Co-production of **Climate Services**

A diversity of approaches and good practice from the ERA4CS projects (2017–2021)

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Máñez Costa, M.; Oen, A.M.P.; Neset, T.-S.; Celliers, L.; Suhari, M; Huang-Lachmann, J-T.; Pimentel, R.; Blair, B.; Jeuring, J.; Rodriguez-Camino, E.; Photiadou, C.; Jerez Columbié, Y.; Gao, C.;Tudose, N.-C.; Cheval, S., Votsis, A.; West, J.; Lee, K.; Shaffrey, L.C.; Auer, C.; Hoff, H.; Menke, I.; Walton, P.; Schuck-Zöller, S. (2021). Co-production of Climate Services. CSPR Report No 2021:2, Centre for Climate Science and Policy Research, Norrköping, Sweden.

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EXECUTIVE SUMMARY

This guide presents a joint effort of projects funded under the European Research Area for Climate Services (ERA4CS) (http://www.jpi-climate.eu/ERA4CS), a co-funded action initiated by JPI Climate with co-funding by the European Union (Grant 690462), 15 national public Research Funding Organisations (RFOs), and 30 Research Performing Organisations (RPOs) from 18 European countries. This guide sets out to increase the understanding of different pathways, methods, and approaches to improve knowledge co-production of climate services with users as a value-added activity of the ERA4CS Programme.

Reflecting on the experiences of 16 of the 26 projects funded under ERA4CS, this guide aims to define and recommend good practices for transdisciplinary knowledge co-production of climate services to researchers, users, funding agencies, and private sector service providers. Drawing on responses from ERA4CS project teams to a questionnaire and interviews, this guide maps the diversity of methods for stakeholder identification, involvement, and engagement. It also conducts an analysis of methods, tools, and mechanisms for engagement as well as evaluation of co-production processes.

This guide presents and discusses good practice examples based on the review of the ERA4CS projects, identifying enablers and barriers for key elements in climate service co-production processes. These were: namely (i) Forms of Engagement; (ii) Entry Points for Engagement; and, (iii) Intensity of Involvement. It further outlines key ingredients to enhance the quality of co-producing climate services with users and stakeholders.

Based on the analysis of the lessons learned from ERA4CS projects, as well as a review of key concepts in the recent literature on climate service co-production, we provide a set of recommendations for researchers, users, funders and private sector providers of climate services.

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1. Background

1. Background

Co-production of knowledge is a key element in the development of useful, usable and used climate services. While it is possible to develop climate services without the involvement of end-users, ***climate service co-production*** has significant advantages for usability, and substantially affects the ability of the private and public sector to use climate change data and information to support adaptation. This is particularly true for the use of climate services at the local scale where many steps are needed to transform climate data into wise decision making.

The challenge for climate services to be both useful, usable and used are manifold, and many of these have been identified in the ERA-NET Consortium "European Research Area for Climate Services", (ERA4CS) projects (http://www.jpi-climate.eu/ERA4CS). This co-funded action initiated by JPI Climate with co-funding by the European Union (Grant 690462) and funded by 15 national public Research Funding Organisations (RFOs), and 30 Research Performing Organisations (RPOs) from 18 European countries (see section 10) was designed to boost the development of efficient Climate Services in Europe.

The call for proposals to ERA4CS was opened in 2016, under the title "***Researching and Advancing Climate Services Development***" with a specific focus to improve user adoption of and satisfaction with climate services. A total of 26 projects received funding as a result of this call, with a subsequent project period from autumn 2017 until the spring of 2021. The ERA4CS projects were selected based on their ability to support and accelerate the development of climate services. The ERA-NET Consortium funded research to support the development of better tools, methods and standards on how to produce, transfer, communicate and use reliable climate information to cope with current and future climate variability, particularly in Europe.

This report is a value-added activity of the ERA4CS Programme to understand the practices of the projects with regard to co-producing climate services together with users and developing pathways, methods and approaches to make climate services more useful, usable and used. It is a compilation and analysis of the practices relating to, and lessons learned from co-production in 16 of the 26 projects in the ERA4CS Programme (see section 9).

2. Scope of this report

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One of the outcomes of the ERA4CS mid-term reporting workshop was the establishment of the ERA4CS Co-Design of Climate Services working group (hereafter "Co-production WG" or "working group"). The task of this working group was to:

1. Share the experiences of the ERA4CS projects in their interactions with stakeholders and end-users and diversity of co-production processes; and
2. Prepare a synthesis as a guide of good practices. This report "Co-production of Climate Services" is a result of the deliberations and analysis of the working group (see projects identified in bold text in section 9).

The working group recognised that improving engagement between climate service providers and potential users of climate services was intended as an important benefit of European research initiatives (H2020, JPI Climate ERA4CS). While knowledge is created in several ways, e.g., with or by users, data and information are mostly provided by scientists and boundary agents. It is evident from the outcomes of all the ERA4CS projects (www.jpi-climate.eu/ERA4CS) that collaboration with stakeholders and end-users have become a more important element of climate service design. However, there remains a gap in climate service development to pragmatically (given the effort and cost of transdisciplinary approaches) translate climate data and information into products that are useful, usable and used (Vaughan et al., 2018). The ERA4CS projects offer an ideal opportunity to learn about current approaches and methods that research teams in different geographic contexts, sectors and with varying degrees of transdisciplinarity use to strengthen the practice of co-production. The lessons-learned from the 16 projects offer a valuable source of experiential learning that could be of benefit for future projects, and the conversion of research funding into societal impact.

The working group acknowledges the rationale for the ERA4CS programme which recognises the importance of climate services as drivers for climate adaptation action. Simultaneously, the working group also emphasises the importance of knowledge co-production as essential for the development of useful, usable and used climate services. Co-production is therefore an important element of successful and effective climate services development. It requires that the relationship between scientists, citizens and decision-makers must extend far beyond classical stakeholder engagement.

The overall aim of this guide is therefore to:

> ***Define and recommend good practices relating to transdisciplinary co-production of climate services to researchers, users, funding agencies, and private sector service providers.***

This guide is structured as follows. In section 3, based on the results from a literature review, we outline the key concepts around co-production of knowledge and present the definition that we embrace in this guide. Section 4 is dedicated to assess (and "map") the diversity of user engagement employed in the 16 ERA4CS projects. This section presents the methods and procedures that were used to co-produce climate services. In section 5, we identify and interpret key aspects of climate services co-design presented as a typology. The report concludes with section 6 which contains recommendations for researchers, users, funding agencies, and private sector service providers involved in climate services design processes. The WG advises on the considerations for many possible manifestations of co-producing climate services.

3. Co-production of climate services

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3. Co-production of climate services

For the purposes of this report, the term **co-production of climate services** comprises all elements of the knowledge production process, including co-designing the research outline and methodological approach, the service co-development and co-production principles and process and principles. Co-production and co-creation are considered to be equivalent, and this report uses the first term.

3.1 Introduction

Co-production of knowledge is recognised as a key element in the development of useful, usable and used climate services (Vincent et al 2018; Bremer et al 2019; Vollstedt et al 2021). While it is possible to develop climate services without the involvement of end-users, the WG argues that climate service co-production has significant advantages for the usability and ultimate impact of climate services to support adaptation and mitigation. This is particularly true for the use of climate services at the local scale, where many steps are needed to transform climate data into wise decision-making (Celliers et al. 2021).

The WG took an inclusive view on the concept of "co-production" of climate services. In this report it refers to the process of collaboration between science and society at large, in order to develop climate services and products that enable climate action.

> ***"Co-production" refers to the entire process of joint knowledge creation between experts from different disciplines and sectors and decision-levels including joint problem formulation, knowledge generation, application in both scientific and societal practice, and mutual quality control of scientific rigor, social robustness, and practical relevance (see Polk 2015).***

This broad definition of ***transdisciplinary*** co-production was used to understand and compile good practice from the ERA4CS projects.

Transdisciplinary co-production ("co-production" hereafter) is an important point of departure for climate services development and its eventual use. Transdisciplinarity is considered to be collaborative and participatory, transformative, transcending traditional disciplinary boundaries and hierarchical societal structures (Lotz-Sisitka et al., 2015; Polk, 2015; Rosendahl et al., 2015; Simon et al., 2018). Transdisciplinarity approaches might consider the inclusion of multiple actors affected and/or affecting a particular issue, including actors from private and public sectors (Choi and Pak, 2006; Polk, 2015; Stock and Burton, 2011). This means that stakeholders and users assume a central importance in the co-production of climate services which includes the creation of knowledge and the innovation that arises and increases the know-how of the users to adapt to climate change (Peris-Ortiz et al., 2016). It is primordial to recognise how stakeholders and users of climate service perceive and understand climate change and include their risk perception in the design of climate services, because climate management actions are taken according to the assumptions made by certain groups surrounding a risk (Máñez Costa et. al, 2017).

Co-production is key for the uptake and inclusion of climate services in decision-making processes by increasing the usability of climate data and information. As such, it aims at dissolving the boundaries between the classical disciplinary development of climate services, driven purely by the quantity and quality of climate data. Co-production calls for the involvement of all stakeholders and users, as the "owners", of climate service. Through a participatory transdisciplinary design approach involving the users we reach a co-construction of a shared representation of reality and needs (Máñez Costa, 2011). The users must be included, encouraged to contribute and be empowered from the inception of the project planning and development process. This process requires the combination of scientific data and information with knowledge from different formal and informal sources to generate climate services.

The sources of formal knowledge production are explained by the quadruple helix of innovation (see Figure 1) under which four major actors are needed in the innovation system of co-production: science, policy, industry and society (Schütz, Heidingsfelder, and Schraudner 2019). Most of the ERA4CS projects have included a diversity of combination of these four major actors when developing their climate services. Even considering the state of the art of climate service development, the role and contribution of knowledge co-production can be substantially improved.

Figure 1
Climate Services positioning in the quadruple helix of innovation (adapted from Schütz et al, 2009)

3.2 Key concepts in co-production

Global sustainability challenges, including climate change adaptation and mitigation, are complex, cross-scale and long-term, posing unique problems for resource managers and policy-makers whose mandates are often task-driven and constrained by local and short-term interests (e.g., Cash et al., 2006a; Cash et al., 2006b; Beier et al., 2017). There is often a scale mismatch between what is known, and what has to be managed, but simply producing more data and information is not expected to lead to better solutions (Feldman and Ingram, 2009). There has also been a continuing dialogue on how scientific outputs should become actionable, and more aligned and effective in order to inform decision-making (e.g., Lemos and Morehouse, 2005; Vogel et al., 2007; Lövbrand, 2011; Lemos et al., 2012; Knapp and Trainor, 2013; Young et al., 2014; Beier et al., 2017).

