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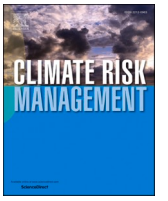

Enabling climate action: Messages from ECCA2021 calling for re-imagining the provision and use of knowledge and information

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ABSTRACT

As the need for climate action increases in terms of timing, nature and scope there is a commensurate call for knowledge and information that can enable such action consistent with policy targets. The European Climate Change Adaptation Conference ECCA2021 virtual session 'At your Service: Climate knowledge and information as enablers for climate action' engaged users and providers of these enablers to seek views and insights as to how knowledge and information are and could better inform and inspire the required action for climate adaptation, resilience and mitigation. The intention of this engagement was to identify successes and where urgent and priority action is needed to enhance the relevance, quality and use of that knowledge and information. The results of deliberations revealed perceptions of successes and actions needed under the four ECCA2021 themes – sharing knowledge, inspiring action on transformation, creating connections and collaborations, and implementing action. Central to most of the highlighted successes and required action is the need to re-imagine the knowledge and information being provided and how they are used to be consistent with and supportive of the evolving nature and scope of required climate action.

1. Introduction

The need to address climate change continues to pressure governments, organisations and society at large to take action (IPCC, 2021). This need for action is increasingly apparent as changes to our climate and their impacts become more prevalent and pervasive. As such the required action is not just better understanding of the problems and challenges but identifying and implementing solutions that can increase resilience and address the root causes of the changes in our climate (See Fig. 1).

It is with this focus on solutions that the 5th edition of the European Climate Change Adaptation Conference (ECCA2021) was held – "Bringing adaptation solutions to life: Inspiring climate adaptation actions today for a resilient future". Through a series of nine webinars each focusing on a specific climate adaptation challenge topic in the run-up to a high-level event, ECCA2021 intended to inspire action by showcasing solutions, exchanging knowledge and creating connections.

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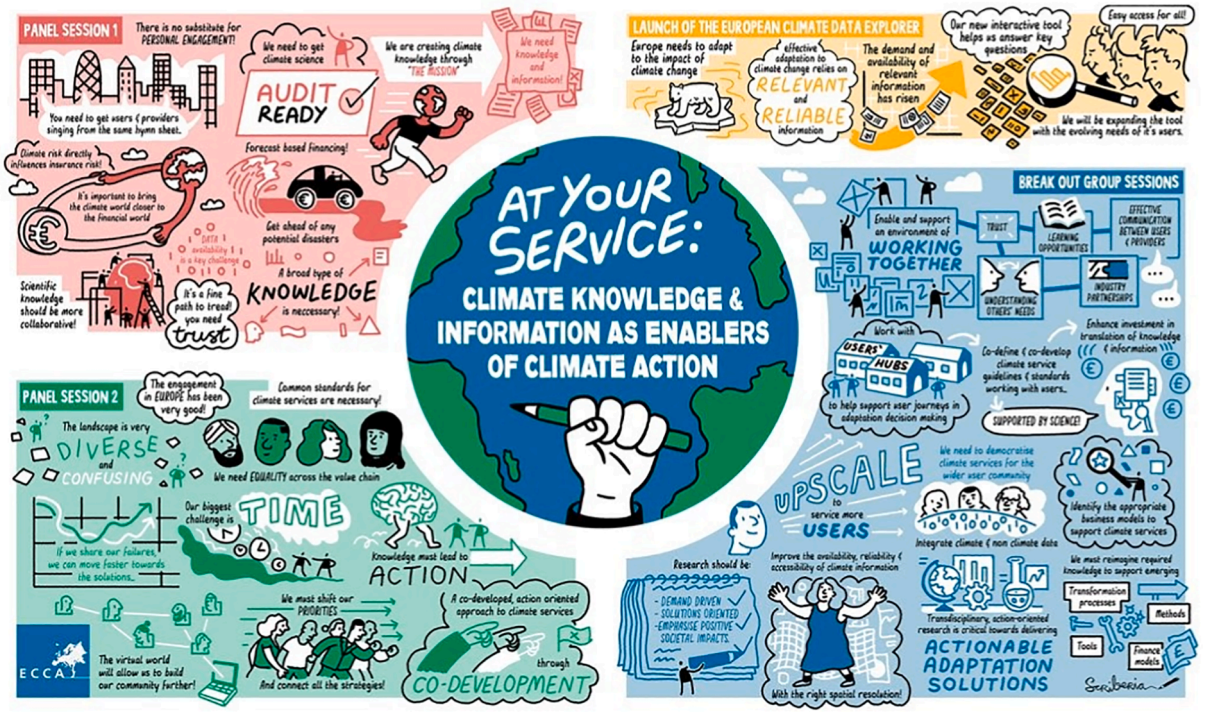

Fig. 1. Illustration highlighting the nature of the deliberations during the 'At your Service' webinar providing an overview of the nature of those deliberations and the messages as they developed with reference to the elements comprising the webinar. Produced by Scriberia.

One such climate adaptation challenge topic was 'At your Service: Climate knowledge and information as enablers of climate action'. This webinar and the supportive resources focused on the use and development of the enablers within climate services and climate adaptation (knowledge) platforms (CAPs[1]) as means of inspiring and informing climate action (adaptation, resilience and mitigation). The webinar was designed to provide a forum in which those using and developing the enablers could share their views, knowledge and experiences on how climate services and CAPs are and could better inform and inspire the actions needed to address today's climate challenges and those foreseen as we move to a climate-resilient and net-zero carbon future.

This paper presents those shared views, knowledge and experiences in the form of highlighted messages (italicised and bolded text). It draws on the deliberations during the webinar (two panel sessions and seven breakout group discussions) and the associated virtual library contributions and resources intended to inform the webinar deliberations. As these messages are drawn from that shared, they do not necessarily reflect a consensus view by all participants or the organisers. A consensus view was not the intention. Rather, the webinar was designed to give voice to a broad spectrum of those involved in using and developing knowledge and information as enablers of climate action. The intention of this paper is to bring the highlighted messages to the attention of the broader climate services and CAPs communities.

The paper begins (Section 2) by highlighting participants' views and experiences related to limitations/barriers to the knowledge and information that is available and being developed. Section 3 presents messages participants shared on what they believe is working well and where further priority and urgent actions are needed to meet existing and emerging knowledge and information requirements. In presenting that shared by participants, this paper uses the themes of the ECCA2021 conference:

- **Sharing knowledge** - Research findings and lessons learnt; knowledge across disciplines and across regions; transdisciplinary knowledge; local knowledge; digitalization
- **Inspiring action for transformation** – inspiring action now and in the future; multiple benefits (CCA, DRR, etc); action supporting sustainable development; supporting transformational adaptation; case studies and users' journeys
- **Creating connections and collaboration** – connecting people, building partnerships, private–public partnerships, effective engagement and communication
- **Implementing action** – what is needed to make change happen; financial and human resources; leadership and skills; lessons learnt

[1] https://www.weadapt.org/knowledge-base/climate-change-adaptation-knowledge-platforms/the-ke4cap-project.

2. Highlighted current limitations

The following messages (italicised and bolded text) reflect participants' views and experiences as to areas where the current state of available knowledge and information or their design and development are lacking in terms of supporting/informing the required climate action either currently or in the perceived future. They reflect areas that are providing barriers to that required or that are challenges that require further attention. Together these messages point to the need to re-imagine the knowledge and information being produced and how they are presented to ensure that available remains relevant, usable and legitimate in terms of supporting the evolving nature of required actions.

