NEUROCLIMA

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ABBREVIATIONS

Abbreviation	Full name
AI	Artificial Intelligence
DMP	Deliberative mini-public
FAIR	Findable, Accessible, Interoperable, Reusable
ML	Machine Learning
NAM	Norm Activation Model
NLP	Natural Language Processing
SDT	Self-Determination Theory
SES	Social-Ecological System
STPs	Social Tipping Points
TPB	Theory of Planned Behaviour
TTM	Transtheoretical Model
WEIRD	Western, Educated, Industrialised, Rich, Democratic

EXECUTIVE SUMMARY

This document, output of **T3.1** and **T3.2** within **Work Package WP3**, titled "The NEUROCLIMA climate-theme sensitive scaling mechanism" is a conceptual and operational model designed to synergistically **scale deliberation and inclusive practices**. Its purpose is to offer pitfalls and suggestions to guide climate-related deliberation processes and small-scale practices. Although this document was initially intended to focus mainly on deliberative strategies — in line with what was decided under **T4.1** — we have slightly broadened its scope to include the other sets of other tools designed so far, since the approach we wish to pursue is systemic and not limited to isolated components.

This deliverable is based on the conceptual foundations set out in *D3.3 - A Conceptual Framework for Behavioural and Systemic Change for Climate Change Adaptation*, ensuring methodological continuity and coherence throughout **WP3**. While **D3.3** introduces the behavioural and systemic change framework that supports NEUROCLIMA's approach to climate adaptation, this document takes an operational approach, translating these theoretical principles into actionable pathways for **scaling out, deep and up**. Moreover, this deliverable builds upon key outputs and outcomes from WP2: the *Ethnographic research review and innovation landscape analysis on social tipping points and leverage mechanisms* (**D2.2**), the *Pilots definition and user requirements definition* (**D2.3**) and the *Technical, operational and interoperability specifications and reference architecture* (**D2.2**)**,** provided an initial overview of the overall system architecture.

This deliverable is also connected to the work done in the context of T1.3 (***D1.5** — Data Management Plan)*, for what concerns scaling data and the reflection on the FAIR framework.

As a result, the work presented in this deliverable and done under T3.1 and T3.2 is **closely linked to ongoing T3.3, T3.4, T3.5 and** parallel work undergoing in WP4 and WP5, specifically to the output presented in *D4.1 - Initial version of the NEUROCLIMA climate-sensitive policy co-creation framework*. For instance, the **review of tools and cases** presented in Section **§2** has informed, is informing, and will inform the future development of **T3.3**, **T4.3**, **T4.4** and **T5.1**. Finally, given the operational scope of this deliverable, it will also serve as a valuable resource in supporting **pilot implementation** activities (**WP6**).

The document is a PU-Public Deliverable and the intended readership, besides CM are also other stakeholders and HE projects members interested in the topic of scaling dynamics especially in relation to inclusive deliberation practices. The document is organised into 5 sections to comprehensively address NEUROCLIMA's climate-theme sensitive scaling mechanism.

- Drawing from insights from T3.2 and D3.3, Section **§2** examines the barriers and role of AI in Climate Change Adaptation and delves into behavioural change methodologies and Scaling Dynamics in the AI-Climate Change Adaptation nexus, bringing the "Science of Scaling" as a methodological approach.
- Section **§3** discusses deliberative democracy as a mechanism for scaling innovation and ensuring inclusive governance, including the analysis of relevant cases.
- Section **§4** presents Scaling Dynamics in NEUROCLIMA.
- The discussion is articulated in Section **§5.**
- Section **§6** is dedicated to Annexes and concludes this document.

1. Introduction

Climate change adaptation is a complex challenge that demands integrated responses across individual behaviours, collective engagement, and systemic policy transformations. In line with the objectives of Sustainable Development Goals, the NEUROCLIMA initiative seeks to advance **inclusive** and **scalable climate responses** by **embedding Artificial Intelligence** (AI) within **participatory** and **adaptive governance systems** (Del Río Castro et al., 2021; Rolnick et al., 2023)

This deliverable presents NEUROCLIMA's climate-sensitive scaling mechanisms—designed to connect individual behavioural change with collective and institutional processes. **At the heart of this approach lies the recognition that AI is not only a computational tool but also a socio-technical and governance instrumen**t. (Coeckelbergh, 2021). Indeed, as demonstrated by various authors providing in-depth reviews (Cowls et al., 2023; Dwivedi et al., 2022; Rolnick et al., 2023). It helps tracking emissions and optimizing infrastructure for smart cities development (Allam & Dhunny, 2019; Bibri et al., 2024; Weil et al., 2023) to fostering environmental literacy (Kuksa et al., 2024), enabling community participation (McKinney, 2024; Savelli & Morstyn, 2021), and promoting climate justice (Coeckelbergh, 2021). Hence, **Artificial Intelligence can support the translation of complex climate data into accessible formats** (Skarzauskiene et al., 2023), support ***reflexive* behavioural nudging** (De Liddo et al., 2020), and **scenario modelling** (Elsawah et al., 2020; Jain et al., 2023), making it a **very key enabler of climate action**. (Butler et al., 2024; Whitmarsh et al., 2021)

However, this potential must be critically attuned to democratic values, equity, situatedness and **responsibility**. For this reason, we want to place emphasis on the **interplay between individual agency and behavioural change and collective decision-making**. This includes the role of AI in shaping not just what people do, but **how they understand complex climate data related to interconnected events and engage with climate transitions**. Hence, promoting adaptation depends not only on motivating individuals to act sustainably, but also on embedding these actions within **systems that scale and persist** (Ajzen, 1991; Deci & Ryan, 1985). NEUROCLIMA's scaling framework reflects this ambition through mechanisms that are **responsible, adaptive, participatory, and sensitive to local capacities and cultural contexts** (Moore et al., 2015).

Indeed, NEUROCLIMA's approach emphasises how knowledge management, participatory processes and diverse educational agents (from newspapers to schools, youth education centres and civil society groups) **can bridge everyday concerns with broader environmental goals**, fostering locally rooted yet globally impactful change. It shows how identifying **Social Tipping Points (STPs)** (Eker et al., 2024; Winkelmann et al., 2022) can trigger people's concern from local issues to global stakes.

NEUROCLIMA promotes an integrated platform offering Lens (our AI-supported search engine trained on reliable climate change information and able to identify Social Tipping Points) and Bot (our LLM-supported bot trained on reliable climate change change and able to identify Social Tipping Points) to support Learn (our e-learning platform) and Dialogues (our e-deliberation platform). By using data and AI under the FAIR principles (Findable, Accessible, Interoperable, Reusable, Responsible), the integrated solution aims to identify STPs at multiple scales and drive behaviour-change pathways through network-scale dynamics. (Figure 1) Moreover it offer NeuroClimaPlay, a digital collection of interactive playful experience and a set of toolkits on participatory design, creative expression and cinematography to be integrated in hybrid activities.

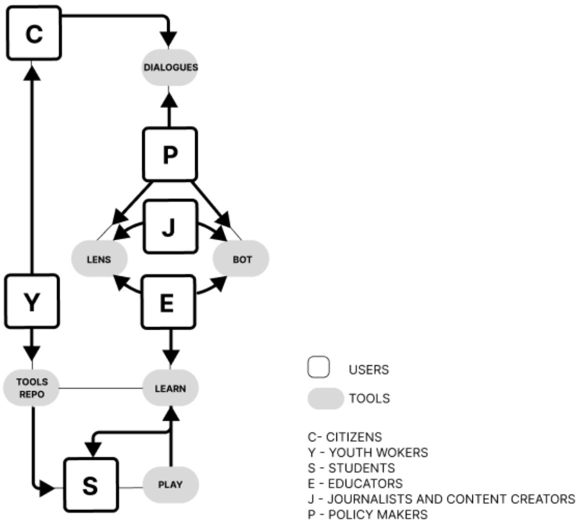

Figure 1: The overall structure of the NEUROCLIMA integrated solution with main users.

1.1. Methodology

The first research actions were devoted to review of literature and case studies. In the context of T3.1 and T3.2, a literature review was conducted by Task members, focusing on behavioural change, scaling dynamics, inclusive policy making, digital technology/AI applications, and climate change adaptation. This review explored the role of AI in climate policy and its influence on citizen engagement and behavioural change.

A significant part of the methodology involved the analysis of deliberative democracy as a means/tool for scaling innovation and inclusive governance.

- Case studies from the literature were mapped and coded by partners, drawing from sources like *Participedia*[1] and *People Powered*[2] reviews.
- These cases, selected based on their relevance in using digital or hybrid technologies and focusing on climate change adaptation, were analyzed through specific lenses including use of digital technology, inclusivity, recruitment, scalability, and results.
- These cases were then presented and validated during a Webinar in January 2025. Insights from the review and case analysis were integrated with co-creation activities involving project partners.
- "Card Sorting"[3] activities (Spencer, 2009) allowed for mapping selected cases based on the role of digital technology and the type of deliberation supported.

In parallel, we run a second workshop "*Exploring Scaling Dynamics*", in January 2025. In this activity, partners explored the scalability potential (Scaling Up, Scaling Out, Scaling Deep) of specific NEUROCLIMA use cases, along with their associated levers and barriers.

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[1] https://participedia.net/

[2] https://www.peoplepowered.org/platform-ratings

[3] Card Sorting is a co-design tool helping uncover user's mental models for understanding how to organise information.

2. Leveraging Digital Technology and Artificial Intelligence for Inclusive and Scalable Transformation

In the context of climate adaptation, Artificial Intelligence (AI) is emerging as a powerful, multi-faceted tool. Far more than just a technology, AI is reshaping how societies assess risks, design solutions, and engage people—from individuals to large institutions—in the shift towards sustainability.

This section explores AI's transformative potential across these levels. We'll dive into how AI can effectively integrate with behavioural change models to drive meaningful action. Recognising that even the best ideas need to scale, we'll then unpack the methodological challenges of expanding social innovations, emphasising the rigorous approaches needed for success. We'll address the critical need for responsible AI deployment, examining its technical, ethical, and environmental safeguards. Ultimately, this section advocates for a paradigm shift. It argues we must go beyond simple AI 'nudges' and instead foster participatory AI governance. This approach can empower communities and strengthen democracy in our collective climate future.

These ingredients—the strategic application of AI, a deep understanding of behavioural change, a framework for scaling, and a commitment to responsible and participatory governance—are precisely what is needed to effectively address the complex challenges that NEUROCLIMA aims to tackle.