Transdisciplinary research and sustainability science emphasise the need for knowledge co-production (e.g., Hessels et al., 2018, Mauser et al., 2013, Mielke et al., 2016, Photiadou et al., 2021). Such co-production has been established as an important element in science-policy models intended to increase the usability of science (Frantzeskaki and Kabisch, 2016; Ziervogel et al., 2016; Djenontin and Meadow, 2018), and the production of 'actionable science' (van den Hurk et al., 2016, Grove et al., 2016). Furthermore, the discussion on science as a more responsive, collaborative and transparent process has been part of a larger dialogue about citizen and stakeholder participation in governing change and producing the necessary information – such as helping to improve the alignment of supply and demand (e.g., Ostrom, 1996; Jasanoff, 2004; Sarewitz and Pielke Jr, 2007; Mielke et al., 2016; Wyborn et al., 2019).

Definitions of co-production and related concepts (co-creation, co-design, etc.) vary (e.g., Brudney and England, 1983; Ostrom, 1996; Alford, 2014; Brandsen and Honingh, 2016; Alexander and Dessai, 2019). Essentially, they all refer to collective, typically voluntary, collaborative transformation of inputs (e.g., data, knowledge, information, ideas) into products and services. Ideally, co-production efforts should also improve understanding among actors (Bremer et al., 2019). And yet, despite of extensive literature on the subject, with many studies providing substantial empirical knowledge, methodological approaches often differ (e.g., Jack et al., 2020; Mielke et al., 2016), the co-production concept remains elusive and difficult to generalise (e.g. Brandsen and Honingh, 2016; Miller and Wyborn, 2018). For example, the academic fields of public administration; science and technology studies; and, sustainability science have all developed different theories about how co-production can contribute to the normative design of scientific initiatives (Miller and Wyborn, 2018). For some, the rationale for co-production can be viewed as either citizen empowerment, the depoliticization of the science-policy interface, or a necessary precursor to the transformations that are needed to address complex problems on the horizon (Turnhout et al., 2020). In turn, the different intellectual orientations have resulted in diverse expectations for the type of impacts and outcomes that will result from collaborative research contexts and processes.

Thus, "co-production" has been methodologically implemented using a broad range of approaches and principles (e.g., Lang et al., 2012; Meadow et al., 2015; Djenontin and Meadow, 2018; Norström et al., 2020; Vincent et al., 2020). There remains a need to develop a set of recommendations aimed at improving the outcomes of co-production. Be that as it may, there is agreement that successful co-production should result in products or services that are useful, usable and used (Vaughan et al., 2018). Some recommendations to improve the outcomes and impact from co-production include considerations of the actor coalition (who participates); the context and discourse (acknowledgment of diverse perspectives and knowledge systems); collective definitions for problems and goals; the presence of incentives (such as tangible societal impacts); and available capacities (material, cognitive, social; e.g., Hegger et al., 2012; Knapp and Trainor, 2013; Wyborn, 2015; Djenontin and Meadow, 2018). The coalition of diverse groups of actors has been reported to result in significant improvement of engagement from participation as a mere procedural and possibly legal "ritual", to one where co-production has the power to steer the outcome of the process (Arnstein, 1969). Participation in such processes can be strengthened by the early, precise, and continuous identification of existing as well as potential stakeholders; a careful selection of "entry points" (where and when the stakeholders start engaging), and the degree of engagement among actors; and the balancing of influences or distribution of power among actors in the coalition (Luyet et al., 2012; Vincent et al., 2020). The role of the stakeholders in the co-production chain is also very important. The internal or external stakeholder involvement, the conditions of the broader governance context, and the associated dependencies in which stakeholders act, must be carefully considered in co-production activities (Wamsler 2017).

3.3 Co-production in the climate services field

Concepts and approaches of co-production have experienced a surge of interest in the field of climate science over the last years, and in particular in the field of climate services. In the EU Roadmap for Climate Services, it is referred to as ''enabling co-design, co-development and co-evaluation of supportive climate services with refinement and validation'' (EC 2015). Acknowledging usability gaps of climate information (McNie, 2013; Zulkafli et al., 2017), climate science scholars increasingly adopt collaborative (with society) research as a promising approach to engage with (potential) users of climate information (Vincent et al., 2020). Weichselgartner & Arheimer (2019) propose that for climate services sor adaptation, such transformative changes are required due to the ongoing emphasis on data and information, as opposed to the need for climate change knowledge which can be used for better decision-making (McNie, 2013). By focusing on knowledge production, it is more likely to deliver on its potential to support climate (change) related decision making. In summary, the literature and theory on the topic of co-production indicates that a shift is needed from top-down single or multi-disciplinary science-produced services to bottom-up, polycentric approaches for climate services development that are driven by practice and organised by multiple societal actors (Weichselgartner & Arheimer, 2019).

Similarly, Vincent et al. (2018) argue that co-produced climate services should be decision-driven, process-based and time-managed. They should result from a process that is inclusive, collaborative and flexible. This is important because the range of actors involved in the value chains of climate information becomes more heterogeneous (Weichselgartner & Arheimer, 2019). The consequence of this "blurs" the conventional distinction between users and producers of climate information (Bremer et al., 2019; Vaughan et al., 2016).

The increasing prominence of co-design, co-development and co-production is embedded in a paradigmatic shift in the production model of climate knowledge, from delivering climate information to (co-)producing climate services (Harjanne, 2017; Keele, 2019, EC 2015). This is far from a straightforward process, and Bremer and Meisch (2017) observe that co-production in climate research is attributed to a wide array of meanings, depending on discipline, purpose and research themes. Their conceptual analysis shows that co-production in climate research is very much in development, shaping and shaped by the practices and contexts in which it is implemented. It is important to note that co-production is not a target to be reached at any cost, and cautiousness is always required in order to minimise the trade-off and maximise the benefits of co-production (Oliver et al., 2019). We argue hereto, that climate service supported (adaptation) management solutions should take into consideration the possible disservices of the politics of science and the influence of societal factors into science (Jasanoff, 2004).

A core objective of the co-production process is to help climate services providers to better understand the climate information needs, values, and decision contexts of users, as to provide better tailored products or services (McNie, 2013). To that end, Bremer et al. (2019) warn against a narrow framing of co-production in climate science as merely a mode for iterative and interactive research and production of climate services. They emphasise the need to account for the multi-faceted nature of co-production in order to meet its potential to facilitate usable climate services. This implies that when embarking upon user-oriented co-production, a wider scope of issues should be considered beyond only relevant climatological parameters (Vaughan et al., 2016). For example, Parker and Lusk (2019) propose, building on the inductive risk view, to employ co-production based on the objective to understand user values. Importantly, they state that attention should be paid to errors and uncertainties in climate service products that can result in negative consequences for users. Otto et al. (2016) demonstrated that recognition and reporting of uncertainty contributes to the development of trust between users and producers of climate services. Co-production of climate services can help reduce and overcome trust issues. It can also improve the understanding of data uncertainty based on the transparency of data interpretation (i.e., information chains), the layering of information complexity and the disclosure of knowledge gaps in methodology and data processing.

The 'servitization' of climate science (Harjanne, 2017) using co-production as a mode of collaboration, is a directed process for climate data to circulate from producers to users. This signifies a shift in user-oriented collaboration toward climate information as an end-to-end service (McNie, 2013). There are a number of implications that result from the commoditization of climate knowledge, for example, who gets access to climate information, at what price and which types of partnerships are prioritised (Harjanne, 2017; Keele, 2019). The service business model underlying this shift thus reflects hegemonic power structures rooted in private market dynamics that signify the broader service delivery paradigm. Vincent et al. (2020) noted that power imbalances and equity issues in the co-production of climate services, particularly when embedded in North-South partnerships, are often based on a paradigm of knowledge deficits and capacity development. Keele (2019) concluded that the consultancy roles emerging in climate knowledge systems highlight a 'climate services paradox' of producing customised climate information without creating exclusion.

The knowledge base of good practices for co-production in climate service development is growing. Simultaneously, there is an iterative working mode, to bridge theory and practice and build trust between stakeholders. This implies collaborations that often are more openended in its outcomes than the conventional purpose-oriented approaches prevalent in climate science (Weichselgartner & Arheimer, 2019). As such, the emerging and broadening application of co-production approaches in climate knowledge development is providing quasi-experimental contexts in itself to learn what 'works', even though this demands considerable amounts of resources and careful time management (McNie, 2013; Vincent et al., 2018). Sharing such lessons is especially important to avoid creating asymmetries when communicating, divulging or analysing requirements for climate information, including also capacity development to increase the uptake of climate information (Vaughan et al., 2016).

In the following sections, we explore insights from ERA4CS projects and provide examples of good practices of co-production.

4. Mapping the diversity of co-production of climate services

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4. Mapping the diversity of co-production of climate services

In order to assess the extent and nature of user engagement and how that relates to knowledge co-production in the ERA4CS programme, the working group developed a survey with which to gather information. The survey queried the existing processes and practices that have been implemented to involve stakeholders and users in the development of climate services in the funded projects. The questions were designed to extract good-practices examples on climate service co-design and co-development for a broader audience to increase the uptake and usability of climate services. The questions focused on the process of developing the climate services and not specifically on the climate service product.

In the spring of 2020, the survey was disseminated to all 26 ERA4CS funded projects with a total of 16 projects responding to the request and returning completed questionnaires (hereafter "survey" or "questionnaire"). Thus, the survey was conducted about one year prior to the completion of the projects and may not fully reflect the final achievements and results from the projects. The survey methodology was effective in collecting good-practices from a broad range of project types although there were some limitations. The survey was completed by self-selected respondents who also represented the research partners in the respective projects. Some projects had multiple case studies and locations, and even different services per case study. As a result, the respondents represented the average or general perspective of the project across the different cases and often did not provide the case specific context and co-production challenges and lessons learned. This is considered a bias in the results, as well as limitation in the data on co-production practices.

Additionally, to the written survey, the WG conducted semi-quantitative interviews (hereafter "interviews") with selected projects in order to address some of the perceived biases and to collect additional information on the transdisciplinary co-design processes.

