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From multi-level governance to adoption: co-producing policy recommendations for climate adaptation in seven European regions within an EU-funded project

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European countries are developing ambitious climate adaptation strategies, yet implementation remains fragmented, underfunded and frequently misaligned with multi-level governance capacities. Developed within the Horizon 2020 IMPETUS project, this study presents a multi-method, co-production-oriented approach that connects the assessment of governance, policy and financing barriers with the development of actionable policy recommendations across seven European regions. The approach combined stakeholder mapping and analysis, Theory of Change application, multi-level governance assessment and structured policy mapping with (i) seven regional policy-and-finance workshops, (ii) targeted semi-structured interviews with public-administration representatives and decision-makers from industry and finance, and (iii) a policy-recommendation co-creation session involving regional representatives. The methodology developed supports action-oriented knowledge co-production, cross-regional comparison and the integration of perspectives across the Quintuple Helix, including public authorities, industry and finance stakeholders, academic and research organizations, and civil society, with the natural environment treated as a cross-cutting dimension. The process resulted in 34 co-produced, regionally grounded policy recommendations organized in five areas: governance, policy, funding, legislation, and awareness. Five recurrent implementation barriers were identified across the regions: fragmented governance and unclear responsibilities; limited and uncertain financing; weak integration of adaptation into policy and legislation; insufficient administrative and technical capacity; and uneven stakeholder awareness, participation and ownership. Uptake of co-produced outputs followed a continuum, from stakeholder validation and policy-ready plans to operational use, rather than formal policy adoption. By linking multi-level governance analysis with policy co-production, the study shows how shared and context-specific barriers can be translated into feasible regional implementation pathways. The IMPETUS approach therefore contributes to moving climate adaptation from strategic

commitment toward actionable adoption that is regionally anchored and responsive to different institutional contexts.

KEYWORDS

adaptation finance, climate adaptation, co-production, multi-level governance, policy recommendations, stakeholder engagement

1 Introduction

Climate adaptation has become an increasingly urgent policy priority as climate-related impacts intensify across Europe and globally (World Economic Forum, 2026). Although adaptation strategies have proliferated, their implementation remains a persistent challenge. In Europe, all 32 EEA member countries have adopted national adaptation policies, yet implementation and measurable outcomes remain limited, with persistent gaps in financing, monitoring, cross-border cooperation and the translation of plans into concrete action (European Environment Agency, 2026). The EU Strategy on Adaptation to Climate Change similarly calls for adaptation to become smarter, faster and more systemic in order to progress toward a climate-resilient Europe by 2050 (European Commission, 2021).

A central challenge is therefore no longer only the formulation of adaptation strategies, but their effective implementation across territories and governance levels. Research shows that the existence of adaptation policies does not automatically lead to effective implementation or measurable outcomes (Berrang-Ford et al., 2021; Runhaar et al., 2018). This policy-implementation gap is particularly relevant at regional and local levels, where implementation depends on responsibilities, resources and regulatory frameworks distributed across multiple governance levels (Aguiar et al., 2018; OECD, 2011). Although climate adaptation responses must address context-specific risks, the regional level provides a relevant scale for coordinating actors, resources and policy instruments across municipalities and governance levels. Regional approaches can therefore help bridge locally specific adaptation needs and the broader institutional arrangements required for implementation. Barriers such as fragmented governance, limited financing, insufficient institutional capacity and weak stakeholder coordination can further constrain the integration of adaptation into policy and practice (Biesbroek et al., 2013; Lee et al., 2022).

Addressing this gap requires approaches that connect knowledge about implementation barriers with the actors and institutions responsible for adaptation decisions. Co-production offers one such approach by involving researchers, policymakers, practitioners and other stakeholders in generating knowledge relevant to decision-making (Cash et al., 2003; Dilling and Lemos, 2011). At the regional level, this engagement can help identify implementation constraints, clarify institutional responsibilities and formulate policy responses that reflect specific territorial conditions.

However, while the value of co-production for climate-related decision-making is well-established, less attention has been paid to how different sources of evidence and stakeholder perspectives can be systematically combined to inform policy recommendations addressing regional adaptation barriers (Harvey et al., 2019; Norström et al., 2020). The research gap addressed here therefore concerns the practical application of co-production to connect the identification of implementation barriers with the formulation of context-specific policy recommendations.

Accordingly, this paper focuses on how co-production connects the identification of regional climate adaptation barriers with the formulation of policy recommendations. It addresses the following research question:

How can co-production inform policy recommendations addressing climate adaptation implementation barriers across diverse European regions?

To address this question, the study examines the co-production process developed within the Horizon 2020 IMPETUS project across seven European regions. Combining stakeholder engagement, governance and policy analysis, interviews and participatory workshops, the study examines how identified barriers informed regionally grounded policy recommendations. Its contribution lies in analyzing this connection across different regional contexts, highlighting both shared implementation challenges and context-specific policy responses.