The challenge or barrier identified in some of the highlighted messages have had some level of attention such as within a specific research/innovation project or when developing a climate service or product. The requirements are to test and confirm the validity, upscale and/or adapt what has been learnt.

2.1. Knowledge and information are primarily developed based on a siloed (climate hazard) perspective and have been developed based on climate science and varied understandings of users' needs.

The early uses of climate information for decision-making were primarily characterized by users taking whatever information and knowledge that were available or accessible at the time (Hecht, 1984; Vaughan and Dessai, 2014), and in such a situation it is not always clear to what extent producers considered users' needs. However, the landscape has moved on markedly and the situation today is more of a balance between some knowledge and information being generated through research activities striving to better understand climate and climate hazards, and other research and innovation activities that are designed to address societal and decision needs. Both approaches yield knowledge and information that is potentially of use to address users' needs. Evidence and experience suggest that regardless of the original source of the information, it is critical that more needs to be done to provide knowledge and information that meets the needs of the users, i.e. a user- or decision-driven approach. There is also room for innovation and speculative development of what and how knowledge and information is provided which can lead to further advances in the relevance and usability of climate services (Hewitt and Stone, 2021).

2.2. Available knowledge, information and resources are failing to create sufficient trust and to create an appetite for such – Acting as and reinforcing barriers to picking up (and the pull for) knowledge and information that support climate action.

Building and sustaining trust are critical to enhancing the pull for climate knowledge and information thereby creating a vibrant and viable environment that can enable climate action [European Commission, 2015]. Identified barriers to building and sustaining such trust highlighted concerns related to the state of a user-centric focus:

- That available is not always easy to use and not always produced to 'high enough' or agreed [known] standard often leading to misuse and unintended consequences.
- Not linking climate knowledge and information with that needed to inform action (adaptation and resilience), including what many believe is a huge gap between what is actually required and what is or can be provided – user focus is in its infancy.
- Co-design, co-production and co-evaluation (Co-X see Mattelmäki and Sleeswijk Visser, 2011; Bojovic, et al., 2021) are recognised concepts but not well understood, embraced or delivered in practice.

Behind these barriers is that much of that available focuses on available climate science without sufficient understanding of the targeted user's decisions and decision-making processes and capabilities. Designing and developing climate knowledge, information and supportive resources such as they are relevant, usable and legitimate, as well as credible, from the intended users' perspective and demonstrated as such are critical to enabling climate action (Cash, et al., 2003). Without such, the resulting knowledge, information and supportive resources often lead to lack of utility and subsequently to a lack of confidence and trust in that produced. This situation becomes further problematic when the standards to which the products and services have been developed are unclear, not consistent with users' requirements or non-existent. The result is a gap between that available and that required, leading to a lack of pull based on low trust and confidence levels.

In addition to advances in climate science, addressing these barriers has also been the focus of research and innovations related to enhancing Co-X processes and the development of agreed standards and quality assurance/control (QA/QC) processes. These processes and standards are seen as critical to the success of climate services and CAPs - building capacity, relationships and trust and thereby providing a powerful partnership that can promote the use and demonstrate the value of climate information and knowledge.

There is clear recognition that user engagement, while challenging and time-consuming, is critical (Hewitt et al., 2017), particularly in terms of considering and reflecting on users' journeys when designing, developing and subsequently evaluating the required services and products. Criticality is reflected in the clear recognition of the value of Co-X as the basis for climate knowledge and information. Co-X processes that build relationships, users' and providers' capabilities and trust towards realising joint ownership, thereby stimulating 'user pull' for the resulting products and services and enhancing their value.

However, Co-X is composed of approaches that are generally not well enough understood and differentially applied. Adopting and implementing such Co-X processes requires proper expertise, which is often missing in natural/physical science-dominated climate services providers. Such expertise is particularly important when working with users to define and reach agreement on an appropriate Co-X process, including when enhancing the willingness and ability to invest time and effort throughout the development while

considering various constraints under which both users and providers operate.

It is worth noting that Co-X becomes increasingly important when developing standards and QA/QC processes for that required to enable action that goes beyond incremental to transformational (and proactive) adaptation, and when supporting system-wide adaptation. In these latter cases, credibility, legitimacy and transparency of the supportive knowledge, information and resources are particularly critical.

Efforts have been made in the development and use of Co-X processes that have enhanced the relevance, usability and legitimacy of climate knowledge, and information both within climate services (Christel et al, 2018; Andre et al., 2020) and within CAPs (Palutikof et al., 2019). In addressing associated barriers there are important roles to play for all across the climate services value chain (or value web) to communicate what is required, what can be provided, and determine gaps requiring further investments and development (see Hewitt et al., 2021 for examples).

3. Highlighted messages - challenges needing attention

There have been considerable investments in research and innovation supporting the provision of climate services (e.g., within Horizon 2020 and national programmes in Europe) and in better understanding the public and private markets. It is also clear that there is an ongoing need for further investments in climate knowledge and information as evident in:

- The increasing call for a climate-resilient and low-carbon society and economy as indicated within the European Green Deal (European Commission, 2019) and within the COVID-19 recovery investments
- The increasing requirements related to consideration of climate-related risks within the investment and banking sectors (FSB, 2020; TFCD, 2021; Fiedler et al., 2021)
- The recognition of the fundamental importance of climate services to the success of the EU Horizon Europe missions (European Commission, 2020a); and
- The importance of climate services to delivery of the EU Adaptation Strategy (European Commission, 2021) and the Climate Pact (European Commission, 2020b)

With respect to the five Horizon Europe missions, four include to varying degrees the need for sustainable actions that address climate change - Adaptation to climate change, including societal transformation; climate-neutral and smart cities; healthy oceans, seas, coastal and inland waters; and soil health and food. As a result, climate knowledge, information and supportive resources are fundamental to delivery of these missions. These include accelerating the transition to a climate prepared and resilient Europe by accelerating the transition and building deep resilience and will require a step change/reimagining in the scope, volume and accessibility of climate knowledge and information (European Commission, 2020a).

Central to these drivers for change is the emphasis that the knowledge and information required are those that can inform and support identifying and implementing solutions. Additionally, there is an ongoing need to increase efforts to enhance the marketability and quality of climate services as perceived by those using and those that should be using climate services (Palutikof et al., 2019; European Commission, 2015).

3.1. On sharing knowledge

Much has been learnt through research and innovation investments on effective means of sharing knowledge and experiences both within climate specific investments (Chisita and Fombad, 2020; AdriAdapt, 2021; EEA, 2015; KE4CAP, 2022; Reidler et al., 2020) and related research and innovation investments in other disciplines (e.g., social sciences exploring user engagement, Co-X and developing a public and private market).

Within the academic community, the Climate Service Journal[2] has been an effective means of sharing knowledge on the development and use of climate services intended to support climate action. This success is reflected in the announcement within the 2020 Impact Factors that the journal received an inaugural impact factor of 5.656. Further evidence is the trend in the number of publications on climate services and climate decision-support (Larosa and Jaroslav Mysiak, 2019; Palutikof, et al., 2019). Although these analyses do not include fully publications within the grey literature, they provide an indication of the growth in publications and of the sharing of knowledge being generated.

There is now a need to step-up the sharing of knowledge and information both in terms of scope and reach, building on and upscaling what has been learnt. The following messages point to identified areas where urgent and priority actions are needed to enhance and broaden knowledge sharing capabilities and reach.