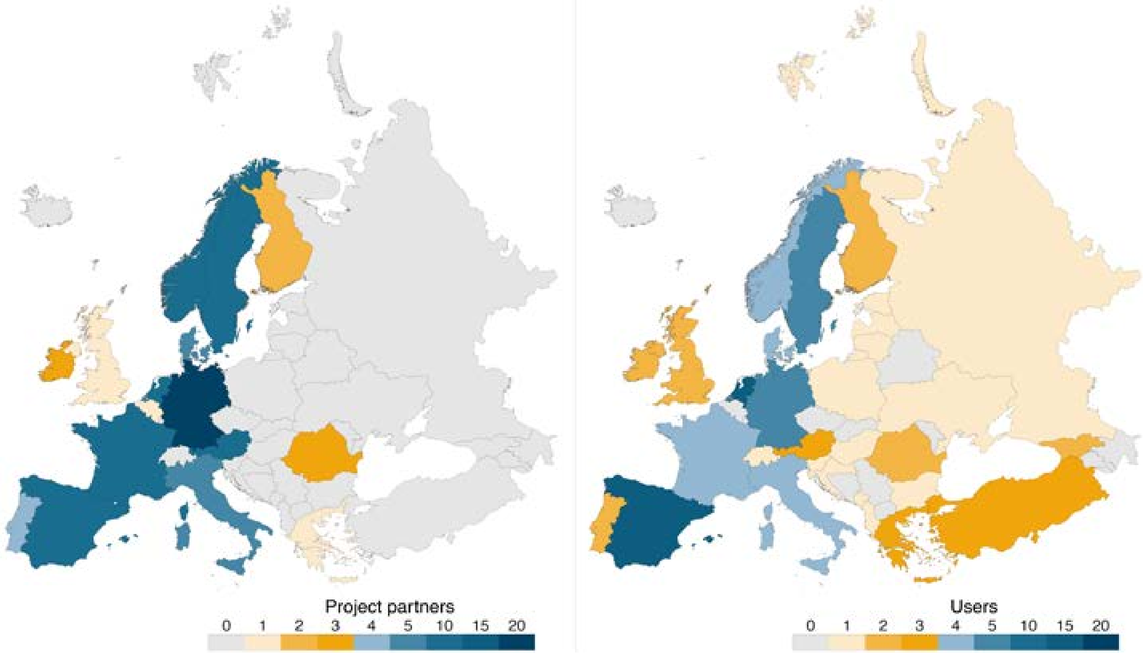
The following sections present the overarching results to illustrate the diversity of sectors, scales, types of stakeholders as well as climate services that have been developed.

4.1 Scales and sectors

ERA4CS projects that were surveyed developed climate services primarily for European countries, with case studies in Western Europe being more prevalent. There were some projects with case studies in the Mediterranean, Central-Eastern Europe (i.e., Austria and Romania), as well as case studies in North and West Africa, the Caribbean and Asia. Figure 2 illustrates the spatial distribution of project activities on the European continent. Most of the projects from the Water-Energy-Food sectors included case studies or developed the climate services for a specific catchment/river basin or water body and associated areas (n=5). A small number of projects focused on the urban scale or having urban climate service applications (n=3).

Figure 2

Spatial distribution of ERA4CS funded projects (that have completed the good-practice survey on co-production, n=16). Colour coding indicates number of project partners per country (left panel) and number of users per country (right panel)



In addition to the spatial scale, the various projects utilised (and in some cases generated) climate data as well as produced climate services representing different temporal scales. Figure 3 illustrates this with the different projects mapped along a temporal scale that reflects the climate service typology. The placement of each project is based on a qualitative assessment of the project's response describing the temporal scale of climate services being developed for the project's specific context. Five of the 16 projects make use of more than one type of temporal climate data in their climate services production.

Figure 3

Temporal scale of climate services developed in 15 of the analysed projects of the ERA4CS Programme

The majority of ERA4CS projects that completed the survey simultaneously engaged stakeholders in multiple sectors. Multi-sector projects that focussed on the Water-Energy-Agriculture Nexus develop services for sectors including hydropower, food production, wind and solar energy, and water management. A small number of projects (n=4) focused on creating services for other sectors such as tourism, health, disaster risk management, fisheries, aviation and the marine sector.

The degree to which user-needs were considered within the sectors varied amongst the projects. Some projects emphasised user engagement and addressed specific user-needs. Other projects focused on improving the availability and translation of new climate change data and were considered to have a predominantly science-production perspective. A number of projects considered both users and science production in different ratios and thus had a mixed perspective. All projects included an element of user engagement, and 8 of the 16 projects were considered to have a balance between user and science perspectives in identifying the topics addressed in the project and striking a balance between usability and functionality of the developed service.

To some degree, spatial and temporal scales, and the characteristics of the sector of interest determined the types of stakeholders that were involved in co-creating climate services. Interviewed project participants also have pointed out differences between stakeholders in public and private domains, the relevance of sector specific governance arrangements and varied perceptions of urgency to take climate action. Moreover, the capacities of stakeholders to interpret high-quality climate data in order to anticipate socio-ecological impacts on local, regional and national scales vary among stakeholder groups. Depending on these contextual conditions, stakeholders may hold diverging demands, needs and resources for climate adaptation.

4.2 Stakeholder identification

The survey identified between users (those that will directly engage with and use the climate services) and stakeholders (those that may indirectly benefit, interested or involved in the climate service). However, the responses demonstrated that there was generally limited distinction between these two categories in the ERA4CS projects. Therefore, these categories are used interchangeably in the following discussion.

For the most part, projects preselected stakeholders using existing and previous collaborations and networks. About half of the projects indicated that they used some form of stakeholder identification method (survey, mapping, template) and one project identified stakeholders partly based on a literature review to determine who are the most vulnerable users.

Interview respondents recognised the importance of involving pre-established contacts and networks (e.g., from other projects). A common view amongst interviewees was that pre-existing relationships based on trust and reliability are key for successful stakeholder engagements. For example, one interviewee reported about being closely embedded into the local contexts of stakeholders:

"So, in that instance, when we developed projects, we had a very good understanding of the problem of society, in engagements with them or even just knowing what they struggle with. And then setting the problem and then inviting the stakeholders into that setting is very easy."

In this case, the identification of stakeholders could be matched to fit with project goals and societal relevance of the climate service. However, other respondents also expressed concerns about inadequate institutional settings in academia that may impede opportunities to continue, expand and consolidate stakeholder networks. For example, the establishment of long-lasting relationships with non-scientific partners could be limited due to project durations, fluctuation of scientific personnel or a lack of incentives and reward systems for stakeholder activities.

Users and stakeholders of ERA4CS projects were selected from national, regional, and local level policy-makers and government officials, as well as the general public. The selection of private sector stakeholders was common as well as those from the knowledge industry (researcher institutions and academia). A few projects included international level policy-makers and only one project specifically focused on the role of educators as a stakeholder group. The knowledge on climate and the level of education of these different users/ stakeholders also varied and included, to a large degree all possible levels. All projects included experts related to the topic (some form of specialisation relevant to the issue, e.g., knowledge or practical experience, e.g. engineering) and half of the projects also included non-experts (interested and affected parties). Projects generally catered to non-experts by tailoring climate services to their level of expertise.

Users and stakeholders also have diverging motivations to participate in climate service development according to their own professional or private needs. These ranged from receiving accurate seasonal forecasts that could secure business objectives in times of climate change to simply participating in innovative research.

4.3 Modes of engagement in the co-production process

The role of project or research team can be categorised along a continuum that passes through three main axes throughout the project lifecycle. This continuum describes the relationship of the research team with users and stakeholders throughout the project lifecycle. These axes are:

- **Advisory role:** the project team provided advice and information to assist the development of climate services.
- **Production role**: the project team was responsible for the development of the complete climate service. This implies that the science team took the lead role in development and engagement.
- **Knowledge broker role:** the project team facilitated the conversion of climate change data to information and finally to knowledge production but did not create the climate services.

Using the same categories as above, half of the projects surveyed indicated that the research teams had a combination of roles. In six of the projects the research teams had both a production role and a knowledge broker role and at least two projects functioning in all three; advisory, production as well as knowledge broker role.

Considering that the research team forms part of the engagement and co-production process, their roles depend on prior experiences with production approaches. The survey indicated that co-production expertise of research teams was varied. Most project teams reported having at least some knowledge about methods, tools and theories of co-production. In some instances (n=2) projects teams considered themselves not well prepared for this task. For these topics, the intentional and close collaborations with users were in addition to the established scientific process to which they are used to.

Project teams that assumed an **advisory role** gave advice about the development of climate services that were not included in the project outputs. One such project connected the stakeholders to available data and products and other potential information or science developments that could address their current and future climate knowledge needs. Other projects played double advisory roles. On the one side dealing with user needs and user uptakes, and on the other side supporting additionally the creation of climate knowledge. Another project supported citizens in climate-related risk management and enabled local governance stakeholders to understand to what extent climate information could inform and improve their public services.

Project teams that assumed a climate service **production role** participated in the entire process of development. This included participation in initial data and information delivery, service conceptualization and design, to testing and final delivery of the climate services. The majority of climate services developed were based on existing climate datasets, climate models, human thermal models, etc.

In many instances, project teams actively contributed to purely scientific outputs by developing and extending for example climate models to contribute to improved, more specific, specialised and personalised climate services. It was argued that such models were needed to enable a highly customised climate service for a specific sector, and/or a group of stakeholders and users. Other project teams produced climate services starting with the creation of novel datasets, then undertaking a design process which often included evaluation of the climate service by the user. A number of projects played supportive roles throughout the co-design process, and in creation of a risk management system.

Projects that facilitated the conversion of data to science-based information assumed a **knowledge broker role**. Concreted examples include projects that worked with users / stakeholders to translate data and information into adaptation actions and connected the data providers with users. Another project incorporated existing international standards into a climate service, making the standards accessible and easily understandable to users. Some projects focused on defining decision-making processes of users and acted as an intermediary to produce climate services to fit user processes.

Besides the creation of climate knowledge through transfer and communication of science-based data and information, brokering also includes the integration of stakeholder perspectives into climate modelling activities. For example, one respondent points to the definition of indicators by users:

"You as a user have to define which is the specific indicator you want to have. [...] The idea is not only to generate temperature and precipitation, which are our traditional variables in the climate domain. But a specific indicator, a specific variable. And this is something to be defined by them."

In view of this statement, relevant information from stakeholders has to be translated into scientific terminologies and framings in order to fit the corresponding modelling approaches. Since users of climate services usually include technical experts from different sectors or political institutions, service development must be sensitive to the organisation, political and environmental (including climate) context of stakeholders. Against this background, the role of knowledge brokers includes the facilitation of feedback between practitioners and stakeholders and climate and adaptation scientists.