2 Materials and methods

This study took place between 2021 and 2025 within the Horizon 2020 IMPETUS project and adopted a qualitative, co-production analysis research design (Yin, 2018). It aimed to identify and compare the barriers and enabling conditions shaping climate adaptation implementation across seven regions in Europe, and to examine how these informed the co-production of actionable policy recommendations and pathways for institutional uptake.

The investigated regions, hereinafter referred to as IMPETUS Demo Sites (DSs), correspond to different European biogeographical and territorial contexts, including: Continental (Berlin-Brandenburg, Germany), Coastal (Catalonia, Spain), Mediterranean (Attica, Greece), Atlantic (Zeeland and Rijnmond, the Netherlands), Arctic (Troms and Finnmark, Norway), Boreal (Zemgale, Latvia), and Mountains (Valle dei Laghi, Trentino, Italy). The main adaptation focus and the description of each DS is collected in Table 1 below. The unit of analysis was the DS, understood as the regional adaptation-implementation ecosystem

Abbreviations: DS(s), Demo Site(s); GAT, Governance Assessment Tool; IPCC; Intergovernmental Panel on Climate Change; Approach; SME, Small and medium-sized enterprise.

TABLE 1 Regional cases included in the comparative study.

DS	Regional setting	Description	Principal adaptation focus
DS1-Continental	Berlin-Brandenburg, Germany	A metropolitan and surrounding regional system with extensive rivers and lakes, increasing drought and heat pressures, and strong interdependencies in water management between Berlin and Brandenburg. The region combines dense urban areas with agricultural and ecosystem water demands and requires coordination across federal-state and local governance levels.	Water availability, cross-state water governance, modeling and strategic planning
DS2- Coastal	Catalonia, Spain	A densely populated Mediterranean coastal region combining major urban areas, tourism, agriculture, critical infrastructure and environmentally sensitive coastal and delta systems. Competing demands for land and water increase vulnerability to drought, coastal erosion and other climate-related pressures.	Coastal and delta resilience, drought, water management and tourism
DS3-Mediterranean	Attica, Greece	A highly urbanized metropolitan region centered on Athens, together with peri-urban and agricultural areas undergoing rapid land-use change. Population density, pressure on water resources and fragmented responsibilities across authorities create significant challenges for sustainable water and climate management.	Water reuse, sewer mining, urban water planning and digital decision support
DS4-Atlantic	Zeeland and Rijnmond, Netherlands	A low-lying delta and port-industrial region strongly shaped by water, with substantial exposure to flooding and sea-level rise as well as increasing heat and drought risks. The area combines highly developed water-management institutions with major industrial and urban activities.	Flooding, heat stress and regional decision-support systems
DS5-Arctic	Troms and Finnmark, Norway	A sparsely populated Arctic territory characterized by dispersed settlements, extensive infrastructure networks and economic activities including fisheries, aquaculture, tourism and reindeer herding. Communities are increasingly exposed to avalanches, landslides, unstable snow conditions and coastal climate risks.	Marine spatial planning, snow and landslide risk, municipal planning
DS6-Boreal	Zemgale, Latvia	A predominantly agricultural lowland region with an extensive river network and strong dependence on groundwater and land-based economic activities. Intensive agriculture, flood risk and water-quality pressures create important challenges for regional and municipal adaptation planning.	Flood early warning, regional adaptation planning and institutional coordination
DS7-Mountain	Valle dei Laghi, Trentino, Italy	An Alpine valley characterized by abundant water resources, small and dispersed municipalities, and economic activities linked to agriculture, food and wine production, hydropower, forestry and tourism. Rapid climatic change in mountain areas increases pressures on water management, ecosystems and local economic activities.	Integrated water management, agriculture, tourism, insurance and ecosystem

of policies, governance arrangements, financing mechanisms, institutional capacities, adaptation solutions and stakeholders.

Two participant groups contributed to the research and co-production process (Figure 1): core participants, namely IMPETUS consortium partners, and external stakeholders from government and public administration, industry and the economy, academia and knowledge organizations, and civil society, media and culture, identified through stakeholder mapping.

The empirical design combined five complementary components (Figure 2). We first (1) mapped stakeholders using the Quintuple Helix framework (Carayannis et al., 2012) and developed site-specific Theories of Change (Andrews et al., 2023, 2024). We then assessed (2) multi-level governance by applying the Governance Assessment Tool (Van Dam and Munaretto, 2022) to national, regional and local policy documents (see Supplementary material). This assessment was complemented by (3) semi-structured interviews ($n = 28$), comprising 23 regional interviews on multi-level governance barriers and five interviews with industry and finance stakeholders on financing barriers. The interviews were conducted online and coded deductively (Braun and Clarke, 2006).

