one provider mentions one category several times, depending on the way to depict the situation, this can shift the overall impression so that this category seems disproportionally important to all providers.

Keeping these limitations in mind, we will now discuss the input of the interviews, following the core questions of the interview guideline.

Results according to the above aspects tackled in the interviews:

Official aspects

General conditions of CS providers

With regard to the official mandate of the CS providers, all of the national meteorological and hydrological services (NMHS) as well as one NCCS have either the legal mandate or are commissioned by the government to develop their climate services. In the case of the national meteorological and hydrological services (NMHS), this typically means that they provide climate data and develop climate scenarios by request of the government and sometimes regulated by law. *"We are the national climate services. So […] our boss is the government"* (Meteo France 2024). And as one scientist from NCCS CH (2024) explains, Meteo Swiss, which NCCS CH is a part of, *"has the mandate via a decision by the Federal Council to provide new and current climate scenarios, not continuously, but at regular intervals"*.

In terms of whether they are focusing more on upstream (research) or downstream (consulting) activities, many providers situate themselves at the interface between research and practice. This applies to both national climate service centres (NCSC), two of the NMHS as well as one research institution. This seems appropriate as climate service centres have an explicit focus on developing a service for users and therefore a more practical approach than classic NMHS who typically also have other core competencies and tasks. As one scientist from GERICS (2024) states, *"our founding mission 15 years ago was to bring climate change adaptation knowledge from research into practice and the*

other way around to see, what needs arise in practice that are not yet covered by research in order to then initiate projects to address those needs".

Five of the providers identify themselves as research institutions. This applies both to NMHS and NCSC, as both often have to conduct research in order to generate data or develop an according service.

Only three of the interviewed providers see themselves as consultants. This for one applies to the both consulting companies as well as for one of the NMHS. The latter, UK Met Office, has a wide portfolio in terms of services offered and targets both the government and commercial organisations.

Financing

When it comes to financing, most of the providers are (basically) funded by the government or they provide their services to public bodies and ministries, who either commission specific products and services or provide funding, so it is *"typically connected to calls for tenders or direct contacts with ministries"* (GERICS 2024). This applies to three of the NMHS, both research institutions and both NCSC. Many of them also need third-party funding through research projects for further research and development, *"of course EU projects and whatever else there is, such as the German Federal Environmental Foundation and others"* (PIK 2024). This concerns NSCS, research institutions and some of the NMHS. One research institution and two NMHS also include students via theses, *"from bachelor theses to projects"* (DWD 2024), helping them to conduct their research. The consulting companies on the other hand usually finance themselves solely via customer orders.

Thematic focus

The providers have different foci: Most of them address or provide input for others to cover hydrological and water issues, such as *"sea level rise, groundwater estimations, a lot of water management, coast protection"* (KNMI 2024), *"flooding […] or future water supply"* (UKMO 2024) or ground water management in general. This applies to several NMHS, both research institutions as well as one NCSC. Most of those service providers are located in countries that have access to the sea.

The focus mentioned the second most is insurance & finance. This is a topic that NMHS, research institutions, NCSC and consulting companies work on. In several cases, this means conducting climate risk assessments in the context of the EU taxonomy regulation or CSDR (corporate sustainability reporting directive).

Another main focus that is predominantly covered by NMHS and NCSC is traffic & infrastructure. Often this goes hand in hand with other foci, such as *"water management around roads, for example"* (KNMI 2024), informing decisions on how to adapt those infrastructures to climate change *"or how we design infrastructure to be resilient towards flooding"* (NCCS Norway 2024).

Less dominant but still relevant to the providers are the areas of health and nature conservation, both covered by one NMHS, NCSC and research institution each. In terms of health, this often means involving relevant ministries and public health actors in order to provide information e.g. on heat mortality and develop education material.

Urban and spatial planning is a focus covered by one research institution and one NCSC, while sectors such es building & construction, energy, industry, nuclear industry, and catastrophe management are only addressed in singular cases, mostly by various NHMS.

Figure 3 illustrates the dominance of the thematic orientation of the described CS. The underlying metric for the dominance is the counted number of nominations for each topic. A higher number of nominations is reflected by a larger area.

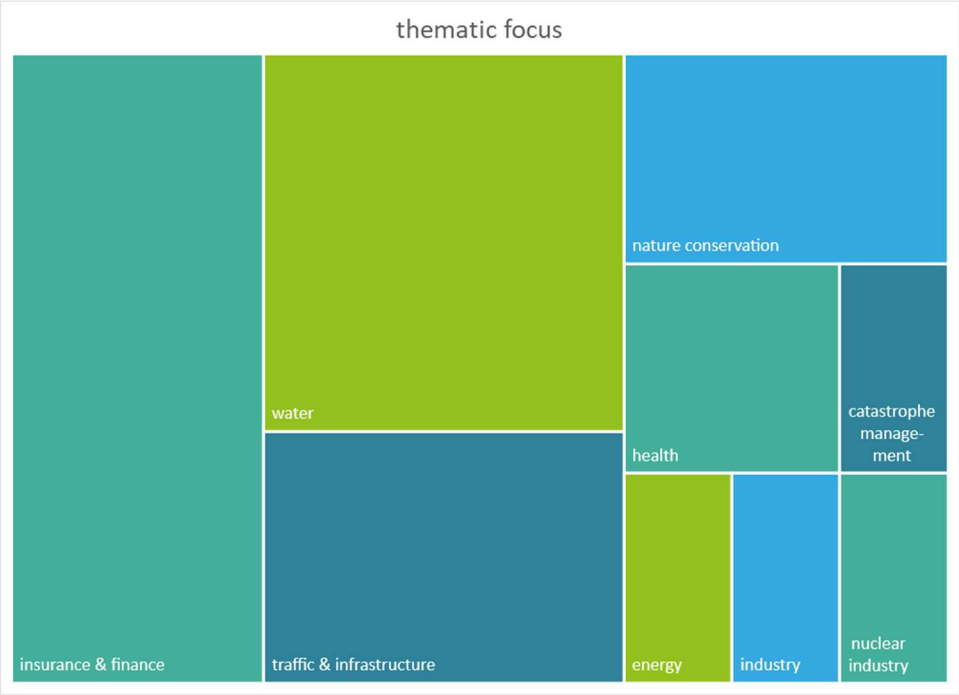


FIGURE 3: DOMINANCE OF THEMATIC FOCI IN THE INTERVIEWS REPRESENTED BY THE EXTENT OF THE AREAS.

