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Structuring climate service user groups for capacity building: A European Delphi-based approach

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ABSTRACT

Defining and categorizing users within climate services is essential for effective capacity building, yet existing classifications remain ambiguous, particularly regarding their roles in collaborative processes. While the literature commonly categorizes users based on their roles in the production chain—from data providers to end-users— there is a need for a more nuanced understanding of these roles, particularly in relation to the knowledge and skills required for capacity building. This study aims to systematically identify and distinguish different target groups within climate services and identify the specific competencies required for effective participation. Using the Delphi method, we engaged a panel of expert trainers from CS capacity-building programs in three rounds of questionnaires. These questionnaires were designed to explore and refine their understanding of key target groups and the knowledge and skills required for each. Additionally, we assessed the trainers' confidence levels in their evaluations of these aspects. Our findings establish a consensus on four primary target groups—Producers, Intermediaries, Enablers, and Reach-Out—each encompassing distinct sub-groups. Despite some overlap, the fourteen identified sub-groups possess unique knowledge and skills essential for the collaborative climate services. The results underscore the diversity of target groups in the climate production chain and highlight the necessity for tailored capacity building programs to address their specific needs. By enhancing the understanding of target audiences, climate services training initiatives can more effectively support the development of relevant competencies, ultimately strengthening the collaboration needed for climate services.

1. Introduction

The term "user" is central to tailored climate services, yet its interpretation remains both contested and complex (Findlater et al., 2021; Hewitt et al., 2012; Weichselgartner and Arheimer, 2019; Wilby and Lu, 2022). While "users" are understood as individuals or entities that utilize climate-related information, the specifics of their engagement with and application of such data are often ambiguous (Skelton et al., 2019). More than simply information consumers, users encompass a broad range of actors involved in the production, translation, and application of climate services (WMO, 2017). The literature typically categorizes users into three main categories based on their roles in the climate information production chain: providers, Intermediaries, and end-users. Providers generate and develop raw numerical, observational outputs by numerical models, meanwhile Intermediaries function as bridges between providers and end-users by providing information that is processed, analyzed, or contextualized to another user in the climate production chain or actionable information to the end-users (Findlater et al., 2021; Hewitt et al., 2012). Despite these classifications, this tripartite structure oversimplifies the diversity of roles and interactions across multiple sectors and governance scales (Weichselgartner and Arheimer, 2019). A more granular understanding of users is needed to tailor capacity-building initiatives effectively and to foster the collaborative nature of climate services.

1.1. The Consequences of inadequate capacity building in climate services

A lack of targeted capacity-building weakens the entire climate services value chain, affecting not only end-users but also Providers, Intermediaries, and decision-makers. Without sufficient capacity,

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providers may generate scientifically robust but inaccessible climate data, Intermediaries may struggle to translate complex information into actionable insights, and decision-makers may misinterpret or underutilize climate services in policy and planning (Kirchhoff et al., 2013; Lemos et al., 2012; Vaughan and Dessai, 2014). These gaps can lead to poor adaptation decisions, ineffective disaster risk management, and reduced trust in climate information. For example, inadequate training in uncertainty communication has led to the misinterpretation of probabilistic forecasts, while weak integration of climate information in infrastructure planning has increased vulnerability to extreme events (Basher et al., 2006; Hansen et al., 2011).

When actors across the climate services ecosystem lack a shared understanding of data interpretation, uncertainty, and decision-support tools, the value chain becomes fragmented, reducing the effectiveness of climate adaptation efforts (Briley et al., 2015). In sectors such as finance and energy, limited capacity to integrate climate projections into risk models has resulted in mispriced risks and ineffective investment strategies (Surminski and Thieken, 2017). Strengthening capacity across all levels—not just among end-users but also within climate data production and intermediary roles—is essential for ensuring climate services are both scientifically rigorous and decision-relevant, ultimately enhancing their societal impact.

1.2. Existing Limitations in climate services Capacity-Building efforts

Despite its importance, capacity-building literature in climate services remains limited and often focuses on Producers and Intermediaries, with an emphasis on one side: improving their technical ability to generate and analyze climate data, or improve end-users' capacities to understand climate information (del Pozo et al., 2022; Dexter and Necco, 1998; WMO, 2018). This narrow dual focus neglects the training for collaboration among actors within the value chain, who ultimately integrate climate services into real-world applications to end-users (del Pozo et al., 2022; Kirchhoff et al., 2013). If these actors lack the knowledge and skills to critically assess and apply climate information within collaborative processes, even well-developed climate services may fail to influence adaptation and mitigation decisions (Cash et al., 2003; del Pozo et al., 2023; Lemos and Morehouse, 2005). Furthermore, training programs that do not align with users' prior knowledge and contextual needs may lead to disengagement and ineffective learning (Biggs, 2003; Fink, 2013).

1.3. Advancing a structured approach to capacity building

In response to this gap, previous research from the C3S User Learning Services (ULS) emphasized the need for a more refined categorization of climate service users to inform targeted capacity-building efforts (del Pozo et al., 2022). By the end of the C3S ULS, an initial classification of four primary user groups—Producers, Intermediaries, Outreach, and Discerning users—along with eleven sub-groups was proposed (Dankers, 2024). These categories emerged from a combination of a literature review, interviews with course designers, and the analysis of user personas employed within the C3S (ECMWF, 2024). However, this initial classification primarily reflected course designers' perspectives rather than a broader expert consensus. As a result, the specific knowledge and skills associated with each group remained unclear, and many trainers reported uncertainty regarding distinctions between sub-groups.

1.4. Study Objectives

This study builds upon the preliminary C3S ULS classification and aims to refine the identification of target groups and sub-groups for capacity building in climate services. Specifically, we seek to validate and distinguish these groups through expert consensus, defining their key knowledge and skills while assessing confidence levels associated with these categorizations. To achieve this, we employed a Delphi study, systematically engaging a panel of climate service trainers and capacity-building experts in an iterative process of evaluation and refinement. Our study focuses on three key research questions:

What are the key target groups and sub-groups relevant for climate services capacity building?
What specific knowledge and skills are required for each target group and sub-group?
To what extent do trainers and experts express confidence in these group definitions, and what are the sources of this confidence?

By clarifying these distinctions, our research contributes to the development of a structured approach for designing targeted capacity-building programs, ensuring that training efforts are aligned with the specific roles, expertise, and learning needs of diverse climate service actors. Ultimately, addressing capacity-building gaps can enhance the production, dissemination, and use of climate services, supporting more informed decision-making and improved climate resilience.

2. Method

2.1. Initial target groups and sub-groups from user learning services

The User Learning Services (ULS) program, part of the Copernicus Climate Change Service (C3S), operated from 2018 to 2021 under the European Centre for Medium-Range Weather Forecasts (ECMWF). It delivered twenty-nine training courses across 33 European countries, aiming to equip participants with the skills needed for effective climate service design. These courses attracted a diverse group of learners, including scientists, policy-makers, and citizens.

A follow-up C3S service contract on User Intelligence, initiated in 2023, required a report (not publicly available) that introduced a new user categorization (Ref: C3S2_M152c.2.1.2_202401_New User Characterization Categories). The report, presented by Dankers (2024) used a mixed-methods approach including a narrative review, interviews with two course designers from ULS and the document analysis of personas used within ECMWF. The narrative review on users provided an overview of the current state of user categorization in climate services and climate sciences. Narrative reviews are more flexible, allowing authors to explore themes, concepts, and trends in the literature without adhering to a strict methodological framework (Green et al., 2006). The interviews with course designers aimed to capture their insights on target groups during the development of C3S, while document analysis focused on identifying user personas within ECMWF related to capacity building, communication, and user requirements.