Next, we gathered (4) 101 policies across the regions coded by territorial scope, policy goal, instrument type, sectoral scope and responsible authority (Bowen, 2009) and discussed the findings with stakeholders in seven regional policy and financing workshops (Table 2). Finally, (5) a co-creation workshop (13 December 2024, 90 min) validated the policy mapping, identified opportunities and barriers in current policies, and formulated recommendations targeting regional and European governance levels. The recommendations were organized through thematic synthesis into five macro-areas: governance, policy, funding, legislation and awareness. Evidence from the components was

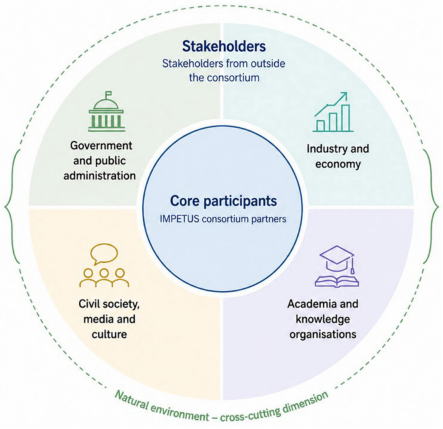


FIGURE 1
Participant structure of the IMPETUS research and co-production process.

triangulated to inform the final recommendations. Further methodological details are provided in Supplementary material.

3 Results

The results address the research question by examining how co-production connected the identification of climate adaptation implementation barriers with the formulation of context-specific policy recommendations across seven European regions. The empirical findings are structured around three interconnected dimensions: (i) the common implementation barriers and their region-specific manifestations; (ii) the contribution of stakeholder engagement and co-creation to translating these barriers into actionable policy recommendations; and (iii) the institutional conditions influencing the potential uptake of co-produced outcomes. Together, these dimensions illustrate how co-production can bridge the gap between identifying regional adaptation challenges and developing policy responses that reflect different governance arrangements, capacities and territorial priorities.

3.1 Cross-regional conditions shaping climate adaptation implementation

The combined analysis of stakeholder perspectives, multi-level governance arrangements, policy frameworks and financing conditions identified five recurrent barriers to climate adaptation implementation: (1) fragmented governance and unclear responsibilities; (2) limited and uncertain financing; (3) weak integration of adaptation into policy and legislation; (4) insufficient administrative and technical capacity; and (5) uneven stakeholder awareness, participation and ownership.

These barriers represented common challenges across the participating regions, although their relative importance and specific manifestations varied according to institutional arrangements, climate risks and territorial characteristics. For example, governance fragmentation was particularly relevant where responsibilities were distributed across administrative levels, while capacity constraints were more pronounced in smaller or geographically dispersed municipalities. Similarly, financing difficulties ranged from dependence on short-term public funding to limited private investment opportunities and uncertain market demand. The barriers also tended to occur together rather than in isolation.

The identification of these shared patterns and regional differences was an important outcome of the co-production process. Stakeholder engagement helped contextualize the barriers, clarify the actors and institutional responsibilities involved, and identify the conditions under which potential policy responses could be implemented. The following subsections summarize the five barriers, focusing on their implications for developing regionally appropriate recommendations.

3.1.1 Fragmented governance and unclear responsibilities

Governance fragmentation emerged as a recurrent challenge across the seven DS, particularly regarding the distribution of responsibilities, coordination between administrative levels and integration of adaptation into existing decision-making processes. The multi-level governance assessment and stakeholder interviews highlighted communication gaps between local, regional, national and European institutions, as well as uncertainty regarding institutional mandates and responsibilities for implementation.

Although these challenges were shared, their expression depended on national and regional governance structures. In particular, stakeholders identified tensions between top-down policy frameworks and the need for flexible, place-based adaptation responses. The long-term nature of adaptation also created difficulties in aligning implementation priorities with shorter political and administrative cycles.

Stakeholder engagement contributed to identifying these coordination gaps and clarifying where stronger institutional cooperation, more explicit responsibilities and improved communication mechanisms were needed. These findings established the basis for recommendations addressing multi-level governance coordination and institutional accountability.

3.1.2 Limited and uncertain financing

Financing constraints were identified across all seven DSs, although their characteristics differed depending on regional institutional capacity, available funding mechanisms and private-sector involvement. Stakeholders frequently reported insufficient or unpredictable financial resources, with adaptation measures often depending on existing public budgets, European funding programs or temporary research projects.

