



## Short Communication

## Standardisation of equitable climate services by supporting a community of practice

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## ABSTRACT

Climate services are essential to support climate-sensitive decision making, enabling adaptation to climate change and variability, and mitigate the sources of anthropogenic climate change, while taking into account the values and contexts of those involved. The unregulated nature of climate services can lead to low market performance and lack of quality assurance. Best practices, guidance, and standards serve as a form of governance, ensuring quality, legitimacy, and relevance of climate services. The Climateurope2 project ([www.climateurope2.eu](http://www.climateurope2.eu)) addresses this gap by engaging and supporting an equitable and diverse community of climate services to provide recommendations for their standardisation. Four components of climate services are identified (the decision context, the ecosystem of actors and co-production processes, the multiple knowledge systems involved, and the delivery and evaluation of these services) to facilitate analysis. This has resulted in the identification of nine key messages summarising the susceptibility for the climate services standardisation. The recommendations are shared with relevant standardisation bodies and actors as well as with climate services stakeholders and providers.

## 1. Climate services and standards

There is an increasing demand for tailored, actionable climate information and knowledge to support communities, organisations and institutions to adapt to climate change and variability, mitigate the sources of anthropogenic climate change, ensure robust climate risk

reporting, and support disaster risk reduction. The services generating demand-driven, contextualised climate information to support the decision-making processes in these communities, organisations and institutions are commonly known as climate services<sup>1</sup> (Vaughan and Dessai, 2014; Hewitt et al., 2017). They aim at both avoiding or minimising negative outcomes and making use of climate-related

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<sup>1</sup> The Climateurope2 project defines climate services as the provision of climate information in such a way as to assist decision-making by individuals and organisations. The service component involves appropriate engagement, an effective access mechanism, and responsiveness to user needs.

opportunities that may arise. Climate services are tools and processes that provide timely climate information to a broad range of climate-sensitive decision-making processes. While many of the tools are technology-intensive and science-based, they need domain-specific, social and cultural competence to identify specific knowledge needs, to deal with different forms of knowledge and to tailor context-specific solutions.

Climate services play a key role in both developing a resilient society and achieving climate neutrality. In particular, climate services are central to a climate-resilient Europe, consistent with the policy and socioeconomic context established by the Paris Agreement (United Nations, 2015), the European Green Deal (Fetting, 2020), the European Climate Change Law (European Parliament, 2021), and the European Climate Change Adaptation Plan (European Investment Bank Group, 2021). Key actors in climate services are the Copernicus Climate Change Services<sup>2</sup> (C3S) and the Global Framework for Climate Services (GFCS), proposed and managed by the World Meteorological Organisation (WMO) (Hewitt et al., 2020). However, beyond these very visible actors, the community of practice, which includes individuals and organisations underpinning, designing, providing, and studying climate services, has a strong granularity and is difficult to identify (Larosa and Mysiak, 2019; Cortekar et al., 2020). In addition to the climate services developed by governmental organisations at international, national and, sometimes regional level, the private sector is quickly engaging in the development and delivery of climate services for a broad range of purposes, including the reporting of climate risk to investors (Walela and Kahihu, 2023).

Climate services of demonstrable quality, e.g., those that demonstrate credibility, legitimacy and salience (Cash et al., 2003), are expected to underpin successful decisions (e.g., Condon, 2023). The wide diversity of stakeholders<sup>3</sup> and demands, as well as of approaches, interests, and products, unavoidably leads to multiple ways to define the suitability, value, and quality of climate services, when they are all considered. The absence of widely agreed measurable, comparable, and auditable criteria related to climate services tools, processes and products, based on well-established standards and guidance, often hinders further development of transparent, trustworthy, effective, and equitable climate services and a market<sup>4</sup> growth of these characteristics.

Standards are measurements, descriptions, sets of requirements, conventions or design specifications aimed at inducing conformity of practice or behaviours (Mohla, 2017). Standards, best practices and guidance are typically developed in a consensus process and coordinated by legitimate organisations.<sup>5</sup> If properly supported by ethical principles such as equitability, the availability of standards can offer a level playing field for both providers and users. Standards, best practices and guidance can also ensure product functionality, compatibility and/or interoperability. Standards also reflect the generally acknowledged state-of-the-art<sup>6</sup> to minimise risks to the health and safety and fundamental rights of people and systems according to the applicable law. Standards

can provide technology-, process-, efficiency-, or methodology-based specifications in relation to the design, development, and delivery of climate services. This creates the basis for verification, validation and testing procedures that can draw objectively verifiable criteria, and implementable methods to assess compliance.. Standardisation creates terminologies, shared vocabularies, and methodologies such that products, processes, and services can be widely understood and compared (Danish Standards Foundation, 2015). The terminology must build as much as possible on glossaries adopted at the international level and be aligned with all other relevant standards. These aspects of standards and guidance can support better quality climate services, i.e., services that are more credible, salient and legitimate.