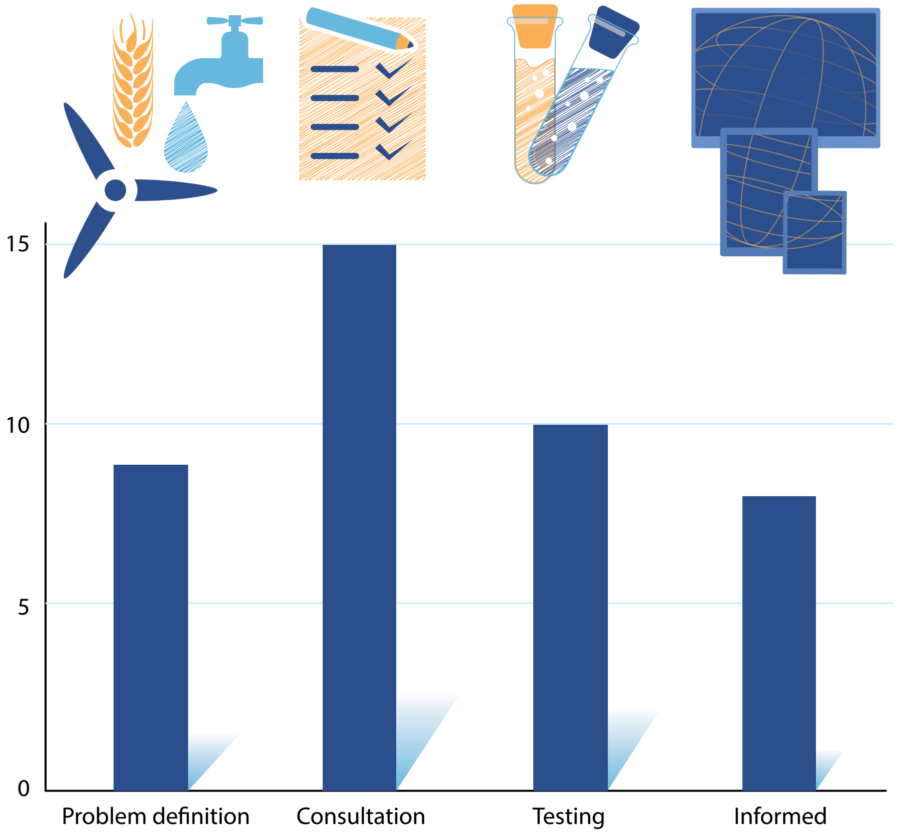
4.4 Methods of stakeholder involvement and engagement

The 16 projects surveyed employed **multiple methods** to engage with **different stakeholders** at different stages (entry points or phases) of the project. Most of the projects (11) engaged with stakeholders **throughout** the project, with 9 projects engaged with stakeholders from or at the start of (and in several cases also prior to) the project.

In a number of projects (7) the methodology for stakeholder engagement was dynamic as their knowledge needs, capacity and objectives were defined. Figure 4 shows the frequency with which stakeholders were engaged during different project phases. Many projects engaged stakeholders at the beginning of the project to define the problem. Throughout the project, stakeholders were consulted in all projects and to different degrees tested the climate services and were informed about project outputs depending on the case and the level of climate service development. Continuous testing of climate services with users and stakeholders was also a common in most projects, using different methods (e.g., through the use of surveys, user testing in usability lab and other methods for collecting feedback.

Figure 4

Stakeholder engagement during different entry points of the project (as indicated in the completed project templates)



The list of methods and approaches **that directly or indirectly facilitating engagement with stakeholders in** the surveyed projects included:

- Scoping and co-design workshops,
- Questionnaires,
- Face-to-face and telephone/online interviews,
- User surveys,
- One-on-one, focus group, online and/or open discussions,
- Participatory mapping,
- Living lab approaches (using a diversity of engagement methods),
- Serious gaming,
- Field trials and trips,
- Demonstration service testing,
- Field and usability lab testing,
- Use of dedicated "engagement points",
- Attendance at stakeholder forums, conferences, and seminars,

- Engagement with or creation of "user" boards,
- Training and capacity building,
- On-line feedback loops.

The most frequently mentioned types of stakeholder engagement included: stakeholder workshops (9 projects) and interviews and/or surveys (6 projects).

4.5 Analysis of co-production

Three aspects of co-production employed in ERA4CS projects were analysed by the WG.

- Processes/tool or mechanism of engagement used;
- Possible changes experimented on the engagement mechanisms throughout the project to improve the engagement in the process;
- Metrics used to evaluate the success of this process.

4.5.1 Processes, tools and mechanism of engagement

Engagement between project research team members

The most common form of engagement between team members was the use of in-person meetings, usually linked with project kick-off meetings and general assemblies once a year. The survey found that almost all projects considered these meetings important for strengthening relationships between partners:

"These meetings enabled collaborations to ensure an efficient dataflow … also allowed the consortium to overcome challenges and to adopt more efficient synergies".

Respondents also reported that these meetings were key to resolving difficulties of engagement for new staff of the different partners in the project. Thematic workshops were also a common tool used and these were often focused on data and information exchange among some project partners. They also contributed to the analyses of particular challenging aspects of the project work plan e.g., technical aspects (i.e., climate modelling, downscaling techniques, design of specific product) or user engagement methodologies.

The project survey also highlighted the need for more continuous communication throughout the project lifecycle. Methods that were used to facilitate communication with project team members included monthly advisory board meetings, creation of specific task working groups. The emerging COVID-19 pandemic forced many projects to reconsider and adapt engagement strategies by making use of online communication tools such as emails, video conferences, software development platform, and other internal communication applications).

Engagement between project partners and users/stakeholders

Building trust between project partners, users and stakeholders was mentioned as the crucial aspect for co-production. Strategies for co-production common among projects included; direct individual contact, specific workshops, seminars and training events. Survey responses highlighted the use of specific science-stakeholder tools already available in certain sectors:

"They were relevant tools when used in combination with other methods (i.e interviews) particularly in the stage of the problem definitions. Low-cost approach to elicit local and experimental knowledge from a wide range of users that would otherwise be difficult to reach".

Serious gaming was also used as tool for engagement in two projects: ***"[...] gaming followed by a structured, well-developed debriefing session better suited in the elicitation of difficult to articulate, abstract information than traditional surveys or interview questionnaires".***

In some projects, users were included as project partners, which facilitated direct involvement of and engagement with users. Some projects were also challenged by the difficulties to connect and engage users:

"When meetings that would have gathered stakeholders/users were suggested, they rarely took place because of the limited time available for these groups."

The engagements between project team members and users may be challenged by specific workflows and related timeframes differences between both groups. One interview partner suggested that:

"Scientists tend to be slower and careful and like to explore the uncertainties in the data sets. Make sure that what they are providing is rigorous. While the companies want the information, which seems possible. Because they will have the information and use it for whatever they need to do. So, this tends to be a difference in terms of timescales."

4.5.2 Method adjustment during project lifecycle

Another method of evaluating co-production is to **monitor and subsequently adjust methods** during the project to improve the engagement in the process (Durham et al., 2014; Misser et al., 2015). This adaptability is an important aspect of co-production. This has implications for how research proposals are developed, and how such projects are implemented. Interestingly, more than half of the ERA4CS funded projects that completed the survey acknowledged changing their original engagement methodologies. The changes in methodologies that were described fit into three broad categories:

a) **Restructuring of user groups.** User interest and commitment varied during the project life cycle. A number of projects dealt with this by restructuring existing or creating new user groups that may not have been specified in the proposal phase. Some projects also shifted to a higher level of interaction with those users more committed to participate. Users' commitment may also be due to their own agendas, personal interest and time available. So, the users that are interested may not be the users with agency to achieve the objectives of addressing a need or challenge.

b) **New modes of communication.** In some projects, insufficient communication among different agents in the co-production process were detected in some projects highlighted the need for new and more proactive efforts of reaching agreements on objectives and actions.

c) Continuous **user feedback in Climate Service development.** Most projects reported that the climate services were improved through continuous feedback provided by the users. This ranged from narrowing the scope of the service offered, proportional reduction in the importance of climate change information in favour of impact assessments, or even methodological changes proposed by users and stakeholders.

4.5.3 Metrics of evaluation of the climate service

The **specific metrics of evaluation** of the climate services developed are the third aspect that was evaluated by the WG. This was done to reflect on and learn from the co-production processes used in ERA4CS projects. In some cases, projects conceded that the climate services were completed, and metrics were not proposed. For completed climate services, both qualitative and quantitative metrics of evaluation were proposed by projects (Figure 5). The qualitative and quantitative metrics were further thematically categorised, based on the parameter to be evaluated which included:

- User engagement;
- The data quality of the climate service;
- The degree of climate service implementation; as well as the,
- Life cycle of the climate service.

Most of the metrics were qualitative in nature, open to some subjectivity and therefore potentially difficult to replicate. Although the quantitative evaluation methods appear more tangible and in theory easier to replicate, they have the disadvantage of being very project specific and therefore also not immediately to transferable or applicable to other projects.

The WG interviews pointed out that the different perspectives on what constitutes criteria for climate service success or performance between scientists and practitioners was a challenge. Projects reported a dependency on the view of the evaluator, and on the specific criteria for measurement of success. One interviewee reflected on these differences:

"It's very interesting when you come to a point to evaluate the service based on their criteria. Or they have a different way of evaluating, if the service is successful or not. And that is very interesting to see: In my eyes it was successful. And in their eyes, it was not."

Figure 5

Summary of the metrics of evaluation for climate service co-production and user engagement in a sample (n=16) of the ERA4CS projects

User engagement	• Development of innovative engagement instruments • High level of discussion with users • Sharing ideas with bigger groups from those initially proposed • Evaluation questionnaires during the project' lifetime • Feedback forms • Number of key aspects proposed by users and stakeholders and implemented in the Climate Service	• Number of engagements • Statistical test about significance in mean values of number of engagements • Number of stakeholders contacted and informed about the expected results of the project • Number of stakeholders who provided feedback • Number of ideas co-generated with stakeholders and implemented in the project
Climate Service quality		• Metrics of performance of targeted users' variables • Purpose specific metric defined by the users • Objective verification skill scores applied to targeted users' variables
Degree of Climate Service implementation	• Degree of operational performance • Achievement of the initial issue/scope • Evaluation questionnaires about final user' perception • Targeted information • Vulnerability of the current sectorial situation covered • Degree of learning about new ideas or impact reports • Assessment of technology-readiness levels	• Assessment of changes introduced by the Climate Service
Climate Service life	• Willingness of stakeholders to continue working with the consortium • Level of inclusion of broad community • Climate Service fits users' purposes • Climate Service is used by the initial users or by external users through a new implementation process	• Lifetime of the project network • Number of installations of the app

Photo © Amy Oen

5. Good practise in climate service co-production

5. Good practise in climate service co-production

This section presents a summary of three key elements in climate service co-production processes:

1. Forms of Engagement;
2. Entry Points for Engagement; and,
3. Intensity of Involvement.

Based on each of these categories, we discuss enablers and barriers, and outline key ingredients to enhance the quality of co-producing climate services with users and stakeholders.