Interviews with industry and finance representatives further revealed barriers to private investment, including uncertain returns, long implementation horizons, difficulties monetizing avoided climate losses and limited market demand. In other words, they characterized adaptation as an emerging and fragmented

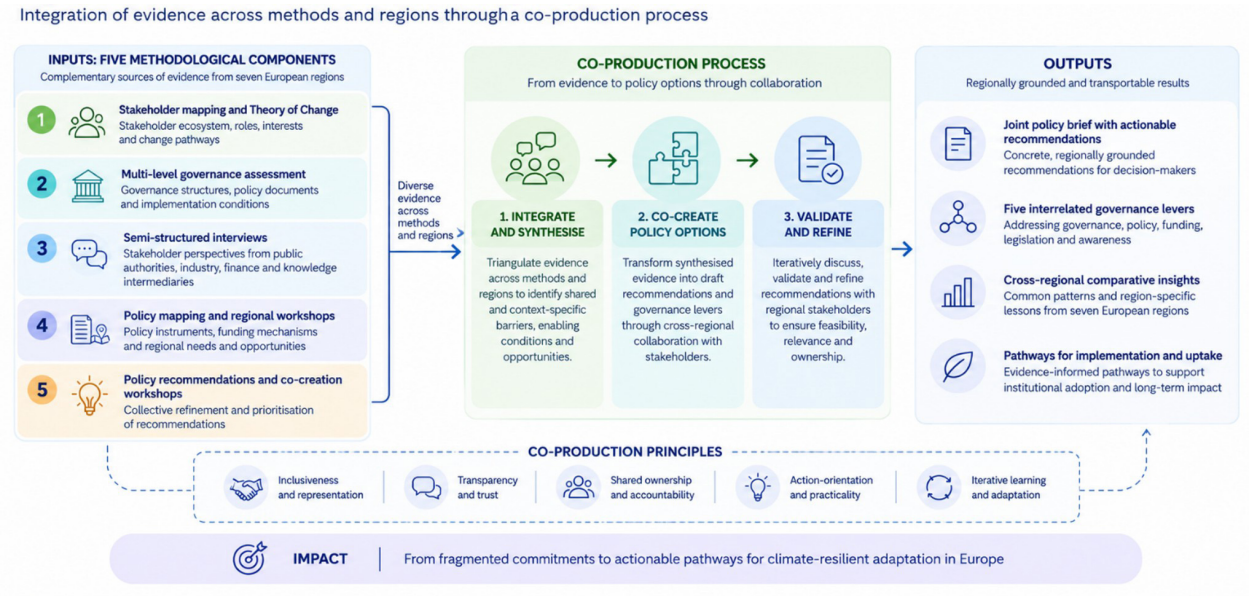


FIGURE 2
Empirical design of the study.

TABLE 2 Description of the IMPETUS participants by DS.

DS	DS1-Continental	DS2-Coastal	DS3-Mediterranean	DS4-Atlantic	DS5-Arctic	DS6-Boreal	DS7-Mountain
Number of IMPETUS professionals	5	7	6	3	7	4	6
Number of IMPETUS organizations	4	5	4	2	2	4	3

investment area. These conditions were particularly challenging for start-ups and small and medium-sized enterprises developing adaptation solutions.

Public-private collaboration consequently emerged as an important market-enabling condition. Public authorities can reduce investment risk through procurement, validation environments, blended finance and regulatory signals, while private stakeholders can contribute technical capacity, market access and investment expertise. Adaptation markets therefore require policy frameworks that create demand, reduce uncertainty and support private participation.

3.1.3 Weak integration of adaptation into policy and legislation

Regarding the policy mapping and analysis, these activities confirmed that climate adaptation is present along all participating regions, but that it is not yet embedded with the same maturity or operational clarity into day-to-day actions as climate mitigation. From the categorization of the 101 policies identified, more than half of them were classified as climate mitigation policies (52%) while 25.5% were classified as climate adaptation policies and 22.5% combined mitigation and adaptation objectives.

The analysis also revealed an imbalance in the types of policy instruments available to support implementation. Regulatory instruments represented the dominant category across the mapped policies, followed by broad framework policies or instruments combining multiple types of intervention. By contrast, economic and fiscal instruments, direct investment in physical infrastructure, research and innovation funding, and informational or non-mandatory instruments appeared less frequently. This result suggests that adaptation implementation across the regions is often supported by legal or strategic frameworks, but less consistently by dedicated financial incentives, market-oriented instruments, investment programs or capacity-building tools. The gap between policy recognition and operational support is therefore not only a question of the number of policies in place, but also of the type of instruments used to translate policy objectives into more concrete actions.

Stakeholder discussions reinforced this finding by highlighting gaps between policy recognition and implementation capacity, including unclear mandates, insufficient financing and limited alignment with sectoral planning. These findings informed recommendations aimed at mainstreaming adaptation into existing policy frameworks while strengthening the instruments needed to support implementation.

3.1.4 Insufficient administrative and technical capacity

Administrative and technical capacity constraints emerged as an additional barrier, particularly among smaller municipalities and local organizations with limited financial resources, specialized personnel and access to technical knowledge. These challenges were more pronounced in geographically dispersed territories and regions facing demographic pressures, where local authorities were often expected to implement adaptation measures without corresponding institutional support.

Stakeholder engagement helped identify where additional technical assistance, capacity-building and cooperation mechanisms could strengthen local implementation capabilities. This highlighted the importance of adapting policy recommendations to the resources and institutional capacities of the actors responsible for their implementation.