3.1.1. *Bringing knowledge and information to those that need it so that what is provided is closer to the skills and requirements of targeted users – Translating to enhance relevance and usability; and Work with national or regional knowledge and information platforms as an effective way of enhancing reach, impacts and knowledge sharing*

Access to high quality (relevant, usable, legitimate and credible) climate and non-climate knowledge and information is vital for

[2] https://www.journals.elsevier.com/climate-services.

effective climate action. There has been considerable attention with commensurate progress made on developing and providing access to climate supportive resources. However, supporting climate action also requires credible and plausible societal and economic scenarios (that help define exposure and vulnerability and the adaptation measures). Provision and coordination of non-climate resources (e.g., societal and economic scenarios) are much less advanced than climate resources, raising the question whether there is a need (nationally, Europe-wide and globally) for improved coordination in this respect (e.g., a Copernicus-like capacity for social and economic (including technology) scenarios).

Providing access to user-relevant knowledge and information is why CAPs have become prevalent and are recognised as an effective element in delivering and sharing knowledge to support action (EEA, 2015; EU Adaptation Strategy, 2021). National and regional CAPs have demonstrated that they can connect people with the information and knowledge they need to act – understand climate risk, plan strategically, formulate and implement effective actions, and monitor progress (EEA, 2015; Palutikof et al., 2019). They are increasingly recognised as credible and legitimate sources of knowledge, information and supportive resources, and have a convening capability with their respective targeted audiences. This recognition is reflected by the support these platforms receive from national governments and by their recognition within respective adaptation strategies and plans (e.g., European Commission, 2021; Kazuaki, 2021).

Greater use could be made of these platforms by research and innovation projects, either as an alternative or supplement to a project-specific website, as an effective means to enhance their reach and impacts. In addition, national funding bodies could facilitate that process by encouraging the use of such platforms by relevant research and innovation projects that they fund.

But developing and sustaining effective CAPs for a multitude of users is fraught with challenges. Adaptation needs and the science and knowledge behind adaptation and resilience are both evolving and understanding of what works and does not work is expanding. Climate service providers and CAPs are also challenged by the need to ensure that the knowledge and information provided is and remains relevant, usable and credible from the perspective of their targeted users. Doing so requires translation of the knowledge and information often generated by research or disciplinary practitioners such that its relevance and contributions are recognisable, and it can be used within the intended users' decision-making processes. This translation requires interdisciplinary expertise and engaging and working with the intended users through Co-X processes to ensure quality and credibility. Furthering this challenge is the lack of recognised legitimacy of such translation activities by research funding organisations (RFOs) and research producing organisations (RPOs).

Connecting knowledge, science and action through user-centred, action-oriented research and innovation such as foreseen within the Adaptation Research Alliance and embedding/seconding within users' organisations those trained to work at the science-practice interface (Jacobs and Street, 2020) have the potential to strengthen science-implementation linkages and promote greater learning and capacity building.

3.1.2. Much has been learnt on the best way to interact with the intended users – Co-X approaches. There is now a need to enhance understanding of what Co-X should be and how it should be delivered in practice, including by upscaling what has been learnt and sharing those lessons.

The value of the Co-X is reflected in the extent to which the concept of Co-X has been embraced by providers (Daniels, et al., 2020) but also by the recognition of its benefits by those users engaged (e.g., see European Research Area for Climate Services (ERA4CS) co-design contribution within the ECCA 2021 virtual library contributions[1]).

There is still considerable diversity in what is understood and practiced as comprising Co-X, although there are some guidance/frameworks available (e.g., Daniels, et al., 2019; Bojovic, et al. 2021). Informed diversity in the implementation of Co-X approaches can be good where it reflects the capacities and capabilities of the intended user(s) and provider, an agreed value proposition, and is based on an understanding of Co-X and its implementation (which requires further attention).

There is a need to build capacity and engender innovations in Co-X processes, including the use of a broader range of strategies and methods (considering what works where, when and why). This should include increasing the understanding of Co-X by learning from others and understanding of Co-X processes and strategies developed within other disciplines (McDougall, 2012; Blanco-M (FUB), 2020). This should also include capacity building within provider teams, and sharing knowledge gained and good practices through publication and use of forums and dialogues in which the focus is on the nature, scope and rationale for Co-X processes.

Strategies for strengthening Co-X practices include explicitly requiring user engagement in research and innovation calls and engaging expert reviewers of proposals with experience in transdisciplinary approaches and social sciences; considering new forms of research governance; and ensuring credible user engagement throughout the knowledge and information design and development processes, including in associated monitoring and evaluation activities.

The engagement between the science community and the finance/investment sector is an example of where innovations are being developed and practiced as there is considerable interest within the sector and by providers. For example, the Climate Resilient Enterprises Mission launched in 2020 by Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO) has established an industry collaboration roundtable (ICR) with that innovation objective in mind. The membership of the ICR consists of organisations from across the climate intelligence "value chain" and represents a step up in the way that Australia can develop a sovereign climate risk capability. The emergence of climate related prudential regulation is a key driver of innovation as it requires banks and their counterparties to identify both risks and opportunities over the timeframe to 2050. Some initial areas for innovation include tools and capabilities to fully assess climate risks and adaptation solutions in broad scale agriculture, the design of methodologies and systems to provide assurance over climate related financial risk disclosures and the deployment of high-resolution spatial analysis for material but non-insured risk in the domestic mortgage sector (personal communications, Nick Wood, Chair ICR, August 2021).

3.1.3. Linking science and enhanced learning including through communities of practice and knowledge exchange – More could be done by sharing learning and addressing common challenges together.

Given the amount of scientific knowledge that exists and the need and growing thirst to use that knowledge for climate action, there clearly are opportunities to link the realms of science and action for mutual benefit. For the science communities there are benefits in better understanding and learning more about societal challenges, decision- and policy-makers' needs and enhancing potential societal impacts. For those looking to act there are benefits in guiding scientific developments, as well as learning from the scientific community and generated knowledge to better-inform action. Undertaking all of this together, through communities of practice for collaboration, networking and knowledge exchange, is proving to be successful, as evidenced in the Horizon 2020 Climateurope project's network (Hewitt et al., 2021) and ERA4CS. More can and needs to be done through, for example, ensuring better links with under-represented communities, and linking with additional disciplines to address the growing scope of climate action and required knowledge and information more effectively.

3.2. On inspiring action for transformation

Recent climate events (IPCC, 2021) have signalled that targeted and urgent actions are needed, including those that address the existing and emerging adaptation and resilience deficit. The pervasive nature of the impacts of these events requires that actions include more than adjustments around the margins (i.e. transformational changes). In addition, the large and quickly growing body of research and policy literature is converging on the need for a deep, radical or fundamental change, as opposed to minor, marginal or incremental changes, in the way development is conceived, understood and practiced. Despite the remaining conceptual and methodological diversity on which features make a change transformative or transformational (Barnes et al., 2020; Fazey et al., 2018; Feola, 2015; Nalau and Handmer, 2015; O'Brien, 2012; Thomalla et al., 2018), there is recognition that supporting the required transformations will require a commensurate deep, radical or fundamental change in the knowledge and information consistent with supporting emerging needs – supporting users' journeys – capable of fostering and enabling the required actions.

Investments in science have supported the development of climate strategies, plans and related policies that include recognition of the need for transformational changes (EU Adaptation Strategy, 2021; European Commission, 2020a). It will require improving the availability, reliability and accessibility of climate and non-climate information; improving information on costs and effectiveness through systematic gathering and comparison across countries, regions and sectors; and supportive resources such as strategic system-level climate risk assessments and decision support tools.