5.1 Forms of Engagement

As presented in section 4 of this report, a large variety of methods have been used to co-design and co-develop climate services with stakeholders and users. The forms of engagement applied in ERA4CS projects were varied and often used in different combinations, depending on the case study and thematic context. These forms of engagement can be described as:

A) **Informing stakeholders and users** (one-directional): Different methods have been used to inform stakeholders and users about the climate service that were developed in the ERA4CS projects. These ranged from public and invited talks and presentations, to training courses, and seminars with students and other users.

B) **Learning from stakeholders and users** (one-directional): Questionnaires and surveys were regularly used to determine the needs of stakeholders and users and to evaluate climate services and products. Such quantitative methods provide the opportunity to reach a large number of recipients and are a standardised way to gather general information relevant to a user group. In addition, more qualitative methods based on interviews with stakeholders and users were common in ERA4CS projects. These were considered useful to gather information about the case study contexts in which a climate service was to be implemented, including information about local, and informal knowledge and existing and specific user needs.

C) **Learning with stakeholders and users** (two-way): This form of engagement refers to workshops or other types of participatory exercises, where researchers, stakeholders and users meet to mutually influence perspectives. In such a way knowledge from both practitioners and data and information from scientists can be combined and negotiated to find agreement on the objective of the project and the purpose and functionality of the proposed climate service.

ERA4CS projects have used different methods of engagement, often at different stages of the project, depending on the research design and the type of climate service they developed (c.f. Section 4). Similarly, researchers played different roles in the project collaboration, ranging from “advisory”, “leading”, to “knowledge brokers” (see section 4.3).

The composition of the project consortium itself was a critical consideration for facilitating the co-production processes and development of climate services. To some extent, the method of engagement as well as the role that researchers took in the co-production process, depended on the background and compilation of the research team, and to what extent multi- and transdisciplinarity presented a challenge or opportunity to the consortium. While the engagement of multiple disciplines in the project is considered a good practice, and frequently a precondition of the research funding, it is not without challenges. In the questionnaires, some of the ERA4CS conceded that more engagement between project partners would have been useful. Social scientists, in particular, expressed frustration due to a lack of common understanding about the state of the art of social sciences and its role in co-producing climate services. Some expressed the concern whether co-production ambitions could or could not realistically be achieved within the scope of the project. There were also partners (of the consortiums) that were not convinced about the importance or value of co-production and stakeholder involvement. Such perceptions might have also influenced to what extent projects aimed for different methods, in terms of informing stakeholders, learning from and learning with stakeholders.

Overall, experiences from the ERA4CS project showed that collaboration between natural and social scientists is a strength for interacting with end-users. Social scientists were often responsible for running workshops or interviews with end-users, while natural scientists contributed expertise of a technical nature. The combination appeared to be crucial to facilitate an early dialogue within the research team about the aim, scope, and relevance of participatory and transdisciplinary research.

It was therefore important to invest both time and resources dedicated to the co-production process within the consortium and across all disciplines that are represented in the project team. Close collaboration between social scientists, natural scientists and technical developers, together with stakeholders appeared to be a critical element for transdisciplinary co-production of climate services. One of the good practices identified in ERA4CS projects was to invest in regular internal reflection and learning among interdisciplinary project partners (interviews, scenario workshop, etc), to increase the awareness of the strengths and synergies of different expertise and to improve the collaboration within the consortium.

5.2 Entry Points for Engagement

Another good practice in the transdisciplinary co-production of climate services related to decisions regarding the timing (when) and duration (how much) of interactions with societal stakeholders and potential users. The timing of initiation of engagement is important in terms of the quality and extent of interactions and the resulting outputs or products.

The timing and duration (entry points) for engagement varied across different approaches and contexts of the projects. In the ERA4CS projects, entry points for engagement were identified in different phases of the project: (1) proposal, (2) project inception, (3) development, and (4) implementation and evaluation.

The focus and direction of climate service development are often determined at the beginning of projects. Early engagement allowed discussions about the topics and questions of a project together with stakeholders and users. If there are pre-existing contacts and networks with a variety of actor groups (e.g., from other projects) the engagement is easier to initiate. The demonstration of preliminary or prototype climate service products was a useful activity to engage practice partners and encourage their participation at an early stage of the project.

Engagement often becomes more structured in the middle of the project (development phase) as topics and research questions are settled or become stable. An important task of climate service researchers in this middle phase was to enhance the practical relevance during the design of climate service products. It was important to encourage stakeholders to articulate their perspectives and contribute their local and experiential knowledge in this phase of the project.

While each phase of the project opened up opportunities for engagement, some ERA4CS projects reported that involving stakeholders from the beginning, i.e., already in the proposal phase, provided significant advantages for engagement as well as the relevance and legitimacy of the co-production process. Project reported on scoping activities and stakeholder mapping as particularly useful activities to ensure the representation of relevant stakeholders in the process. In general, trust, personal and frequent contact were identified as important for developing relationships with stakeholders at any stage of the process. Several of the projects pointed out that user engagement is resource intensive and needs to be carefully planned and targeted.

The engagement with pre-existing stakeholder and user networks is both a substantive strength and also a potential weakness of the projects that were surveyed. Practically, it is good to build projects around known and pre-existing users and stakeholders based on the previous work of scientists or project teams. The short funding cycles demand that scientists work with people and organisations they know and get along with. However, it is a weakness because it is a bias towards known people and organisations. However, some users and stakeholders, particularly those with more power and ability to shape decision-making are often excluded because they are busy and possibly even difficult to work with.

ERA4Cs projects included a wide range of relationships between research team and stakeholders and users. Results from the interviews indicated that the science-society relationship at the onset of the project had major implications for the cost, process and methodology for co-development. Our assessment identified a "complexity and demand nexus" that determined the extent, desirability and intensity of co-production. Where the problem space was not highly complex and solutions more certain, (and especially if fewer user groups were involved, and demand and risks are low) a more 'applied science' model (i.e., science driving innovation) was more useful. In cases with highly complex issues and large and varying user groups, the co-production process was of greater importance. As such, the fact that some projects (with "simpler" issues and solutions) engaged less intensely and later in co-production processes, might not necessarily have been a disadvantage.

5.3 Intensity of Engagement

While co-producing a climate service demands engagement with intended users of the service, the **intensity of the tasks and timing** of engagement can vary. It may also involve different stakeholders and users, as presented in section 4.4. Here, we differentiate between the following three categories:

A) **Low levels of engagement**: normally in science-driven climate service projects, or in project phases intended for scientific data analysis. In these cases, the aim is primarily to communicate the latest scientific results to a wider public audience. Scientists provide new facts, scientific explanations, and projections and their implications for stakeholders and users. Stakeholders and users may then, at their own initiative, engage further with this information. Low intensity engagement is also found in projects with persisting knowledge uncertainties or relation to new emerging research topics.

B) **Balanced levels of engagement**: where there is mutual or equal engagement between scientists and stakeholders and users. Several of the ERA4CS projects had a balanced level of intensity, including periods of intensive co-production engagement and periods with lower intensity during which e.g., prototypes were developed and tested with smaller groups, or only for some cases/pilots.

C) **High levels of engagement** were commonly found in projects, where the ownership of climate services development process was handed to stakeholders and users. Here, stakeholders and users influenced scientific practice to a much greater extent. The process was then steered by practice partners who also decided on the questions that were submitted to scientists. In ERA4CS projects, this was exemplified by projects that for instance handed the identification of indicators to the stakeholders or started the co-development of the climate service based on the interactions and needs of the stakeholders and users.

The professional profile of stakeholders and users as well as the relevance of the climate service determined the intensity of interaction. ERA4CS projects demonstrated that developing climate services in highly technical and/or highly regulated domains almost mandates a high intensity of involvement. This is necessary to ensure the relevance and credibility of the climate service, which should be as specific and as accurate as the domain they aim to cater for.

Several projects reported challenges with attracting the interest of relevant users in developing a climate service, particularly when attempting to attract new users. When stakeholders were engaged, projects also experienced challenges in keeping these stakeholders committed throughout the entire process, and high turnover of users were common. Another challenge that influenced the level of engagement was related to language, for instance in terms of terminology, the implicit inclusion of scientific paradigms and methodological conventions. Similarly, communicating a projects' scope and aims was reported as a challenge.

A general good practice for co-production that was identified from the experiences of some of the ERA4CS projects was to ensure that sufficient time and capacity to plan stakeholder engagement activities in order to minimise stakeholder fatigue. Furthermore, several projects reported that the normal project cycle of three years was not sufficient to reach the objectives for transdisciplinary co-production of climate services. Co-production during the project lifecycle is commendable and appropriate as elaborated on in this guide, but there is a case for the continued involvement of transdisciplinary science-society partners to be engaged beyond project end-dates. It seems reasonable to expect more investment in science-policy-practice interfaces able to ***"[...] understand the local needs and interests of relevant stakeholders and balance pre-existing power structures*** and ensure transparent information" (Tudose et al., 2021). In this respect, finding a balance between ambition and pragmatism of the climate service, and the expectations and needs of stakeholders/end-users was a struggle and influenced the experienced relevance of the project and the climate service by users.

6. Disentangling co-production:

Recommendations for providers, users and funders of climate services

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6. Disentangling co-production: Recommendations for providers, users and funders of climate services

6.1 The way forward

Climate services by definition are developed for users and as such it is reasonable to expect a high degree of co-design with the users of the service. When we refer to co-production, we are addressing the intrinsic need for a well-balanced, customised and iterative development of a science-based service starting with quality climate data. By co-producing climate services, it is possible that we open the metaphorical Pandora's Box. This is meant twofold: on the one hand, the box may contain not only a (science) perceived need for climate data and information but also other issues that might trigger or drive the users' interests desire for co-production. On the other hand, the Pandora's Box of climate service co-production also opens up the possibility of more uncertainties and ambiguities inherent to the process of transdisciplinary co-production. The co-design of climate services as we have observed in the ERA4CS projects is well positioned to serve wicked problems.

Co-production has been interpreted as a compound of criteria that allow the intrinsic participation of users from the very beginning of the innovation process (that results in a useful and used climate service). Many of the ERA4CS projects have used methods to include users at different intensities in the production of the climate services.

Previously in the sub-section 6.3, we have illustrated three levels of intensity of engagement:

(1) Low level of intensity: users take up the information from science.

(2) Balanced level of intensity: mutual influences from science and practice.

(3) High level of intensity: Ownership is given to the users in practice.

The co-production process happens gradually through the intensity levels. In most of the ERA4CS projects there has been a gradient of involvement that fits the descriptions of Stauffacher et al. (2008). This is that the projects have presented a variety of understanding of co-production that goes from simply informing users about the existence of a product to empowering users in the decisions and steps to follow, where users are themselves at the forefront of decision-making (see Figure 6).