2.1. Potentials of Artificial Intelligence for Inclusive Climate Adaptation

In climate adaptation contexts, AI serves as both a **technological enabler** and a **socio-informational agent**, facilitating decision-making processes at individual, community, and institutional levels. (Lewis et al., 2024) Its role is multifaceted and intersects deeply with how societies assess climate risk, design responsive systems, and engage diverse publics in sustainability transformations. (See **ANNEX I**)

At the **individual level**, AI is already empowering citizens. It tracks personal emissions in real-time – across energy, water, transportation, and waste – fostering more informed lifestyle choices and behavioural change. (Rolnick et al., 2023) AI-powered home energy management systems and smart meters, for instance, provide tailored feedback, encouraging climate-conscious daily routines. Furthermore, predictive AI tools help individuals assess the long-term climate impact of actions such as dietary shifts or switching to electric vehicles, thus facilitating proactive personal adaptation planning. (R. Evans & Jim, 2016)
Moving to the **collective level**, AI systems are becoming central to **climate policy modelling, scenario planning and risk anticipation**. Governments and research institutions use AI to simulate complex climate-environmental interactions, model the effectiveness of different policy interventions, and prepare for region-specific climate risks. (Cowls et al., 2023; Ukoba et al., 2025; Wei et al., 2015) These predictive capabilities inform infrastructure planning, disaster preparedness, and urban development decisions. Furthermore, AI acts as a watchdog by monitoring large-scale environmental variables – such as industrial emissions, deforestation, and water consumption – through satellite imagery, sensors, and automated data analysis, helping authorities identify non-compliance or inefficiencies. (Salam, 2020)

In terms of **communication and public engagement**, AI increasingly plays the role of a translator by converting complex climate data into accessible formats. Through natural language processing (NLP), **generative AI**, and data visualisations, climate information is being made more comprehensible to non-expert audiences, improving environmental literacy and participation. (Rolnick et al., 2023) Platforms like *UrbanistAI* exemplify this approach by combining geospatial data with AI-generated visualisations to help communities imagine future climate-resilient urban spaces, encouraging proactive engagement in adaptation planning as well as ongoing climate education. AI also functions **as a**

knowledge co-creator. It synthesises vast amounts of climate research, identifies knowledge gaps, and detects emerging trends. AI-based literature mapping and trend detection tools help scientists and policymakers keep pace with rapidly evolving evidence, while recommendation systems streamline evidence gathering and offer personalised learning and action suggestions (Cowls et al., 2023)

Beyond operational efficiency and public engagement, AI is now being applied in **climate resilience planning and anticipatory governance**, where adaptive capacity must be continuously recalibrated for evolving climatic, environmental, and socio-economic data. For example, AI-driven dynamic risk maps – updated in near real-time using remote sensing, satellite data, and socio-economic indicators – are being used by urban planners and disaster risk managers to design flexible infrastructure and evacuation strategies in flood-prone or heat-vulnerable areas (Jain et al., 2023). These systems are being piloted in cities like Rotterdam and Singapore, where climate-aware urban design relies on AI models that simulate long-term adaptation pathways under different climate scenarios. (Srivastava & Maity, 2023) This application of AI extends its role from static planning to supporting **real-time adaptive management**, enabling authorities to respond more effectively to uncertainty and complex environmental feedback loops.

Finally, the role of AI in **climate justice and equitable adaptation** is gaining attention as scholars and practitioners call for more inclusive and accountable AI design and deployment (Coeckelbergh, 2021). While AI systems can enhance efficiency, they also risk reinforcing existing inequalities if they rely on biased data or are inaccessible to marginalised communities. Recent work focuses on developing **community-informed AI frameworks**, where local knowledge and needs shape model parameters and evaluation metrics. For example, participatory mapping tools enhanced by AI are used in indigenous and rural communities to document environmental vulnerabilities, assess risks and plan adaptive responses rooted in local priorities. (Robinson et al., 2016) This shift toward **AI for climate equity** emphasizes not only what AI can do technically but how it is governed, who it serves, and whether it enhances or undermines democratic control over adaptation processes. AI is not just a computational tool but a governance instrument – one whose design and deployment must be critically attuned to power, representation, and justice in the climate transition.

Despite growing capabilities, much of the current discourse underplays the **synergy between individual and collective action**. As Rolnick et al. (2023) emphasize, **personal behaviour change is necessary but insufficient on its own**.

2.2. Integrating Behavioural Change Models in Climate Adaptation

As deeply described in D3.3, in NEUROCLIMA, we have identified four main behavioural change models, applicable to Climate Change Adaptation and taken into consideration in the NEUROCLIMA Solution design process.

2.2.1. Key Behavioural Models

- The **Theory of Planned Behaviour** (TPB) (Ajzen, 1991) explains that individuals' intentions—shaped by their attitudes, perceived social norms and sense of control—influence choices around energy use, transport and policy support; yet structural barriers like cost or accessibility often produce an intention–behaviour gap (Bamberg, 2013; Jain et al., 2023).
- The **Norm Activation Model** (NAM) (Schwartz, 1977) argues that pro-environmental action arises when people recognise the negative consequences of inaction and feel a personal moral obligation to avert harm; climate adaptation campaigns can activate these norms by linking individual responsibilities to collective outcomes (Rau et al., 2022; Tounsi & Temimi, 2023).

- The **Transtheoretical Model** (TM) (Prochaska & DiClemente, 1984) views behaviour change as a staged progression—precontemplation, contemplation, preparation, action and maintenance—and suggests tailoring information and support to each phase to guide gradual engagement with climate-safe practices (Rau et al., 2022).
- Finally, **Self-Determination Theory** (SDT) (Deci & Ryan, 1985) emphasizes that lasting change comes when actions satisfy needs for autonomy, competence and relatedness; community-led resilience projects and co-design processes foster this internal commitment (El Kirat et al., 2024).

While these methodologies are distinct, they are not mutually exclusive. Each offers valuable insights for designing adaptive strategies. Combining them enables a more comprehensive approach that considers psychological readiness, social context and motivational complexity. For instance, TPB can inform the framing of initial messages, NAM can instil a sense of moral urgency, TTM can influence the pacing of interventions, and SDT can promote deeper engagement.

2.2.2. The Role of AI in Amplifying Behavioural Change

AI can amplify and support each of these approaches. By providing real-time feedback and personalised suggestions, AI helps bridge the TPB intention–behaviour gap through enhanced perceptions of control. It can deliver contextualised alerts and visualizations of climate risks to reinforce NAM's moral imperatives. Stage-detection algorithms enable TTM-aligned interventions, deploying content and prompts that match a user's readiness to change. And through gamified progress tracking and peer-network features, AI strengthens the autonomy, competence and relatedness central to SDT. When these AI-enhanced methodologies are woven into supportive policies, infrastructure and participatory platforms, they create the enabling environment necessary for individual actions to coalesce into systemic, sustained climate resilience.

Finally, behavioural change is most effective when embedded in **enabling environments** where individual action cannot substitute for institutional support. Therefore, behavioural methodologies should be paired with systemic interventions, policy coherence and inclusive infrastructures to ensure that change is both possible and meaningful.[4]

2.3. Understanding Socio-Technical Transitions for Sustainable Development

Geels (2005) defines "system innovation" as 'a transition from one socio-technical system to another' and occurs when the socio-technical system functions differently and thus there is a requirement for **fundamental structural change.** While acknowledging the critical role of technology in tackling sustainability challenges, it's also recognised that cleaner technologies alone are insufficient to solve environmental issues unless accompanied by cultural and behavioural changes. Hence, sustainability transitions differ from historical transitions as they are intentional, focusing on long-term environmental sustainability, a goal that often conflicts with private sector incentives due to its nature as a collective good. Importantly, technologies alone cannot deliver sustainability unless accompanied by cultural and behavioural changes. These systemic changes involve comprehensive alterations across critical societal domains such as transport, energy, and agriculture (Elzen et al., 2004; Geels, 2004). Geels (2002), using the Multi-Level Perspective (MLP), outlines four phases of socio-technical transitions: innovation emerges in niches without clear purpose, gradually matures through community formation and specialization, breaks into mainstream due to external pressures, and ultimately integrates into society, replacing older systems. This framework reflects broader changes in

[4] Behavioural science, in this approach, should be more taken as an umbrella concept combining the concerns of several scientific disciplines (psycho-sociology, sociology, anthropology, communication science, neuroscience, political science, at least), than a strict disciplinary perimeter in its own terms.

Western European governance, shifting from centralised state control to more decentralised, collaborative policy-making—commonly termed "governance" (Kooiman, 1993).

2.3.1. Strategies for Scaling Social Innovations

The process of scaling social innovations to achieve systemic impacts involves three different types of scaling: scaling out, scaling up, and scaling deep. Large Systems Change (LSC) often requires a combination of these types to create meaningful and lasting impact (Moore, Riddell, & Vocisano, 2015).

The NEUROCLIMA climate-sensitive scaling mechanism takes into consideration these three main stages of scaling, supported by the integration of Social Tipping Points that can suggest where to intervene in a system in order to accelerate and promote behavioural change.[5]

- **Scaling Out:** Focuses on replicating successful initiatives to impact greater numbers and spread innovations geographically while ensuring the fidelity of the original approach.
- **Scaling Up:** Involves embedding changes within policy and law, advocating for reforms to address the roots of societal problems and ensuring that innovative approaches are institutionalised.
- **Scaling Deep:** Targets cultural shifts, recognizing that deep-rooted change in values, beliefs, and practices is necessary for transforming problem domains. This requires strategies that invest in transformative learning and the re-framing of societal norms.

Combining these three types of scaling is vital for tackling complex societal challenges. Each type addresses a different aspect of systemic change. Achieving large systems change requires a nuanced strategy that adapts to **context-specific needs**, **leveraging scaling out for wider adoption, scaling up for institutional support, and scaling deep for cultural transformation.**

However, scaling is not simple. Many pilots fail when expanded because of issues like false positives, sample bias, poor replication, cultural mismatches, and implementation drift. Effective scaling requires rigorous methodology. Hence, in the next section, we will bring some **operational reflections on how to design robust, adaptable, and cost-aware interventions.**

2.4. The Science of Scaling: A Methodological Framework

The path to successful scaling is littered with failed attempts to expand promising ideas. The most hazardous obstacle is *"the illusion of knowledge arising from misleading data, hidden biases, or outright deception"* (Kohavi et al., 2022). Understanding this unintuitive specificity shapes the entire methodology for scaling effectively (List, 2022).

[5] Taking the NEUROCLIMA ecosystem as an example: we will deploy NeuroclimaLens, Bot, Dialogues and Play in Brussels, Athens, Lisbon and Dublin, translated facilitator guides and modular game kits—so local NGOs and schools will spin up workshops in French, Greek, Portuguese and English with minimal overhead;insights from Athens's Bot-mediated wildfire discussions will inform Greece's forthcoming national adaptation guidelines, Lisbon's Play modules will be integrated into Portugal's updated climate-education curriculum, Brussels's Lens narrative reports will appear in Belgium's next urban resilience strategy, and Dublin's Dialogues outputs will feed into Ireland's future municipal climate plans; and Scaling Deep, each city will host regular "Climate Cafés," classroom rituals and community game nights where citizens will Play and the repository of Toolkits to co-create local stories—seeding a lasting participatory climate culture.