The report identified four target groups—Producers, Intermediaries, Discerning and Outreach—along with seven sub-groups (see Annex 1). End-users were excluded from the analysis, as the focus was on users within the climate production chain. Results from both Producers and Intermediaries showed consistency across different methods. Additionally, two new groups were identified through interviews and document analysis. These groups, though not direct users of climate information, were involved in the development and implementation of climate services. However, the report also concluded that further assessment and understanding of these groups were essential to ensure accurate representation. Therefore, these target groups and sub-groups served as the foundation for this current validation study.

2.2. Expert panel

The C3S ULS courses were developed in close collaboration with climate experts and course designers from the contracted service (project partners), as well as 1–2 local trainers from each country. Local trainers were selected through an open call to become C3S trainers, bringing a diverse range of backgrounds and expertise, typically spanning consultants and researchers across various natural science disciplines. These trainers represented 33 European countries. Further details on the geographical distribution or specific expertise of the trainers are withheld to maintain anonymity in this study. Additionally, ECMWF representatives from both the C3S User Learning Service and User Intelligence contracts were invited to participate in the study. From the 46 invitations – 34 local trainers, 8 climate experts, 2 course designers, and 2 representatives from ECMWF- 27 responded positively. In this study, the term “experts” encompasses local trainers, experts from the contracted service, and ECMWF representatives.

2.3. Delphi method and survey development

The Delphi method was chosen to facilitate iterative expert engagement and consensus-building on defining target groups and sub-groups in climate services. This aligns with participatory approaches in co-production research, which emphasize iterative knowledge exchange and stakeholder involvement to ensure that diverse perspectives shape decision-making (Norström et al., 2020).A Delphi study involves multiple rounds of anonymous discussions, where a facilitator gathers and shares expert opinions, including response statistics, to achieve consensus (Dalkey and Helmer, 1962; Rowe and Wright, 2001). The number of rounds varies depending on the study’s goals and the complexity of the issues, with three rounds commonly used to generate a stable group opinion (Rowe and Wright, 2001). This study was structured around three survey rounds involving expert panels.

We combined the Delphi method with a member-checking approach, also known as a validation method. In this approach, data and results were returned to participants for accuracy and resonance with their experiences (Birt et al., 2016). The integration of the Delphi approach with member checking enhances the credibility and legitimacy of the results, encouraging participants to reflect on their opinions considering the anonymized feedback from others, aiming for collective consensus.

The first survey aimed to gather a comprehensive assessment of target groups and sub-groups by evaluating the extent of experts’ agreement with the provided definitions (Annex 2). Experts rated their agreement on a 10-point Likert scale, ranging from 0 (totally disagree) to 10 (totally agree). If a rating of six or below was given, respondents were prompted to provide feedback and suggest improvements. Additionally, they could indicate if any sub-groups were missing at the end of each section. Categories within both target group and sub-groups that received 80 % or less agreement (see Table 1) were revisited in the second survey for further discussion and feedback.

The second survey sought to further refine the definitions of target groups and sub-groups and obtain a more specific understanding of their knowledge and skills. Experts were again asked to rate the definitions of target groups and sub-groups that had received an average agreement below 80 %, as well as any new sub-groups identified in the previous round. This survey was accompanied by a summary of the ratings and explanations provided by all trainers for each target group and sub-group (see additional material). If a respondent rated their agreement as six or lower, a follow-up question prompted them to explain their rating and suggest improvements. In the last section, experts reviewed a set of knowledge and skills per sub-group, selecting elements they disagreed with or adding any that they felt were missing, which they believed represented the respective sub-group. When specific knowledge and/or skills elements were selected, an open-ended question appeared, allowing respondents to provide justification or suggestions for improvements.

The final survey aimed to assess the extent of experts’ agreement with the aggregated results from all target group and sub-group definitions, as well as the knowledge and skills identified in the first two rounds. Experts rated their agreement on a 0–10 scale regarding the definitions, knowledge, and skills. In this round, respondents could provide additional suggestions and improvements regardless of their agreement ratings.

The final survey aimed to assess respondents’ confidence levels and sources regarding their knowledge of the discussed groups and sub-groups. Participants rated their confidence on a scale from 0 (not confident at all) to 10 (totally confident) and identified the sources of their confidence, which included personal and professional experiences, insights from the ULS, assumptions, or other factors. This assessment not only provided insights into the validity of the obtained results but also highlights which groups and sub-groups exhibited lower confidence based on assumptions and may benefit from further research.

Three online surveys were created using Qualtrics software (Qualtrics, Provo, UT), with the questions written in plain English to help experts overcome any language barriers (Belton et al., 2019). The surveys were pre-tested with five experts in different fields within environmental sciences who did not participate in this study. Through cognitive interviews, we sought to understand respondents’ comprehension, decision-making and response processes while completing the survey. This approach allowed us to identify potential improvements and reduce response errors (Willis, 2005).

Table 1
Agreements (right) and confidence (left) thresholds to evaluate consensus applied in the study.

	Agreement level (0–10) Individual question	Percentage Agreement (%) Data Analysis	Confidence level (0–10)	
Strongly Disagree	≤5	≤7	Individual question	
Disagree	≤6	≤80	<6	Low
Neutral agree or disagree	>6–7	70–80	7–8	Medium
Agree	>7–8	80–90	≥8	High
Strongly Agree	≥8	≥90		

2.4. Survey Procedure

The surveys were implemented between January and March 2024, with trainers given two weeks to respond to each survey (Fig. 1). After one week, a reminder was sent to encourage completion, followed by a personal “last call” email sent one day before the deadline. Repeated reminders can help achieve a higher response rate, and a personalized approach can enhance participants’ willingness to participate (Belton et al., 2019).

The response rates for the subsequent survey rounds were n = 27, n = 23, and n = 17, respectively. Acceptable response rates for online surveys in Delphi research are not standardized (Mahajan et al., 1976). Meta-analyses using online surveys, found various response rates, ranging from averages of 30–44 % (Burgard et al., 2020; Diamond et al., 2014). Given that experts in Delphi studies participate in multiple rounds, the response rate of around 63 % of trainers invited in the first survey can be considered more than acceptable.

2.5. Survey analysis

Both quantitative and qualitative analyses were conducted on the survey responses. The degree of consensus among participants regarding specific statements or propositions was quantified, measuring levels of agreement or disagreement (Toni Lange, 2020). The analysis examined the percentage of agreement among experts across defined target groups and sub-groups, including assessments of knowledge and skills. While many Delphi studies do not specify a threshold percentage for consensus (Barrios et al., 2021), consensus in the literature is typically reported to range from 50 % to 97 %. In this study, we applied a threshold of 80 %, placing it at the higher end of the accepted range of 70–80 % (Diamond et al., 2014; Foth et al., 2016).

Confidence levels, rated on a scale from 0 to 10, were categorized

Fig. 1. Research design used in this study using Delphi method to evaluate target groups and sub-groups.

into three groups: low, medium, and high. Table 1 summarizes the thresholds used to evaluate agreement and confidence levels for the analysis.

The qualitative analysis involved a systematic examination of all provided suggestions and comments to identify common themes and derive actionable insights for improving the definitions, knowledge, and skills of target groups or sub-groups. The first author analyzed the data to identify new target groups/sub-groups, revise existing definitions, and suggest additional knowledge and skills. All decisions made by the first author were compiled in a report and made transparent to the other three authors for validation.