Intentional background of the climate service

For most of the providers, the beginnings of their respective climate services lie in the intention to provide climate information to users. This approach includes two of the NMHS, both NCSC as well as both research institution. One provider argues that they wanted to anticipate such incoming requests, while another one states that they want data to be used sensibly and thus provide support in that area. As one scientist from NCCS Norway puts it, they started *"because we saw the need for providing standard national climate projections to the users, because there was a tendency for shopping around for the best projections and it would be quite random what they ended up using"* (NCCS Norway 2024). Therefore, one of the main goals is to provide standardised representations of climate information, *"we see it as a part of our societal responsibility"* (NCCS Norway 2024). Sometimes, this information is provided to intermediary organisations who then spread the information to other users, as UKMO (2024) for example states that UK CP provides *"the basis for climate services rather than taking those all the way through and getting to the tailored products that people need"*.

The EU taxonomy and/or CSDR played an important part in the development of their CS for both consulting companies and one NMHS: *"Driven by the [EU] taxonomy and CSRD, there's a lot of climatre*

risk analyses incoming" (Denkstatt 2024). The respective products and services are thus *"very regulatory driven"* (Deloitte 2024).

Three of the NMHS also wanted to include some new capabilities and scientific developments or the newest available SRES scenarios into their CS:

"One [reason] is that you get a material shift in the science, which tells you that the existing projections would change significantly if we run a new set. […] And the third is that there may be a new capability that can help us to meet existing or new user needs that previously we couldn't meet." (UKMO 2024)

Two NMHS and one NCSC developed their CS because of user requirements. In one case, the CS was specifically established for the water management. In another case, a scientist of GERICS (2024) explains that users were directly involved in the development of the service and *"we identified the demand and what we can cover"*.

For one NMHS and one NCSC, the intention was to help strengthen the resilience of infrastructure or society as a whole. The integration of information on exposure & vulnerability with climate data was the ambition of one NCSC, as they want to offer CS that take a risk perspective into account. They also argue that they wanted to provide an objective source of information that is not politically or otherwise driven.

Development of the CS

technical aspects

In terms of technical aspects, the providers bring up various topics:

The NMHS mention the resolution of the climate scenarios as they sometimes offer their CS in different spatial resolutions, typically with a highest resolution of between 5 x 5 km and 1 x 1 km grid. Typically, they started from a lower resolution, e.g. *"because at the time we didn't have the capability to downscale from a wider range of models"* (UKMO 2024), and applied different downscaling processes to compile them.

Four NMHS and one research institution base their CS amongst other sources on observation data, *"because those are simply facts"* (PIK 2024), which they then run a bias correction on, or in case of one NMHS also a delta correction. Another NMHS and one research institution mention they conduct reanalyses.

In terms of the models that form the baseline for the CS, all NMHS and one research institution draw on recent CMIP versions. Similarly, four of them as well as both NCSC also use EURO-CORDEX data. Drawing on EURO-CORDEX data as a base, a scientist of DWD (2024) explains how they *"have now developed a three-stage quality control chain, which takes into account the global models, then the EURO-CORDEX models for the whole area and then the smaller regions within Germany."* In some cases, both CMIP and EURO-CORDEX data are used: *"We want to use EURO-CORDEX projections, but also CMIP projections and integrate observations with the observational constraint and mix all sources of available information."* (Meteo France 2024). Only part of the institutions (two NMHS and one NCSC) run their own model simulations. Others mainly adapt the EURO-CORDEX projections by bias correction or use statistical downscaling techniques. One of the research institutions (UK Met Office) developed its own data pipeline to run ensembles.

Two NMHS state they provide information on extreme events, because *"extremes is what it's about. Because in general, at least in the Netherlands, the country is relatively well developed and well adapted to the average climate […]. So then it is the extreme situation that you want to prepare for."* (KNMI 2024). Two also provide climate indices *"such as tropical days, heating degree days etc."* (KNMI 2024), sometimes specifically for different sectors.

Both consulting companies draw on existing parameters and data, because otherwise *"this always creates uncertainty, meaning you have to throw together different parameters yourself. […] Everything we can get from science is extremely helpful. But we also have to know that these risk parameters are correct and that they are reliable"* (Denkstatt 2024). One consulting company draws on the riskfab risk factors of the World Bank, while one NCSC draws on the data of one of the NMHS.

user-centered development

In terms of user-centered development, the CS providers have made some adjustments to their CS based on user requests and requirements:

Three of the NMHS as well as one NCSC and one research institution offer locally and/or regionally tailored information for their users. Often starting off with a local or regional example, this helps to make climate information more understandable and relatable for users, as it is *"a good entry point for the people"* (Meteo France 2024), embedded in their everyday experience context. This includes factsheets specifically designed for municipalities and regions or the development of a GIS based interface to illustrate climate changes on a local authority scale. On the other hand, they receive feedback from the users if they can relate to the example and information or not, which can in turn help to adapt the CS: *"It is sometimes testing a little bit how people react to it. And after certain examples, they think 'oh yes, that sounds logical', and other people, well, you still see them thinking and you should use an other example."* (KNMI 2024).

Two NMHS have changed their CS to a higher resolution. One NMHS has also adjusted their data intervals in terms of providing seasonal data for winter and summer in terms of rainfall patterns and the resulting change in ground water levels.