- ***Problem of false positives***, those deceptive signals that make ideas appear more promising than they actually are (Cohen, 1988). Most pilot studies suffer from inadequate statistical power, with median power levels below 0.6, leading to unreliable effect estimates (Gelman & Carlin, 2014). In experimentation, false positive results frequently lead to misallocated resources and scaling failures (Koning et al., 2022). This reality drives the cornerstone principle of scaling methodology: **systematic replication**. Decisions to scale should never be made based on a single successful test, no matter how promising. Instead, one should seek independent replication by teams with no vested interest in success (Camerer et al., 2016), conducting the same study three or four times with the same population type before establishing confidence (Cooper, 2008).
- ***Audience heterogeneity and selection bias***. Systematic differences between early adopters in pilots and broader target populations create a fundamental methodological challenge (Heckman, 1979). Self-selection occurs when individuals who stand to benefit most disproportionately participate in trials, creating overly optimistic results. Convenience samples lead to dramatically different conclusions when extrapolated to general populations (Peterson, 2001). Perhaps most profound is the challenge of cultural heterogeneity - interventions designed in WEIRD (Western, Educated, Industrialised, Rich, Democratic) contexts often fail dramatically in non-WEIRD settings with different cultural norms and behavioural patterns (Henrich et al., 2010). Addressing these challenges requires ensuring sample representativeness through randomisation rather than convenience sampling. The solution might be to test in three demographically distinct cities, or couple culturally distinct countries such as Spain, Germany, UE, Sweden, and Latvia - to capture population diversity during pilot phases (Olds et al., 1997). Successful scaling demands heterogeneity analysis that examines differential effects across subgroups rather than focusing solely on average treatment effects. Developed approaches must embrace adaptive scaling strategies allowing market-specific customisation rather than rigid standardisation.
- ***Implementation fidelity & compliance drift***: The methodology must also grapple with maintaining implementation fidelity during expansion. This requires distinguishing between **"non-negotiable" components** with infinite value to the endeavour and "negotiable" elements that can be modified without fatal consequences (Lancaster, 1966; Rosen, 1981). Human capital presents particular challenges when it represents a non-negotiable component, as unique skills and talents are inherently limited and cannot be easily replicated (Becker, 1964). Less visible but equally critical are organisational non-negotiables like tacit knowledge, routines, and cultural elements that prove difficult to replicate at scale (Nelson & Winter, 1982). The compliance challenge compounds these difficulties representing a fundamental barrier to scaling interventions (Sabaté, 2003). Implementation drift from original design specifications occurs frequently during scaling, resulting from resource constraints, local adaptations that violate core principles, or simple misunderstanding of critical elements (Durlak & DuPre, 2008)
- Managing these challenges requires backward induction - reasoning backward from the scaled end-state to design interventions compatible with realistic constraints (Dixit & Nalebuff, 1991). Rather than optimising for pilot conditions with exceptional resources, successful scaling designs for the median quality available at scale. This involves mapping all non-negotiables including hidden organisational elements, designing for compliance from the outset deploying a choice architecture (Thaler & Sunstein, 2008), establishing monitoring systems for continuous **fidelity assessment** (Fixsen et al., 2005), and testing under realistic conditions rather than idealised pilots (List, 2022).
- A critical yet underappreciated dimension involves ***spillover effects*** - unintended impacts that emerge when interventions reach critical mass. These externalities represent consequences extending beyond direct participants. General equilibrium effects prove particularly significant, as system-wide adjustments occur when interventions disrupt market equilibria (Heckman et al., 1998). Small-scale job training programmes may show impressive wage gains, but these can evaporate when programmes scale sufficiently to increase know-how supply, with benefits to

participants coming partially at the expense of non-participants through displacement effects (Crépon et al., 2013). Social spillovers through peer effects create behavioural interdependencies that can dramatically amplify or dampen intervention impacts. Research demonstrates that these spillovers can amplify programme benefits by factors of ten or more when properly measured (List et al., 2020). Network effects add another layer of complexity, where value increases with participation, creating dynamics with increasing rather than diminishing returns to scale (Katz & Shapiro, 1985). Managing spillovers requires systematic mapping of potential channels during pilots (Pearl, 2009), empirical strategies like cluster randomisation that capture effects (Baird et al., 2018), theoretical modelling projecting scaled impacts (Todd & Wolpin, 2006), and adaptive management with continuous monitoring to detect and respond to unexpected effects (Pritchett et al., 2013). **The insight is that scaling occurs within complex adaptive systems where interventions trigger responses across multiple dimensions.**

- ***Economic viability*** represents the final critical dimension, as even successful innovations can fail if **cost structures** deteriorate at scale (Christensen & Raynor, 2003). Human capital-intensive services face particular challenges, as skilled resources often become more expensive with increased demand, creating what Baumol (1967) termed "cost disease" in many sectors. The interplay between fixed and variable costs fundamentally shapes scaling trajectories. While high fixed costs can enable dramatic economies of scale once amortised, solutions with high variable costs may experience negative unit economics that worsen with expansion (Aspinall & Hamermesh, 2007). This reality drives a fundamental insight: perfection is the enemy of scale. The pursuit of optimal quality in pilots often creates unsustainable cost structures. The concept of "satisficing" - seeking satisfactory rather than optimal solutions - proves essential for scaling methodology (Simon, 1956). Cognitive biases compound these challenges throughout the scaling process. Confirmation bias prevents seeing contradictory evidence (Nickerson, 1998), while bandwagon effects silence diverse perspectives as leaders dominate discussions and influence decisions (Surowiecki, 2004). The sunk cost fallacy leads to continuous investment in low-return activities simply because substantial resources have already been committed (Arkes & Blumer, 1985).

Having presented a framework for responsible scaling up, deep and out interventions we will see how methodological guardrails are essential when we deploy AI in Climate Change Adaptation.

2.5. Responsible AI for Climate Change Adaptation

Implementing AI for climate change adaptation presents several interconnected technical and non-technical barriers (Cowls et al., 2023; Del Río Castro et al., 2021; Rolnick et al., 2023). Indeed, while AI can bring value and opportunities in climate change research and action, it can also reinforce and exacerbate some existing barriers related to:

- ***Technical and data-related challenges*** that could lead to a lack of transparency and model interpretability and Data Quality issues. Indeed, good quality region-specific data is always irrelevant but often lacking, especially in vulnerable or low-resource areas (Andries et al., 2023). Climate adaptation decisions based on AI outputs require *interpretability*; yet current models are often “black boxes,” limiting transparency and stakeholder trust (Barredo Arrieta et al., 2020). Visual representations are often employed to present climate related trends, patterns and predictions, they can very much affect the understanding of a complex system. However, if not designed properly, can lead to misinterpretation and misinformed policy decisions (Daron et al., 2015). Indeed, end users, such as urban planners and farmers, **often lack the technical capacity or climate literacy** to effectively interpret and apply digital climate data in their decision-making (Oliveira & Garcia, 2019).

The application of the *FAIR* principles, ensuring that data is Findable, Accessible, Interoperable, and Reusable, is foundational to building robust, accountable AI systems, but remains difficult to implement in practice. (Butler et al., 2024) Climate-related data is often generated by disparate actors – government agencies, research institutes, private sector organizations, NGOs – each operating under different legal regimes, licensing terms, and data formatting standards. (Jain et al., 2023) This fragmentation not only hinders cross-sectoral data sharing and collaboration but also limits the volume and diversity of high-quality, annotated datasets available to train and validate AI models. Without harmonised data protocols and infrastructures, AI systems risk being biased, non-generalisable, or overly context-specific, thus weakening their value for adaptation at regional or global scales.

- ***Political and governance challenges:*** Coordination among diverse stakeholders, including governmental, private, and civil society actors, can be difficult to establish and sustain (Stefanovic et al., 2014). One major issue is the misalignment between digital innovation and environmental goals, where AI development may prioritize technological advancement without addressing its ecological or social impacts (Meinhold et al., 2025).
- ***Ethical and social risk of using AI*** which implies potential emerging bias from the use of big data models (Jain et al., 2023; Tsamados et al., 2022) that could result in distortions, hallucinations and inaccurate recommendations that affect vulnerable populations. Using AI to "nudge" individual behaviour toward pro-environmental actions raises concerns about **autonomy** (N. Evans et al., 2017). Hence, striking a balance between large-scale climate policy implementation and the protection of individual freedom is challenging. (Cowls et al., 2023; Taddeo & Floridi, 2018). AI systems in climate-related applications (like energy or agriculture) often require large datasets, raising risks of personal data exposure (Carmody et al., 2021; Leal Filho et al., 2022). AI systems risk bias if marginalised communities (and climate marginalised communities) are not involved in their design (Sakapaji & Puthenkalam, 2023)
- ***Environmental impact of AI itself***: The environmental cost of AI itself is notable, as AI technologies contributed to 1.4% of global greenhouse gas emissions in 2015 (Cowls et al., 2023). Gupta in (Dwivedi et al., 2022) recognises the role data centers play in this game, having massive power computing needs for training and storing AI data. Balancing AI's energy consumption against its efficiency gains remains an open and relevant challenge, urging the AI industry, particularly in the EU, to invest in greener data infrastructures and transparent, open-source assessments of AI technologies.
- ***Explainability and trust:*** Many cutting-edge models, especially those based on neural networks and other deep learning techniques, provide accurate predictions but do so through opaque internal mechanisms that defy easy interpretation, even from experts. For policymakers and stakeholders to trust and adopt AI-generated insights, particularly in sensitive domains such as resource allocation, disaster planning, or climate vulnerability assessments, they must understand how and why specific outputs are produced. (Papadakis et al., 2024) This is especially true in deliberative or participatory contexts, where **transparency** is not just a technical requirement but a democratic imperative. The lack of explainability can undermine stakeholder trust, ethical concerns, or the rejection of otherwise valuable AI applications. Hence, Aligning AI with the FAIR principles, and making it explainable and democratically accountable, are not just technical goals. (Cai et al., 2019; Suresh et al., 2021). They are essential for equitable, trusted, and effective climate adaptation.
- ***Institutional and regulatory gaps:*** In addition, the challenge is not only technical but also institutional and societal. Many organizations lack the resources, expertise, or incentive structures to ensure data quality, maintain transparency, or adopt interpretable AI frameworks. There is also a gap in regulatory frameworks that address the accountability of AI systems in

environmental governance. (Cheong, 2024) Without clear guidelines, AI-driven decisions can escape scrutiny or disproportionately impact marginalised communities.

The analysis of Artificial Intelligence's potential and challenges in climate change adaptation highlights its dual function: AI serves not only as a technical enabler but also as a **socio-tech actor influencing public engagement, governance, and collective decision-making**.

2.6. From Personalised Nudges to Participatory AI Governance

To achieve systemic, long-term behaviour change in adaptation, AI must go beyond one-off nudges and be anchored in policy, infrastructure, and culture.