The actionable insights were summarized, resulting in revised target

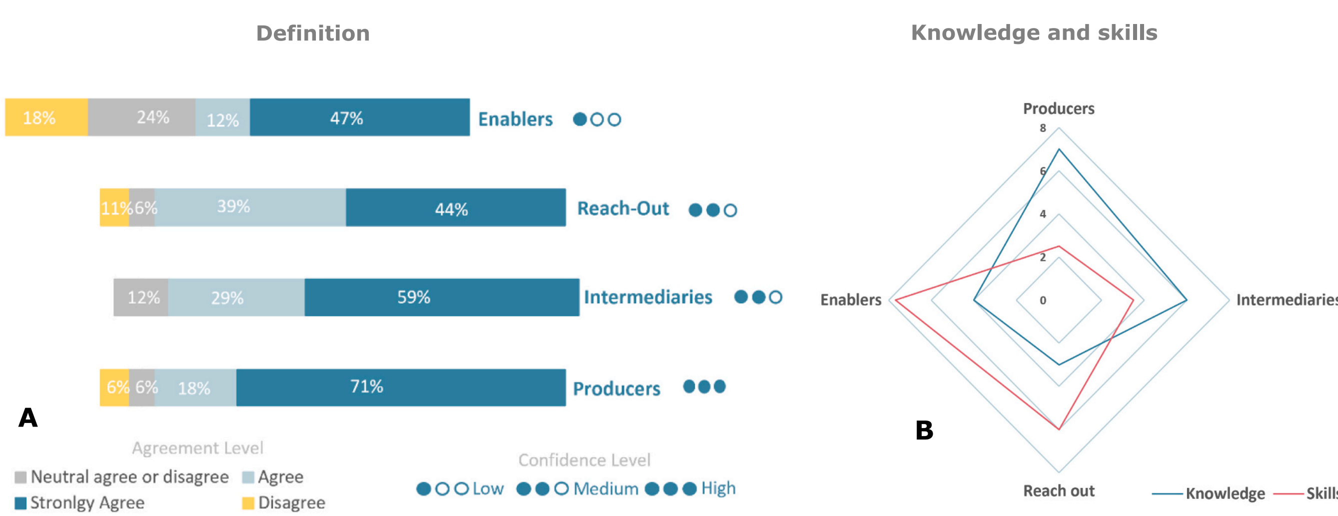

Fig. 2. (A) Agreement on four target groups, and their definitions, identified through Delphi method and the confidence levels and (B) the number of elements within the knowledge and skills for each targeted group.

groups and/or sub-groups. The analysis, including common themes and derived actions, was documented in a report (see additional material). In this study, we focus on the consensus assessment from the final survey.

3. Results

3.1. Target groups

The three rounds of the Delphi approach identified four target groups—Producers, Intermediaries, Reach-Out, and Enablers—within the context of capacity building for climate services, as illustrated in Fig. 2A. The final target groups diverged from the initial classifications, notably changing the name from "Discerning" to "Enablers." All definitions received strong support (above 80 %) from respondents.

The results showed that highest consensus among experts in the Delphi method for Producers (89 %) in their definition: ''Experts in generating climate data by development and/or use of models, creating and refining information about the Earth's climate. Producers, who are often providers of climate services, might play a dual role as both generators and users of data, contributing to the development of models and offering tailored climate services to diverse types of end-users in collaboration with Intermediaries''.

The analysis of knowledge and skills across different Producers sub-groups – Climate modelers, Climatologists and Meteorologists, Sectorial modelers (initially called Environmental professionals) and citizen scientists summarized in Annex – reveal several common characteristics. Respondents identified more knowledge elements for Producers (Fig. 2B) compared with other targeted groups with a broad understanding of climate sciences, with varying levels of in-depth knowledge. Mathematical and statistical skills are essential for data analysis, climate modelling, and interpretation. While each sub-group approaches climate modelling differently, it remains a core competency, emphasizing tools for validation, evaluation, and understanding uncertainty. Additionally, programming and data visualization skills are crucial for analysing complex datasets and effectively communicating findings. Although sector-specific knowledge differentiates sectorial modelers and citizen scientists, there is significant overlap in technical skills and a collective understanding of the need for adaptation and mitigation strategies.

The results showed a high consensus among experts for Intermediaries (88 %) in their definition: ''Experts in refining climate data into useful information, ensuring accessible services that meet the specific needs of decision-makers while connecting Producers with the user community." Respondents highlighted that it is important to consider Intermediaries may not always be follow up by the end user; instead, it could be another intermediary in the value chain. This emphasizes the dynamic nature of the intermediary role in facilitating the climate information flow through the value chain to meet the specific decision-makers' needs. Disagreements regarding Producers and Intermediaries remain low, with some respondents pointing out the natural overlap that might exist between these two target groups.

All Intermediaries – Engineers and infrastructural designers, Data analysis and visualization experts, Sectorial advisors, planners, and managers, and Integrated system specialists – with balanced knowledge and skills demonstrate a strong emphasis on collaboration and communication, as well as the ability to work across various sectors and disciplines. They widely share problem-solving, data analysis, and an understanding of the impact of climate on their respective domains. Through specialized knowledge relevant to each sub-group—such as professional software for engineers, data visualization for analysts, or policy frameworks for sectorial advisors and integrated system specialists—Intermediaries play a crucial role in translating complex climate data into actionable insights. Furthermore, interdisciplinary knowledge and the ability to navigate socio-political and technical constraints are essential for Intermediaries in fostering adaptation and mitigation strategies, positioning them as critical connectors between technical expertise and real-world climate solutions.

The results showed also a high consensus among experts for Reach-Out (88 %) in their definition: ''Experts in dissemination and communication of climate information, encompassing the translation of complex scientific findings into accessible and educational materials for increasing awareness and understanding of climate-related issues of the public or other professionals''. While disagreements remain low, respondents noted that certain wording could be improved. In particular, the term "educational" was highlighted as potentially limiting, as it may imply a focus solely on formal education, as it may imply a focus solely on formal education rather than encompassing informal and professional learning contexts. Additionally, suggestions were made to include phrases like "through various media" at the end of the definition.

The Reach-Out group – Educators, Media and Lobbyists –demonstrates a strong understanding of societal climate challenges and their implications, as well as a grasp of the socio-political context. This group is characterized by a significant emphasis on skills, highlighting the importance of communication and collaboration for effectively conveying climate information and engaging diverse audiences. Both educational roles and specialized media professionals utilize facilitation and cross-boundary skills to address climate issues, employing a variety of tools, from educational methodologies to social media and journalism. Networking skills are also critical within this group, aiding in the creation of partnerships and the dissemination of information. This interconnected skill set fosters a cohesive approach to enhancing climate education and public awareness.

The results showed the lowest consensus among experts for Enblers (59 %) in their definition: "Experts in shaping and optimizing business strategies and policies by making informed and strategic decisions that facilitate and enable businesses, secure funding, and formulate policies, allowing the development and enhancement of climate services for all kind of users of climate information". This group experienced higher disagreement, with 18 % expressing differing views; however, no additional feedback was provided. Only one respondent noted that this group remained vague.

Enablers – Business managers and leaders, policy-makers and politicians – possess a fundamental understanding of societal climate challenges and their implications, characterized by a broader skill set. They each bring expertise in strategic planning and organizational skills, which are crucial for developing and implementing effective policies and business strategies. Communication and collaboration skills are essential across these roles, enabling engagement with stakeholders, influencing public opinion, and driving climate action. Additionally, networking skills are pivotal for building connections and fostering partnerships. Together, these skills support a cohesive approach to addressing climate issues through policy development, business innovation, and political leadership.

Overall, confidence levels indicate strong certainty among the Producers targeted group, followed by medium confidence from Intermediaries and Reach-Out, while Enablers exhibited the lowest confidence levels. High and medium confidence levels were primarily derived from respondents' professional and personal experiences, whereas responses with lower confidence were largely based on personal assumptions. This trend also revealed a greater number of requests for clarification, detail, and additional information in the last survey associated with higher confidence levels, in contrast to the often-limited feedback when confidence levels were lower.