Research and innovation investments are enhancing capabilities in developing and providing the required knowledge and information as enablers of climate action. The need for further such investments is to some extent being reflected in research and innovation frameworks and agendas (e.g., European Commission, 2020a). The following are urgent and priority areas for action to overcome remaining bottlenecks to supporting and informing transformational change highlighted during the 'At your Service' webinar (Webinar).

3.2.1. Knowledge and information are needed to inform implementation of strategies and plans that include transformational changes (e.g., EU Adaptation Strategy and European Green Deal)

Knowledge and information have been deemed as being critical in developing national adaptation strategies and plans (Russell et al., 2014; Canadian Centre for Climate Services, 2021) and the EU Adaptation Strategy. This is also the case for implementing these strategies and climate action more broadly. The criticality of such is recognised within the frameworks and agreements comprising the post-2015 agenda (Griggs, et al., 2021), including in the context of broader social, economic and environmental transformational goals (e.g., United Nations, 2015; European Commission, 2020a).

The need for knowledge and information to inform implementation of actions is particularly evident within the EU Adaptation Strategy (EC, 2021) and the EU Horizon Europe missions. In the former, the objectives include adaptation and resilience that are smarter, systemic and timelier (urgency). In all cases, there is a recognised need for improving the quality and accessibility of knowledge and information that can inform and inspire climate action:

- more and better climate-related risk and losses data - avoiding 'climate blind' decisions.
- contributing to strategic, system-level decision-making consistent with the need to inform transformational actions.
- supporting policy development at all levels of governance, society and the economy and in all sectors by improving adaptation strategies and plans.
- integrating climate resilience in macro-fiscal policy, local adaptation action and promoting and accelerating the development and rollout of adaptation solutions.
- stimulating cooperation regionally and across borders and enhancing the guidelines on national adaptation strategies; and
- promoting the use of digital technologies and climate services to underpin decision making.

Developing the knowledge, information and supportive resources that directly supports implementation of actions will put further pressure on climate service development; ensuring development embraces more effectively the need to be decision-relevant and decision ready and is more consistent with a systemic approach that better connects non-climatic and climate data/knowledge (Swart, et al., 2021). The deliberations during the Webinar saw these requirements as critical to developing services that better support the implementation of solutions across all scales and levels (including individuals, communities and organisations as well as landscapes, regions, etc.).

3.2.2. Need to better articulate what is and what is not working – Case studies/users' journeys co-designed and co-produced

Drawing upon previous experiences and sharing lessons learned, whether they be success stories or otherwise, is integral to an effective and developing market. In recent years the exchange of knowledge regarding the co-design and co-production of climate services has increased (Larosa and Jaroslav Mysiak, 2019). For example, the Climateurope project produced a report entitled 'Lessons and practice of co-developing Climate services with users' (Climateurope, 2017) where success stories were shared along with noting the barriers to co-development, the latter of which, related to 'what is not working'. This latter aspect can often go unreported/unpublished in the shared literature as there is a reluctance to share 'failure' with others.

Reviewing the available literature regarding the co-development of climate services with users it is clear that there are copious success stories available. In Europe for instance, the EUPORIAS project (Buontempo et al., 2018), OASIS Hub (Hattermann et al., 2018), and the CLIPC portal (Swart et al., 2017) are relevant examples. Other case studies from outside of Europe include Golding et al. (2017a,b) where the approach of developing climate services in China that was based jointly on user needs and scientific capability was shared.

Although improving, there remains a gap in the climate services literature regarding the evaluation and subsequent reporting of the outcomes of climate services after the initial co-design and co-production steps. For example, it is still difficult to know if user needs have been sufficiently included in a climate service, how effective they are/or have been in supporting adaptation policies, or what societal impact they have had (Clar and Steurer, 2018; Webber, 2019; Máñez Costa et al., 2022). Nationally and locally relevant case studies demonstrating the results and value of user engagement, along with a broader set of enablers such as knowledge-brokering and communities of practice can provide learning and capacity building opportunities. Such case studies should be based on the experiences of the user community (rather than just the scientific community) to promote peer-to-peer learning.

3.3. On creating connections and collaboration

Engaging the communities involved in developing and using information and knowledge and putting in place the infrastructures and mechanisms that support that engagement are seen as fundamental to knowledge-based decision making (European Commission, 2015). The nature of the engagement required is that needed to build trust between data, knowledge and information providers and users and to enable them to work together, understand each other's needs and capabilities and build capacities – providing opportunities for learning and generating knowledge and information that inspires and supports action.

There have been investments in building and engaging such communities and networks (e.g., Climateurope, KE4CAP, ERA4CS and

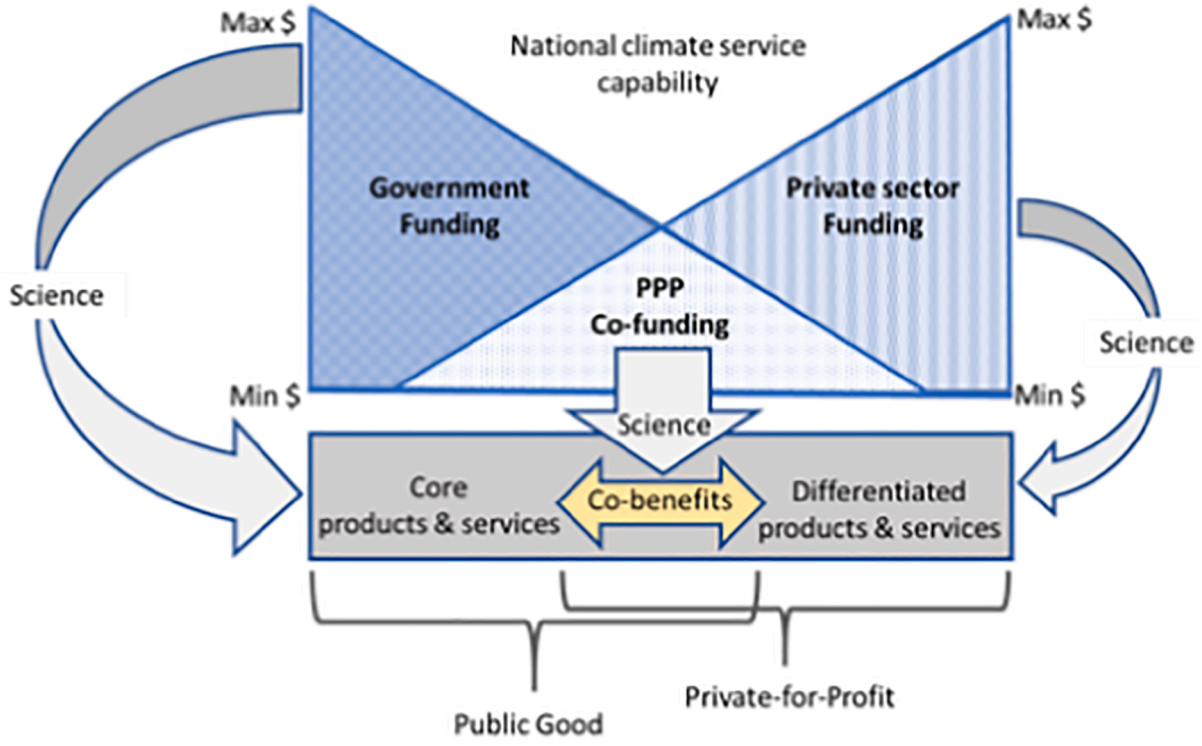

Fig. 2. Conceptual representation of the interdependencies across public and private (e.g., consultants, engineering firms, etc.) sectors and PPPs in the development and delivery of core and differentiated products and services, along with indicative proportional financial investments in the sciences underpinning an enhanced national climate service capability. The arrows represent the nominal source, directional flow and relative scale of benefits and co-benefits (NESP ESCC Hub, 2021).