Going beyond individual behaviour, AI enables systemic simulation and monitoring of enabling environments, supporting the co-creation of public engagement platforms and institutional alignment (Bibri et al., 2024; Leal Filho et al., 2022). In socio-technical transitions, AI acts as a *translator* between technological innovation and cultural legitimacy, aligning citizen behaviour with sustainability goals through predictive modelling and scenario planning (Cowls et al., 2023; Rolnick et al., 2023). At the governance level, **participatory AI platforms facilitate community involvement in adaptation planning, enhancing transparency and local ownership** (Cortés-Cediel et al., 2021a; Tan & Taeihagh, 2020).

The potential of AI in climate adaptation that we want to leverage in this deliverable and that will explore deeply in the next sections lies in its **integration with inclusive deliberative and participatory processes.** Indeed, as pointed out by Whitmarsh (2021), while many interventions rely on **automatic** cognitive mechanisms (nudges), climate adaptation also demands **deliberative** engagement, where individuals and communities actively reflect on values, trade-offs, and long-term outcomes. Participatory methods such as citizen assemblies, digital visioning tools, and co-design platforms allow communities to **guide AI development and influence adaptation strategies in ways that reflect local priorities and lived experience** (Alemanno, 2018; Cortés-Cediel et al., 2021; Mariani et al., 2025; Oliveira & Garcia, 2019; Whitmarsh et al., 2021)

Moreover, **AI can support scaling** by distinguishing between adaptable and core elements of interventions, improving fidelity across diverse contexts (Fleming et al., 2020), and tracking behavioural spillovers (León et al., 2022). In other words, it has a lot of co-design potential in strengthening them by making behavioural science scalable, policies adaptive, and transformations socially grounded.

Building on this understanding, and as a key component of our T3.1 research and review, the forthcoming section will explore how deliberative democracy—leveraging its digital and AI-supported extensions—can serve as a framework for fostering inclusive innovation and effective climate governance.

3. Deliberative Democracy as a Mechanism for Scaling Innovation and Inclusive Governance

As anticipated in the subsection above, one relevant point where collective and individual action, along with behavioural change, can align is when citizens and stakeholders are actively engaged in co-designing and co-implementing solutions for systemic change. **Citizen participation** is central to this reflection, and in the following section, we provide an overview of **deliberative democracy**, exploring its role in **scaling innovation and fostering inclusive governance.**

Deliberative participation has long been a cornerstone of democratic engagement, with foundational models like Arnstein's Ladder (1969) helping to conceptualise degrees of citizen involvement—from **manipulation** to **full citizen control**[6]. Subsequent scholars have refined Arnstein's model by adding extra steps to capture subtler degrees of involvement. Others have shifted its focus toward empowerment. For example, Rocha's ladder, aimed at professional planners (especially in local government and educational organizing), retains the ladder metaphor but reorients the stages around empowerment: from individual empowerment, through mediated or collective forms, up to full political empowerment. It's likewise intended as a practical tool for designing, assessing, and deepening citizen engagement.

These frameworks raise essential questions about the origins of participatory processes: *do they emerge from grassroots mobilisation demanding change, or from top-down initiatives seeking legitimacy?* Understanding this genesis is crucial, as it influences how participation unfolds over time—shaping citizens' roles, levels of motivation, and whether efforts result in symbolic gestures or substantive policy impact, particularly on complex, climate-sensitive issues.

As participation increasingly intersects with digital technology, including AI, new challenges and opportunities arise. Digital platforms do not eliminate traditional hurdles such as communication gaps, conflicting interests, or power asymmetries—they may even amplify them. Thus, human facilitation remains relevant. Mediators, participation specialists, and inclusive design are essential to ensure that technological tools support deliberative depth and equity. Moreover, attention must be given to the digital divide. Digital tools promise scalability, inclusivity, and efficiency. However, they may also exclude those who lack digital skills or come from marginalised communities.

The NEUROCLIMA system, as detailed in deliverable *D2.2 - Technical, operational and interoperability specifications and reference architecture (M10)* and in *D4.1 - Initial version of the NEUROCLIMA climate-sensitive policy co-creation framework (M18)*, aims to address these challenges. It integrates AI-driven tools for data and information (*NeuroclimaLens* and *Bot*), deliberation (*NeuroClimaDialogues*), eLearning (*NeuroClimaLearn*), interactive storytelling (*NeuroClimaPlay*) all

[6] As Arnstein's ladder dates back to the 60's, and although it still represents a reference when it comes to envisaging the diversity of participatory processes based on the political agency focus, a lot of discussions and proposals have taken place since then. Worth mentioning for instance Collins and Ison (2006), who emphasised the dynamicity of the ladder' steps, not to be seen as fixed rungs, but considered in a social learning perspective, a way to embrace more collaborative and emergent forms of participation. To this important nuance, Davis and Jane (2017) added the depth and richness of such processes as co-creation and even consultation, as part of an approach leaving room to reflexivity and gradual power sharing options in context-specific practices, a pragmatic viewpoint strengthened in its own term by the LISODE guide (2017), which showed the importance, regarding flexibility and learning, beside the variety to be associated with the territorial anchoring of participation, to the techniques, tools and settings involved. Worth completing this brief look at how the Arnstein ladder may be used in a contemporary debate is the revisiting work done by Varwell (2022) who covered a comprehensive review integrating the diverse forms of digital engagement, leading to a multi-dimensional model of the ladder.

underpinned by a rich repository of participatory design, creative expression and cinematography tools. By synthesizing and presenting complex evidence, *Lens* & *Bot* keep policymakers up to date on emerging research and help them identify, model and propose the most suitable policies in debates. At the same time, *NeuroClimaPlay* and *Learn* ensure that citizens receive clear, engaging education tailored to their context. Armed with these insights and well-defined participation criteria, everyone can contribute meaningfully on the NeuroClimaDialogues platform. This combination makes deliberation more engaging, inclusive, and adaptive. It also helps citizens and policymakers reach better-informed, consensus-driven decisions.

3.1. From Participation to Deliberation

Hence, there are levels to which citizens can engage in policymaking and politics. In the European Union, the most widespread and well-known form of participation is **voting**, which forms the basis of representative democracy. Participatory and direct democratic methods go further, allowing citizens to engage to a greater degree in policymaking via deliberation, referenda, etc. Over the last decade, there has been a proliferation of participatory commitments and experiments in the Union at Memberstate and EU level.

The Treaty on European Union (TEU), which is one of the primary Treaties of the EU and lays down the basis of EU law, requires citizen participation in Article 10.3: *Every citizen shall have the right to participate in the democratic life of the Union. Decisions shall be taken as openly and as closely as possible to the citizen*.

Alberto Almanno (2018) and Russack (2018) highlighted the following mix of bottom-up and top-down tools in the EU's participatory toolbox:

- the European Citizens Initiative (ECI),
- the availability of input mechanisms (such as public consultations) during policymaking,
- administrative and monitoring actions that citizens can take (such as requesting access to EU documents, contacting the EU Ombudsman, or petitioning the Parliament),
- the ability to legally challenge EU actions,
- Citizens' Panels or Citizens' Dialogues.

The 2021 Conference of the Future of Europe and the series of European Citizen Panels since then are deliberative sessions with randomly selected citizens from EU Member States. While none of these tools are perfect, they signal a willingness from the part of the EU to foray into deliberative democracy.

Deliberative democracy is a type of participatory democracy that emphasises the importance of reasoning, discussion, and mutual justification in joint decision-making. Instead of simply aggregating existing preferences (like in voting), deliberative democratic policies are the result of accessible, respectful, and reasoned deliberation among free and equal citizens. Its proponents argue that it is a normative standard – an idea about how democracy *should* work. (Fishkin, 2009, 2011) In other words, deliberative democracy refers to a democratic practice in which deliberation plays a central role. Deliberation, for instance, can occur prior to voting, enabling citizens to become better informed and to comprehend and collaboratively navigate differing viewpoints (Bächtiger et al., 2018)

Deliberative Mini-publics (Table 1) are forums that aim to reproduce the perspectives of the public at a smaller scale, typically through sortition based on demographic characteristics like age, gender, ethnicity, location, etc. (Bächtiger et al., 2018) The deliberative activities of these mini-publics (*Deliberative Mini-publics*) can take many forms, such as Citizens' Assemblies, Citizens' Juries, Deliberative Polls, or Planning Cells. Ideally, these fora are carefully designed to foster deliberation by providing balanced information, access to experts, trained facilitators, and sufficient time for discussion and reflection. Realistically, the quality of deliberation and the outcomes of these fora depend heavily on financial and logistical restrictions, on the ability of the organisers to include varied perspectives, and on the institutional backing of the outcomes.

Table 1. Deliberative Mini Publics. Application of Deliberative and inclusive practices in the context of Climate Change Adaptation.

Method	Origin Year	Description
Citizens' Juries	1971	A small group of randomly selected citizens deliberates on an issue over a few days to produce informed recommendations.
Planning Cells	1970S	Large groups are divided into smaller "cells" to deliberate on policy issues and generate a collective report.
Consensus Conferences	1987	Lay citizens discuss scientific or technical topics with experts to develop a consensus report over several days.
Deliberative Polls	1994	Randomly selected citizens are polled before and after structured deliberation to measure informed opinion shifts.
Citizens' Assembly	2002	Large representative groups deliberate over several weeks to develop detailed policy recommendations, often influencing legislation.

There is a tremendous amount of potential for digitalisation and digital tools to further deliberative democracy (Mikhaylovskaya, 2024). Digitalisation can help increase the scale of deliberation, help with translation, summarising and visualising discussions, facilitation, and information-gathering. It is for this reason that NEUROCLIMA joins a host of deliberation actions in piloting digital deliberative tools in its use cases.

Deliberative mini-publics (DMPs), such as citizens' assemblies, have gained prominence in climate governance, particularly following high-profile examples in France (*Convention Citoyenne pour le Climat)* and the UK (*Climate Assembly UK*). For example, the UK Climate Assembly supported aligning COVID-19 recovery with climate goal[7]s, and France's assembly backed ecocide legislation[8]. Such assemblies can help break political deadlock, offer legitimacy to controversial policies, and enhance public trust, as citizens are more inclined to accept recommendations developed by peers through fair and informed deliberation.

3.2. Deliberation in Climate-Related Initiatives

The landscape of deliberative democracy in practice has a rich variety of methods, each with distinct approaches to recruitment, inclusion, and scaling, applied across diverse topics. The *Participedia* repository provides a comprehensive collection of cases focused on deliberation and public participation in climate change-related initiatives.
For the purposes of NEUROCLIMA, we selected the **most relevant cases— involving digital or hybrid technologies where digital tools play a significant role—and where the focus is on climate change adaptation or mitigation efforts.**[9] To lay the foundation for a deeper analysis—one that enabled us to

[7] https://participedia.net/case/climate-assembly-uk-and-the-covid-19-crisis
[8] https://theecologist.org/2020/jul/15/incorporating-ecocide-french-law
[9] The cases we selected were gathered following an initial search on Participedia conducted on January 29, 2025, using the query ("deliberation" AND "climate change"). From the 113 results obtained, we selected only those most relevant in terms of use of digital technology, and we excluded non-European cases, with the exception of a few particularly relevant ones, such as e-Democracia and the Morris Area Rural Climate Dialogues.

examine the case and reflect on participatory actions from a systemic perspective—we analysed them through a specific set of lenses, which are outlined below.