3.2. Producer's sub-groups

Within the target group Producers, the Delphi method resulted into the four sub-groups – Climate modelers, Climatologists and Meteorologists, Sectorial modelers (initially called Environmental professionals) and citizen scientists – with large agreement on their definitions as shown in Fig. 3.

The results showed a high consensus among experts for Climate modelers (88 %) on its definition: "Experts in

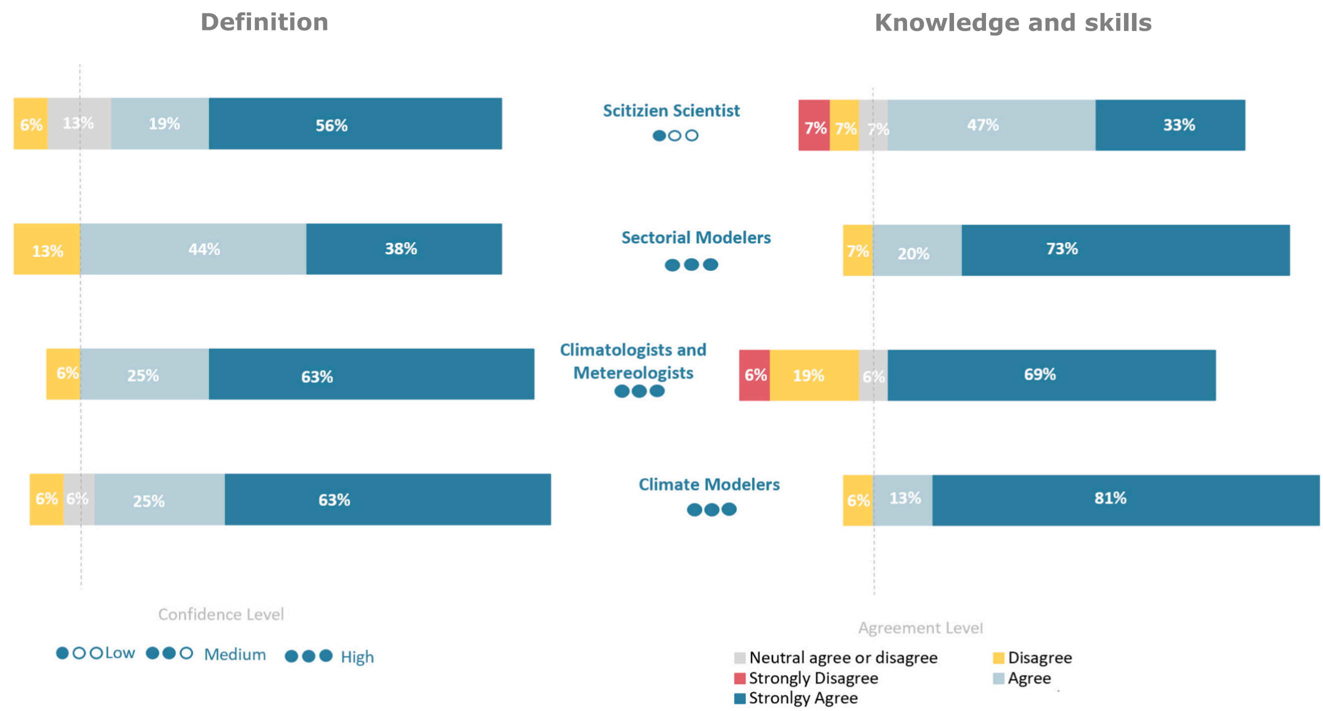

Fig. 3. Agreement on definition and confidence levels and on knowledge and skills for the sub-groups of Producers.

the development and utilization of climate models. Some specialize in parameterization and refining models, simulating specific aspects or processes of the Earth's climate system. Others, work with model information without delving into parameterization intricacies. Climate modelers go beyond predicting future climates. They also generate various climate data types, including information on past conditions and downscaled regional data". Disagreement pointed towards an additional sub-group of 'climate scientists that "only" use climate models. Respondents also highly agreed (94 %) on climate modelers' expertise based in their distinctive in-depth knowledge of atmospheric and earth system processes, advanced mathematical and statistical skills and skills in using specific climate modelling validation techniques.

The results showed the same high consensus among experts for Climatologists and Meteorologists (88 %) resulting in the definition: " professionals experts in weather and climate, respectively, specializing in the comprehensive understanding of weather and climate data, and information into trends and patterns. Meteorologists focus on studying and predicting short-term weather patterns, translating this knowledge into actionable information for the general public and specific sectors on a day-to-day basis. Climatologists, on the other hand, specialize in the study of long-term climate trends and patterns. Both groups use data to analyze current weather conditions, make forecasts, and conduct climate studies, contributing to a deeper understanding of the broader climatic context for specific regions.".

Climatologists and meteorologists possess a broader understanding of atmospheric and climate processes, weather patterns, and climate trends, with a focus on interpreting climate models and analysing regional and global climate patterns, as well as their impacts on various systems and sectors compared with modelers. 75 % of the respondents showed agreement on the knowledge and skills. A suggestion was given to distinguish between medium-term versus long-term forecasting, that might require a focus on different knowledge and skills.

The results showed the same high consensus among experts for Sectorial modelers (88 %). Respondents, thus agreed, to the following definition: "Experts in development and utilization of (sectorial) models for research and innovation of practical applications within their sector. Some specialize in parameterization and refining models, impact assessments and/or simulating specific aspects or processes of their specific sectorial system. Others, work with model information without delving into parameterization intricacies. It is important to note that sectorial modelers are in the boundary between Producers and Intermediaries as they both leverage climate data alongside sector-specific data to produce new data sets and work with other Intermediaries to produce tailored climate services for specific sectorial user communities". One suggestion that was made was that the definition did not clearly state that sectorial modelers, which may include impact research modelers, also are often users of data from climate modelers.

With high agreement (93 %) among respondents on the knowledge and skills of sectorial modelers, climate modelers stand out for their in-depth technical expertise. They focus on understanding sector-specific impacts of climate change and effectively utilize decision-support tools.

Citizen scientists resulted the lowest agreement from Producers (75 %) resulting in the following definition: "Individuals from the general public actively engaged in scientific research, contributing to data collection, monitoring, and analysis related to climate science through community-based projects. This target group may also serve as potential Reach-out actors, utilizing their involvement in research to disseminate climate knowledge. Citizen Scientists demonstrate proficiency in collecting and utilizing climate data, acquired through their active participation in climate science projects, enhancing their role in contributing valuable insights to climate services". Suggestions for refining the initial definition pointed out that a citizen scientists contribution is beyond "collecting and utilizing climate data". Further feedback on the definition highlighted the citizen scientist double role as both Producer as well as Reach-out within their community.

Citizen scientists are quite different from the others in knowledge and skills because they typically have a basic understanding of climate science, focusing on local environmental issues and data collection methods, rather than advanced technical or sector-specific expertise. Their strengths lie in collaboration, and communication within communities, whereas professionals like climate modelers or meteorologists possess deeper, specialized knowledge in areas such as climate modelling, data analysis, and decision-support tools. Citizen scientists' knowledge and skills are also the less strongly agreed among respondents without further feedback for improvement.

3.3. Intermediary's sub-groups

Four sub-groups under Intermediaries target group – Engineers and infrastructural designers, Data analysis and visualization experts, Sectorial advisors, planners, and managers, and Integrated system specialists – resulted from the Delphi method with an overall agreement both in their definition, knowledge, and skills shown in Fig. 4.