The point to include users as early as possible in the development is mentioned as pivotal by two NMHS. As a scientist from UKMO (2024) mentions, *"we have to be honest, [we] learned that the hard way from our earlier initiatives not bringing users in early enough into the process. And we learned that we can't decide what the products are going to be and then ask users to tweak them at the end."*

Two NMHS and one research institution now include climate projections along with some examples of impacts into their CS. They want to make climate change more tangible for users in terms of how they will be affected, because *"if you show them that climate change can have [an] impact on their personal life, on their health for example, that's one of the points where you get their attention"* (KNMI 2024). One of the NMHS and one research institution also mention they include indices and thresholds. In some cases, the users can set these thresholds themselves according to their needs.

Three providers have different products and services to offer for different users as *"now we really understand that you have to be able to offer several things at different entry points"* (UKMO 2024). That includes different types of reports, webportals and tools, varying in terms of the language they use or the figures used and how they are explained, so *"there are many […] different levels of*

sophistication" (UKMO 2024). All of the NMHS, one NCSC and one research institution have also adapted their websites to help users to find content faster, *"because we receive more and more inquiries, also from people who are not that deeply involved"* (DWD 2024). One website now has the option for users to use their own photos to generate a local fact sheet, and the providers work on generating a user interface that is really usable, *"we want to improve that in the future, we just have to think about how"* (NCCS CH 2024).

After some user requests to include additional scenarios, two NMHS adapted their CS accordingly. Another topic two NMHS work on is their display of uncertainties, and *"how can people understand it, because the whole topic is of course unbelievably complex"* (DWD 2024).

One NMHS took a global warming level approach to illustrate changes in climate instead of using several scenarios by a request of the government. However, they transformed this approach into a trajectory, *"because until now, the previous adaptation plan, we're only considering a +2 global warming degree. […] And then the adaptation actors say that they cannot just adapt to a plus three degrees. They have to know, when."* (Meteo France 2024). So, they linked the global warming levels to a time horizon in order to make it more user friendly "*and give them one set guideline to follow. In their experience, that helps users to take measures to achieve a set goal more easily than if they have to take different scenario into account and have to chose for themselves, which one to follow.*" (Meteo France, 2024)

One NMHS has received user requests to provide information in terms of future energy demands because of a changing climate. Another NMHS describes their shift to include probabilistic models and scenarios into their CS as the biggest step to meet user requirements.

A tool that is used by one NCSC to reach their users better is the implementation of several personas that represent different users, *"and they were very well received, so we decided to keep them"* (NCCS CH 2024). That helps to visualise different scenarios and make them more tangible for the users.

visualisation

More than half of the providers mention the use of figures as essential aspect in terms of visualisation for their CS. This includes three NMHS, one consulting company, one research institution and one NCSC. They argue that illustrating information graphically helps to bring the message across to users, as *"trying to explain the same information in different ways can sometimes help and sometimes with a nice figure as visualisation, this can also help"* (KNMI 2024).

Another popular way of graphical processing amongst the providers (two NMHS, one consulting company, both research institutions and one NCSC) is the use of WebGIS tools, dashboards and other web-based tools where users can for example change color scales dynamically or set things to a specific spatial extent, *"maybe a bit more like gaming really, […] this playful way to approach people"* (NCCS CH 2024). They tailor their services to their respective target groups *"to reduce the complexity a bit, most of our users should not have to do too much there"* (PIK 2024). One provider reflects that this might be similar to gamefying approaches, where users are motivated to interact with the material by themselves.

Both consulting companies and one research institution have their own in-house experts to work on the graphic design of their CS.

One NMHS and one NCSC use animations. These are usually used to addresse the general public as users in order to provide a low-threshold service. The animations can serve as a shorter summary of the climate scenarios, as one provider argues.

language

Several providers (2 NMHS, one NCSC and one research institution) state that they pay a lot of attention to formulate explanations. *"So, we always try to provide a note: Together with the data where we provide information about […] how robust this data is or how you should interpret it"* (NCCS Norway 2024). That includes explaining figures, information in different levels of detail or *"what is included and what is not"* (KNMI 2024).

Other providers (one NMHS, NCSC, consulting company and research institution each) adapt their CS according to their target groups in terms of language. *"When I write a [risk] report […] that addresses the general public, I will use simpler words than if I'm writing a risk report for a risk manager"* (Denkstatt 2024). CS for the general public will thus differ for example regarding the level of detail of the message, the amount of animations that are used, the extent of a brochure, or also the terms and definitions that are used. *"There are of course multiple uses, it is clear, it is also nice if you do not have just one product for exactly one group, but it is quite clear [who is adressed]"* (NCCS CH 2024).

Two of the providers – one research institution and one consulting company – offer their CS in different languages, *"even if it is not perfect […] in order to simply reduce the threshold for use, so to speak"* (PIK 2024).

One research institution has an in-house communication department to handle these aspects, and they *"try to use our communication department as much as possible"* (NCCS Norway 2024).

Current offer and evaluation

key target groups and areas

The target group that is mentioned the most are administration stakeholders, ranging from state governments to the regional and down to the municipality level. They are addressed by three NMHS, both research institutions, both NCSC and one consulting company. Typically, CS for this target audience include locally and regionally tailored data and information, for example fact sheets, ground water level estimations, or input to inform adaptive measures.

Impact modelers are a target group for the majority of providers (all 4 NMHS, 2 research institutions and one NCSC). Another target area covered by all NMHS, one research institution and one consulting company is agriculture & forestry. Users in that area are often interested in seasonal information, future water supply or crop yield development.

The private sector is also amongst the most prominent target groups, being targeted by two NMHS, two NCSC, one consulting company and one research institution. As one representative of Denkstatt (2024) argues, they nowadays are often approached by companies they are already consulting *"because they are now required to comply with CSA"*.

A NMHS and a NCSC both have consultancies amongst their target groups. Another NMHS and an NCSC target users from communication and media. That includes data journalists and people working for administration especially. Another NMHS and one research institution have teaching as a target area and either work together with schools or develop teaching materials.

Two of the NMHS, both research institutions and one NCSC see the general public as one of their target groups. Typically, they offer specific CS to make them easier understandable for these users, *"so it's […] improving the whole chain from production to distribution to services"* (NCCS Norway 2024). On the other hand, two NMHS, two NCSC and one research institution have researchers amongst their target groups, who often use those CS as input for their own models and further studies.