There is already a body of literature on recommendations, best practices, guidance, guidelines and conventions for different aspects of climate services, such as for the identification of the ecosystem of actors and co-production process (WMO, 2018; Baulenas et al., 2023), or for aspects of the delivery mode and evaluation, such as visualisation (Terrado et al., 2022), upscaling (Guentchev et al., 2023), or for targeted and specific purposes such as adaptation (Boon et al., 2024). However, this literature and expertise is not exhaustive nor structured, focuses only on some aspects of climate services, or represents academic work that does not have the needed granularity and verifiability characteristics or the legitimacy of consensus building processes across stakeholders, proper of standards organisations. A comprehensive set of guidance and good practices that considers all aspects required to frame the production of climate services and that takes into account the socio-economic, financial and other contextual factors is still missing.

Moreover, the distinction between what components of climate services can be standardised and which ones should not or are not mature enough to be standardised is also needed. The absence of established best practices and standards also implies that a certification mechanism and labelling criteria, as well as a set of accredited actors, are also missing. These actors depend on the standards that are the basis of assurance mechanisms. All these elements, among others, limit the implementation of appropriate business models for climate services providers (Larosa and Mysiak, 2020; Damm et al., 2020), or the proper evaluation of the effectiveness of existing services in the market, which for several authors fails to be effective in guiding society (Arribas et al., 2022; Pitman et al., 2022; Hoehn et al., 2024). In addition, standards for climate services need to be aware of an existing complex landscape of standards, standardisation activities, and actors that should complement the process of standardisation of climate services (Box 1 and Fig. 1).

The broad nature of climate-related decisions requires climate services to be varied and context dependent, which poses a challenge to standardisation efforts. To address this complexity, the community needs to identify the different components of climate services (see Section 2) and provide either guidance or standards for each one of them. To reach this objective, the creation of a robust comprehensive set of criteria for standardisation through the involvement of all relevant actors (e.g., Vedeld et al., 2020) is needed to assure the demonstrable quality of climate services. The equitable involvement of all actors has been identified as a necessary condition for building two-way trust between the supply and demand of climate information (Hewitt and Stone, 2021). This paper discusses an approach to address these challenges as implemented by the European research project Climateurope2.

#### Box 1: Landscape of standardisation activities related to climate services

Fig. 1 presents the landscape of existing standards and standardisation activities related to climate services across five overlapping themes and four different scales. The five themes are:

- Climate change and sustainable cities: This theme addresses standards and activities in the intersection of climate change and sustainable cities and communities. It focuses on the general frameworks and reference standards essential for building climate-resilient and sustainable urban environments. The corresponding

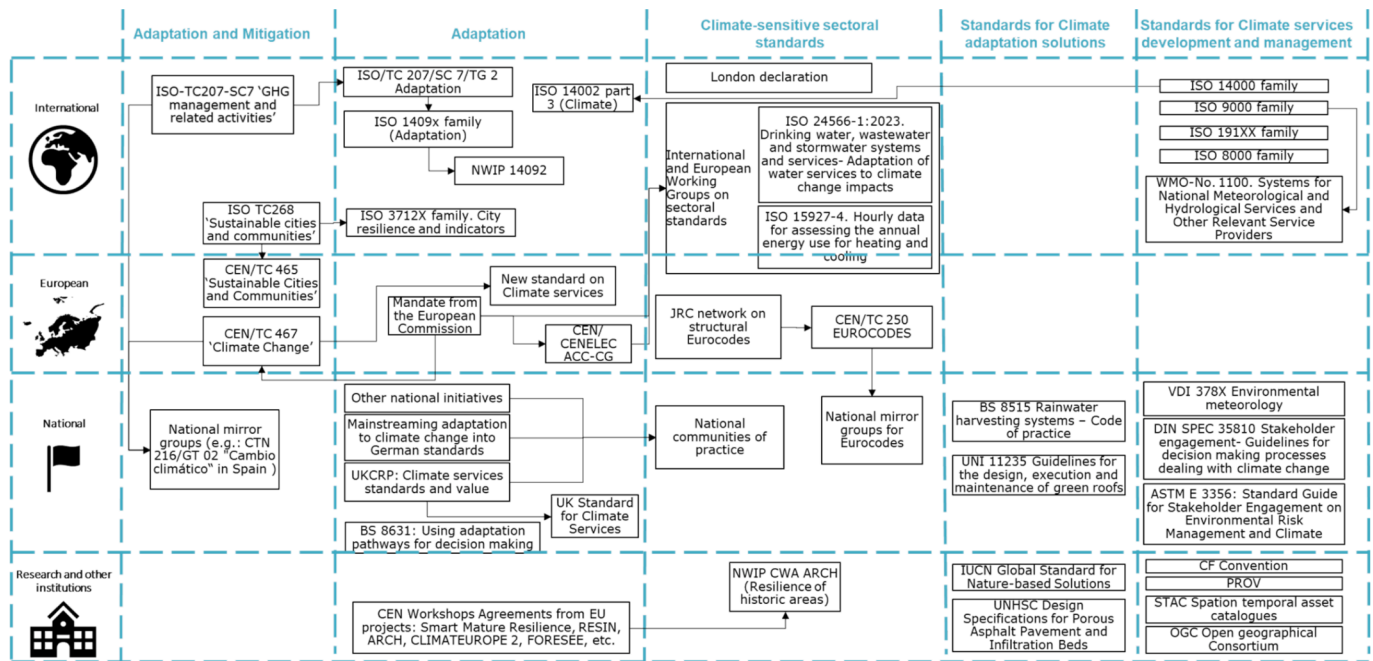
<sup>2</sup> <https://climate.copernicus.eu/> (accessed 28 March 2024).