The results showed a high consensus among experts for Engineers and infrastructural designers (80 %) in the definition: "Experts utilizing climate and weather data to design and construct resilient buildings, transportation systems, and other infrastructure, ensuring they can withstand and cope with the impacts of climate change. Their contributions might extend beyond the technical aspects of design to actively participate in policy-making and decision-making processes related to climate change adaptation and mitigation". Further feedback pointed out towards the type of data used towards climate data (statistics) for design, and not weather data. However, another respondent pointed out that this sub-group is, in general, not including the impact of climate change (yet), but increasingly this is considered when relevant.

Knowledge and skills were similarly agreed (80 %) for Engineers and infrastructural designers. This sub-group is distinctly different from other Intermediaries in their knowledge and skills because they focus on applying engineering principles and practices to design and construct resilient infrastructure. Their expertise lies in understanding the technical aspects of construction materials, methods, and the impact of climate and weather on infrastructure.

The results showed a highest consensus among experts for Data analysis and visualization experts (86 %) within the Intermediaries target group. Respondents agreed on the definition: "Experts in translating complex information into understandable patterns and trends and creating informative visuals. While they may not work exclusively with climate data, their contributions enhance the understanding and communication of climate-related information within collaborative contexts." Feedback for improvement stressed that visualisation experts can use or excel in a variety of visualisation techniques like colours, graphs, and maps or infographics and videos for a broader audience.

The results showed a lower consensus (67 %) among experts for knowledge and skills of Data analysis and visualization experts. Data analysts and visualization experts differ from other Intermediaries in their specialized focus on extracting insights from climate data and creating accessible, informative visualizations. Their skills are centred around data analysis methodologies, statistical techniques, and the principles of effective visualization. Respondents provided further feedback to add knowledge on familiarity with statistical techniques, graphical design principles and aesthetics.

Sectorial advisors, planners, and managers had the lowest agreement (60 %) compared to the other sub-groups within Intermediaries on the following definition: "Experts in development and evaluation of management and planning strategies at the local or regional level. This group, which includes government officials, sectorial managers, and planners (e.g. water managers, urban and rural planners, agro-forestry managers, landscape architects, etc.) in a more operational level".

Respondents identified a slightly higher average agreement (73 %) on the knowledge and skills from Sectorial advisors, planners, and managers. The sub-group is distinct from other Intermediaries due to their general expertise in specific sectors like energy, agriculture, water, and health. Their knowledge is centred around the policies, regulations, and socio-political factors that influence (climate adaptation and mitigation strategies) within their sectors. No further feedback or argumentation was given by respondents considering the medium confidence levels.

The results showed a high consensus (80 %) among experts for Integrated system specialists, or a generalist as a respondent suggested, in the definition: "Experts in the socio-political, environmental and/or economical context, including social scientists, policy analysts, consultants and professionals. Proficient in analysing and understanding climate policies, public perceptions, and societal impacts, they guide equitable strategies and engage communities for effective climate action. These specialists collaborate across diverse fields, tailoring information to specific contexts and user needs. While certain specialists

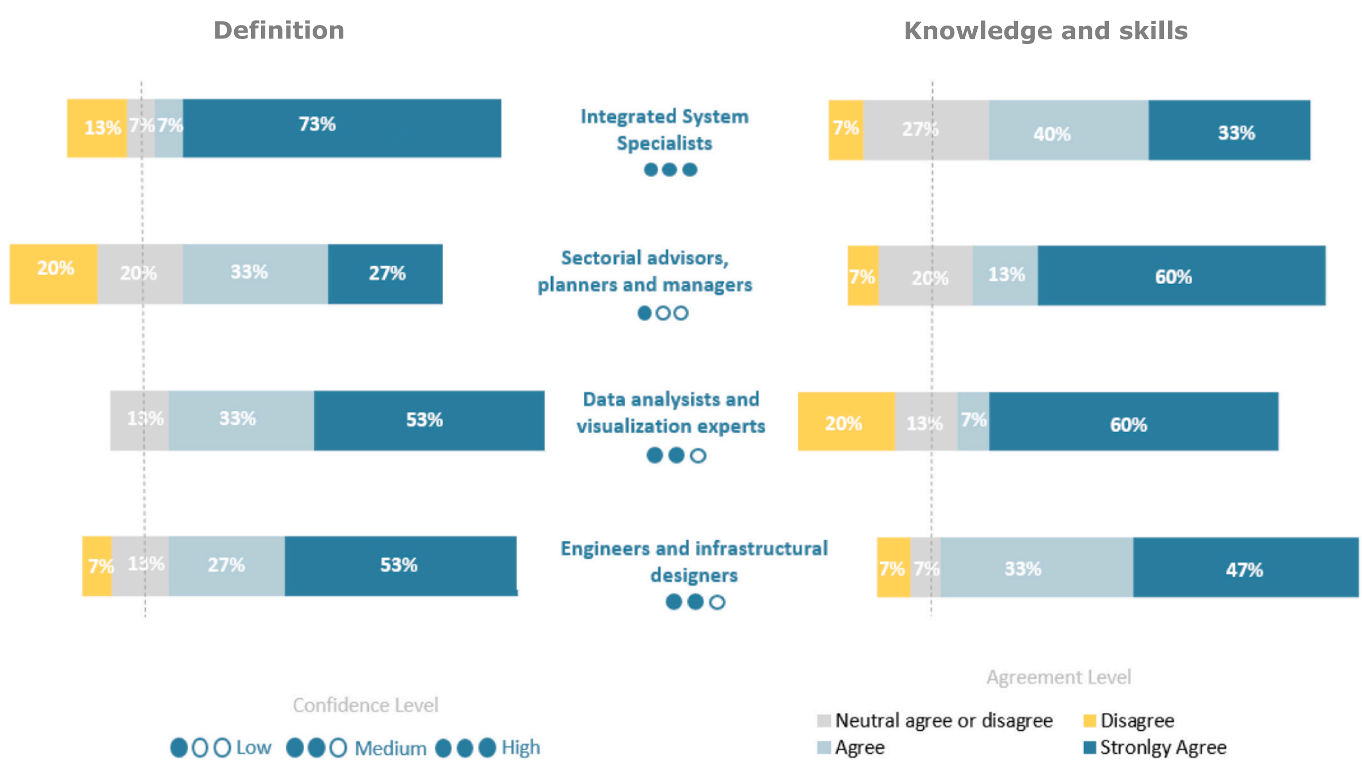

Fig. 4. Agreement on four sub-groups under Producers identified through Delphi method and confidence levels.

actively incorporate climate data, others focus on broader socio-political aspects, utilizing information to contribute insights to adaptation and mitigation planning contexts”.

Respondents algo had an average agreement (73 %) on the Integrated system specialist’s knowledge and skills. This sub-group is unique among Intermediaries because they focus on the socio-political context of climate action, analysing climate policies, public perceptions, and societal impacts. Their expertise lies in navigating the complexities of adaptation and mitigation strategies within “wicked problems” and fostering cross-boundary collaboration across different fields.

3.4. Reach-Out sub-group

Three sub-groups under Reach-Out target group resulted with an overall average agreement both in their definition, knowledge, and skills, with a medium confidence level shown in Fig. 5. Educators had average agreement (74 %) on its definition: “Educators at various levels play a crucial role in utilizing climate data and information for educational Out-Reach. This involves educators teaching and learning about climate science, environmental studies, and the impact of human activities on the climate. Educators guide students in effectively communicating comprehensive climate-related information to broader audiences, which may include fellow students, local communities, or the public”. The main disagreements centred on defining education as more than just knowledge and skills, emphasizing the development of attitudes and cohort building. Educators were seen as not just guides but also as essential in raising awareness and promoting effective climate action.