Figure 6

The correlation between co-design and levels of engagement intensity observed in the ERA4CS projects

	Co-design level	Engagement level
Empowerment	Decisions are with the stakeholders	High level
Collaboration	Same rights between researchers and practitioners	Balanced level
Cooperation	Decisions are made by researchers	
Consultation	Consulting practitioners	Low level
Information	Outreach/publicity	

As it was mentioned in Section 1, co-production needs to include the entire process of joint knowledge creation between experts from different disciplines and sectors, users and decision-levels including joint problem formulation, knowledge generation, application in both scientific and societal practice, and social robustness, and practical relevance (see Polk 2015). Quality control of the scientific data and information must be sufficiently transparent to ensure trust in the science products by the non-scientific partners and practitioners. In principle, it represents a fundamental change in the traditional met- and climate services design because it allows not only the providers of the climate service to be active in its design, but it also enables users to become creative in the formulation and design of the climate service. As presented in Figure 5, this process goes beyond pure information about climate change and sees the user as central to the design process. In many cases this process also involves the transformation of the provider in a kind of facilitator between the scientific knowledge and capabilities and the users' need and knowledge to support and transform visions for a product or a service (Steen, Manschot, & De Koning, 2011).

Users/stakeholders are usually presented as a grey-mass in many research areas, but users' involvement is the beginning of understanding a co-production process properly. There is a variety of users and not everyone might be the "best partner"; nevertheless, the users' perspective is the one that should guide the co-production process.

Diversity is a general feature of all steps of climate services development. Even the concept of climate services itself, the role of public and private actors in their development and delivery and the amount of the public effort needed to significantly improve their implementation is subjected to a diversity of views. Given this diverse landscape in all aspects related to climate services, the diversity of users is merely one additional element in this complex issue. To this conundrum we also have to add the lack of clearly defined standards for climate services.

Many authors have investigated and analysed the different categories of users, theirs needs in terms of services related to climate, and their level of expertise in their respective sectors. Some sectors very much affected by climate have since long made use of climate related data or services. This is for example the case of renewable energy, water management, insurances among others. Their activity has been always consubstantially linked to a relatively high degree of expertise in climate and climate related fields. Others, on the other hand, have historically made no use or a marginal use of climate information, although they may be aware of the sensitivity of their activity to climate conditions. These two broad categories of users imply different approaches for their involvement in the co-production process of climate services.

When it comes to the difference between developed and developing nations, the IPCC (2018) has called attention to the asymmetries framing climate change and to the central role of ethical considerations and the principle of equity for shaping fair responses to environmental threats. Drawing upon extant research, the report highlights the following four specific framing asymmetries associated with global warming: (i) differential contributions to the problem: the observation that the benefits from industrialization have been unevenly distributed and 'those who benefited most historically also have contributed most to the current climate problem and so bear greater responsibility'; (ii) differential impact: 'the worst impacts tend to fall on those least responsible for the problem, within states, between states, and between generations', (iii) asymmetry in capacity to shape solutions and response strategies: 'the worst-affected states, groups, and individuals are not always well represented', and (iv) asymmetry in future response capacity: 'some states, groups, and places are at risk of being left behind as the world progresses to a low-carbon economy' (IPCC, 2018, 55).

Addressing the differential contributions to and impacts of climate change through effective and fair processes of co-production of climate services entails facilitating knowledge transfer to developing countries, as well as including the most vulnerable states and communities in processes of co-production of knowledge. Co-production processes can challenge pre-existing knowledge systems rooted in inequality, and unfair power dynamics between institutions in the Global North and South. Understanding other knowledge systems and enabling partnerships in which institutions in the Global North and the Global South are equally positioned is key for commitment, trust and effective co-production. 'This can be achieved by providing equitable decision-making control over funding to all partners, promoting equitable governance arrangements, and establishing expectations and incentives at the start of the proposal' (Vincent et al., 2020: 2). Equitable North-South partnerships in the co-production of climate services are not only key for developing effective science-led tools for sustainable development, but also for supporting climate justice by acknowledging the differential contribution to global warming and compensating those who have benefited the least from industrialization.

6.2 Recommendations

6.2.1 Recommendation for researchers

The following recommendations aim to help researchers to propose, initiate and implement inclusive, fair and effective co-production processes that contribute to create usable, useful and used tools as well as to challenge pre-existing knowledge systems rooted in inequality and unfair power dynamics.

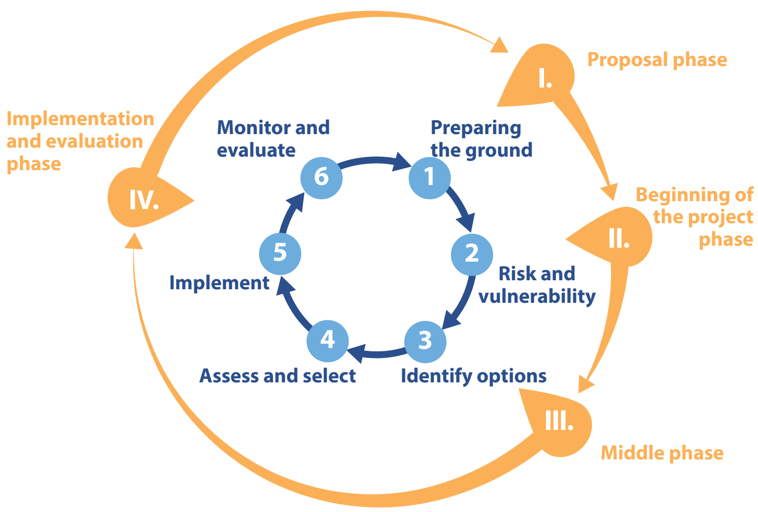
Combine bottom-up and top-down perspectives to initiate co-design process

Combining a mixed perspective of both user-driven and science-driven approaches from the beginning of the project can support effective co-design. The facilitation of workshops with user boards that are guided by science-driven issues identified during the preliminary stage of the project can provide a solid starting point for the co-design process. It is important that, when possible, the selection criteria for both users and research objectives and indicators are defined in parallel, in order to satisfy users' requirements.

Promote inclusivity by paying attention to the diverse needs of users at the beginning of and throughout the process

Co-production can occur in different phases of the project and there are roughly four entry points for engagement phases: (1) proposal, (2) project inception, (3) development, and (4) implementation and evaluation (please see the sub-section 5.2). For instance, depending on the users' progress in the adaptation policy cycle in the project (Figure 7), there are different types of users, and their needs should be accommodated according to their progress throughout the process. The users at the beginning of the adaptation steps focus on preparing the ground for adaptation. Therefore, the co-production process should address users' needs on supporting their initial set-up of the activities around awareness raising, getting multi-level support, having funding mechanisms in place, and setting up the process in a structured way.

Figure 7
The adaptation policy cycle and the phases of project implementation observed in the ERA4CS projects



Address the inequalities framing climate change and promote inclusivity through intersectionality and capacity building

Inclusive co-production processes should contribute to counteract asymmetries in capacity to shape solutions. To support inclusivity, it is vital to integrate intersectional perspectives into all stages of the process. This can enable researchers to identify and engage vulnerable groups and individuals across the intersections of gender, age, race and/or ethnic group, class and/or level of access to education and information. Capacity building is key for achieving real inclusivity by providing potential participants in co-design processes with the skills for shaping solutions. Together, inclusivity and capacity building throughout the process are vital for preventing that some states, groups, and individuals are left behind as the world uses climate services for supporting the implementation of mitigation, adaptation and transformation strategies.

Include multiple types of users

In addition, having a more inclusive approach to stakeholders can contribute to both the effectiveness of the co-production process and to maximise the impacts of research outputs. Stakeholders include not only users, but also other researchers involved in knowledge transfer, and the general public, who are also decision-makers shaping policy and introducing variables for the co-development of climate services.

Organise training events for users to address/clarify current limits of science

Climate science has its own limits that should be well perceived and understood by users. Most users are relatively familiarised with weather concepts, and they frequently request a similar level of accuracy or skill for climate products, in particular for climate prediction products. Organization of workshops mainly aiming to convey information from the research side to users on the current limits of climate science is essential to bridge gaps between what science can provide and what users can reasonably request.

Establish a common language and shared concepts

Climate science has its own world of concepts and specific language/jargon that frequently is not fully understood by users. Even some concepts or terms may have a different meaning for climate and sectoral communities. Establishment of some common core of concepts is essential for a fruitful interaction between researchers and users. Moreover, the weather and climate science communities should collaborate more strongly in order to provide a common and seamless understanding of concepts, information formats and products for their respective intended audiences.

Integrate the work of researchers from both Science, Technology, Engineering and Mathematics (STEM) and Social Sciences and Humanities (SSH) to carry out interdisciplinary research and co-design

There is an increasing need for addressing socio-ecological problems with an impact on interconnected physical, natural, social, and economic systems. Therefore, climate services need to change the actual data-centric paradigm to more information and wisdom driven services. This means that co-design processes should be guided by transdisciplinary approaches, undertaken by multidisciplinary teams including Social Sciences and Humanities (SSH) researchers and users, that allow for the meaningful integration of different knowledge systems.

6.2.2 Recommendation for users

These recommendations should be understood as ingredients to consider when starting the process of developing climate services or when ordering climate services to adapt to climate change.

Keep in mind the distinction between final users and intermediate consultants (or knowledge brokers) – which user are you?

The main objective for the design of a new climate service is to bridge the gap between the data and tools already used by researchers, and the needs of end users and stakeholders who are making decisions or taking actions. However, there are a number of intermediate players, such as intermediate consultants or knowledge brokers, who are very relevant for multiplying the outreach through scaling up and replication. Your needs as end users and intermediate players are clearly different and to consider both profiles will considerably help when defining your role in climate services co-production.

Pre-assess your needs – what is my need analysis?

Climate services are developed to improve decision making in specific contexts, and naturally involve certain assumptions about those contexts (Vaughan and Dessai 2014). It is key to be able to categorise your own needs and deliver information on your own problem to solve or adaptation need. It is crucial to identify climate elements that may help or contribute to the decision-making process. The origin of the problem and the knowledge around it should be clearly formulated. A detailed and deep analysis of this process and how science-based climate information and forecasts may contribute to empower your decision to manage opportunities and risks derived from climate variability and change is key for the proper development of the climate service.

Assess existing knowledge and opportunities for knowledge co-production – which knowledge do you already have and how can be this complemented?