3.1.5 Uneven stakeholder awareness, participation and ownership

Stakeholder awareness and participation varied across the DSs, influencing the extent to which adaptation was perceived as a priority and supported by relevant actors. Public authorities generally demonstrated willingness to engage, while broader participation from private-sector organizations, civil society and vulnerable groups remained uneven. Stakeholders also highlighted insufficient attention to social inequalities within existing adaptation policies.

The perceived urgency of adaptation was frequently influenced by recent extreme weather events, while the preventive and long-term nature of many measures made it difficult to sustain political and public attention. These findings highlighted the importance of communication, inclusive participation and stakeholder ownership in supporting adaptation implementation.

Through engagement activities, regional actors contributed to identifying participation gaps and the need for more inclusive decision-making arrangements. These insights informed recommendations addressing awareness-raising, capacity-building and the integration of stakeholder perspectives into adaptation planning.

3.2 From implementation barriers to co-produced policy recommendations

The recommendations generated were developed as direct responses to the barriers described in Section 3.1. As displayed in Figure 3, findings from the different analytical components were consolidated and refined through a cross-regional co-creation process linking implementation problems with proposed actions and expected outcomes.

The contribution of co-production was particularly relevant in connecting the analytical identification of barriers with the practical knowledge of stakeholders operating within different institutional and territorial contexts. Rather than applying uniform policy responses to common challenges, the process enabled regional representatives to contextualize the findings, identify implementation priorities and formulate recommendations reflecting their specific governance arrangements, available resources and adaptation needs.

The process resulted in 34 co-produced regional policy recommendations structured into five main areas: (i) governance, (ii) policy, (iii) funding, (iv) legislation, and (v) awareness.

As shown in Table 3, governance and policy accounted for the largest number of recommendations (10 each), followed by funding (8), legislation (4), and awareness (2). This distribution reflects the prominence of institutional coordination, policy integration and financial enabling conditions among the barriers identified. It also illustrates that the recommendations extended beyond technical adaptation measures to address the institutional and policy conditions necessary for their implementation.

Three interrelated contributions of co-production can be identified from the findings. First, stakeholder participation helped validate and contextualize the barriers emerging from the governance, policy and financing analyses, ensuring that the recommendations responded to implementation challenges recognized by regional actors. Second, the integration of perspectives from different stakeholder groups supported the identification of potential actions, institutional responsibilities and enabling conditions. Third, cross-regional exchange facilitated the identification of common policy priorities while preserving flexibility to address differences in territorial risks, governance structures and institutional capacities.

The importance of this contextualization was particularly evident where regions faced similar adaptation challenges but required different policy responses. For instance, water management represented a shared concern in Berlin-Brandenburg, Catalonia, Attica, and Valle dei Laghi. However, the resulting recommendations addressed different implementation needs, including inter-administrative coordination, drought management, regulatory procedures, technological maturity and ecosystem-based planning. This illustrates how co-production helped translate a common adaptation challenge into differentiated policy priorities, rather than assuming that similar environmental pressures necessarily require identical institutional responses.

A comparable pattern emerged for governance and financing barriers. While the need for stronger coordination, stable resources and institutional capacity was recurrent across regions, the proposed actions reflected different opportunities for implementation. Depending on the regional context, recommendations emphasized strengthening local mandates, improving regulatory alignment, supporting private-sector participation, developing technical capacities or reinforcing stakeholder communication and engagement.

Overall, the findings indicate that the principal contribution of co-production was not simply the generation of recommendations, but the connection of shared implementation barriers with regionally appropriate policy responses. By combining comparative analysis with stakeholder knowledge, the process supported the formulation of recommendations that were sensitive to local priorities and the institutional conditions affecting their potential implementation.