Educators had a slightly higher agreement on knowledge and kills (80 %). The sub-group is distinct within the Reach-out group as they focus on disseminating climate knowledge and scientific findings for educational purposes. Their expertise encompasses a comprehensive understanding of current climate challenges, educational tools, and methodologies for teaching climate science and environmental studies. Educators were the sub-group with the highest confidence levels based on respondent’s professional experience (80 %).

Media received an average-high agreement (80 %) in the definition: “Communicators of scientific findings to the public, raising awareness about climate-related issues, and facilitating informed public discourse. Through news coverage, documentaries, and other forms of communication, the media helps bridge the gap between scientific research and public understanding, fostering a more informed and engaged society in addressing climate challenges. The dual role of the media in both positive and potentially obstructive ways underscore the complexity of its influence”. With no direct disagreements, main suggestions stem from the broad definition of the term and the debate over its dual role. Two respondents questioned the term’s inclusiveness, suggesting it should focus on professional media by incorporating elements like journalistic principles, such as fact-checking and balanced reporting. Others noted that media convey not only scientific findings but also public opinions and concerns about climate change. Additionally, the dual role of media has been contentious; while it was included in response to earlier disagreements, some felt it only served to broaden the definition further.

Respondents similarly agreed (80 %) for Media’s knowledge and skills. Media expertise includes a basic understanding of societal climate challenges, the socio-political context, and the ability to identify societal and political bottlenecks. Additionally, they possess skills in journalism, social media, data analysis, and visualization.

Lobbyists received in average-low agreement (60 %) on the definition: “individuals, ranging from non-governmental organizations (NGOs) to scientists, professionals, and experts, who seek to influence decision-making by engaging in advocacy, and activism through persuasive narratives of climate change issues. Lobbyists, specializing in influencing a diverse audience, including decision-makers, policymakers, the public, and professionals, play a crucial role in shaping climate discourse, fostering awareness, and collaborating with stakeholders. Recognizing the diverse motivations of lobbyists, it is important to note that their influence can be wielded for the benefit of restricted/

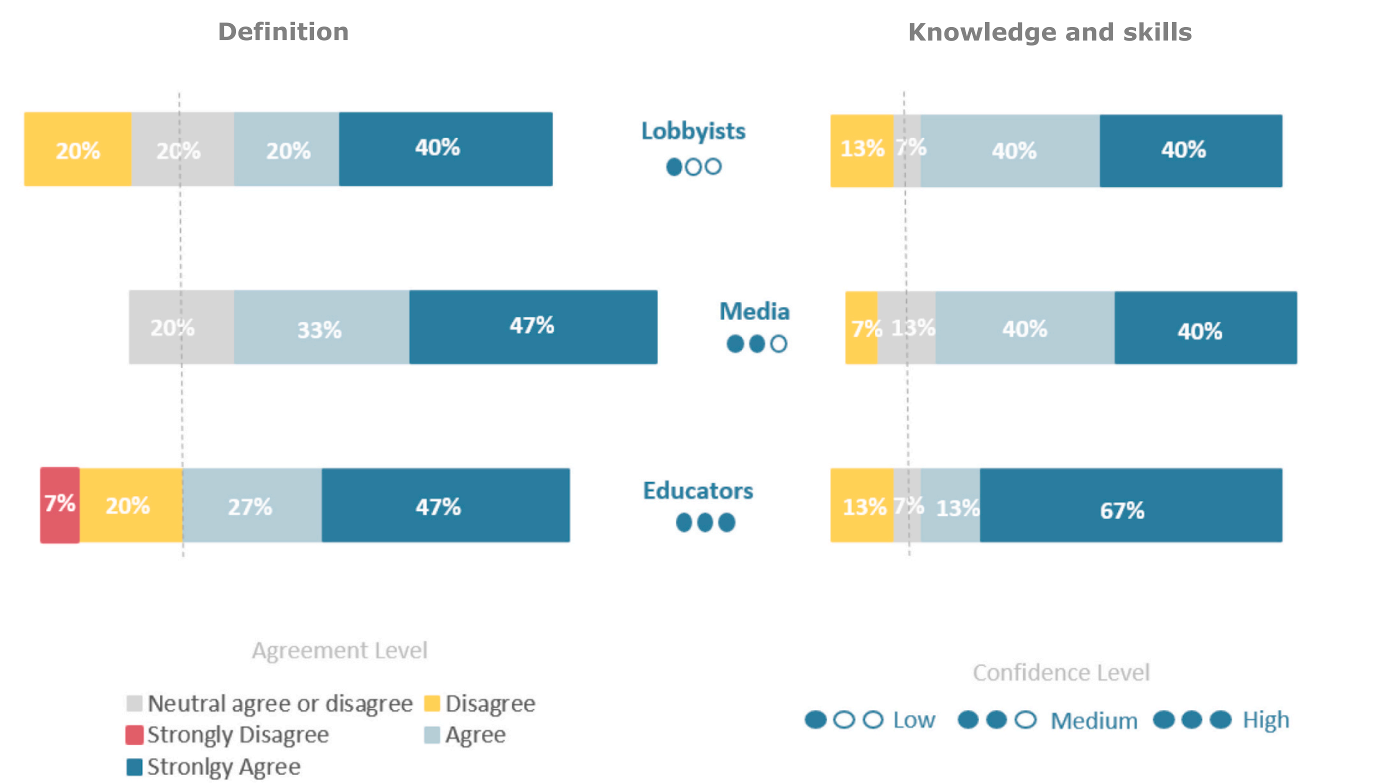

Fig. 5. Agreement on three sub-groups under Reach-Out identified through Delphi method and confidence levels.

private stakeholders or companies, rather than solely for the common interest and public good contexts." Although the indicated disagreement, respondents did not provide no further feedback.

Contrary to the definition agreement levels, the agreement on Knowledge and skills was significantly higher (80 %). Respondents agreed that Lobbyists are distinct within the Reach-out group by advocating for climate-related issues by influencing policy and public opinion. Their expertise includes a basic understanding of weather, climate, and socio-political contexts, along with a solid grasp of societal climate challenges. They excel in networking, collaboration, communication, and organizational skills, which they use to mobilize support, engage in activism, and drive policy changes related to climate adaptation and mitigation.

3.5. Enablers sub-groups

Three sub-groups under Enablers target group resulted with an overall average agreement both in their definition, knowledge, and skills, with a medium confidence level shown in Fig. 6. All three sub-groups shared a low confidence level coming from professional experience (average three sub-groups 60 %) and assumptions (40 %). Policy-makers had an average-low agreement (63 %) with no direct disagreements in their definition: "Experts in designing and implementing specific national and European adaptation and mitigation policies that facilitate the use of information at lower scales and enable subsidy programs. Policy-makers serve as end-users utilizing information to aid decision making and governance development in public affairs, and simultaneously function as Enablers for climate services development. This dual role extends beyond policy decision-making to include all decision makers, encompassing those in non-policy contexts". Respondents provided further feedback in its definition adding other levels such as local, regional, etc. In addition, another respondent highlights that Policy-makers might do not necessarily facilitate the use of information at lower scales.

Policy-makers showed a relatively average agreement (74 %) on their knowledge and skills. This sub-group is distinctive for its deep understanding of adaptation and mitigation policies, as well as the specific domains they regulate, with a particular focus on strategic planning and navigating public debates. Respondents suggested adding knowledge on legal and governance constraints and opportunities, along with networking and persuasion skills.

Business managers and leaders had an average high agreement (81 %) in its definition: "Professionals in leadership and management roles guide organizational change by strategically integrating climate services and information into the business or institutions and/or leveraging climate services as a new business opportunity and commercializing them effectively. Additionally, they collaborate or might be part of private and public funding agencies to secure investments for climate services business developments and public services, fostering financial support and ensuring sustainable growth in the climate services sector". Respondents did not suggest improvements or argumentation for their rating.