JPI Climate). There have also been investments across the natural, physical, social and engineering sciences and humanities, as well as in interdisciplinary research and innovation that have included furthering understanding and implementation of such engagement.

The resulting enhanced engagement is showing dividends in building capacities and leadership. The following messages are areas highlighted during the Webinar where urgent and priority further action is needed.

3.3.1. Coordination, knowledge exchange and networking are essential to effective knowledge sharing, building trust and capacities; and Need to bring the user communities and CS community closer together

Reimagining knowledge, information and supportive resources that enable climate action necessitates engaging the different actors along the value chain in further developing the vision of what these comprise and how they can contribute to enabling the required climate action. Connections and mechanisms are needed to enable such engagement, upscaling what has been learnt without over complicating. Research and innovation calls (e.g., Horizon Europe and those by RFOs) and the implementation of the Horizon Europe missions provide opportunities for piloting and validating such connections and mechanisms.

Establishing and sustaining connections across user and provider communities are particularly important in the context of developing and enhancing the utility of knowledge, information and supportive resources that enable climate action. These include enabling collaborations that facilitate the co-design and co-development of relevant, usable, legitimate and credible knowledge, information and supportive resources, including supporting investments in knowledge and information translation.

For example, Co-X necessitates collaboration, and facilitates sharing knowledge, and building trust and capacities. However, coordination, knowledge exchange and networking extend beyond the Co-X activities, and offer benefits across the entire knowledge and information value chain (Hewitt and Stone, 2021). For example, as noted earlier, those involved in generating information and knowledge upstream in the value chain would benefit from better understanding how their outputs underpin climate services and how the services are used in decision-making downstream by the intended users, with the aim of co-developing new information and knowledge of greater value to those users. Similarly, the users of climate information and knowledge would benefit from understanding the applicability and limitations of the upstream capability with the aim of using that available appropriately, as well as to be able to guide future developments of capability and services. In Europe, the Climateurope project has successfully brought together actors across the value chain through a managed network to share knowledge, collaborate and reduce fragmentation (Hewitt et al., 2021).

Also required are establishing and supporting new partnerships where knowledge information and data providers can interact for example by establishing a 'platform' (or a network of 'platforms') to facilitate sharing experiences and lessons learnt and collaboration on mutually interesting challenges. This should also include connecting public and private sector climate service providers and purveyors. Such connections recognise the potential of partnerships in facilitating innovations and cost effective and efficient development and delivery of climate services with mutual benefits.

Both public and private sector providers and purveyors have significant roles as part of the climate service value chain operating as a stand-alone capability, as intermediaries between climate science and targeted users and in partnership. Fig. 2 provides a schematic representation of the conceptual and relative interdependencies between the sectors, including funding of provided services, which supports the suggestion for a connection/partnership (See Fig. 2).

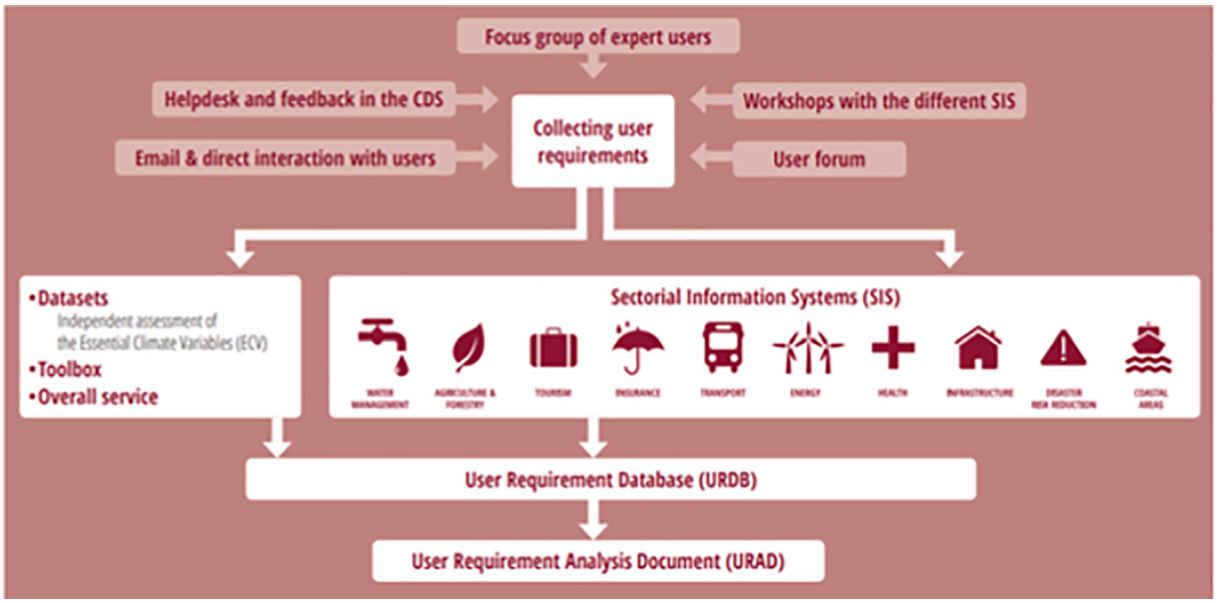

Fig. 3. *Sources of user requirements and analysis process,* https://climate.copernicus.eu/user-requirements-gathering-and-analysis.

3.3.2. Investments in natural, physical, social and engineering sciences and humanities, as well as enhancing the level and quality of inter and trans-disciplinary research and innovation supporting climate services.

Supporting climate action aligned with addressing the breadth of challenges (e.g., as reflected within the post-2015 agreements and frameworks (Peters, et al., 2016)) requires the recognition that there is a need to introduce a socio-ecological system approach that focuses on understanding complexity, restoring functions and social relations as the basis for adapting critical systems, i.e. socio-economic and ecological systems. Introducing such an approach can only be done through engaging, along with supportive investments, a combination of the best inter- and transdisciplinary science, supported by innovative digital tools and practical experience with the aim of supporting and catalysing the development of knowledge, information and supportive resources that can inform and support multi-scalar action in all types of systems.

Attributes of the required framing and context of the climate risks and required action support the need to broaden the engagement of disciplines and enhance the inter- and *trans*-disciplinary of the processes related to the development of supportive knowledge and information. For example, there is a growing recognition of the need to put people and nature (e.g., wellbeing) at the centre (OECD, 2019) of understanding the risks and identifying and implementing appropriate action. Doing such requires an understanding that climate action, particularly any transformational changes, must be just, fair, inclusive and compatible with socio-economic development. This requires framing actions and the knowledge and information within the social, institutional and governance fabric underpinned by the values and preferences of relevant actors.

3.3.3. Need to consider the diversity of users and diversity of needs and capabilities – Balancing the use of in-person and digital platforms

Significant efforts have been undertaken in Europe and around the world to understand user needs and typologies in key sectors, for instance dividing users by their expertise or maturity in using climate data and information; by their risk appetite, often relating to the certainty of information required or the emissions scenarios considered; or by their place along the value chain, and their role in taking action or decision-making (e.g. Visscher et al., 2020; Nkiaka et al., 2019; Williams et al., 2020a,b; Larsen et al; 2021; Bessembinder et al., 2019, Hewitt and Stone, 2021). Examples of related activities include those feeding into the Copernicus User Requirements Database, including focus groups, workshops for individual Sectoral Information Systems (SIS), and user fora; and activities under the SECTEUR project (Alexander et al., 2016). Fig. 3 provides an example of sources of user requirements and analysis process (see Fig. 3).