The tailored climate-related knowledge and information feeding climate services historically have been generated by academic and research organizations, focusing primarily on data compilation, modelling and product development. Private-sector actors have later begun providing value-added climate services to inform long-term planning, and some sectors that are very sensitive to climate conditions, e.g., energy and insurance, have created their own climate risk management teams and/or hired consultants to help them prepare for climate-related risks. In both cases the generation of targeted climate services relied initially on pre-existing climate knowledge which was in many cases adapted and tailored to meet the needs of very specific sectors. Additionally, there is a huge amount of necessary local information in the hands of users, for example in the agricultural sector for which locally collected data are essential.

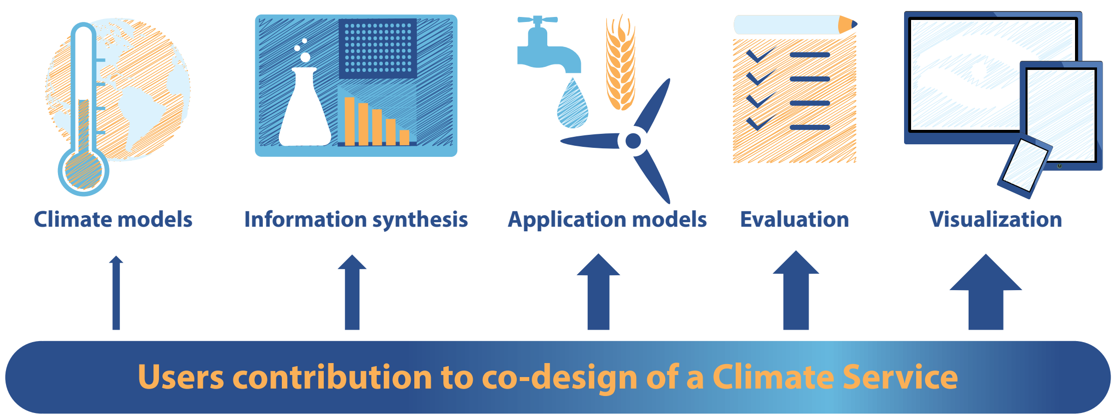
Analyse capabilities to use climate services – what additional skills do you need?

Decision making is a complex process involving many elements, e.g., information, knowledge, ability to judge, qualitative and quantitative aspects, pluri-disciplinarity, etc. Frequently, users are not fully aware of the potential value of incorporating and using climate information in their businesses and activities. Therefore, capacity building and awareness raising is sometimes necessary before being able to use a climate service.

Assess different users' roles for each step leading to a climate service – which role will you have in the development of a climate service?

As outlined in section 6 and in the introduction to this section, users can have a low, balanced, or high engagement level in the co-production process. Additionally, and as presented in the Figure 8, during the process of developing the climate services your capability to contribute might increase towards the end of the co-production.

Figure 8
Diagram with a simplified climate services chain based on climate predictions. Users' contribution to co-design is represented by the gradual increase in thickness of the arrows



6.2.3 Recommendation for funders

In the last years climate services projects have been in the list of fundable projects at national and international level. Funding agencies have created a diversity of possibilities to support research on and for climate services co-production and development. The ingredients for a "fundable" project were not always clear. With the following list, we would like to contribute to the possible future ingredients list for funders to consider when funding climate services co-production projects. We believe that it is key to agree on key performance indications that will help funding agencies to differentiate between "bad" and "good" co-production projects. The conditions for successful projects should have:

Pre-assess user engagement and needs

Users at all levels require accurate information to design and initiate science-based management measures. Information on the users' context, plays an important, supportive and in many cases decisive role for climate services co-production. The selection criteria for objectives, indicators and users should be defined in parallel, and in line with local, national, regional and global policy objectives.

Ensure that projects include continuous Monitoring and Evaluation

These research components make sure that a) the co-production process is being successful in terms of producing an appropriate climate services and b) the service delivered is reaching a high Technology Readiness Level (TRL) level.

Based on the previous tasks, include corrective measures, when necessary, to reach a higher TRL level

Projects should include the flexibility to implement corrective measures allowing flexibility in the final deliverables due to changes in users' needs and adaptation to those needs.

Ensure accessibility and fairness in the co-production process

During the whole project, partners and users should be ensured the access to all data and information to enable the understanding in the conception of climate services (from data to wisdom) and facilitate the final uptake and implementation of adaptation measures using the co-produced climate services.

Facilitate Interdisciplinarity and focus on communication research

As highlighted earlier in this report, to turn data-centric paradigm to more information and wisdom driven services reveals a focus on users that is introducing new qualitative variables in the co-design of climate services. In a research and funding landscape that tends to reduce communication to its applied elements of outreach and dissemination, it is imperative to bring back into the discourse the research dimension of the discipline of Communication, which investigates flows of information, and therefore, has both epistemic and applied implications for researchers at the intersection between the social, physical and natural sciences. Communication research outputs that enable information flows – by understanding not only how messages work, but also the role of actors and the socio-ecological systems involved in processes of exchange of information – are particularly relevant for researchers seeking to connect different systems of knowledge and disciplinary expertise. Enabling both communication research and interdisciplinarity, more specifically, provides valuable knowledge and tools to face the challenge of translating datasets into scientific information that can be effectively explored, visualised, managed and understood by users, while being Findable, Accessible, Interoperable and Reusable (FAIR).

6.2.4 Recommendations for the private sector service providers

Climate services were conceived to also provide an opportunity for the private sector to become involved and to create a market for the provision of customised scientific services. As such there are a number of recommendations for knowledge co-production by private sector climate service providers. As would be expected from the developer of services, the needs and the capabilities of the client (stakeholder or users) remains paramount. The creation of a useful and used service is the basis for economic success of any private sector concern. As such the principles of knowledge co-production is equally if not more relevant for private sector providers. This guide also offers a number of other recommendations with regards to the co-development of climate services by private sector providers.

Acknowledge science as the primary source of knowledge and the key role of research and innovation aiming to expand collective capacity to create a more sustainable and climate resilient society.

The quality of scientific input to the development of climate services remains fundamentally important. Quality scientific data as the basis for service development will result in appropriate and defensible services in which the user can trust. These services provide a factual basis for decision-making that influences the well-being and safety of civil society, local and regional economies and the future sustainability of communities. Quality climate change data are the basis for the continued use of services by users unfamiliar with the need for quality control and the use of best-available data.

Ensure fairness, social and environmental responsibilities.

Private sector providers also have a fundamental moral and ethical responsibility not only to their clients, but also society that may be influenced by decisions based on the climate services. Knowledge co-production remains relevant for all services irrespective of the type of developer, e.g., academia, research institutes or private sector.

Contribute to build capacities and to create highly qualified jobs.

The development of human capacity is a key requirement for the continued use of climate services which is the basis of the financial reward for private sector providers. As such, the creation of a skilled and capacitated pool of users would ensure the demand for climate services. If the services are embedded in the work flow of users, and they are able to use such services with confidence, which results in appropriate and defensible decisions, the market for climate services are created.

- Commitment with an equitable and inclusive energy transition recognising and addressing impacts on communities and economic sectors
- Competition to reduce costs
- Contribute to Standardisation work including interoperability along the climate data value chain.

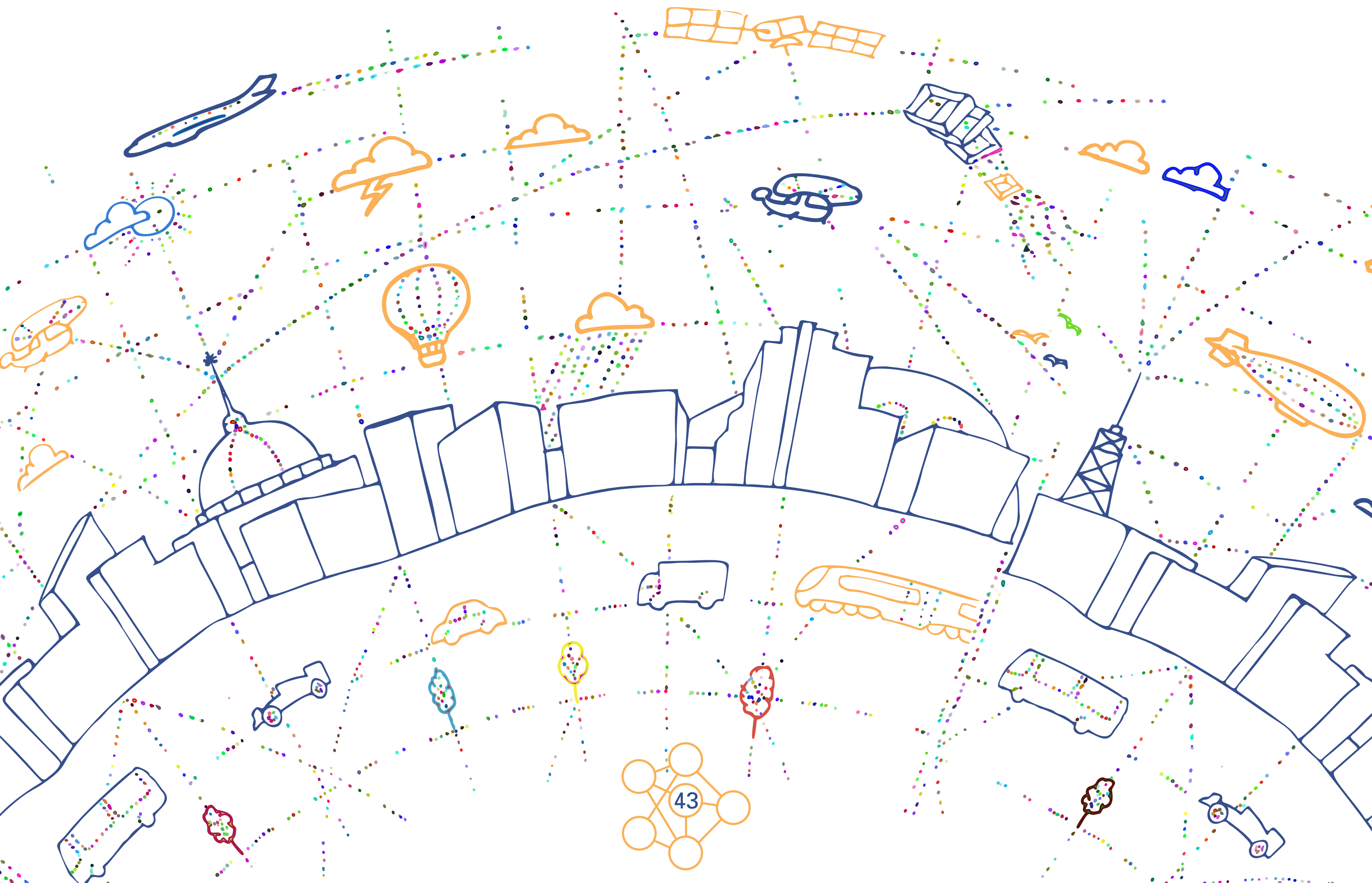
Climate services of the highest standard and with the best returns on investment implies that private sector outputs can be distinguished on a quality and trustworthy spectrum. This means that private sector firms that produces high quality services, and which can be certified as such, should be able to capture a larger part of the climate services market. The development of quality standards benefits both the private sector producer and the clients.