<sup>3</sup> Climateurope2 considers all sectors vulnerable to climate variability and change, taking into account that they might have different degrees of vulnerability, even within a specific sector, as well as sectors that demand climate information for the implementation of efficient mitigation measures.

<sup>4</sup> The text considers the market in a broad sense, including open and free, and paying services.

<sup>5</sup> See <https://www.iso.org/developing-standards.html>, <https://www.bsigroup.com/en-US/Standards/Information-about-standards/Different-types-of-standards/> or <https://www.nbn.be/en/using-standards/what-are-standards> also for a distinction on the regulatory power of a guidance versus a formal standard (all accessed 28 March 2024).

<sup>6</sup> State-of-the-art is used as a developed stage of technical capability, accepted as good practice, at a given time as regards products, processes and services, based on the relevant consolidated findings of science, technology, and experience. It does not necessarily imply the latest scientific research still in an experimental stage or with insufficient maturity.



**Fig. 1.** Summary of standardisation initiatives relevant to climate services across five themes (columns) and four different areas of action (international, European and national standardisation agencies plus other institutions and projects, each of them in a separate row) that may influence the development and implementation of climate services. Arrows represent the influence between activities and standards linking, for instance, the institution or initiative that promotes or coordinates an activity at a higher level to more concrete outputs or specific examples of the activity typologies cited in the text.

technical standardisation committees, for example, at the European level, the European Committee for Standardisation<sup>7</sup> CEN/TC 467 and CEN/TC 465 technical committees, deal with the management of greenhouse gas emissions and the adaptation to climate change to achieve a sustainable development considering both smartness and resilience.

- **Adaptation:** This theme delves deeper into the topics covered in the previous theme focusing on specific issues that can impact the design and execution of climate adaptation strategies such as the conceptual framework for climate-related risk assessment. This theme has been identified as particularly relevant to Climateurope2.
- **Climate-sensitive sectoral standards:** Focusing on sector-specific standards influenced by climate variability and change, this theme highlights the need for integrating climate information into sectors like agriculture, energy, and water management. The importance of this theme for Climateurope2 lies in the identification of sectors that currently use mainly historical climate observations to offer additional guidance from climate services for the design and management of multiple activities and sectors.
- **Standards for climate adaptation solutions:** This theme is centred on standards that guide the implementation of adaptation measures, even when they are not explicitly designed for climate adaptation and may not necessarily require climate information. It emphasises the technical and practical aspects of adaptation solutions, recognising the impact of climate variability and change on their performance. Some of these standards have not been promoted by standardisation bodies, but by other organisations like research groups.
- **Standards for climate service development and management:** This theme includes management standards (e.g., quality) to which climate services or its components will or may need to adhere to support aspects like quality and transparency, among other elements. Examples are the International Organisation for

Standardisation ISO 900X family for quality system management as well as WMO guides like the “Guide to the implementation of quality management systems for national meteorological and hydrological services and other relevant service providers” (WMO, 2017), which helps to implement a quality management system for these key actors. There are also other climate community standards not promoted by formal standardisation bodies, such as the CF convention<sup>8</sup> for storing and sharing climate data or the PROV documentation<sup>9</sup> for interoperable exchange of provenance information.

Standards and standardisation activities are conducted at different scales of influence and consensus: 1) international, 2) European, and 3) national standardisation organisations, as well as by 4) other institutions. For example, at international level the subcommittee ISO/TC207/SC7 “Greenhouse gas and climate change management and related activities”<sup>10</sup> is the most relevant for climate services due to its close connection with the climate perspective (e.g., the ISO 14090 family on climate change adaptation includes several standards directly related to the use of climate information for climate risk assessment and adaptation). However, other technical committees such as the ISO/TC268 “Sustainable cities and communities”<sup>11</sup> promote related sustainable standards that are also of interest for climate services. The ISO/TC207/SC7 activities are overseen at the European level by the CEN/TC 467 “Climate change”<sup>12</sup> technical committee. Similarly, CEN/TC 465 “Sustainable and smart cities and communities” (CEN/TC 465, 2021) covers the topics addressed by ISO/TC268. These structures of knowledge are subsequently incorporated at the national level by the national mirror bodies, with freedom to initiate their own programmes. An

<sup>8</sup> <https://www.cfconventions.org> (accessed 28 March 2024).  
<sup>9</sup> <https://www.w3.org/TR/prov-overview> (accessed 28 March 2024).  
<sup>10</sup> <https://www.iso.org/committee/546318.html> (accessed 28 March 2024).  
<sup>11</sup> <https://www.iso.org/committee/656906.html> (accessed 28 March 2024).  
<sup>12</sup> [https://standards.cencenelec.eu/dyn/www/f?p=205:7:0:::FSP\\_ORG\\_ID:2878377&cs=1584E5ACD38B787B7168B368988A37979](https://standards.cencenelec.eu/dyn/www/f?p=205:7:0:::FSP_ORG_ID:2878377&cs=1584E5ACD38B787B7168B368988A37979) (accessed 28 March 2024).