Policymakers are explicitly targeted by a NMHS, a research institution and a NCSC. This often involves offering them consultation *"covering the areas of citizens' dialogue and education"* (PIK 2024), as they feel *"the scenarios are not just for scientific use, but should actually be used by decision makers"* (NCCS CH 2024). Similarly, three providers (NMHS, NCSC and consulting company) mention public sector organisations as target groups.

A NCSC has special interest groups amongst its target groups such as fisheries. A consulting company deals with stakeholders working in the area of sustainability of companies. Planners and engineering companies are amongst the target groups of a research institution and a NCSC.

One of the consulting companies as well as one research institution address stakeholders in risk management with their CS.

The military is a target group of one NCSC, who is interested in climate change and its impacts. One NMHS informs regulatory instances that develop requirements for other organisations to integrate climate change in their planning.

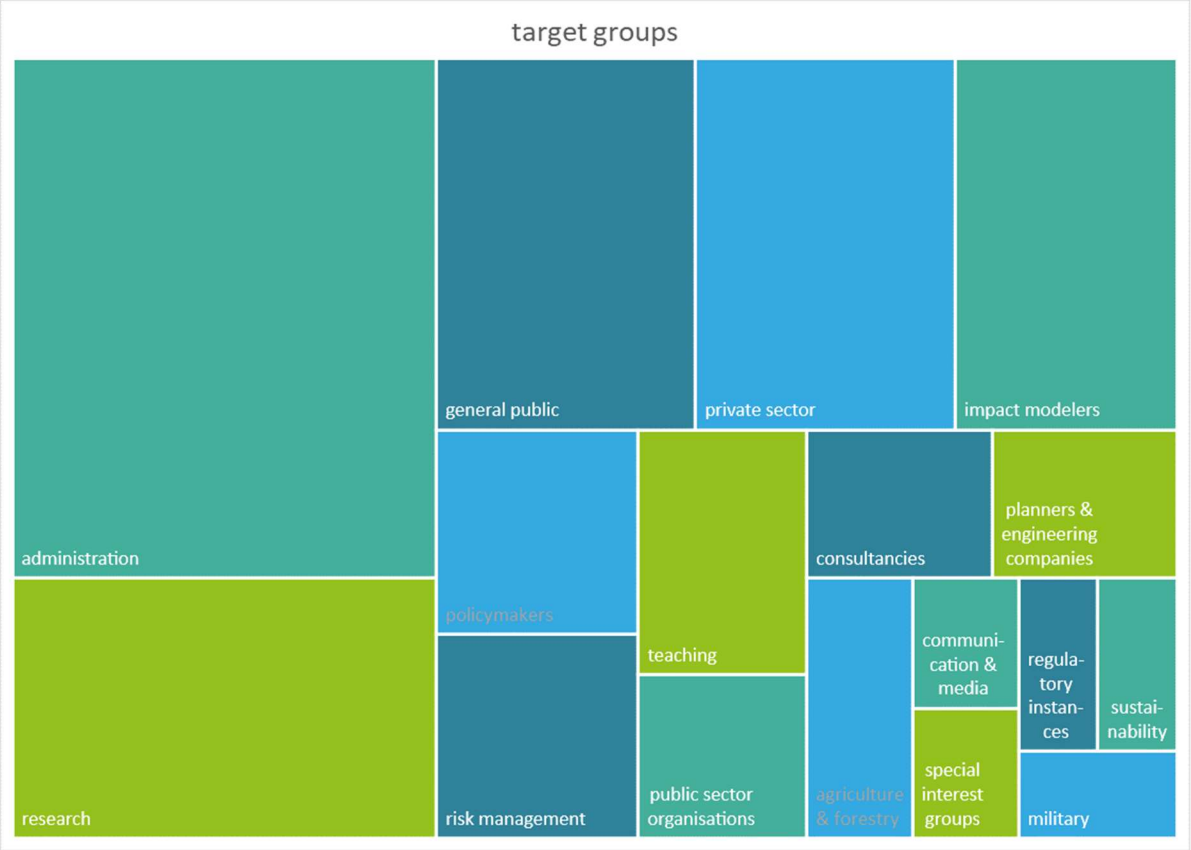


FIGURE 4: ILLUSTRATION OF THE ORIENTATION TOWARDS SPECIFIC TARGET GROUPS OF THE OF THE DESCRIBED CS. THE HIGHER THE NUMBER OF NOMINATIONS THE LARGER IS THE AREA RESERVED FOR EACH TARGET GROUP.

use cases

Two of the NMHS, both research institutions and one NCSC identify impact assessment as a use case of their CS. In some cases, they developed their CS specifically to inform impact assessment, such as the Climate Impact Atlas by KNMI (2024) which *"is used for what we call [a] climate stress test [for municipalities]".* Another example is the NCCS-Impacts programme that aims at providing a basis for decision making processes (NCCS 2023), and that originated *"exactly because […] we wanted to make sure, that the climate scenarios are really implemented in practice"* (NCCS CH 24).

Almost all of the NMHS, one research institution and one NCSC state to offer their CS to be used to support climate change adaptation. *"It is about how we can use it [our CS] to support adaptation and transformation processes at the local and regional level, right? So where should this information ideally be included in any decision-making processes, in what form and so on"* (GERICS 2024).

Climate risk analyses are one of the main use cases for both consulting companies, but also one NMHS refers to user inquiries using their CS to conduct climate risk analyses. *"And climate scenarios are an essential building block there, because all the forward-looking aspects with short, medium and long-term perspectives must always be viewed in relation to scenarios and they also provide the basis for risk assessment and risk definition" (Denkstatt 2024).*

Two NMHS and one NCSC provide CS revolving around climate monitoring. One NMHS and one research institution also focus on climate projections.