The lenses are: *Use of digital technology, inclusivity, and scalability.*

- **Use of digital technology:** Technology plays an increasingly common role in democratic innovation projects, but its use is often limited to enabling interaction rather than supporting *deliberation*. In many cases, online platforms and tools are employed primarily to provide information, collect feedback, and facilitate communication, rather than to foster deep, iterative deliberative processes. For example, Brazil's *e-Democracia* platform offers various tools—such as video chats, forums, and surveys—as well as spaces like *Wikilegis* for collaborative input on legislation. While these features enable public engagement, they do not necessarily constitute a fully integrated *e-deliberation* system. Similarly, the *Participatory Redesign of Tempelhof Airport* in Berlin included online phases such as brainstorming and moderated discussion. These mechanisms allowed participants to submit and discuss ideas, but again, within a framework more aligned with consultation or idea collection than with sustained deliberative exchange. Social media and ICTs are also widely used in democratic innovation projects—such as *Geraldton 2029 and Beyond*, and the *IDEAL-EU Social Networking Platform*—mainly for campaigning, raising awareness, and encouraging participation. However, these efforts generally lack integration into deliberative platforms that would guide participants through structured reflection and decision-making processes. Online formats have enabled broader participation in climate-related citizens' assemblies, including those in *Adur and Worthing*, *Bristol*, *Herefordshire*, and *Brighton and Hove*. Although digital tools facilitated access and inclusivity—sometimes using sortition algorithms to ensure representative recruitment—deliberation often occurred in parallel or hybrid settings, rather than being driven by a coherent, purpose-built digital deliberation environment. Even projects like e-Democracia, which explored multi-channel outreach through email, SMS, and community radio, focused more on expanding access than on developing a deeply integrated e-deliberation process. Some technical support was provided to ensure participant inclusion, and outcomes were documented online to promote transparency. Yet these features serve primarily as interaction tools rather than components of a unified deliberative system. In summary, while technology is widely adopted in participatory projects, it is most often used to support communication and engagement—less frequently as the foundation for integrated, structured *e-deliberation.*
- ***Inclusivity:*** Including diverse perspectives is crucial for deliberation. Unfortunately, marginalised populations (such as ethnic minorities, youth, people with disabilities, or people with low levels of education) are often left out of deliberative activities, tokenised, or spoken over. Countering this requires organisers to devote resources to raise the participation rates of underrepresented communities through steps like affirmative recruitment or providing necessary accommodations (e.g., alternative text, interpretation, accessible venues, etc.). Technology can be used to facilitate this involvement by making it easier to scale up deliberation, join remotely, provide translation, or moderate participation so no-one is left out - but digitalisation can also exclude those with low digital literacy or limited access to the necessary equipment. In our sample, the most commonly reported practice for increasing inclusivity was **stratification during recruitment**. Recruitment strategies across projects varied in approach and ambition, reflecting differing goals around inclusivity, legitimacy, and feasibility. Most climate assemblies, including *Adur and Worthing*, *Herefordshire*, *Leeds*, and Brighton, relied on **stratified random sampling**, often aided by organizations like the Sortition Foundation[10]. These methods ensured demographic

[10] https://www.sortitionfoundation.org/

representation across age, gender, ethnicity, geography, and income. The *Global Assembly* adapted this approach globally by deploying local outreach teams and translating materials into over 30 languages—an effort necessary to overcome the lack of reliable global demographic data and to include participants with limited literacy or internet access. In contrast, the *e-Democracia* platform in Brazil adopted a more open-access model, encouraging mass participation via online platforms, social media, and offline civil society outreach. This crowdsourced model was inclusive in scale but traded off representativeness. Similarly, *Termoli's Public Debate* relied on self-application from individuals representing "legitimate interests," such as associations and institutions, which raised questions about impartiality and the democratic depth of the deliberation. There were also hybrid efforts: *Uster* and *Camden* complemented stratified sampling with **outreach and support service**s (e.g., childcare, compensation) to mitigate barriers to participation.
- **Scalability:** A major contribution of digitalisation is that i**t has the potential to scale up deliberation**. As the *Ardur and Worthing Climate Assembly* noted, "online formats may increase transferability to higher governance levels by reducing logistical costs". However, they noted that greater use of technology would "limit the spread of their deliberative model in areas with low digital literacy". Most of the reflections on scalability and replicability in the sample of the method or outputs of deliberation had to do with the substance of the deliberation or its sociopolitical context. For example, the *Herefordshire Citizen's Climate Assembly* remarked that their findings were more suitable for rural contexts, and the *Morris Area Rural Climate Dialogues* (organised thrice in Minnesota) were said to have a political context suited for deliberation.

Each case mentioned can be explored in more detail via the direct links and description provided in → **ANNEX II**.

From this review of climate-focused deliberative practices and cases, it's clear that while digital tools and e-deliberation platforms do have a role at the EU level, they must be embedded within a structured, participatory ecosystem to succeed. NEUROCLIMA is positioned to deliver on this need: by integrating an e-deliberation platform (*NeuroClimaDialogues*) into a broader suite of digital tools (*NeuroclimaLens, Bot, Play, Learn and Tools*) and support mechanisms (such as *Social Tipping Points*), it can facilitate inclusive engagement, collaborative co-design, and meaningful dialogue among diverse stakeholders across Europe. Some examples of participatory ecosystems supporting e-deliberation are mentioned in the following section.

3.3. Participatory Ecosystems Facilitating E-Deliberation

In recent years, the integration of digital technologies into deliberative democratic practices has opened new pathways for inclusive, scalable, and interactive citizen engagement. (Mikhaylovskaya, 2024) Capturing the collective intelligence and diverse perspectives of the public requires meaningful engagement, yet doing so at scale presents significant practical hurdles. In response, innovative digital platforms specifically designed to foster deliberation – structured discussion, shared learning, and reasoned argumentation – have emerged as powerful tools. These technologies are being adopted globally to create new avenues for citizen participation, **bridging the gap between decision-makers and the communities they serve.**

These tools support a range of functions – recruitment, agenda-setting, information sharing, discussion, decision-making, and feedback loops – enabling more flexible and responsive democratic processes. At the most basic level, **online discussion forums** and **moderated chat platforms** (such as *Discourse*[11] or *Slack*) allow for asynchronous dialogue among citizens, often guided by facilitators or structured prompts. (Fujihira, 2025) **Digital polling tools** like *Mentimeter* or *Slido* are frequently used in real-time deliberations to capture preferences, assess consensus, or prioritise topics. More sophisticated platforms such as *Decidim*, *CONSUL*, and *Your Priorities* offer end-to-end **participatory ecosystems** that support proposal submission, collaborative deliberation, voting, and transparency in public decision-making. (Borge et al., 2023) These systems often include integrated modules for participatory budgeting, collaborative document editing, and tracking of government commitments, thereby linking deliberation with tangible policy outcomes.

Artificial Intelligence and Machine Learning (ML) technologies are increasingly employed to **structure debates, summarize citizen input, detect emerging themes, and visualise areas of consensus or polarization**. (Kargupta et al., 2025) For example, tools like *Pol.is* use unsupervised ML to map the distribution of opinions in large-scale online discussions and help identify points of convergence. Natural Language Processing (NLP) techniques are also used to analyze open-ended responses, filter abusive content, and support multilingual deliberation through automated translation. (G K, 2023) For example, *BCause* app structures group reasoning into four clear phases—Map, Discuss, Reflect, Decide—while AI-powered argument mapping turns raw transcripts into navigable dialogue graphs that help participants trace evidence, spot gaps, and converge on well-informed outcomes (Anastasiou & De Liddo, 2025). *Democratic Reflection* transforms passive viewing of speeches or debates into an active, real-time dialogue by letting audiences select reflective “nudges” via a second-screen interface, thereby strengthening moment-by-moment engagement (De Liddo et al., 2020). Additionally, **geospatial mapping tools** and **digital twin models** are being used in urban and climate-related deliberations to allow participants to interact with visual simulations of policy outcomes, enhancing comprehension and engagement. (Ali et al., 2023)

These digital approaches can complement traditional face-to-face methods or serve as fully online alternatives, particularly when accessibility, geographic dispersion, or public health concerns – such as those experienced during the COVID-19 pandemic – limit in-person participation. Importantly, technology-enabled deliberation expands participation opportunities for underrepresented groups, including younger populations, individuals in rural or remote areas, people with mobility limitations, and those with limited time availability. (Gherghina et al., 2021) Furthermore, these tools enable the collection and analysis of large volumes of participant input in real time, making it possible for decision-

[11] https://www.discourse.org/

makers to process diverse viewpoints and integrate them more systematically into policy development. As these technologies evolve, they hold the potential to significantly strengthen the legitimacy, transparency, and effectiveness of participatory governance at local, national, and transnational levels. (Mikhaylovskaya, 2024) From a **digital implementation perspective**, **deliberation is significantly more complex to manage** than simpler forms of engagement such as **consultation, polling, or brainstorming**. While these lighter tools gather quick feedback or preferences, deliberation requires supporting structured dialogue, critical reflection, and interaction among diverse participants—challenges that demand more sophisticated platform design, moderation, and often, hybrid (online and offline) processes.