<sup>7</sup> <https://www.cencenelec.eu/> (accessed 28 March 2024).

example is the United Kingdom's Climate Resilience Programme on Climate Services Standards.<sup>13</sup>

At the European level, the European Commission is expected to issue a mandate to the European standardisation organisations leading to the development of a new standard for climate services while boosting the work of CEN-CENELEC's Adaptation to Climate Change Coordination Group (ACC-CG).<sup>14</sup> This mandate will lead to the revision of dozens of standards, like those applicable to sectors with climate-sensitive activities, to accelerate climate adaptation. Additionally, the London Declaration, signed by both ISO and CEN-CENELEC, guarantees the incorporation of climate science into the development of all new and revised standards and publications. This process has already started with the review process of existing standards such as the ambition of considering climate projections in ISO 15927-4 (ISO, 2005). In other cases, new instruments are being developed with the objective of including future climate considerations in sectoral activities such as ISO 24566-1:2023 (ISO, 2023) created by the ISO/TC224/WG16 working group.

Recently, research projects have been instrumental in driving the development of standards related to climate change and resilience. At the European level, the CEN Workshop Agreement (CWA) has proven to be the most suitable mechanism to transfer knowledge. For instance, the CEN Workshop Agreement CWA 17727:2022 "City Resilience Development – Guide to combine disaster risk management and climate change adaptation – Historic areas" (CEN, 2022) has been developed by the ARCH project.<sup>15</sup>

## 2. The Climateurope2 approach

Climateurope2 is a Horizon Europe coordination and support action that started in September 2022 and will run until 2027, involving 32 parties. To address some of the challenges for the effective use of climate information, the project supports a climate services community in Europe and elsewhere to identify the minimum requirements for quality-assured and equitable climate services. More specifically, the project goals are (a) to contribute to the demonstrable quality of climate services, both in Europe and beyond, through a set of recommendations for their standardisation, (b) to identify ways to optimise the always limited resources (human, financial, scientific) by offering a meeting place to the climate services community, (c) to increase the uptake of trustworthy climate services by those vulnerable to climate variability and change, and (d) to contribute to current climate mitigation and adaptation efforts with equitable and quality-assured climate services.

The project builds upon and continues the community-building activities and outcomes of the earlier project Climateurope (Hewitt et al., 2021). The continuation of these activities involves establishing a network across the vast number of climate services-related research projects and actors in Europe and beyond. The network is used to harvest experiences, good practices, and requirements to define what climate services components are suitable to be standardised, the limits to standardisation, and guidance for components that cannot (yet) or should not be standardised. All this while applying the principles of equity, diversity, and inclusion.

Climateurope2 has identified four main climate services components that are used to structure the discussions (Fig. 2):

- The decision-making context for which climate services must deliver value: It refers to the kind of decisions the climate service supports, including its geographical, social, and political context.
- The ecosystem of actors and co-creation processes involved: It identifies the actors involved in co-producing, evaluating, and taking up climate services, as well as the actors that might become relevant because of a particular decision context. This component also addresses the co-production processes that are relevant for different actors and different stages of the climate service development process.
- The different knowledge systems, information, and processes that contribute to co-develop successful climate services: This component relates to climate data, but not only. Environmental, social, economic and technical, as well as engineering data and local knowledge to develop and implement local adaptation and mitigation strategies, are relevant here too. This is also the case of all selection, evaluation and translation processes related to this data, as well as data accessibility, storage and stewardship.
- The delivery mode and its co-evaluation: This refers to the way a climate service is delivered and how this delivery is evaluated. It should include the tailored aggregation and combination of data and processes to match the decision and context of the service client.

Good practices and conventions for the climate services components, like the co-production and co-development of the climate information, the approaches for user engagement, the delivery mode, the evaluation procedures, the documentation, among many others, are either not available, exhibit a wide range of heterogeneity in the way key attributes such as quality and interoperability are considered, or are scattered across a large number of existing norms and conventions.

To achieve its goals, Climateurope2 harvests knowledge and experiences across all relevant scientific fields, from natural to social sciences and humanities, from its participating partners. In addition, it works toward the participation of the private sector, public administration actors, standardisation experts, and technology providers, as well as with a large number of research projects, such as those that are part of the European Mission on Adaptation to Climate Change,<sup>16</sup> to assemble the knowledge produced so far and being produced by the academic community. Their engagement is addressed through the creation and support of a connected community of practice of European climate services actors that is also expanded beyond Europe.