However, while these activities can provide some indication of commonality between groups of users and their needs for climate services, they also demonstrate the fundamental diversity, even within a restricted geographical and cultural location and within sectors. The use of prototypes focusing on the process of co-development and evolution of bespoke, user-driven services clearly demonstrate the benefit of tailored climate services, aiming to address a specific decision-making need and drawing on the trust, capacity development, and ownership built by these methods (see for e.g. Larsen et al 2021; Donnelly et al 2018; Golding et al., 2017a). Hewitt et al. (2020) highlight benefits of this process such as increasing the engagement between providers and users, making users more aware of how climate information can be of use in their decision-making, giving the climate service providers a better understanding of the users' requirements for climate information, and shaping future scientific research and development.

While these advantages are clear, close user interaction and bespoke development of tailored information is reliant on much higher investment of time and financial resource than a multi-user climate service which aims to provide benefit to hundreds of users with a single service (Hewitt et al., 2017; Golding et al., 2017b). Activities such as the Climate Futures tool developed in Australia, and the UK climate projections portal are examples of where multi-user online platforms are attempting to combine with close user interaction and support to try to achieve the best of both approaches.

More work is needed (e.g., Bessembinder et al., 2019) to understand better the range of user needs and capabilities, and in particular how to develop strategies for realising the benefits of effective and sustained user engagement that can deliver user- or decision-driven services and products informed by science (EC, 2015), with the efficiencies and community benefits of multi-user or mass-user services. More examples of successful upscaling of climate services and the transition from single- to multi-user services are required. These would benefit from identification of multi-user Co-X processes and the development of services tailored to meet multiple and flexible decision-making needs (e.g., cases where the provision of new climate change scenarios is well advanced but the accessibility of data or the transfer of capability to make use of data lags.

The diversity of users' needs and capabilities has led to a diversity of platforms and other resources providing knowledge, information and data to inform users' adaptation journeys. This diversity of resources can be beneficial as it allows a wider range of users to learn about climate change and access the knowledge, information and resources available, and enhances the potential that they will take action. To minimise the potential of misinformation and of confusing users it is essential that there are connections across these platforms and resources that create a consistent and trusted knowledge ecosystem while still supporting the diversity of users' requirements and capabilities, especially where systemic and transformational actions are needed. There are challenges associated with establishing and maintaining such connections, including those related to data interoperability and sharing, and differences in remits and resourcing.

Particularly challenging for CAPs are identifying and implementing knowledge exchange that achieves an appropriate balance between digital and in-person approaches. Achieving such a balance is essential where there is a diversity of capability to access and use digital resources, a commensurate need to enhance the reach to include all portions of society (e.g., leave no one behind), and where there is the need to reflect all of society's needs, knowledge and capacities in the knowledge and information available. Addressing this challenge requires engaging communities in identifying and establishing appropriate mechanisms, establishing and maintaining the capability to deliver such with appropriate governance and commensurate resourcing (see KE4CAP EU-Australia and EU-Canada events).

3.3.4. Improve roles of those along the value chain, including addressing concerns related to equity and inclusion (e.g., enhanced democratising, sharing and access to knowledge)

The value chain (Porter, 1985) includes actors involved in research, development, production, delivery and use of climate knowledge and information. Each actor has a specific role to play in the value chain aligned to their respective remit and to their skills or circumstance. However, there can be great benefit in expanding their roles to spread further across the value chain, bringing their different knowledge and skills to others in the value chain, as well as benefiting from the knowledge and skills of others in the value chain (Hewitt and Stone, 2021).

Towards expanding and improving their respective roles, practical education and re-education of practitioners (e.g., engineers, city planners, accountants, etc.) on how to understand, and use climate knowledge and information, and how to incorporate them along with other knowledge and information into their decision-making processes can also be beneficial. This should include working with the associated professional organisations and CPD initiatives. Additional benefits of expanding roles are the potential to improve equity of actors across the value chain thereby reducing issues related to dominance or overbearing and ensuring that all voices are heard and respected. Striving for such inclusion to enable wider involvement can lead to enhanced uptake and use of climate knowledge and information.

3.3.5. Recognising the nature and role of collaborations required across science, policy, practice and humanitarian processes to deliver sustainable and just climate action and lifestyles, including

- ***Shift gears in the development and use of knowledge and information enablers to better reflect societal and political priorities and an agreed vision – support moving us towards a Paris Agreement lifestyle and wellbeing; and***
- ***Enabling integrating of knowledge and information from multiple sources recognising that decisions are seldom taken just to address climate impacts and using just climate knowledge and information.***

The complexity, breadth and interrelatedness of climate and other societal challenges, the rate at which these challenges are emerging along with the scope of required actions (e.g., contributing towards achieving a Paris Agreement lifestyle and to enhancing wellbeing), and the range of data, tools and methods required justify the need for reimagining the nature and role of knowledge and information as enablers of climate action. A reimagining that is based on transformational relationship and capacity building that is capable of both drawing on and informing science, service and practice (Jacobs and Street, 2020).

Critical to such reimagining is reflecting on the nature and scope of decisions and actions to which knowledge and information are being and will need to be used. The intention is to move beyond identifying and addressing physical risks to also include broader social-ecological challenges and the need to achieve and sustain a visioned wellbeing (e.g., that foreseen within the Paris Agreement, 2015 and EU Green Deal (European Commission, 2019)). The greater the nature and scope of the decisions and actions to be supported the greater the requirement for consideration of integrating knowledge and information from a diversity of sources in informing the required actions. The need for this integrative capability is further heightened by more and more strategic thinking and policy and decision making recognising the need to incorporate values (e.g., planet, people and profit) and justice into climate action.

For example, decision-making processes that incorporate such considerations require more than just climate knowledge and information if they are to deliver the required decisions and actions. As a result, climate knowledge and information must be designed such that they can be integrated with non-climate knowledge and information essential to the targeted decision-making and implementation processes. The ability to do such requires an enhanced ability to integrate and create new knowledge, drawing on multi [trans]-disciplinary and novel ways and respecting the different types of knowledge. It also means the development and provision of tools and an enhanced ability to identify and use wisely the different technologies that facilitate extraction, processing and integration of required knowledge, information and data.

This aspect of re-imagining should also include recognition of the full scope of activities for which such knowledge and information are needed. Requirements must go beyond just that needed to identify physical impacts and undertake risk assessments. Climate services are required to support vulnerability and adaptation assessments, and implementation and evaluation in the context of the larger social-ecological systems within which decisions are taken and climate actions occur.

3.4. On implementing action

Highlighted ingredients for success in implementing action begin with a clear understanding of the existing and emerging decisions and decision-making processes that are used in making change happen, including users' journeys when implementing those processes and decisions – knowledge and information that are decision-driven and science-informed. This should involve more than just identifying users' needs but also understanding the larger social-ecological systems within which decisions are taken and climate actions are implemented and evaluated. As mentioned above, effective climate action is more likely to follow from knowledge, information and supportive resources and the associated standards, QA/QC processes and ethical considerations that have been co-designed and co-developed from the onset engaging those across the value chain.