In the list below, we present the 10 highest-rated platforms according to People Powered in 2025[12]. For our purposes, we include Open Source platforms that place greater emphasis on deliberative processes[13]. The full list can be accessed in **ANNEX III**. We refer to them as "e-deliberation" platforms because they are digital tools designed not only to facilitate participation and dialogue, but also to **support the analysis of both the deliberative process and its outcomes.** Hence, a clear trend emerges: **e-participation is increasingly shifting from simple consultation toward deeper forms of deliberation**. According to Wilcox's ladder of participation (Wilcox, 1994; Willis et al., 2022), deliberation represents a more **substantial and meaningful form of citizen engagement—moving beyond consultation as one of the first steps toward real influence and shared decision-making. (Figure 2)**

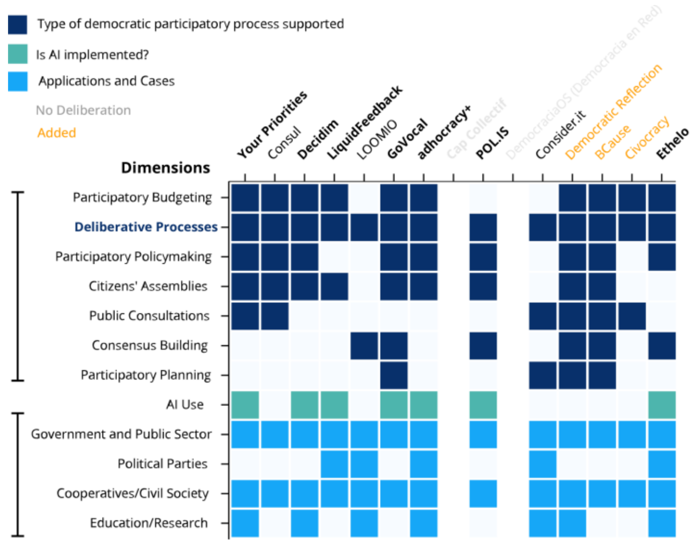
- The *Your Priorities* platform, developed by the Citizens Foundation in Iceland, has been used worldwide, including in Estonia and the UK, to enable collaborative citizen input into policy. The platform allows users to propose ideas, engage in argumentation for and against proposals, and vote on them. It was notably used during *Reykjavik's Better Neighborhoods* initiative to allocate funding for local environmental and infrastructure improvements. (Silva et al., 2025)
- The *CONSUL* platform is another open-source technology used globally for participatory governance, notably in Madrid. It supported a city-wide deliberative process on climate and urban planning policies, combining digital input with offline workshops. Citizens could submit and comment on proposals, participate in debates, and vote on initiatives through the platform. Its structured process helped over 400,000 residents engage in policy formulation between 2016 and 2019. (Arana-Catania et al., 2021)
- One prominent example is *Decidim*, an open-source participatory democracy platform developed in Barcelona, which supports proposal creation, debate, prioritization, and voting across various participatory processes, including climate action planning. Decidim has been widely adopted by cities across Europe, enabling large-scale citizen engagement in municipal decision-making. For example, in Helsinki and Paris, the platform was used to run participatory budgeting and environmental consultations, facilitating deliberation on urban sustainability projects and climate resilience initiatives (Borge et al., 2023)
- LiquidFeedback is an open-source platform designed for collaborative proposal development and decision-making in medium to large groups. Developed by Interaktive Demokratie, it supports deliberative processes, participatory budgeting, and citizens' assemblies, and is widely used by governments, political parties (e.g., Pirate Party Germany), CSOs, corporations, and cooperatives. The platform enables **hybrid integration with in-person activities and is accessible, mobile-friendly, and multilingual** (supporting languages such as French, German, Spanish, and Greek). It has been applied globally—including in Germany, the UK, Argentina, and Myanmar—with notable

[12] https://www.peoplepowered.org/platform-ratings

[13] People Powered's classification tags each platform by the services it offers; we've included only those that support deliberation.

use cases like Friesland County's first citizen participation initiative and the Yorkshire Climate Consultation (2023).

- *Loomio*, originally developed in New Zealand, is a decision-making tool for groups to deliberate, discuss proposals, and reach consensus, and is widely used by community organizations and public sector projects, grassroots environmental groups, and policy consultation groups. (Rafał Olszowski, 2021)
- *Go Vocal*, (formerly Citizen Lab) is a **multifunctional platform** widely used in Europe. It leverages language processing and data analysis to improve online discussions and decision-making. Despite being relatively new, it has already supported participatory initiatives in over 500 cities worldwide, including Oslo, Vienna, Copenhagen, Cape Town, Seattle, and Toronto. (Aeken, 2017)
- *Adhocracy+* is a German open-source platform used by over 400 institutions in at least six EU countries. It facilitates a wide range of democratic processes—such as citizens' assemblies, participatory budgeting, and climate policymaking—through a multilingual and accessible web interface. The platform structures participation into three phases: *defining topics* (via brainstorming and polls), *discussion* (with debate modules and text reviews), and *decision-making* (using idea challenges and budgeting tools). It offers dedicated pages with guidelines and recipes for carrying on activities[14]
- The *Pol.is* tool uses machine learning to visualise opinion trends and highlight areas of consensus or division among participants, and has been used for policy debates on tech regulation, privacy, gig economy, and environmental issues[15]
- *Consider.it* is a U.S.-based platform designed to support focused online dialogue by **visually summarizing community opinions and their underlying reasoning**. It has been used in various contexts—from city consultations (e.g., Seattle, Denver) to strategic planning by nonprofits, political parties, and co-housing communities. With support for multiple languages and global use (e.g., U.S., Brazil, Slovakia), the platform offers tools for data visualization, moderation, and secure discussions.
- Ethelo is a Canadian digital platform designed to facilitate fair and inclusive group decision-making, particularly in complex and contentious scenarios. It combines advanced algorithms with collaborative tools to help organizations and communities reach broadly supported outcomes.



[14] https://adhocracy.plus/info/use-cases/online-diskussionen/

[15] Polis Case Study

Figure 2: Classification of e-Deliberation Platforms

Moreover, we would like to highlight that *PeoplePowered* is currently conducting an ongoing analysis of emerging participation tools that leverage AI[16]. At this stage, they have not yet produced a formal rating or evaluation. While we have already selected and considered some of these tools, part of our work in the coming months will involve examining them more closely and assessing their potential.

3.3.1. National and Municipal Initiatives in Europe

Across Europe, digital tools have been increasingly integrated into deliberative democracy initiatives, often as part of broader efforts to modernise citizen engagement and policy-making.

- In **Finland**, the government developed *Otakantaa.fi*, a national online consultation platform that allows citizens to comment on legislative proposals, participate in surveys, and engage in discussions on various policy issues. Notably, it was used during the drafting of Finland's Climate Change Act, helping gather citizen views on emission reduction targets and adaptation strategies. The platform's transparent discussion forums and open data model helped increase trust and visibility in the decision-making process.
- In **France**, the **"***Grand Débat National***"** in 2019 marked a large-scale national deliberative effort, heavily supported by online tools. Citizens contributed over 1.9 million comments via an online platform addressing topics such as ecological transition and taxation. Though criticized for top-down framing, the platform enabled wide participation and facilitated large-scale textual analysis of citizen feedback, which was used to inform national policy direction. Beyond the Grand Débat National, the city of **Paris** employed its *Madame Mayor, I Have an Idea* platform as part of its participatory budgeting process. Citizens submitted and deliberated on thousands of proposals, many related to climate action, such as green space development and energy-efficient building upgrades. The digital platform enabled city-wide deliberation and voting, with the most popular ideas receiving implementation funding. This model, supported by structured online deliberation and real-world impact, was subsequently adopted by other French cities.
- **Germany** has piloted several digital deliberation tools in regional planning and climate policy discussions. For instance, the *Online Planning Dialogue* in Hamburg allowed citizens to deliberate on infrastructure and environmental policies related to urban mobility and climate adaptation. The platform facilitated thematic discussions, supported by moderators and background documentation, and was credited with increasing transparency in regional decision-making.
- In **Estonia**, the *Rahvaalgatus.ee* platform enables citizens to submit and support policy proposals, including on environmental issues. The platform facilitates debate through commenting features and forwards citizen proposals to the national parliament once they surpass a signature threshold. It's a strong example of a low-cost, high-impact digital deliberation tool embedded in formal legislative processes.
- In **Scotland**, the *Scottish Climate Assembly* combined in-person and online deliberation methods due to COVID-19 restrictions. Participants met via Zoom and used an online learning hub and structured deliberation tools, including polls and breakout groups, to discuss climate action. The digital infrastructure enabled full participation from all members, regardless of location, and was critical to maintaining engagement across multiple weekends.
- In **Belgium**, the *Ostbelgien model* includes a permanent Citizens' Council that sets agendas for rotating Citizens' Assemblies. While primarily offline, it incorporates digital feedback tools, such as collaborative platforms for proposal refinement and digital voting mechanisms, allowing

[16] https://www.peoplepowered.org/platform-ratings see section "New tools"

broader participation from residents unable to attend in person. The model is often cited as one of Europe's most institutionalised and tech-assisted deliberative ecosystems.

These examples highlight how European governments and institutions increasingly use digital tools not just for consultation, but for **structured, inclusive deliberation**, especially on complex and future-oriented issues like climate policy. The convergence of democratic innovation and digital infrastructure offers key lessons for scaling participatory practices such as those envisioned in NEUROCLIMA.

3.4. Assessing Deliberative Initiatives Through Digital Technology and Participatory Lenses

To better guide the classification of cases (either from *Partecipedia* and from *PeoplePowered*) in relation to the NEUROCLIMA solution, we asked task partners to map selected representative cases from the literature along two main axes. The first axis reflects the role of digital technology, ranging from **minimal to intensive use.** The second axis focuses on the scale of deliberation, conceptualised as a ladder of **increasing depth and inclusiveness in the deliberative process**.

We selected 20 original cases relevant for the project being all expressions of deliberation initiatives related to climate change across the cases studies and platforms analysed so far for an exercise of Card Sorting (Spencer, 2011) (Figure 3). Each card was equipped with: the title of the case, the deliberation platform (if used), the type of process, the country, the year and the link to their description.

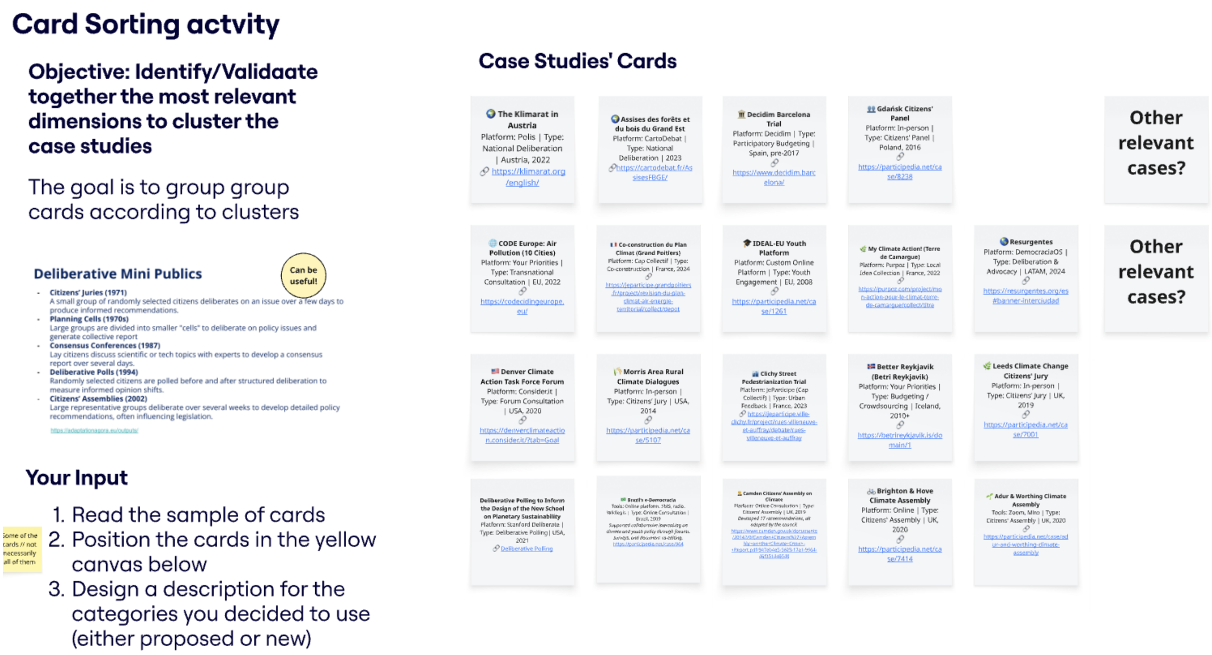


Figure 3: The instruction for the Card Sorting activity and the main canvas on Miro where the irrelevant cases were positioned.