By analysing the existing landscape of standards and standardisation processes (Fig. 1) and the complex climate services market, Climateurope2 is co-developing a framework to support the equitable standardisation of climate services. The framework explores the standardisation opportunities and the maturity for each of the climate services components through a decision tree. The community of practice follows procedures of consensus-building processes to develop recommendations for the standardisation of climate services. The process for consensus-building established in Climateurope2 is depicted in Fig. 3, including how it relates to the project activities. The workflow identifies the main information sources and defines the interaction among the consortium members, extending the outreach to the broader climate services community. This process, implemented with the community of practice, provides the knowledge needed to identify the aspects that can be standardised and the way to do it, and the alternative forms of governance for those that are not susceptible of being standardised.

An important prerequisite for the development of new standards is a common understanding of key terms. Climateurope2 supports this process by co-creating a glossary of key terms required for the

<sup>13</sup> <https://www.ukclimatesresilience.org/projects/climate-services-standards-and-value/> (accessed 28 March 2024).

<sup>14</sup> [https://www.cencenelec.eu/areas-of-work/cen-cenelec-topics/environment-and-sustainability/climate-change/#:~:text=The%20CEN%2DCENELEC%20Adaptation%20to,Change%20\(M%2F526\)](https://www.cencenelec.eu/areas-of-work/cen-cenelec-topics/environment-and-sustainability/climate-change/#:~:text=The%20CEN%2DCENELEC%20Adaptation%20to,Change%20(M%2F526)) (accessed 28 March 2024).

<sup>15</sup> ARCH Consortium: Saving Cultural Heritage, <https://savingculturalheritage.eu/about/project> (accessed 28 March 2024).

<sup>16</sup> [https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/eu-missions-horizon-europe/adaptation-climate-change\\_en](https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/eu-missions-horizon-europe/adaptation-climate-change_en) (accessed 28 March 2024).



## Climate services components



Fig. 2. Components of a climate service as identified in Climateurope2. See text for a detailed description.

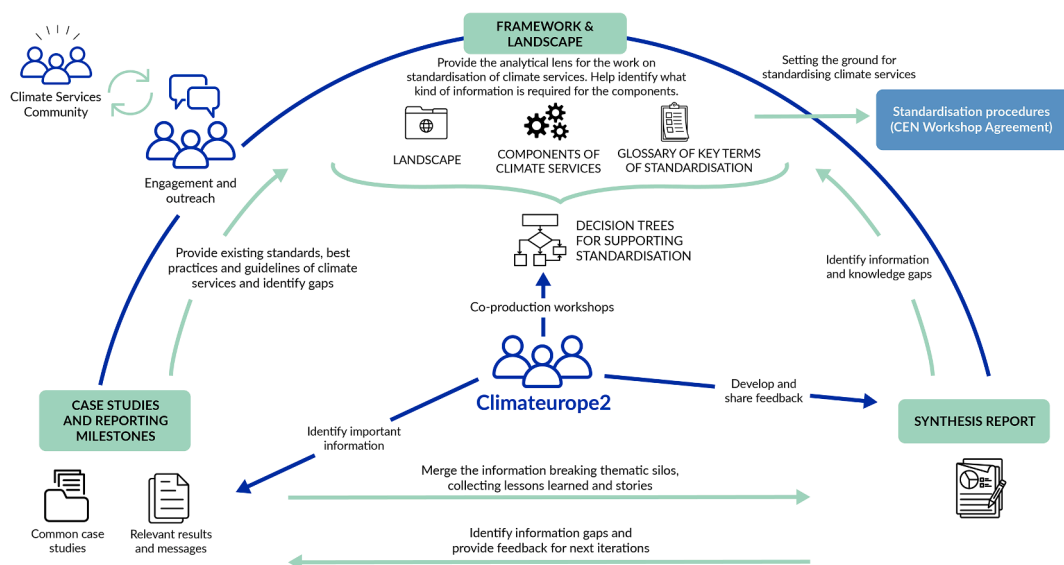


Fig. 3. Workflow established to execute the Climateurope2 framework for the equitable standardisation of climate services, aimed at identifying standardisation needs and assessing maturity levels. The figure illustrates the interconnections between the identification of important information on climate services (case studies and key results), the synthesis report with key messages from Climateurope2, and the proposed framework that sets the ground for developing standardisation procedures and recommendations.

implementation of the framework and to facilitate the engagement of the different communities in the standardisation process. An example of the relevance of the glossary is the term *equitability*: how it is understood and how the principle of *equitability* contributes to key processes in Climateurope2, such as engaging with the community and implementing the standardisation framework.

Always working with the community, Climateurope2 has started to analyse case studies with successful and sometimes not-so-successful outcomes to identify good practices and, especially, what practices should be avoided. As soon as a set of guidelines, recommendations, and conventions is considered mature enough, contacts already established with CEN will be used to contribute to a standardisation process that has been already triggered by the European Commission.