One of the consulting companies states that their core use cases are the assessment of measures as well as developing measures for the reduction of green house gas emissions. The development of measures is also a use case for the other consulting company as well as one NCSC, which ultimately aim at making resilience analyses possible as argued by the second consulting company.

feedback

All of the NMHS along with one NCSC and one research institution organise user workshops to collect their feedback. They describe it as an interactive way to learn from users, what their experience with the CS is like, what should be done additionally and/or differently - *"especially in terms of how the products can really be brought closer to people, that is the most important point in this exchange"* (DWD 2024). And also setting up a workshops for the users to exchange experiences amongst them can prove succesfull: *"And if you then analyse what kind of advice they are giving, what kind of reactions you get, that gives you an idea of what people consider interesting"* (Meteo France 2024).

Both research institutions, one NMHS and one NCSC have been using co-production approaches, *"so it's not just about the definition of the user interface, e.g. whether […] the button is green or blue, or whether it is on the top right or top left"* (GERICS 2024), but rather to develop their CS and implement feedback of users. *"So it's more a learning process"*, as one scientist of KNMI (2024) puts it. The feedback of users helped the providers to adapt their services, e.g. factsheets to be understandable and usable for the users.

Three of the NMHS and one NCSC draw on a network of experts to receive feedback on their CS and *"to identify where the biggest problems lie"* (NCCS CH 2024). These networks include experts from science, administration, economy, natural parks, as well as service designers.

Another quite popular way to collect user feedback used by three NMHS and two NCSC are surveys as a means to reach many users. Conducting interviews, both online and in person with users is another method used by one NMHS, one NCSC and one research organisation to collect feedback, depending on the project rather targeting "more advanced users or a selection of them" (NCCS Norway 2024) or *"focusing on specific topics"* (NCCS CH 2024). Two NHMS use their Newsletters to distribute information on their CS and collect feedback of users.

One consulting company and one NMHS draw directly on their user community to collect feedback on their CS. This means establishing user communities *"dedicated to provide guidance"* (Meteo France 2024) and *"inviting users to specifically arranged community events"* (Deloitte 2024).

Some providers (2 NMHS and 1 NCSC) also use the opportunity when giving talks to collect feedback. Webinars are used by one NMHS and one research institution "so people should participate in a hands-on way" (PIK 2024).

Indirect user feedback, e.g. via downloads or statistics regarding accesses to websites is a way one research organisation, consulting company, NCSC and NMHS each use to assess and adapt their CS.

One research institution mentions the interaction with visitors at a conference to get feedback from users, while one NMHS suggests to facilitate feedback between data providers and end users to identify bugs or inconsistencies in datasets, *"because only by working with the dataset itself, even if it is well documented, you see if there are any bugs or where things don't align well"* (DWD 2024).

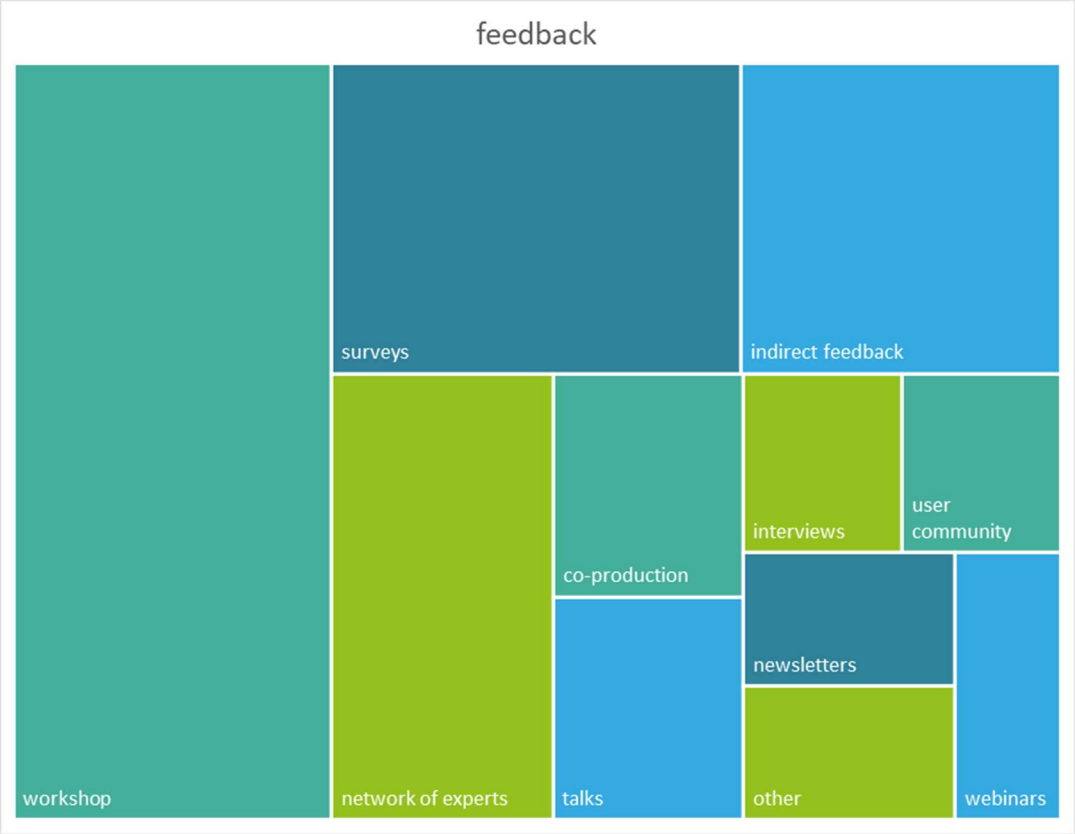


FIGURE 5: VISUALISATION OF THE METHODS USED FOR RECEIVING FEEDBACK FROM THE USERS OF THE DESCRIBED CSS. THE UNDERLYING METRIC FOR THE DOMINANCE IS THE COUNTED NUMBER OF NOMINATIONS FOR EACH TOPIC. A HIGHER NUMBER OF NOMINATIONS IS REFLECTED BY A LARGER AREA.

Further development

Development stages

Two NMHS and both research institutions made changes in terms of the data format, e.g. to enable the direct integration of data into users' simulation models or to offer data both in grid or NetCDF format as well as in tables.