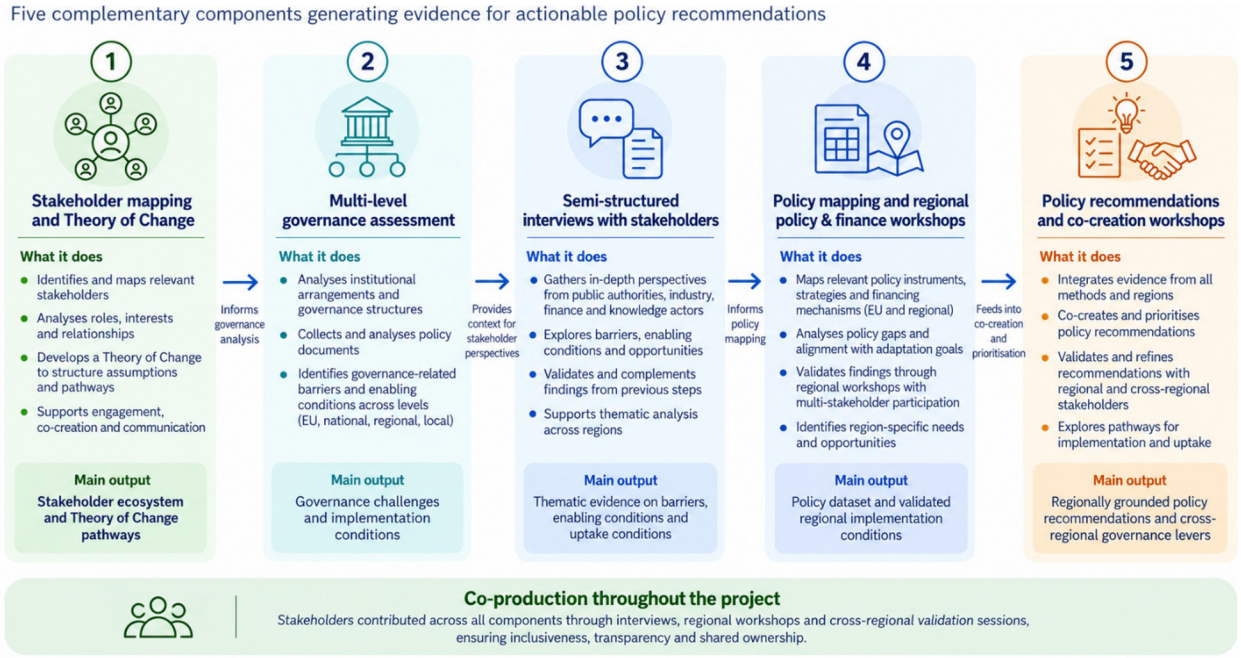


FIGURE 3
Co-production process of policy recommendations.

TABLE 3 Distribution of co-produced recommendations.

Macro-area	Number	Principal focus
Governance	10	Coordination, responsibilities, participation, regional and local mandates
Policy	10	Mainstreaming, territorial planning, risk assessment, digital and ecosystem approaches
Funding	8	Long-term finance, decentralized resources, SME support, guarantees and blended finance
Legislation	4	Regulatory alignment, permitting and implementation roadmaps
Awareness	2	Capacity-building, communication and public engagement
Total	34	Regionally differentiated recommendation package

3.3 Institutional conditions and pathways for the uptake of adaptation outcomes

Beyond the formulation of policy recommendations, the findings provide insights into the institutional conditions influencing the potential uptake of co-produced adaptation outcomes. The analysis examined how project-generated knowledge, tools and planning outputs were connected to existing governance arrangements and decision-making processes. In this context, uptake refers to documented use, integration or continuation of these outputs within institutional processes, rather than the formal adoption of the 34 recommendations as binding policy. The evidence across the seven regions indicates that uptake did not follow a uniform pathway, but rather a continuum ranging from stakeholder validation and institutional dialogue to policy-ready instruments and, in some cases, operational integration within established planning processes.

The first pathway involved stakeholder validation, institutional dialogue and the identification of opportunities for continuation. This was particularly visible in Catalonia and Valle dei Laghi, where engagement activities strengthened relationships among regional actors, supported discussions on implementation priorities and connected project outputs with ongoing policy processes. Although these activities helped establish institutional ownership and potential continuation pathways, the available evidence did not demonstrate formal adoption of the corresponding regional policy recommendations.

The second pathway concerned the development of policy-ready instruments that could facilitate future implementation. In Attica, the preparation of a regional Master and Business Plan for water reuse provided a planning and financing framework for potential scaling. Similarly, in Zemgale, the Regional Climate Change Adaptation Plan and established coordination structures created a basis for integrating adaptation

into regional development processes. These examples illustrate how co-produced knowledge could be translated into planning instruments aligned with regional priorities, although their existence does not necessarily demonstrate formal policy adoption or sustained implementation.

The third pathway involved the operational integration of project outputs into existing institutional processes. In Zeeland and Rijnmond, decision-support systems were reported as being used by municipalities and professional stakeholders for spatial planning and climate-risk management. In Berlin-Brandenburg, water-modeling tools were connected to strategic planning processes involving relevant public institutions. Troms and Finnmark also demonstrated institutional integration through the incorporation of selected planning tools into municipal and regional activities. These cases suggest that uptake was more tangible where project outputs could be linked to established institutional responsibilities, planning frameworks and operational needs.

At the same time, evidence from Troms and Finnmark illustrates that stakeholder interest and institutional engagement were not sufficient to guarantee implementation. While some project tools entered established planning processes, a proposed citizen engagement approach could not be implemented because the municipality lacked the financial resources required for facilitation and participant compensation. This highlights the continued influence of the governance, financing and capacity barriers identified in Section 3.1, even when co-produced outputs were considered relevant by regional stakeholders.

Overall, the evidence shows that uptake was heterogeneous across the seven DSs and occurred through different mechanisms. In some regions, project tools and knowledge were already being used within municipal, regional or national planning processes. In others, uptake took the form of policy-ready plans, financing models, institutional coordination arrangements, stakeholder validation or agreed pathways for continuation and scaling. Therefore, these findings indicate that the potential uptake of co-produced outcomes depended on their alignment with existing institutional structures, the availability of resources and the involvement of actors capable of supporting implementation. Co-production contributed to identifying these conditions and connecting project outputs with relevant decision-making processes. However, the evidence also demonstrates that stakeholder validation, policy readiness and operational integration represent different levels of uptake and should not be interpreted as equivalent to formal policy adoption.