A particular focus of Climateurope2 is to prevent the misuse of climate services and prevent harm caused by a poor understanding of the user needs, insufficient saliency, failed delivery, missing documentation or poor-quality processes and products. The identification of standardisation needs and opportunities takes place in parallel to the activities to expand, engage with and support the communities involved in the development of climate services (e.g., festivals, roadshows targeting underrepresented regions like Eastern Europe, workshops, and an interactive platform (<https://ce2-platform-beta.maris.nl/>) for community engagement that is de facto a permanent meeting point for members of the climate services community), offering an opportunity to all actors

to have a voice (via, for instance, a continuous search of underrepresented actors and sectors, leaving whenever possible the comfort of academic research). So far the project has already conducted in-person and online events that have served as discussion spaces to identify concrete demands from a number of sectors and lessons learnt from a very diverse community of climate services and stakeholders (Fig. 4). The project uses all the information gathered from this community engagement to prepare the recommendations for the standardisation of the four climate services components (Fig. 2).

The workflow described earlier has supported numerous exchanges across the Climateurope2 participants and led to the identification of nine key messages (Section 3). These messages are guiding the next round of engagements both within and outside the project. They will be revised regularly to develop a consensus view of the maturity of the climate services components and the development of the set of guidelines that support the standardisation recommendations.

### 3. Initial key synthesis messages

The following key messages provide the current knowledge gathered through a joint effort at the European research level to identify an optimal strategy for benchmarking climate services and the most urgent recommended next steps for their standardisation, quality assurance and certification, including aspects such as equal access and power balance

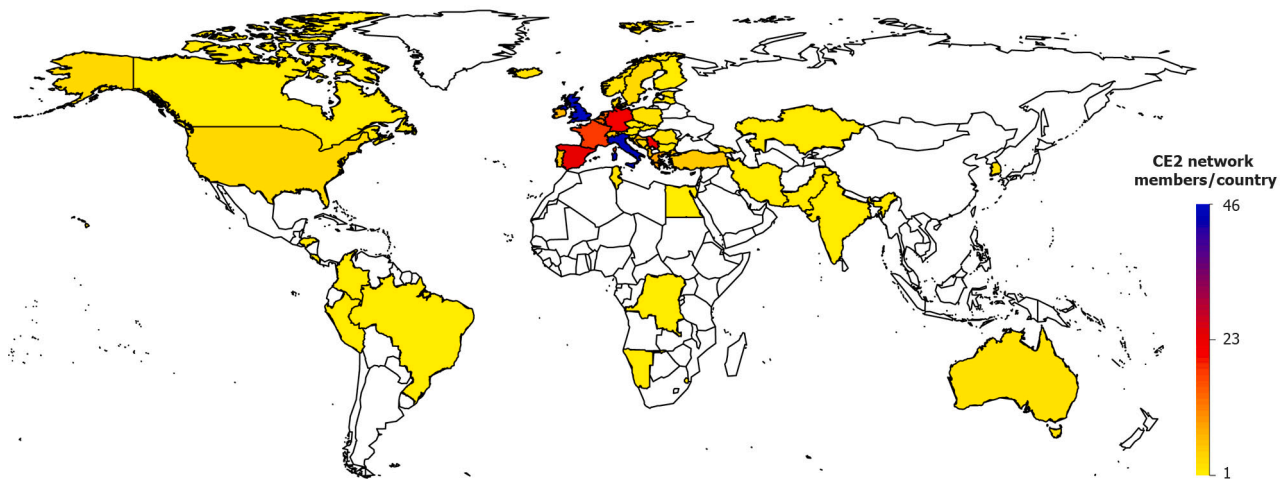


Fig. 4. Number of members per country in the Climateurope2 network as of August 2024 (number of members = 248).

(Fig. 5).

1. Sustainable future: The standardisation of climate services supports evidence-based resilience to climate impacts, green investments, and transformation to a sustainable future.

Criteria supporting the quality of climate services or how they may be fit for purpose need more guidance, regulation and agreed-upon legitimate standards. Standards, quality assurance, and certification schemes have the potential to enhance the demonstrable quality of climate services and raise the bar in the climate services market. Lessons harvested by Climateurope2 can catalyse the dialogue to formulate requirements to be considered in the standardisation of climate services.

2. Climate services components: Breaking down climate services into interrelated components enables the assessment of their quality, efficiency, and effectiveness, and the identification of what should not be standardised.

Given the variety and complexity of climate services and their fluid boundaries, breaking down a climate service into a set of interrelated components is useful. The components identified by Climateurope2 are 1) the decision context, 2) the ecosystem of actors and co-creation processes involved in co-producing, evaluating, and taking up climate services, 3) knowledge systems of different types, and the related selection, evaluation, and translation processes, and 4) the delivery mode and its evaluation.

3. Climate services governance: Climate services can be governed through both formal standardisation processes and alternative institutional mechanisms.