Respondents had an average lower agreement (60 %) on the knowledge and skills from Business managers and leaders compared with the definition's agreement. This sub-group is distinctive based on their knowledge in regulatory frameworks and public debates, being able to leverage innovations and identifying and creating new business opportunities, with a strong understanding of finance and economics. Their skills set it is also broader within Enablers target group, including skills incorporating leadership, creativity, and networking. Respondents gave further suggestions for additions such as business management and potential and related knowledge and skills such as negotiation skills and risk management.

Politicians had the lowest agreement (69 %) within Enablers resulting in the definition: "Elected officials who play a pivotal role in decision-making processes at various levels of governance. As end-users, politicians employ information to inform and guide their decisions, contributing to the development and implementation of climate-related policies. Simultaneously, they can function as Enablers or obstacles for climate services by "advocating supporting or hindering the development and utilization of climate data". No further argumentation or feedback was provided by respondents. This sub-group was suggested in round one of the Delphi method.

Politicians' knowledge and skills received an average agreement (74

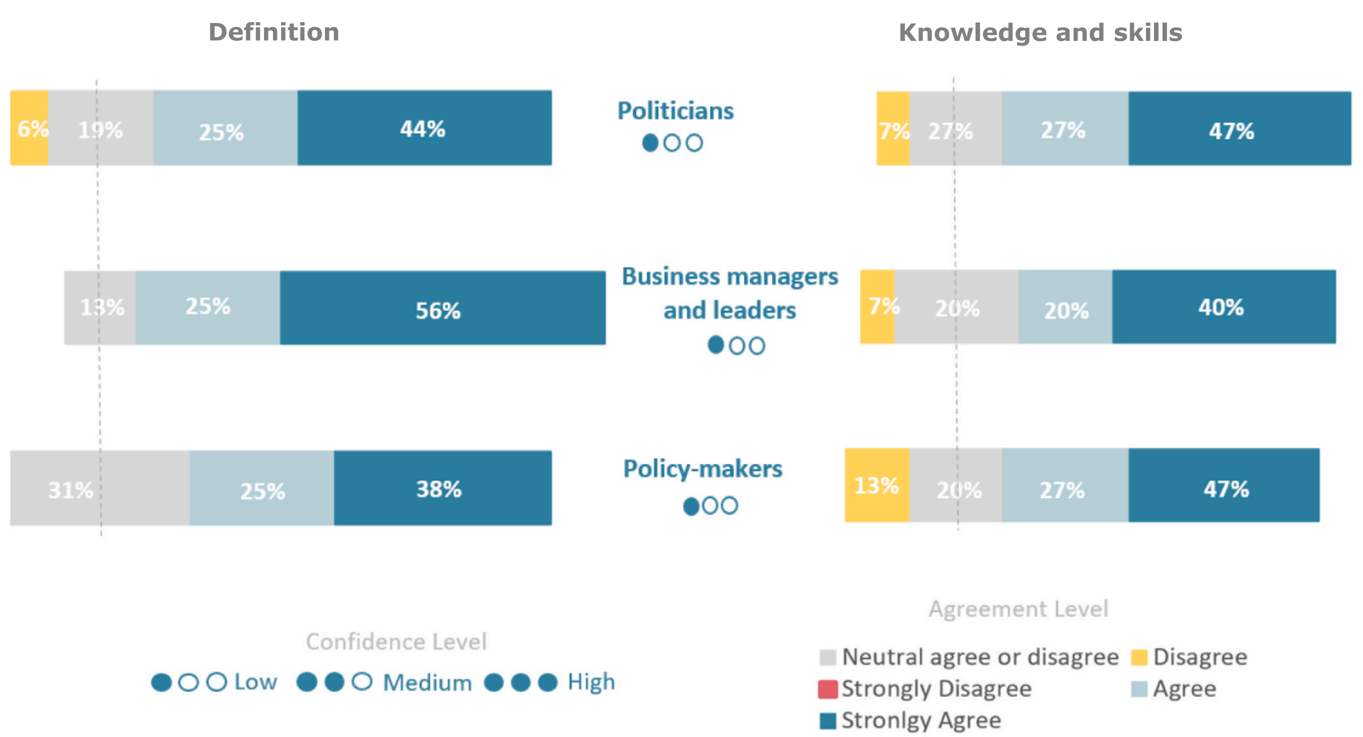

Fig. 6. Agreement on three sub-groups under Enablers identified through Delphi method and confidence levels.

%). The sub-group was distinctive in their understanding the local, national, and international political contexts and the societal climate challenges they must address. Their skills are geared towards leadership, strategic planning, and networking enabling them to influence policy and public opinion effectively within their political spheres.

4. Discussion

Users in climate services have been widely examined in the literature, reflecting their evolving roles in the production, dissemination, and application of climate information. While the World Meteorological Organization (WMO, 2018) describes users in three main categories—end-users, Intermediaries, and Producers—various studies emphasize the heterogeneity of users involved at different stages of a climate service (Dilling and Lemos, 2011; Findlater et al., 2021). As reported in this study, target groups and sub-groups are diverse, operating at different levels, scales, and sectors (Vaughan and Dessai, 2014; Weichselgartner and Arheimer, 2019). However, translating this large complexity into specific target audiences for capacity building requires structuring sub-groups in relation to their knowledge and skills.

Existing literature on capacity building in climate services tends to adopt a binary perspective, distinguishing between end-users who consume climate information and Producers/Intermediaries who generate it (Dexter and Necco, 1998; WMO, 2010). This framing, while foundational, oversimplifies the diversity of actors and their evolving roles in the climate services value chain. Our study addresses this gap by introducing a more refined and actionable categorization based on a Delphi-based consensus, offering a framework that captures the complexity of competencies needed for effective capacity building. Our findings expand this dichotomy by establishing expert consensus on four target groups—Producers, Intermediaries, Reach-Out, and Enablers—encompassing fourteen sub-groups. These groups were defined by their roles in the climate services value chain and their specific knowledge and skills, presenting a more nuanced and actionable framework. This refined classification allows educators and institutions to tailor training initiatives that are both role-specific and competency-based (McKenney and Reeves, 2014).

Our results also challenge traditional assumptions in the literature regarding the separation of technical knowledge and soft skills by showing that these competencies are not mutually exclusive across climate service roles. The findings demonstrate that many sub-groups, such as sectorial modelers or integrated system specialists, combine deep technical expertise with the need for strong communication and collaboration abilities. This integrated skill profile departs from earlier binary distinctions (Cash et al., 2003) and suggests a paradigm shift toward more hybrid capacities within and across user groups. For example, while climatologists and engineers have been assumed to focus primarily on scientific knowledge, and communicators or policy-makers on soft skills (Cash et al., 2003), our findings reveal a more complex picture. Across sub-groups, the emphasis on knowledge versus skills varies depending on context and application. This supports arguments by Dilling and Lemos (2011) and Weichselgartner and Arheimer (2019) that effective climate services require interaction across roles and skillsets, fostering co-learning and co-production. Designing training that promotes this interaction—such as interdisciplinary or co-learning activities—can enhance relevance and responsiveness to stakeholder needs (del Pozo et al., 2022).

In addition, overlapping roles among target groups indicate that communication, dissemination, and collaboration are not limited to Reach-Out actors, but are also fundamental components of roles traditionally seen as technical or scientific. For example, Producers such as climate modelers often engage in interpreting and sharing their findings with policy-makers and other stakeholders, thereby participating in dissemination processes typically attributed to communication specialists. This confirms earlier observations by Dilling and Lemos (2011) and Vaughan and Dessai (2014), who stress the importance of bridging boundaries between information generation and its application. Our results thus highlight the need for integrated training strategies that support both specialized expertise and collaborative competencies across all groups involved in the climate services value chain. For instance, a climate modeler (Producer) may also need to communicate findings to decision-makers, aligning with Dilling and Lemos (2011), who highlight Producers' involvement in dissemination. Similarly, Vaughan and Dessai (2014) emphasize the role of communication in enhancing the usability of climate services. These findings underscore the need to incorporate communication and collaboration training even within technically-focused groups.