4 Discussion

This study sets out to examine how regionally specific governance, policy, financing and stakeholder barriers shape climate adaptation implementation, and how these can be turned into actionable and context-sensitive policy recommendations across seven European regions. While the gap between adaptation strategies and their implementation is established in the literature, our findings provide further insights into how this gap manifests across different regional contexts and how co-production can support the development of actionable, context-sensitive policy recommendations.

4.1 Building the implementation architecture for regional climate adaptation

The implementation gap identified across the DSs was not associated with a single technical barrier, but with the interaction of fragmented responsibilities, weak coordination between administrative levels, limited institutional capacity, uncertain mandates and uneven stakeholder participation. These factors frequently reinforce one another: unclear mandates made it difficult to allocate resources and accountability, while limited access to funding and information constrained the capacity of local and regional actors to integrate adaptation into planning. This finding is compatible with previous research showing that adaptation barriers are multidimensional and interconnected rather than isolated technical constraints (Lee et al., 2022). The comparative contribution of this study is therefore not primarily the identification of new categories of barriers, but showing how familiar barriers combine and acquire different relevance depending on the institutional and territorial context in which implementation takes place. More importantly, the study illustrates how these context-specific barriers can be systematically translated into differentiated policy recommendations through a structured co-production process.

Previous studies have pointed out that climate adaptation is particularly sensitive to governance fragmentation, since many measures need to be implemented locally while regulatory authority, funding and strategic direction are often located at higher administrative levels (Juhola and Westerhoff, 2011). This challenge is further amplified when multi-level governance structures exist formally but lack the capacity to coordinate systemic responses under uncertainty (Granberg and Glover, 2026).

This tension was evident across the DSs, although its institutional expression varied by the capacity of regional and local actors. For example, fragmentation became particularly constraining where municipalities were expected to implement adaptation without corresponding mandates, resources or technical capacity, whereas in regions with stronger institutional coordination the same multi-level structure could provide a pathway for integrating project outputs into existing planning processes. Similarly, financing constraints were most consequential where adaptation depended on short-term project funding or lacked clear market demand, while public procurement, validation environments and established institutional ownership created more favorable conditions for continuation and uptake.

Effective adaptation policy must balance cross-regional comparability with territorial specificity. Although regions may face similar governance or financing barriers, appropriate responses depend on their climate risks, administrative structures, stakeholder ecosystems, and existing policy instruments. The same broad barrier may require different policy responses depending on where authority, resources and implementation capacity are located within the regional governance system. Adaptation

frameworks should therefore provide common implementation principles without imposing uniform institutional models.

Findings from the private-sector interviews are consistent with literature showing that private finance for adaptation is constrained less by a simple lack of capital than by market imperfections, including positive externalities, incomplete or asymmetric information, imperfect financial markets and difficulties in translating adaptation benefits into bankable value propositions (Pauw et al., 2022; Whittaker et al., 2026). The adaptation finance gap therefore also reflects the absence of enabling conditions that allow adaptation solutions to become investable, scalable and integrated into policy and market systems. This distinction is important because it shifts the focus from "more finance" to "better conditions for finance."

At the same time, private-sector engagement should not be understood as a replacement for public responsibility. Private stakeholders can contribute to technical expertise, innovation capacity, investment discipline and market access, but their participation depends on the existence of credible policy frameworks and clearer routes to adoption (Pauw, 2015). Public-private collaboration therefore needs to be understood as a shared implementation arrangement, in which public policy reduces uncertainty and creates demand while private stakeholders support the development, testing and scaling of solutions.

Closing this financing gap, however, is itself a governance and participation challenge: enabling conditions are not designed in isolation but negotiated among the stakeholders who will use, fund and regulate adaptation solutions. Previous research has shown that co-production can increase the salience, credibility and legitimacy of knowledge for decision-making, while more recent work highlights its value for designing inclusive decision processes and robust outcomes under uncertainty (Andrews et al., 2024; Cash et al., 2003; Moallemi et al., 2023). Our findings support this view but also suggest that co-production is especially useful when it is structured around implementation barriers and policy adoption, rather than only around general knowledge exchange.

Still, co-production should not be understood as a neutral or automatic solution. Its potential for transformative outcomes is shaped by participation, power relations and political choices, including whose knowledge is recognized and how competing perspectives are negotiated (Mitchell et al., 1997; Turnhout et al., 2020). In this regard, the effectiveness depends on who participates, how knowledge is integrated, how disagreements are addressed and whether the resulting outputs are connected to real decision-making processes (Reed, 2008; Belcher et al., 2020). Furthermore, these implementation arrangements must also include vulnerable groups; otherwise, adaptation may reproduce inequalities or transfer risks to those with the least capacity to respond (Turnhout et al., 2010; Shi et al., 2016).