Both research institutions as well as one NMHS expanded their CS to include consulting services. This is helpful to explain the data and information they provide, see what users actually need for their respective use cases or *"to explain exactly, what is the difference [between different data]"* (DWD 2024).

Two NMHS and one research institution added explanations to their CS to help users make use of the service. *"Before people did nothing because they say […] 'I don't know what to do with that'. So I just forget and do nothing."* (Meteo France 2024). That along with other adaptations have *"been kind of the game changing component of those scenarios"* for one scientist of UKMO (2024).

Based on user feedback, one NMHS and one research institution adapted their websites and webtools too.

One NMHS and one NCSC developed communication plans and working groups for communication to improve the communication to users or to *"ensure the exchange"* (NCCS CH 2024) with them.

Asked for by users and improving their simulations, two NMHS now offer their CS with a higher spatial resolution, while one research institution expanded their CS to cover a wider geographical area. Two NMHS and one research institution work on harmonising ensembles to develop a standard product best suited for the respective use. On the other hand, one NMHS, NCSC and research institution each made changes regarding the temporal resolution. This includes expanding predictions to include a larger timeframe or including seasonality.

Because of inquiries by the media about an extreme event and its relation to climate change, one NMHS started to do attribution studies. It also started to conduct experiments in order to answer questions that users came up with. This includes inquiries such as how reversing the earth's rotation would affect the AMOC, as many users have been concerned with that recently. This NMHS also offers a hotline *"as a space where users can ask questions to the scientists"* (Meteo France 2024), ranging from 'how can I download data?' to more scientific questions that have to be answered by the scientists working there. Moreover, they sometimes organise press conferences *"and we communicate in the event to anticipate all the requests that will come […] and this is to ease the work of the colleagues [working on the hotline]"* (Meteo France 2024).

challenges

When providing CS, there are a variety of challenges that can arise:

Several challenges revolve in terms of the **underlying data** itself: Two of the NMHS, one research institution, one NCSC as well as one consulting company mention the robustness and soundness of (data)sources as challenge. That is why a representative of Denkstatt (2024) draws on scientific tools *"because then I can simply trust it or say with a good gut feeling that this is peer review, they didn't write down some random mistakes and then somewhere in the evaluation an error occurred"*. However, the providers also see it as a challenge for users, *"because the question always is, where do I get authoritative data? […] Why do I choose a data set from C3s or why do I choose a data set that my state authority provides me with?"* (GERICS 2024). Another challenge mentioned by three of the NMHS and one consulting company is the accuracy of data, e.g. in terms of giving out punctual or local information based on grids with a lower resolution, suggesting *"a higher accuracy and many decimal places, that just doesn't help at all"* (Denkstatt 2024). Two of the NMHS also found the implementation of a bias correction challenging.

Several challenges revolve around the **users**: One of the most prominent challenge from the providers' point of view is the users' competence. As three NMHS, one consulting company, both research institutions and one NCSC argue, many users seem to struggle with using the data correctly, understanding the information and implementing the CS accordingly:

"The last feedback is that even if they now are able to have all this information, they don't know what to do with that. So, I think this is really the challenge that we have now, to synthesise this data, to extract the main messages and to explain, what we can do with these messages" (Meteo France 2024).

Following that, another very dominant challenge mentioned by all of the NMHS, both research institutions and one NCSC is the provision of CS that are understandable for the users. *"I think we're still learning about how people use the data and […] how long it takes users to build up their confidence using particular data types. And so I think to some extent, we're still building these skills in our user community"* (UKMO 2024).

Both research organisations and two of the NMHS state developing and providing products for different users and bridging the gap between different states of know-how as a challenge *"to find the right balance between the tailored services and the general portals"* (Meteo France 2024). One NMHS and one NCSC also mention the difficulty to have active user engagement or users implementing knowledge and measures, as *"knowledge alone is not enough to get people into action"* (KNMI 2024). Another challenge is climate scepticism and a lack of trust amongst users towards the providers of CS, as one research institution and one NMHS argue. Developing a CS and *"make the link to something that is rechable, affordable and possible for people to do"* (KNMI 2024) is a challenge mentioned by two NMHS and one consulting company, because *"internal development only makes sense for products that can be implemented at some point"* (Deloitte 2024). One research institution also questions the relevance of the provided CS for users *"because this is still an open question for us […] what is relevant for the users"* (NCCS Norway 2024). Moreover, one NMHS mentions the difficulty to include uncertainties in a way that users understand it. One of the NMHS states to find it challenging to develop easily understandable figures.

Challenges in terms of the **providers' situation** and setup include a lack of expertise in terms of how to communicate data and information, as both research institutions as well as two NMHS state. Both NCSC see challenges in terms of competition with other providers. The most prominent challenge in that regard though as stated by eight out of the ten consulted providers is a lack of resources in terms human power and budget. This applies for three of the NMHS, both research institutions, both NCSC and one of the consulting companies. And even if a CS is established, *"the maintenance is also very time-consuming"* (PIK 2024). In that line, one NMHS mentions the time lag between the development and the implementation of a CS. For one consulting company and one research institution, budget is also a limiting factor in terms of customers not necessary being willing or able to pay more for a better service.

Decision making processes can be a challenge, especially the larger **number of actors and different interests** are involved, as one NMHS, one research institution and one NCSC state. In that line, working together with various actors is a challenge mentioned by one NCSC, one NMHS and one research institution. Moreover, one research institution and one NCSC mention political considerations as an obstacle they have to deal with. For one NCSC, one challenge is to have a set role in the provider landscape between research and practice.