The analysis of confidence levels provided further insight into group distinctions, offering both validation and direction for future capacity-building strategies. From a learning theory perspective, confidence influences how individuals engage with content and provide feedback (Schunk and DiBenedetto, 2021). High confidence levels among Producers and Intermediaries were linked to more detailed input and stronger critical engagement, which allowed for meaningful refinement of their definitions and skills. Conversely, lower confidence among Enablers resulted in limited feedback, indicating areas where foundational knowledge is still underdeveloped and further training is necessary. This relationship between confidence and engagement reinforces the importance of assessing confidence not only as a metric of certainty but also as a diagnostic tool for identifying where learning support is most needed. Producers showed the highest confidence, followed by Intermediaries and Reach-Out groups. This likely reflects the experts' familiarity with these roles, given their professional background. Schunk and DiBenedetto (2021) note that higher confidence fosters engagement and deeper reflection, which was also evident in the more extensive feedback received for these groups. Conversely, the Enablers group had the lowest confidence levels and the least feedback, highlighting a knowledge gap and the need for further capacity building for actors involved in policy, strategy, and funding (Wallace, 2021). Addressing this gap is essential to strengthen the institutional uptake of climate services (Castle et al., 2015).

Interestingly, higher confidence was often associated with greater disagreement on fine-grained aspects of definitions. This aligns with Koriat (2013), who argues that confident individuals are more likely to request precision and nuance. Such diversity of opinions, even among experts, is consistent with findings by Newell et al. (2005) and Stirling (2010), which emphasize that professional and experiential diversity enriches collective understanding. In our study, incorporating differing viewpoints was essential for refining group definitions and reaching final consensus.

Nevertheless, the findings are shaped by the European context of the User Learning Services, which was explicitly acknowledged to reflect critically on the scope and generalizability of our results. This focus allows for deeper insights into European institutional dynamics but underscores the need for caution when applying these findings elsewhere. of the User Learning Services, which may limit generalizability. In regions with different institutional capacities, socio-economic conditions, and cultural contexts, the structure and learning needs of target groups may differ. Therefore, future studies should test this classification with stakeholders in Africa, Asia, and Latin America to adapt capacity-building strategies to these diverse realities (Tschakert et al., 2023).

While much of the literature on climate services capacity building has focused on end-users (e.g., farmers, policy-makers, disaster risk managers) (Findlater et al., 2021; Vaughan and Dessai, 2014), our study contributes a novel perspective by targeting actors within the production and transformation chain of climate information. These actors shape the quality and relevance of information ultimately delivered to end-users. Although our study did not directly assess end-user training needs, improving the capabilities of upstream actors can indirectly enhance the usability and uptake of climate services. Future research should examine how these actors collaborate with end-users and codevelop information that meets decision-making needs.

Finally, our findings have institutional implications. Differentiating target groups based on their knowledge and skills provides a structure for more effective internal training programs, aligning with operational roles (Reeves et al., 2010; WMO, 2019). Institutions can use this structure to identify skill gaps, promote interdisciplinary collaboration, and refine decision-making processes. Applying co-production frameworks—such as WISER-FCFA (Carter et al., 2019b)—can enhance stakeholder engagement and facilitate learning across departments. For instance, better-defined intermediary roles can improve internal communication pipelines, while clarity around enabler functions can support strategic planning. Embedding these principles in institutional learning ensures climate services are not only technically robust but also organizationally effective (McClure et al., 2022).

Conclusion

This study established expert consensus on a structured classification of climate service users for capacity building, identifying four main target groups– Producers, Intermediaries, Reach-Out and Enablers – along with fourteen sub-groups that reflect the diversity of roles within the climate value chain. These findings confirm that a one-size-fits-all approach to capacity building is insufficient. Instead, tailored training strategies must equip stakeholders with the necessary competencies to process climate data into usable information, ensuring that climate services are accessible and actionable for different users.

Our results highlight that Producers focus on technical and scientific aspects, such as climate modelling and data analysis, while Intermediaries play a crucial role in translating climate data into actionable insights for various sectors. The Reach-Out group is essential for communicating and disseminating climate information, influencing public awareness and stakeholder engagement. Meanwhile, Enablers drive institutional change through policy, business strategies, and governance structures that shape climate services.

Importantly, this classification provides a structured approach for designing more effective capacity-building programs. Recognizing the overlaps and differences between groups allows for the development of both specialized training pathways and collaborative learning opportunities that enhance cross-sector engagement. Future research should further explore how these target groups interact within institutional settings and assess the long-term impact of capacity-building initiatives on climate service effectiveness.

Implications for practitioners.

This study explores the complex landscape of target groups for tailored capacity-building efforts in climate services based on their distinct roles, knowledge, and skills. By assessing consensus among experts in the C3S User Learning Services, we identified four main target groups—Producers, Intermediaries, Reach-Out, and Enablers—encompassing fourteen sub-groups. The varied roles across the groups and subgroups in the climate production chain—from producing and transforming information to communicating and enabling its use—highlight the need for differentiated capacity-building efforts that address specific learning needs.

Capacity building programs should be tailored to the distinct requirements of each targeted group and sub-group. Course designers, trainers and educators should use participants' roles, prior knowledge and skills to structure learning activities that meet their specific learning goals. Our findings reveal that different groups emphasize different areas, such as technical expertise, policy, or communication skills, among others. By developing targeted capacity-building initiatives that deepen expertise in these specialized areas, educators can ensure learning remains relevant and applicable.

In addition to specialization, fostering collaboration across groups can enhance knowledge exchange and improve integration of climate services. Co-learning experiences that bring together participants from different groups could promote the exchange of diverse perspectives, enriching the overall understanding and integration of knowledge throughout the climate services value chain. This collaborative approach would enhance communication and understanding among targeted groups and sub-groups, potentially driving more effective climate services design.

A dual approach—combining specialized training for distinct groups with interdisciplinary learning opportunities—can enhance capacity-building effectiveness. Whether through deeper, specialized training or cross-group collaboration, these methods can improve the effectiveness of climate services and ensure a more comprehensive approach to addressing the needs of various stakeholders.

Additionally, these findings have implications for institutional capacity-building by informing how organizations can integrate structured learning pathways into their internal processes. Differentiating user roles and skillsets can help institutions develop clearer role definitions, improve internal knowledge transfer, and align training programs with operational needs. Strengthening institutional capacity in this way ensures that climate services are not only scientifically robust but also effectively applied across governance and decision-making structures.

Declaration of Generative AI and AI-assisted technologies in the writing process.

During the preparation of this work, the author(s) used ChatGPT to improve the readability and language of the manuscript. After using this tool, the author(s) reviewed and edited the content as needed and take full responsibility for the content of the published article.

CRediT authorship contribution statement

Maria del Pozo Garcia: Writing – review & editing. **Judith Gulikers:** Writing – review & editing, Supervision, Conceptualization. **Bregje van der Bolt:** Writing – review & editing. **Wouter Smolenaars:** Writing – review & editing, Visualization, Formal analysis. **Estella Oncins:** Writing – review & editing. **Perry den Brok:** Writing – review & editing, Supervision, Conceptualization. **Fulco Ludwig:** Writing – review & editing, Conceptualization.

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.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cliser.2025.100575.

Data availability

The data that has been used is confidential.

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