4.2 Institutional implications for the implementation of co-produced recommendations

The seven DSs did not follow a single or uniform pathway from recommendation to uptake. Uptake followed a continuum ranging from stakeholder validation and institutional dialogue, through policy-ready plans and coordination arrangements, to the operational use of tools within routine planning processes (e.g., from Catalonia and Valle dei Laghi's stakeholder dialogue, through Attica and Zemgale's policy-ready instruments, to Zeeland/Rijnmond and Berlin-Brandenburg's operational embedding). This differentiation suggests that institutional conditions play an important role in shaping uptake, beyond the content and technical relevance of the recommendations themselves.

For example, the use of water-modeling tools by public water institutions in Berlin-Brandenburg and the integration of these tools into established regional or municipal processes created clearer continuation pathways. Conversely, even where institutional interest existed, financing and capacity constraints could still limit uptake: in Troms and Finnmark, the proposed citizen-jury approach was not implemented because the municipality lacked the financial resources required for professional facilitation and participant compensation, despite other tools from the same DS being taken up successfully.

Taken together, these patterns indicate that institutional fit and timing were as important to uptake as the content of the recommendations themselves. Thus, recommendations need to be paired not only with a defined action and expected outcome, but with a clear institutional owner and a point of entry into an existing planning or decision cycle, rather than assuming that a technically sound recommendation will generate uptake on its own.

4.3 Limitations and future lines of research

Several limitations should be acknowledged. Despite the extensive stakeholder engagement efforts, stakeholder participation varied across DSs and activities, and the interviews and workshops may not capture the full diversity of actors involved in each regional adaptation ecosystem. In addition, the project timeframe limited the ability to assess the long-term adoption, institutionalization, and impacts of the co-created adaptation solutions beyond the project duration. Moreover, workshops relied on the expertise of core participants.

The policy mapping does not constitute an exhaustive or randomized sample of all climate-related policies in the participating countries; it represents a targeted selection of policies considered relevant to climate adaptation and mitigation in the regions covered by the study. As a result, the number and type of policies identified varied across DSs, which may affect comparability between regions. Furthermore, policy selection may reflect regional priorities, availability of public information and the knowledge of participating stakeholders. To mitigate this limitation, the policy mapping was reviewed and validated with DS representatives during the co-creation process.

Future research should examine whether, and under what conditions, co-produced adaptation recommendations become embedded in policy design, funding decisions, institutional mandates and routine planning. Longitudinal follow-up across the seven DSs would help distinguish between the short-term

use of project outputs, formal policy adoption and sustained implementation, while assessing how governance arrangements, administrative capacity, political support and financing shape these different adoption pathways.

A second line of research concerns the iterative use of theory of change and stakeholder-engagement roadmaps in regional adaptation projects. This work should also involve a broader range of stakeholders, particularly additional local authorities, civil-society organizations, vulnerable communities, infrastructure operators and sectoral agencies, to examine how participation, representation and power relations affect the legitimacy and implementation of co-produced recommendations.

In conclusion, across seven European regions, climate adaptation was present in strategies and policy frameworks but was not consistently supported by the governance, policy instruments, resources and capacities required for implementation. Co-production translated these barriers into regionally differentiated recommendations. The analysis shows that uptake should be reported as a continuum, from stakeholder validation and policy-ready plans to operational, embedded use, without necessarily amounting to formal adoption. The principal implication is that moving from adaptation planning to regional implementation requires an implementation architecture: clear mandates, coordinated actors, balanced policy instruments, sustained resources and mechanisms through which knowledge enters routine decisions. Co-production can help build this architecture when it is linked to decision authority and implementation processes. It cannot substitute for them.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

LA-C: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Visualization, Writing – original draft, Writing – review & editing. MG-D: Conceptualization, Formal analysis, Writing – original draft, Writing – review & editing. MZ-L: Conceptualization, Methodology, Writing – original draft, Writing – review & editing. NC-V: Supervision, Validation, Writing – review & editing. LA: Conceptualization, Investigation, Writing – review & editing. SM: Supervision, Validation, Writing – review & editing. AD: Methodology, Writing – review & editing.

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Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declared that Generative AI was used in the creation of this manuscript. Generative AI was used to support the visual presentation and linguistic editing of the manuscript. Specifically, the author(s) used ChatGPT, powered by the GPT-5.6-sol model (OpenAI, https://chatgpt.com), to create visually appealing graphs consistent with the visual identity of the IMPETUS project. The underlying content, data, categories, and conceptual relationships represented in the graphs were provided entirely by the author(s). The same model was also used to improve the manuscript's writing style, grammar, and clarity without altering its scientific content or conclusions. The author(s) reviewed and validated all AI-assisted outputs and take full responsibility for their accuracy and final presentation.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/frevc.2026.1953437/full#supplementary-material

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