Understand the added value that a climate service brings along the value chain of adaptation and mitigation for the user.

Private sector concerns are developing a market place for their products and a thorough understanding of the position of climate services along the full adaptation or transformation pathway will create new opportunities for novel services. Private sector producers should also be sensitive to the global debate on climate change and the need for adaptation and mitigation by different sectors of society. To some extent, private sectors producers are part of the solution for climate change.

Be aware of your role and aims also in relation to the public sector's mandates.

Like any private sector concern the need for financial viability is a determining concern for its business practices. However, there are numerous examples of climate services that are developed by public funding for the public good. The role of private sector producers remains important but, in some instances, only forms part of wider public sector response to climate change, and the need to adapt and mitigate. Private sector products and services should form part of the work flow of decision-making in the public sector. In some instances, climate services are part of a chain of other information services (economic, social, etc.) and as such should be customised for their role in the work flow. Where possible, private sector producers should also consider the role of integrating some of these services within their own products and services. If not actively integrating, at least ensure that there are no conflicts with public sector mandates and other existing information services.



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8. List of contributors

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Name	ERA4CS Project
María Máñez Costa Louis Celliers Jo-Ting Huang-Lachmann	**INNOVA**
Amy Oen	**EVOKED**
Tina-Simone Neset	**CitizenSensing**
Jennifer West	**CoCliME**
Athanasios Votsis	**DustClim**
Kaylin Lee Inga Menke	**ISIpedia**
Christiana Photiadou Rafael Pimentel	**AQUACLEW**
Ernesto Rodríguez-Camino	**MEDSCOPE**
Mirko Suhari Susanne Schuck-Zöller	**NorQuATrans (extern)**
Sorin Cheval Nicu-Constantin Tudose	**CLISWELN**
Berill Blair Jelmer Jeuring	**SALIENSEAS**
Chuansi Gao	**ClimApp**
Yairen Jerez Columbié	**CLIM2POWER**
Len C. Shaffrey	**WINDSURFER**
Cornelia Auer	**SENSES**
Holger Hoff	**CIREG**

9. List of ERA4CS projects

Photo © Maria Manez Costa

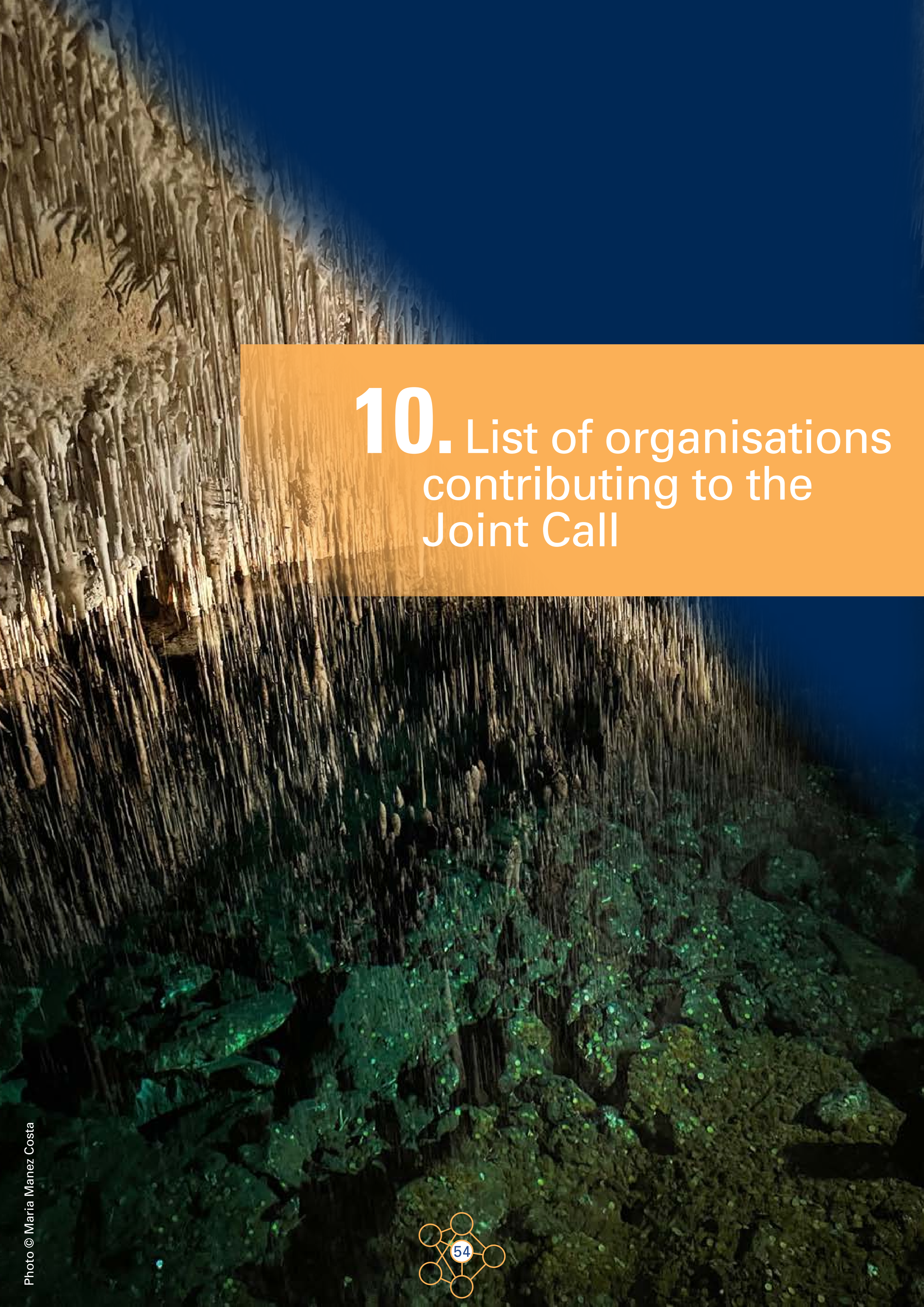
9. List of ERA4CS projects

The table below provides a list over all 26 projects that were granted funding for their proposals to the joint call for "Researching and Advancing Climate Services Development" with a specific focus to improve user adoption of and satisfaction with climate services. Details for all of these projects can be found in the JPI Climate E-magazine (JPI_Climate_e-magazine_17Feb2020.pdf (jpi-climate.eu)).

As mentioned previously, this guide is a compilation and analysis of contributions from 16 of the 26 projects in the ERA4CS programme which are indicated in bold.

AQUACLEW
CIREG
CitizenSensing
Clim2power
CLIMALERT
CLIMAPP
CLIMINVEST
CLISWELN
COCLIME
CO-CLI-SERV
CO-MICC
DustClim
ECLISEA
EUPHEME
EVOKED
INDECIS
INNOVA
INSeaPTION
ISIpedia
MEDSCOPE
SALIENSEAS
SENSES
SERV_FORFIRE
URCLIM
WATERAXR
WINDSURFER

10. List of organisations contributing to the Joint Call



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10. List of organisations contributing to the Joint Call

Partner number	Organisation name	Short name	Country
1	French National Research Agency	ANR	FR
2	Austrian Federal Ministry of Science, Research and Economics	BMWFW	AT
3	Belgian Science Policy office	BELSPO	BE
4	German Aerospace Center	DLR	DE
5	Innovation Fund Denmark	IFD	DK
6	State Research Agency	AEI	ES
7	Environmental Protection Agency	EPA	IE
8	Netherlands Organization for Scientific Research	NWO	NL
9	Research Council of Norway	RCN	NO
10	Fundação para a Ciência e Tecnologia	FCT	PT
11	Executive Agency for Higher Education, Research, Development and Innovation Funding	UEFISCDI	RO
12	Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning	Formas	SE
13	University of Graz	UNI GRAZ	AT
14	Royal Meteorological Institute of Belgium	RMI	BE
15	Helmholtz-Zentrum für Polar- und Meeresforschung - Alfred-Wegener Institut	AWI	DE
16	Helmholtz-Zentrum Geesthacht, Zentrum für Material- und Küstenforschung	HZG	DE
17	Danish Meteorological Institute	DMI	DK
18	Spanish Meteorological Institute	AEMET	ES
19	Barcelona Supercomputing Center-Centro Nacional de Supercomputación	BSC	ES
20	Agencia Estatal Consejo Superior de Investigaciones Científicas (Spanish Research Council)	CSIC	ES
21	Universidad de Cantabria - Instituto de Hidráulica ambiental de Cantabria	UC-IHC	ES
22	Universitat Rovira i Virgili - Center for Climate Change	URV-C3	ES
23	Finnish Meteorological Institute	FMI	FI
24	Finnish Environment Institute	SYKE	FI
25	Bureau de Recherches Géologiques et Minières (French geological survey)	BRGM	FR
26	French Alternative Energies and Atomic Energy Commission	CEA	FR
27	French National Centre for Scientific Research	CNRS	FR

28	Institut national de l'information géographique et forestière	IGN	FR
29	French National Institute for Agricultural Research	INRA	FR
30	Météo-France (French Meteorological Institute)	Meteo-France	FR
31	Greek National Centre for Scientific Research "Demokritos"	NCSRD	GR
32	Met Eireann (Irish Meteorological Institute)	Met Eireann	IE
33	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	CMCC	IT
34	Italian National Research Council - Department of Earth System Sciences and Environmental Technology	CNR-DTA	IT
35	Royal Netherlands Meteorological Institute	KNMI	NL
36	Norwegian Meteorological Institute	MET Norway	NO
37	Romanian National Meteorological Administration	Meteo-Ro	RO
38	Swedish Meteorological and Hydrological Institute	SMHI	SE
39	University of Reading	UREAD	UK
40	UK Meteorological Office	Met Office	UK
41	Natural Environment Research Council	NERC	UK
42	Ministera dell'università e della ricerca	MUR	IT
45	Slovakian Academy of Sciences	SAS	SK
46	Global Change Research Institute CAS	UVGZ	CZ
47	Associação para a Investigação e Desenvolvimento de Ciências	Fciencias. ID	PT

Co-production of Climate Services

A diversity of approaches and good practice from the ERA4CS projects (2017–2021)

JPI Climate

ERA4CS European Research Area for Climate Services