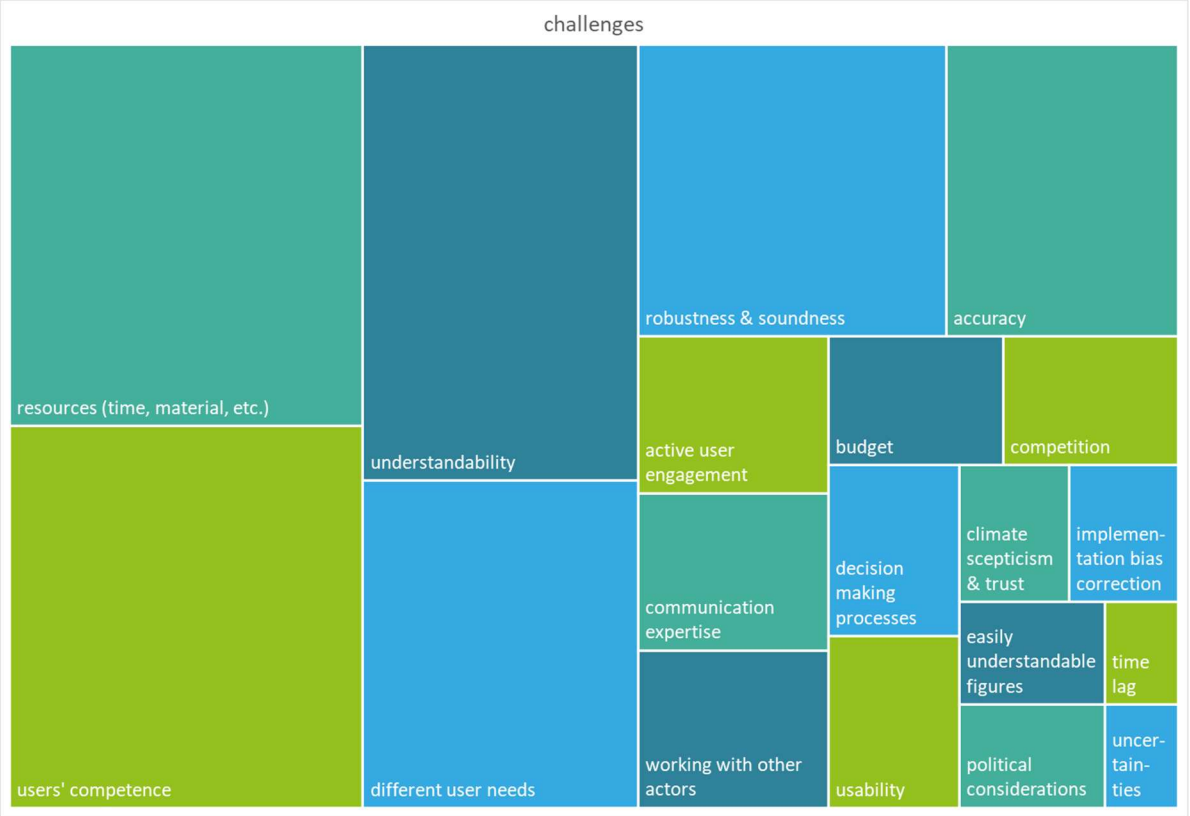


FIGURE 6: ILLUSTRATES THE CHALLENGES EXPERIENCED DURING THE DEVELOPMENT AND PROVISION OF THE DESCRIBED CLIMATE SERVICES. A HIGHER NUMBER OF NOMINATIONS IS REFLECTED BY A LARGER AREA.

Self-image as CS provider

Role/competence in the national/international landscape

One of the main roles the providers state to take on is the provision of data and information. Both research institutions, both NCSC and two NMHS state that they often provide the base for further products and services, as they *"want to bundle and process existing information and data"* (NCCS CH 2024). Developing *"new climate services and then also providing them"* (NCCS CH 2024) is one of the core competencies mentioned by one NCSC, one research institution and one NMHS.

Both of the NCSC as well as two of the NMHS and one research institution see one of their role or core competencies in the area of consulting administration. They provide reports and input for further downstream applications and products. Two of the NMHS, one NCSC and one research institution see one of their roles as providing stakeholders with support for climate change adaptation, often aiming at the local and regional level. *"We have been operating within this area for a long time and with the climate adaptation law [coming up], we now see even more customers coming to us"* (DWD 2024). Both consulting companies as well as one research institution mostly see themselves concerned with consulting customers from the private sector. And one research institution locates one of their core competencies in education and providing education material to schools.

While one research institution underlines its competence in terms of natural sciences, it also highlights its competencies in social sciences, as does one consulting company. One of the NCSC highlights its diverse team as one of their main assets and competencies.

Future prospects

There are a lot of different aspects which the providers want to consider in future endeavours or feel will become important in the future:

Three NMHS, both research institutions, one consulting company and one NCSC see a shift in terms of the **thematic focus** happening in the next years. This ranges from combining mitigation and adaptation information, including information on tipping points to integrating impact information - *"because most people are not interested whether it's 2 °C more or less, they are interested in the impact"* (KNMI 2024). A scientist from PIK (2024) also mentions *"planetary boundaries is a big point, so also beyond climate change, biodiversity, water availability, ocean health, everything in that direction and then also [taking into account] the economic level"*. That focus on economy, looking closer at socioeconomic indicators as well as assessing financial potentials is also mentioned by other providers, *"so I think it is definitely the future, so the market has to regulate itself first"* (Denkstatt 2024). Additionally, they want to provide sector specific information.

Moreover, the **users** have a pivotal role for many of the providers, as three of the NMHS, both research institutions and both NCSC provide different aspects of relevance to them: Raising awareness amongst users is one focus, as is conducting more research to find out what users actually need and want. *"And that brings us to this social transformation and I believe, [...] that is not something that consultancy services do, for example, so I believe that you still have to [create] a great deal of process understanding"* (GERICS 2024). Additionally, some want to offer more trainings for users and overall have more interaction with users, because *"the only real solution […] is around the guidance, around the training that you offer people"* (UKMO 2024).

For both research institutions, both NCSC and two of the NMHS, **communication** will play a much bigger role in the future: Many of them want to provide interpretations along with their data, products and services, so that users *"already have a nice instruction leaflet on the side"* (DWD 2024). This should enable users to use the CS correctly and in the right use cases. Another thing they would want to implement are storylines, e.g. to explain extreme events in the context of present and future climate or to help push key messages in an easily understandable way.