There is no set of guidelines or standards regulating climate services and the current landscape needs to be both more diverse and cohesive. Climate services can benefit from a suite of design or technical standards that benchmark a minimum set of quality criteria for structural specifications (such as data provenance), performance standards setting outcome specifications (such as salience criteria), and procedural standards setting specifications for processes (such as co-production processes). Some components of climate services may not be fully suitable nor require formal standardisation. In those cases, alternative forms of governance and institutional mechanisms can guide their suitability and quality.

4. Benchmarking: Climate services shall demonstrate to be user-focused, science-based, transparent, collaborative, timely, accessible, sustainable, and equitable.

Although there is no single set of quality and usability criteria for the totality of climate services, collecting existing scientific and technical knowledge and evidence from empirical studies for the different components enables identification of key requirements. Climate services fitness for purpose also depends on the interaction and interoperability across different types of knowledge and experiences. A wide variety of stakeholder groups with different roles, interests and goals should be adequately involved in the identification of the climate services value chain in a balanced and democratic manner.

5. Multiple competences: Climate services fitness for purpose requires multidisciplinary, transdisciplinary, and multi-faceted competencies, including domain knowledge.

All decision contexts that require climate services, including contexts in which the climate information is produced, the decision to which it applies, and its local, sectoral or regulatory context, are important conditions for successful services. These conditions can influence the outcome and impact of a climate service and thus, also its quality, efficiency and salience for the decision at hand. Transdisciplinary approaches integrating scientific knowledge with sectoral and domain expertise are critical to take into account local specificities, cultural and normative contexts.

6. Data and information: Climate data-related guidance is available, although often incomplete and driven by providers rather than users.

Communities working with meteorological, hydrological, and climate data often follow broadly accepted conventions for requirements, quality criteria, and technical documentation. However, key challenges remain for data-related aspects, such as data provenance, traceability of derived indicators, data interoperability, curation, and exploitation scenarios. In addition, the diversity of standards and conventions, combined with the importance of integrating climate data with non-climate data relevant to different decision contexts, remains a challenge. Merging multiple knowledge systems and giving equal weight to user's needs during co-production processes is urgently needed.