The selected cases reflect a diversity of participation types, encompassing various forms of civic and multi-stakeholder engagement. (Table 2) Projects were chosen from[17]:

- **Different geographical regions** — with a majority from the EU but also including non-European examples — to minimize cultural or political bias in the sorting activity.
- The sample spans **the last 20 years to ensure temporal variation** and
- Includes a balanced **mix of digital platforms**.

Divided into two smaller groups, consortium members with expertise in digital technology and deliberative processes positioned each case study card within a shared space. They interpreted the scale from "None"—indicating no use of digital tools or absence of deliberative process—to "High," representing either strong support from AI technologies or a high level of deliberation. (Figure 4)

Table 2: Selected cases for the activities, reflecting a diversity of participation types, encompassing various forms of civic and multi-stakeholder engagement.

Examples	Platform	Type	Country	Source
The Klimarat in Austria	Polis	National Deliberation	Austria (EU)	PeoplePowered
Assises des forêts et du bois du Grand Est	CartoDebat	National Deliberation	France (EU)	PeoplePowered
Decidim Barcelona Trial	Decidim	Participatory Budgeting	Spain (EU)	PeoplePowered
Gdańsk Citizens' Panel	In-person	Citizens' Panel	Poland (EU)	Participedia
CODE Europe: Air Pollution	Your Priorities	Transnational Consultation	EU	Participedia
Co-construction du Plan Climat	Cap Collectif	Co-construction	France (EU)	PeoplePowered
IDEAL-EU Youth Platform	Custom Online Platform	Youth Engagement	EU	Participedia
My Climate Action! (Terre de Camargue)	Purpoz	Local Idea Collection	France (EU)	PeoplePowered
Resurgentes	DemocraciaOS	Deliberation & Advocacy	LATAM	PeoplePowered
Denver Climate Action Task Force Forum	Considerit	Forum Consultation	USA	PeoplePowered
Morris Area Rural Climate Dialogues	In-person	Citizens' Jury	USA	PeoplePowered
Clichy Street Pedestrianization Trial	JeParticipe (Cap Collectif)	Urban Feedback	France (EU)	PeoplePowered
Better Reykjavik	Your Priorities	Budgeting / Crowdsourcing	Iceland (EU)	PeoplePowered

[17] This is an illustrative sample, meant as a starting point for the activity. It can, of course, be expanded or adapted with additional cases depending on the context or goals of the discussion.

Leeds Climate Change Citizens' Jury	In-person	Citizens' Jury	UK	PeoplePowered
Deliberative Polling – Planetary Sustainability	Stanford Deliberate	Deliberative Polling	USA	PeoplePowered
Brazil's e-Democracia	SMS, radio, Wikilegis	Online Consultation	Brazil	Participedia
Camden Citizens' Assembly on Climate	Online Consultation	Citizens' Assembly	UK	Participedia
Brighton & Hove Climate Assembly	Online	Citizens' Assembly	UK	Participedia
Adur & Worthing Climate Assembly	Zoom, Miro	Citizens' Assembly	UK	Participedia

The result of this activity involving partners of T3.1, shows that climate-related public participation initiatives differ in their integration of digital technology and the depth of deliberative engagement and we can find some patterns.

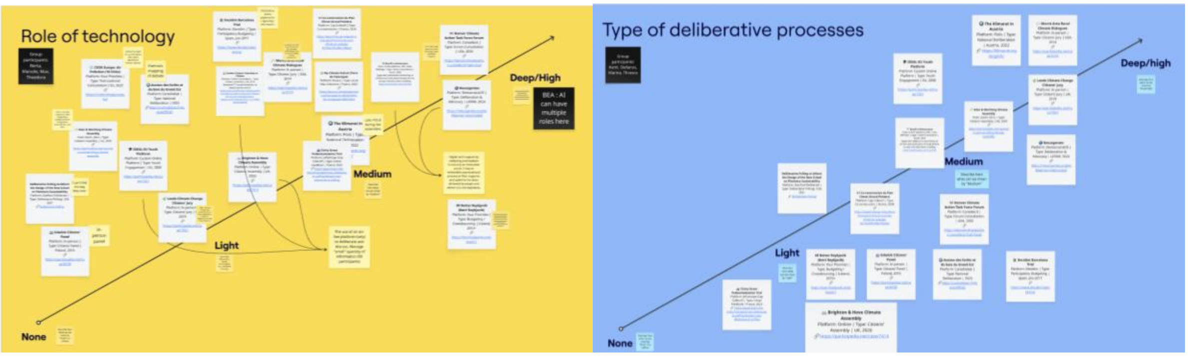


Figure 4: Screenshot from participatory activities illustrating the mapping of cases according to their levels of digital technology use and depth of deliberation.

Plotted along two axes—one measuring the intensity of public deliberation (from light consultation to processes that shape decisions) and the other assessing the sophistication of digital tools used (from static websites to AI-driven platforms), Figure 5 distinguishes between initiatives that leverage participatory platforms for structured deliberation and those that do not.

Cases fall into four broad types, distinguished by the balance between the richness of deliberative processes and the sophistication of digital support:

- **High Deliberation - High Digital:** Schemes such as *Austria's Klimarat* and *Denver's Climate Action Task Force Forum* combine in-depth qualitative citizen engagement with robust online platforms. They integrate interactive digital tools, expert facilitation and structured reflection to swiftly translate public insights into policy briefs.
- **Low Deliberation - Low Digital:** One-off consultations with minimal online interaction typify this quadrant. For example, Brighton & Hove's Climate Assembly employs only basic digital communications and offers little feedback integration, resulting in limited follow-through or tangible policy impact.
- **High Deliberation - Low Digital:** Initiatives such as the Leeds Climate Change Citizens' Jury rely almost entirely on in-person, multi-day assemblies enriched by expert presentations and printed materials. Digital elements are largely passive — used for archiving or broadcasting outcomes rather than for active participant engagement.

- **Low Deliberation - High Digital:** Platforms like Reykjavík's Your Priorities mobilise thousands through online idea submission, argumentation and voting, yet stop short of structured, multi-stage deliberative dialogue. The process remains largely consultative rather than co-creative, limiting the depth of citizen influence on final decisions.

Together, these examples illustrate that while advanced digital tools can extend reach or accelerate synthesis, genuine co-creation of policy demands both meaningful deliberative design and appropriate technological support.

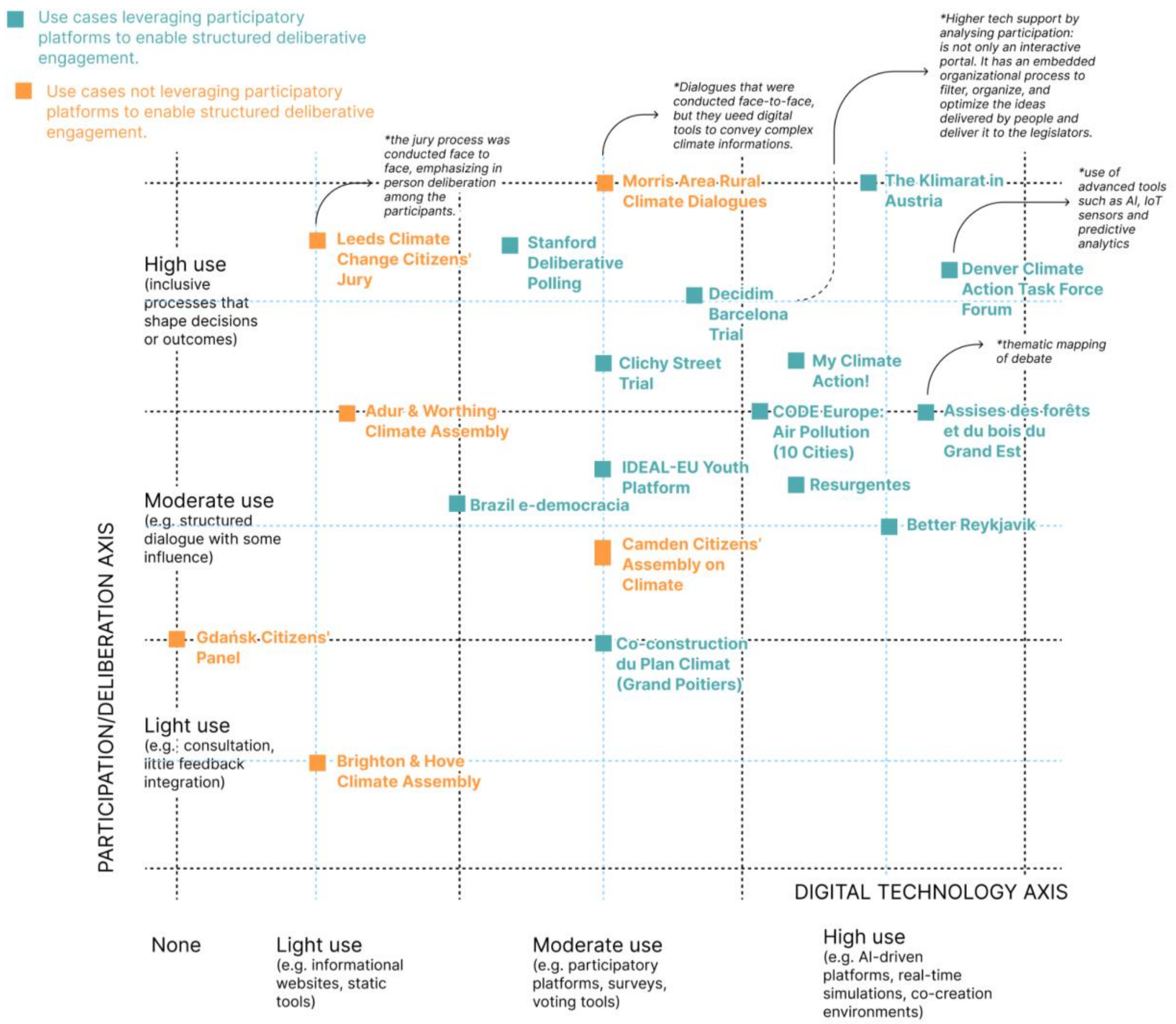


Figure 5: Mapping of initiatives resulting from the Card Sorting activity along two axes: the vertical axis measures the intensity of participatory processes (from light consultation to fully deliberative and decision-shaping assemblies), while the horizontal axis gauges the sophistication of digital support (from static websites to AI-driven platforms).

The visualisation underscores that while digital tools can enhance engagement, meaningful deliberation often also depends on institutional design and inclusive processes, not just technological sophistication.