Three of the NMHS, one NCSC and one research institution highlight the role of **stakeholder engagement**. This mostly refers to establishing new partnerships with stakeholders, *"work more internationally"* (NCCS Norway 2024), *"we really should develop more collaboration with other disciplines"* (Meteo France 2024), and establish an exchange with multipliers who can spread good practices and information further.

For both consulting companies as well as both NCSC and one research institution, the **advancement of their tools** is a clear target for the future. *"The goal should be […] to also find instructions on how one can build their own tools"* (GERICS 2024), or also *"better tailoring, better [responding] to individual target groups"* (NCCS CH 2024). One research institution wants to provide tools that are suitable for the use in the classroom by kids. Another focus is the provision of information on climate risk, especially in the context of the EU taxonomy and CSRD for both consulting companies, because *"what*

we are already noticing is that between taxonomy and CSRD the climate risk analysis and the end result must look massively different" (Denkstatt 2024).

In terms of data, two NMHS, one NCSC, a research institution and one consulting company see a change in demand in terms of the **data** provided: Some of them identify a higher spatial and/or temporal resolution of datasets as important. Others mention the homogenisation of data, a better data availability in general, while a scientist of UKMO (2024) mentions they are *"currently exploring some methods emerging for downscaling, so that could be a shortcut to offering a fuller picture of uncertainty"*. Another example would be the identification of relevant temperature thresholds in terms of health in the context of heat waves, *"that is also on our to do list"* (PIK 2024).

Quality management takes on an important role in the eyes of both NCSC, one consulting company and one NMHS: Several state the importance of developing a clear strategy in terms of which stakeholders should primarily be addressed and what the aims of their CS are. *"So, an important point is the goal of standardising climate services: which parts of climate services can be standardised, which should be, and which should perhaps not be standardised?"* (GERICS 2024). Others want to implement standards for their CS to make sure they are of a certain quality and are actually used, because *"we do recognise that we could have a better framework for this"* (UKMO 2024).

For some of the providers, **advances in research** and their approach are a clear focus for the future: Two NMHS want to advance their attribution studies, while one consulting company sees the role of predictions turning more crucial, especially when it comes down to whether stakeholders have taken adequate adaptation measures or not, *"we will see […] that we will have to advance our methodology"* (Denkstatt 2024). Moreover, they mention the option to couple predictions with attribution studies and coupling of models with feedback, *"we think that could be quite game changing in a number of ways"* (UKMO 2024).

Regarding **technical advances**, two NMHS, one research institution and one NCSC mention different aspects of relevance for the next years to come: The automatisation of processes is one topic mentioned by the providers as there are more and more inquiries incoming "and we simply can't keep up if we have to serve each person individually" (DWD 2024). Another one concerns the operationalisation of their climate services as well as the use of AI, e.g. in terms of weather forecasts.

In an ideal world

When asked what they would like to do if they had no resource limits and other challenges and could develop their ideal CS, the providers had a variety of answers at hand:

Two of the NMHS along with one NCSC and one research institution would like to invest in the development of a communication strategy or enhance the existing ones and *"make sure to think about communication aspects already from the beginning"* (NCCS CH 2024) to ensure that the key messages come across to the users. In line with that, one NMHS would like to offer trainings to users on how to use the data.

For one research institution, its aim would be to develop an app where weather data and climate data could be integrated and put into comparison. One NMHS argues they would like to establish a community of practice for users *"where they can discuss for example how to deal with climate, HR or communication"* (KNMI 2024).

One consulting company and one NMHS would like to integrate climate data with contextual data, as one scientist from Meteo France (2024) argues *"I think the best way to communicate about climate change related to health would be to be integrated into something which is already designed for health"*. On the other hand, one NMHS and one research institution would like to integrate more information on climate change into their CS.

On a more technical level, the automatisation of processes is on the wish list of one consulting company, one research institution and one NCSC. One representative of Denkstatt (2024) argues that the automatic generation of figures and indicators based on the location would save them a lot of time, *"that would be great!"*, and it would give providers the opportunity to *"because then we could concentrate on the more complex requests and questions that we can't cover at the moment because we are simply too busy with the ongoing business"* (DWD 2024). For both consulting companies as well as one research institution, their focus would be on expanding parameters both spatially and in terms of content, *"there is a huge wishlist!"* (PIK 2024), for example to include information on hail, precipitation, wind or also on other world's regions. Two NMHS on the other hand would like to see seamless products in terms of the transition from climate forecasts to climate projections.

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Annex

Annex A: Aspects and corresponding key questions for interviews of CS providers

Official aspects

- What do you consider to be your most important products regarding climate services?
- How are your services financed? - Are these services part of your official duties?
- What was the background or motivation for the development of the specific CS?
- What were the most significant developmetn stages in the past?
- What is (and how do you see) your role/core competence in the national/international landscape of CS providers?

Target groups

- What are currently your most important user groups?
- Have you mapped your current users and taken a closer look at the groups?
- How could you reach important target groups that not yet using your CS?

User involvement

- What role did users play at the time of CS development?
- Which (groups of) users did you involve?
- What did you learn from these users?

Feedback

- Do do you collect feedback from users and, if so, how?
- On which topics do you most frequently receive feedback from users?
- What kind of support or training do users want?
- What challenges or limitations have users experienced so far?
- What was the biggest discrepancy between user wishes and technical possibilities?

Technical aspects

- How are climate data and models selected for integration into CS?
- Have your selection criteria and quality standards changed over time?

Visualization & language

- Did you create a user web interface and, if so, how was it created?
- How were the texts created?
- Do you ensure that comprehensible language is used? For formulations, technical terms, sentence length...
- Were special features or needs of the intended target groups taken into account?

Internal strategic aspects

- How does the collaboration between your development team, scientists and service providers (e.g. graphic design) work?
- How adaptable are the parameters or technical features of your CS to respond to changing requirements?
- Looking back, what decisions would you make differently now?
- Can you give examples of challenging decision you made during the development of your CS?

Future development

- What are your future plans?
- Where will your focus be?
- Which CSs do you think will be needed in the future?