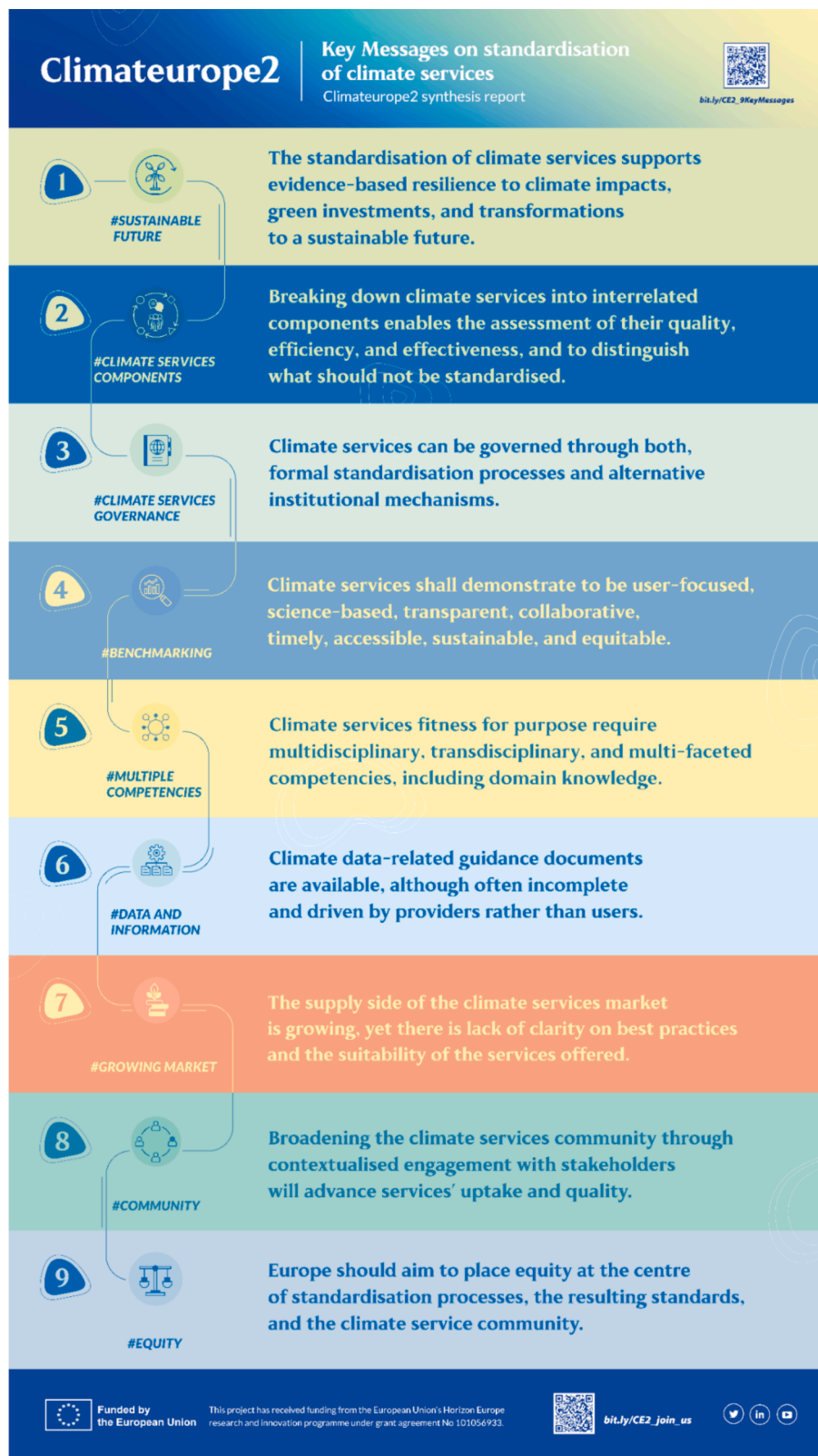


Fig. 5. Key messages on standardisation of climate services.

7. Growing market: The supply side of the climate services market is growing, yet there is lack of clarity on best practices and the suitability of the services offered.

The climate services market has been so far dominated by public

providers who have played a key role in giving access to public climate datasets. There is an increasing number of private climate service providers, who aim to translate climate data into information to satisfy both public and business needs. Although the value of climate services (economic, social, cultural) is still poorly understood, it appears that

market success is built on an understanding of decision-making contexts in priority sectors and on localising the service provision (e.g., to assess health risks or for financial disclosures). Potential innovative climate service business models need further study, as not all (partly publicly funded) innovations have reached the market. A taxonomy capturing success factors of climate services and their components will help identify standardisation opportunities.

8. Community: Broadening the climate services community through contextualised engagement with stakeholders will advance the services uptake and quality.

The climate services community that has so far engaged with Climateurope2 consists primarily of research-focused participants. This may be limiting as there is the potential to miss out on insights from the private sector and other climate service professionals, as well as the wider climate service user community, whether in public or private domains. Creating a tighter knit community will help advance knowledge sharing and open ways to benchmark climate services. There will be no one size fits all: for example, engagement with the private sector will benefit from a sectoral approach. New creative engagement and communication strategies, including the use of artistic practices, need to be considered in reaching out to underrepresented stakeholders. Engagement needs to be respectful and mindful of inclusiveness and carbon emissions.

9. Equity: Europe should aim to place equity of the climate services community at the centre of the standardisation processes, the resulting standards, and the climate services community.

Placing equity at the centre of climate services governance is a choice Europe can make to avoid economic interests to dominate the development and provision of quality-assured climate services. Ensuring an equitable power balance is an ethical choice. At the same time, equity also has an efficiency value. Users tend to have more trust in a climate service to which they have contributed and over which they feel ownership. Standardisation processes need to enshrine all types of mechanisms that ensure equity, empowering stakeholders with different capabilities and accessibility constraints to engage with the process.

#### 4. Summary and next steps

Climate services are an essential element to support climate-sensitive decision making to adapt to both climate change and variability and mitigate the sources of anthropogenic climate change, taking into account the values and contexts of those involved. Climate services are unregulated, resulting in either duplication or underutilisation of the options offered by the growing market. Best practices, guidance, and standards should be identified and analysed to develop standards for climate services. Standards should ensure the credibility, legitimacy, and saliency, i.e. the multiple facets of quality, of climate services.

The Climateurope2 project tries to address this challenge by supporting an equitable and diverse community of climate services with whom recommendations for the standardisation of climate services are being worked out. The project goals are 1) the identification of the elements of climate services that are suitable and mature enough to be considered for standardisation and, when maturity is not reached, for the formulation of guidance, 2) the creation of a climate services network from the fragmented community of practice to support the definition of standardisation criteria through a number of engagement and harvesting activities, and 3) the enhancement of the value and uptake of quality-assured climate services for adaptation, disaster risk reduction, climate risk reporting, and mitigation purposes.

Four components of climate services have been identified to facilitate the analysis and support standardisation efforts. A number of recommendations are being shared with relevant standardisation bodies and

actors as well as with climate services providers. As a first result, nine key messages summarise the latest analysis of the susceptibility for the climate services standardisation. The network is continuously expanded both in Europe and beyond with network members from both the public and private sectors to identify sets of good practices and bad experiences. A detailed mapping of climate services research projects and initiatives is used to proactively identify relevant actors.

Climateurope2 will continue maturing the basis for the development of standards for climate services and additional alternative forms of governance for those aspects not suited for standardisation. The project will hand over a roadmap and a set of recommendations for standardisation to the bodies in charge of developing global, European and national norms that can lead to quality-assured climate services.

#### CRedit authorship contribution statement

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#### Declaration of competing interest

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.

#### Data availability

Data will be made available on request.

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