Investments in leveraging participatory and Co-X processes, including through transdisciplinary, action-oriented research have been instrumental in delivering knowledge and information that can support actionable solutions. Deliberations during the Webinar highlighted areas that participants believed urgent and priority action are needed to support the implementation of required actions.

3.4.1. Need to consider users' (decision-makers') journeys in the development and delivery of knowledge and information – More than just case studies

When looking to provide (and when using) knowledge and information that can support implementation of climate actions there is a clear need to increase the user-focus (decision-driven and science informed) of that being developed and provided. This includes better reflecting users' journeys, an emerging concept within climate services but one that has its roots in other service areas. It is all about tracking and supporting users' decisions throughout the climate action process from a user perspective - from enhancing awareness of the need for action, through impact, risk and adaptation assessments, to implementation (including understanding and addressing implementation risks), and monitoring and evaluation and identifying touch points and tipping points when and where amendments and further action are needed.

This includes understanding and being able to anticipate the diversity and evolution of users' journeys from the perspective of supporting an iterative decision-making process. Users are continuously learning and improving their processes, decisions and actions including recognising they need to consider transformational changes. Those providing knowledge and information to support these users, including involved researchers and innovators, also need to continuously learn and improve what they are providing based on an understanding of those users' journeys.

There is a need to better develop the concept of users' journeys and how these can be developed to inform the research and innovation needed and the development of knowledge and information. In addition, sharing of these users' journeys can have benefits for researchers and innovators, and for users. This latter point should be considered as part of the scope of activities as a basis for creating connections and collaborations.

3.4.2. Existing, applied and recognised QA/QC processes and common standards can enhance pickup and use of knowledge, information and supportive resources to inform action.

Establishing and communicating QA/QC processes and common standards along with the provision of the knowledge, information and supporting resources can contribute to building trust and acceptance (Hewitt et al., 2021) and thereby promoting their use to inform actions and implementation thereof. To these ends there is a need to develop and effectively use such processes and standards such that trust and confidence are established and sustained. Co-X processes with broad based engagement including users (including purveyors), standards experts, providers and researchers, have the potential to build trust and confidence by enhancing transparency, comparability, traceability and credibility. Such an approach could lead to providing a recognised authoritative voice, capable of establishing, potentially through a phased approach, and maintaining the required processes and standards.

Such processes and standards should also benefit understanding and assessing what is being done with that being provided, an essential element to enhancing the quality of the knowledge and information available and being developed, supporting the growth of the market (European Commission, 2015). To deliver these benefits the Co-X processes employed must be explicitly designed for such, including associated expertise, objectives and deliverables.

Establishing QA/QC processes and standards through such Co-X approaches can also provide the means to bring into their development ethical considerations such as integrity, transparency, humility and collaboration (Adams et al., 2015; Pacchetti et al., 2021), critical aspects to providing an acceptable and effective knowledge-based service.

3.4.3. Learning from other areas where data, knowledge and information are being used to inform decisions (e.g., COVID-19 response and recovery) and rethinking the scope for action consistent with national and international priorities

The use of knowledge and information from science to inform policies and other actions have been front and centre within the COVID-19 crisis. In this case there has been the need to draw on and translate rapidly emerging research to inform timely and robust policy and practice. Also similar to addressing climate change, there is a requirement for timely and informed actions which are challenged by uncertainties, the competition (real and perceived) between the proposed actions and economic objectives and the blurring of boundaries between science, policy and politics (Williams, et al., 2020a,b). As such, there is a strong potential that lessons can be learned from the related challenges experienced and tools and mechanisms employed in developing and delivering effective responses to the COVID-19 crisis. There is an urgent need for exploring these challenges and lessons learnt (e.g., Williams et al., 2020a, b; Haworth et al., 2020) and bringing them to bear on the development, delivery and use of knowledge and information that can better inform and inspire the required climate action.

Climate knowledge and information has potential but is underutilised in sustainable development goal implementation (Griggs et al., 2021) and this could be extended to include in informing the development and implementation of COVID-19 economic rescue and stimulus initiatives. To a large extent, this situation is due to the lack of awareness and understanding of the potential value of such in related decisions, lack of availability or usability of relevant and legitimate information and data, and incompatible decision-making processes. Changing this situation will require reimagining climate knowledge and information and associated decision-making processes; considering and including how such climate knowledge and information intersect with economic, social justice, health and humanitarian issues by thinking in a more holistic and non-linear manner. It will also require improvements in knowledge brokering, multi-institutional and multi-stakeholder governance arrangements, including clarifying responsibilities, and research and innovations on understanding systemic risks and actions (Griggs, et al., 2021).

3.4.4. Periodic/regular assessment of knowledge and information as enablers of climate action with a supportive taxonomy of use cases and users' journeys

Finding a pathway forward for the provision of knowledge and information that enables climate action, including its implementation, requires an understanding of where we are on that pathway, the routes taken, and a vision for the future. Assessments

undertaken to inform that pathway have been multifaceted and varied in terms of intentions, scope, and engaged and targeted audiences.

From a European perspective, a seminal assessment was the European research and innovation Roadmap for Climate Services (European Commission, 2015). The resulting framework was developed through extensive consultation engaging users of climate data, knowledge and information within the public and private sectors, providers and purveyors of such and the research community. The intention in developing this Roadmap was to provide a framework to engender a discussion among the identified actors and stakeholders that would enable the development and use of climate service. In terms of an overriding context, the Roadmap recognises that to be effective and viable, climate services need to be decision-driven and science informed and supported by an engaged climate service community. With this context and framing clearly in mind, the Roadmap developed around three research and innovation challenges: Enabling market growth, building a climate service community and the infrastructure to support that community, and enhancing the quality and relevance of the services to be provided. In developing the Roadmap, these challenges and the associated nine main activities and 25 specific actions reflect recognition that a strong and collaborative private and public market are essential to the future availability of quality and relevant climate services.

Two years following the Roadmap, the European Commission DG-RTD working with Climateurope, engaged a range of key stakeholders (representing industry, researchers, innovators, developers, providers, funders, policymakers, academics and international organisations) in a subsequent assessment. The intention was to assess the climate service landscape in Europe and beyond, and to understand the evolution of the associated science, research and innovation requirements. The resulting Climateurope position paper (Climateurope, 2018) reflects the views and opinions of the engaged stakeholders.

The main messages and advice summarized in this position paper are consistent with and built on the Roadmap challenges and a number of the activities and specific actions. The paper also puts forward high-level recommendations that were intended to support the identified messages and advice. These recommendations included the need for:

- Continuing efforts related to defining and building an integrated private and public market framework including agreeing on terminology, setting standards, assuring quality, evaluating services, ethics, governance and legal considerations;
- Combining and analysing initiatives intended to improve the stewardship, uptake and use of climate services through improved engagement and knowledge exchange and developing the capabilities and capacities of the range of actors engaged; and
- Retaining an appropriate balance for investments in fundamental research and its infrastructure with more applied and service-oriented research and innovation.

That same year, an activity within ERA4CS identified climate service research and knowledge gaps, and complementarities, redundancies and synergies between national, European and international programmes and initiatives (JPI Climate, 2017). Based on these, the resulting report put forward recommendations intended to increase the effectiveness, relevance and impact of research and innovations supporting climate services. These recommendations were directed at the JPI Climate and its members and included strengthening cooperation and alignment of research and innovation supporting climate services and enhancing its societal relevance by intensifying efforts to promote interdisciplinary research and innovation.

A second assessment within Climateurope led to a paper in 2019 that presented recommendations for the next Horizon Europe framework programme (Climateurope, 2019) which in turn formed the basis for a peer-reviewed journal publication for a wider international audience (Hewitt et al., 2021). This paper and publication emphasised how research and innovation activities in the fields of climate modelling and climate services can contribute to improving climate knowledge and information as enablers of climate action. In parallel, Climateurope produced a series of three detailed publications (Döscher et al. 2017; Martins 2020; Martins et al. 2019) focussing on the state-of-the-art of European Earth system modelling and climate services.

The recommendations from this second Climateurope assessment span the breadth reflected in the three challenges comprising the European Roadmap and include a strong recognition of the critical role that outputs from climate models play in providing the scientific basis for climate services. Furthermore, the recommendations point to areas where further research and innovations are needed as perceived by the engaged experts that produced this paper. These are summarised under the following seven headings:

- Enhancing understanding of requirements, decision-making context and foresight for climate services related to better understanding the nature and scope of the pull for climate services;
- Enhancing diffusion of innovation and information for climate services – moving from research to operational services;
- Assessing and demonstrating the value of climate services as measures to enhance the uptake and pull for climate services;
- Providing a coherent and agreed set of authoritative standards for climate services towards enhancing trust across supply and demand;
- Strengthening the links between the climate modelling and climate service communities – an essential part of the supportive climate services infrastructure;
- Enhancing support for adaptation and resilience to extremes with the provision of data and information critical to addressing climate risks; and
- Supporting the formulation of adaptation strategies – a critical policy instrument at different scales used to inform climate action.

An ERA4CS workshop held in 2020 took stock of recent achievements and identified remaining knowledge gaps and research needs. It engaged participants from RFOs, organisations or initiatives working in climate services, the ERA4CS community, and representatives of users, including those from the private sector.

Based on identified challenges (ERA4CS, 2020), the ERA4CS workshop identified future research and innovation needs including those related to enabling market growth:

- Shifting from a focus on supporting incremental adaptation to also supporting transformational adaptation, including associated transitions
- Providing an overarching framework and metrics for evaluating climate services; and
- Exploring and identifying good practice business models that support building the market framework.

The deliberations during the Webinar, particularly those reflected in the above highlighted messages, are not only consistent and complementary with the conclusions and recommendations of the above assessments, but also provide further details and opportunities as to potential directions for addressing them. As such, they have utility in informing research strategies and agendas. For example, they have the potential to inform JPI Climate's climate service research goals and implementation of its Strategic Research and Innovation Agenda, including enhancing its role in alignment of EU and national investments with the potential for maximizing impact and synergies of European Climate Services research – a goal of both, research policy makers and researchers.

In finding a pathway forward, the existing and emerging requirements for climate service developments identified through these various assessments suggest that there is a need for an ongoing systematic assessment process that engages the broader climate service community – users, providers, purveyors and researchers, including those within the public and private sectors. The scope and nature of the required assessment process and resulting assessment should be decided by those engaged and should include:

- Consideration of the extent to which requirements for solution- and action-supportive climate services are reflected in the public and for-profit market offerings and are supported by climate products and services currently available and under development.
- The extent to which current research and innovations efforts and related funding are considering the need to support the evolution in climate services
- The extent to which innovations are directed at enhancing the relevance, usability, legitimacy and credibility of climate services and products consistent with what are and will be required to inform actions; and
- The extent to which processes and support mechanisms that are intended to facilitate the transition of research and project-created products and services to operations are sufficient/effective.

Based on such an assessment of current capabilities and existing and emerging challenges and gaps, the systemic assessment should identify and prioritise activities and specific actions, including suggested responsibilities for those actions. That is, the assessment should provide an effective and viable pathway forward for developing and using knowledge and information capable of enabling current and evolving climate action.

4. Taking these messages forward

The deliberations during the Webinar are not only consistent and complementary with the above-identified assessments, but also provide further details, a direction and potential focus for addressing identified gaps and recommendations. Together they provide guidance on the current state and priorities where action is needed to re-imagine and enhance knowledge and information such as they continue to support and not limit climate action. They challenge the academic, providers', user communities and funders to work together to identify and deliver the required research and innovations that will result in delivering the highlighted knowledge, information, and resources that will support climate action today and in the future.

In terms of re-imagining the provision and use of knowledge and information, the messages and supportive context clearly indicate the need to adopt and strengthen Co-X processes and capabilities (working with intended users and research and innovation communities) and to use appropriate mechanisms and technologies with the aim to provide demonstrable quality knowledge, information and supportive resources that build trust and enhance the pull from those that need to take action.

There are opportunities to address the challenges both in research and innovation and in the development and delivery of climate services. For example, these messages warrant consideration in research and innovation strategies, plans and calls put forward by RFOs at the international (e.g., Horizon Europe and its missions, JPI Climate and the Belmont Forum) and national levels. In addition, they also warrant consideration by those responding to and implementing research and innovation calls (e.g., RPOs), as well as those (public and for profit) organisations providing knowledge and information intended to enable action.

In the case of JPI Climate which pulls together RFOs and RPOs across Europe, these messages could inform its climate service research and innovation goals and implementation of its Strategic Research and Innovation Agenda. They are consistent with the convening role JPI Climate could play in creating connections and collaborations that support the development of the required knowledge and information. This includes enhancing its role in alignment of EU and national investments with the potential for maximizing impact and synergies of European climate services research and innovation – a goal of both research policy makers and researchers.

In addition, these messages warrant consideration by those using and requesting knowledge information and information (e.g., businesses, the financial sector, governments at all levels and communities, as well as the broader civil society and including households). These considerations could inform their discussions and negotiations with providers, thereby increasing the likelihood that the knowledge and information provided is relevant, usable, legitimate and credible. Such discussions would also impact on the overall market, enhancing the demand for knowledge and information that enables action.

There are also opportunities for considering these messages in implementing climate-related strategies, plans and policies at the national level but also transnational level such as the EU Green Deal and EU Adaptation Strategy in Europe. In doing so, such strategies, plans and policies can support the development and dissemination of knowledge and information. This should include calling for and enabling the development of relevant knowledge and information to inform implementation and to address gaps, as well as providing and supporting an enabling environment for knowledge exchange that supports climate action.

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The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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'**User-focused' panel members**: Nick Wood, Climate Policy Research P/L; Liviu Stirbat Deputy Head of Unit DG CLIMA; Marie Scholer EIOPA; Pablo Suarez, Red Cross Red Crescent Climate Centre; and Maria José Sanz, JPI Climate Transdisciplinary Advisory Board.

'**Provider-focused' panel members**: Chris Hewitt, UK Met Office; Daniela Jacob, GERICS; Jaroslav Mysiak, CMCC; Kim van Nieuwaal, CAS; and Rosalind West, FCDO.

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Adaptation Research Alliance - Jesse DeMaria-Kinney/Sydney Church, ARA Secretariat.
ERA4CS - Inès Alterio and Philippe Bougeault, ARN.
Connecting the needs and expertise from private actors to the broader climate service market - Thanh-Tam Le, Climate KIC/Harilaos Loukos, The Climate Data Factory.
Frontiers of adaptation modelling - Jaroslav Mysiak/Elisa Calliari, CMCC.
Establishing a European CS community - Nicola Golding/Stacey New, UK Met Office.
Providing reference climate service in support to climate adaptation – Stijn Vermoote/Samuel Almond, ECMWF.
Knowledge enablers supporting climate action and the SDGs - Maria José Sanz, JPI Climate TAB/Elena Lopéz-Gunn, ICATALIST.

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