Therefore, it is essential to develop an integrated system that not only offers e-deliberation but also provides tools to **facilitate participation**, ensures that **participants are well-informed** on the topic, allows them to **express themselves** in multiple ways, and offers them **appropriate support and protection**. NEUROCLIMA seeks to translate these principles into practice through co-creation activities, real-world pilots, and use case development. The next section illustrates how these elements have been operationalised to explore the dynamics of scaling within the project's ecosystem. (Figure 6)

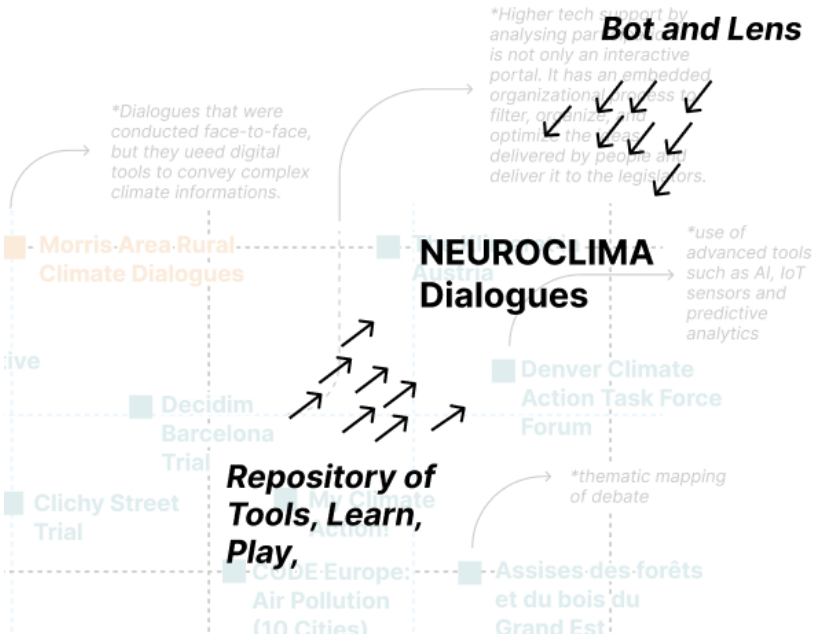


Figure 6: Top right quadrant. Dialogues bridges evidence and engagement: Lens & Bot deliver data-driven insights while Learn, Play & the Repository build participants' capacity and local knowledge for action.

4. Scaling Dynamics in NEUROCLIMA

The concept of a deliberative system has since gained widespread adoption (Parkinson & Mansbridge, 2012 in Bächtiger et al., 2018). At its core, the idea emphasizes the importance of evaluating both the **deliberative quality** of the overall system and **that of its individual components**. A central and complex challenge for deliberative democrats lies in understanding **how various forms and venues of deliberation are shaped by their surrounding contexts, how they interact with established political institutions, how deliberation scales from face-to-face settings to broader public discourse, and how it ultimately contributes to democratic governance.**

Amid accelerating climate challenges, the NEUROCLIMA project harnesses the power of AI to drive urgent and sustainable transformation. This chapter explores the intersection of digital innovation and climate action—demonstrating **how technological advancements can amplify impact**, **foster behavioural change**, and **create more inclusive pathways for adaptation through collaborative and participatory methods**. In particular, by incorporating participatory and deliberative practices, we examine the systemic mechanisms that NEUROCLIMA brings to light, along with the dynamics, challenges, and barriers likely to emerge during its real-world implementation in our Pilots (also detailed in D6.1).

Hence, NEUROCLIMA offers a wide range of tools **aimed at supporting systemic transformation**.

- First, its **technology** —AI-supported mechanisms help stakeholders access the most relevant information through multiple entry points. This information can inform digital debates for policymakers, serve as a resource for journalists and content creators to better inform citizens, and support educators in shaping future-oriented curricula.
- These digital tools are complemented by **non-digital participatory and artistic methods**, which combine strategic planning with creative citizen expression.
- Central to this vision is the notion of **Social Tipping Points**—those individual and also more collective changes that, when nurtured and multiplied, spark broader systemic transformations. Human engagement is therefore indispensable: for AI-enhanced systems to be both trusted and effective, they must be co-designed and verified with the people who rely on them (journalists, policymakers…)

Together, they form an integrated system that empowers informed, inclusive, and imaginative climate-relevant action.

In order to embrace all the potential of educational and participatory processes linked to environmental challenges and the scaling mechanisms we can promote, however, as we should avoid any wishful thinking, it is worth envisaging a realistic approach, considering we have to successfully cope with the concrete struggle between on the one hand positive forces and triggers at work concerning climate change adaptations (among which media and education explanatory activities and the Social Tipping Points already mentioned) and on the other hand, contrary ones that tend to diminish, hinder or even fight such endeavours. Among the factors of this latter kind, to be acknowledged at face value :

1. The complexity of climate change and ways of relating to it (e.g. the local-global gap, circular economy schemes and how to get inserted in them with some measurable efficiency)
2. The cognitive dissonance between what is suggested, nudged, collectively pushed towards climate adaptation and the frequent difficulty of policy-makers to arbitrate between diverging constraints (e.g. the agricultural sector clams and ecological norms) and even the retro-pedalling effect of policy-makers in numerous environmental debates and decisions (and not

only in the US, where we can currently observe the most acute trend of that problem, but also in Europe).

3. Debates and evolving questions, e.-g. electric cars, which are considered as the obvious way to decarbonise traffic and therefore promoted as such by the EU and the MS, until new evidence came up to showing that the abundant rare earths needed for the batteries are, on the one hand, highly pollutive and, on the other hand, induce a dangerous dependency, possibly mitigating the trend toward the all-electric trend.
4. Paradoxes: AI to mitigate climate warming is among the quickest carbon footprint and hydric footprint rising factors of our time.

The purpose of this reminder is not to produce a demotivating picture regarding the urgency of stimulating behavioural change regarding environmental challenges but on the contrary, to anchor this broad effort in the concrete force field of today and tomorrow.

4.1. Scaling Mechanisms and Social Tipping Points

Change takes place all the time and in a multitude of forms, tempos and levels of complexity. NEUROCLIMA, as for itself, is concerned with specific changes, those which involve, through awareness and perception sharing, suggesting the potential for behavioural change that can in its context and own rationale constitute a contributive piece likely to alter the course of a major damaging process, climate change. There are various ways this can take place, for instance, as a predominantly gradual modification generated through cycles of media or/and educational explanations and users/citizens/inhabitants' cause-to-effect understanding of how our behaviour impacts the environment. Another way is linked to the fact that learning and social processes do not necessarily unfold in a linear, planable nor acceptable way, as different diverging or even to some extent mutually averse forces mobilise all individuals and groups of our society. This unevenness leaves room for concentrations of attention and concerns, and at times acceleration of how awareness, decision and action, as key segments of change processes, happen to converge. These particular moments have been coined as social tipping points (STPs). There are STPs of all kinds, NEUROCLIMA is mainly focused on those which can **trigger behavioural change of some level of effectiveness against climate change.**

More than just being concerned or focused upon, NEUROCLIMA is methodologically engaged in identifying those processes so as to help detect these phenomena, support them and show further on to a diversity of stakeholders how they can use the NEUROCLIMA solution to be part of such processes, ranging from such actions as integrating or/and strengthening existing STPs, replicating them or even contributing to envisaging the possibility of, and generate new STPs, in other words, possibly transforming NEUROCLIMA users in climate change actors.

Tipping points are interesting processes where, beyond mere inflections of conditions, individuals and groups can observe (problematic environmental effects, for instance) and hopefully envisage some substantial modifications of contextual factors. In the best case, i.e. the "social" dimension of these tipping points, there is room for sharing perception and understanding, and emerge as groups or communities of interest, and eventually a force of action and therefore change in its own terms.

NEUROCLIMA has created AI-based tools to search and retrieve reliable information on environmental challenges, which can upon these "behavioural springs" that constitute the social tipping points, emphasise and support the possibility for the key stakeholders mentioned in the previous sections to identify and thereupon, if desirable, engage in potentially changing processes. In order to do so, it has nurtured its LLM with key reference cases, i.e. some 10 initial entries duly qualified, to generate 100 and more entries, the learning pieces that the AI needs to be trained upon and starts embodying, if one can say so, the targeted capacities of NEUROCLIMA.

Five qualifying factors were retained as essential.

1. Environmental issues perceived to have significant societal consequences.
2. Shared awareness of the problem: must involve a certain level of social discussion, with the co-evaluation of what has happened, is happening, could or should happen and why
3. Shared understanding, at least to some extent, of the causes and effects related to the environmental issues
4. Expressions of perceived need for changes in habits or lifestyles
5. Socio-political demand for explanations, solutions, and actions, driven by the conviction that problems must be addressed and new qualities or life achieved.

We further distinguish between reference events or problems that have prompted—or are prompting—responses (engaging *reactive STPs*) and those that are being addressed proactively to foster new developments, improvements, or experimental approaches (and which also embody STP characteristics), which we classify as *proactive STPs*.

On this basis, the NEUROCLIMA solution is putting together a capacity not only to provide timely, relevant and reliable information regarding environmental challenges, but t**o facilitate behavioural change processes by connecting, as demanded, a source of information to a collective capacity for change.** More than that, NEUROCLIMA can help detect and strengthen similar processes to a reference type of STPs. This is due to what we called the "genericity" of reference cases (their character of being, to some extent, generic for a class of processes). A flood is a flood and although there may be a lot of possible differences making it happen from one situation to the other, as well as regarding the way local people react and manage to build upon a particular flooding episode the conditions for a structural change, some similarities can be emphasised as help to spot close-to-similar STPs. The semi-automated and then automated LLM capability to qualify and suggest STPs and linked to that, suggest classes of more or less similar phenomena, is also a scaling mechanism of NEUROCLIMA in its own terms.

4.2. NEUROCLIMA Tools: Scenario Development and Use Cases

Starting from the personas and user scenarios created within the framework of WP2 (presented in D2.2), we leveraged our in-person meeting in Athens in November 2024 to co-create new scenarios based on the ongoing development of the Neuroclima Integrated Solution. We invited partners to collaboratively generate these new scenarios, using the previously defined personas as a starting point. The activity followed a "chain" format, where each partner contributed to one step before passing it on. Participants were seated side by side to facilitate this collaborative flow. (Figure 7)

Figure 7. Co-design session identifying scenarios (Step 1).
Athens, November 2024, WP1 T1.1 and 1.2

The activity was structured in three main steps. In the first step (1), each participant identified a specific need related to the assigned persona and topic of interest. This involved describing what the persona needed and the context or purpose behind that need. In the second step (2), participants explored how the persona might have used the different components of the Neuroclima platform to address the identified need. They filled in what type of information or content the persona would have looked for in each module—NeuroClimaDialogues, Lens, Bot, Learn, and Play—based on the needs expressed in the previous step. Finally, in the third step (3), participants described the expected outcome. They explained what the persona gained from using the platform and what new capabilities or understanding they had achieved as a result. (Figure 8)

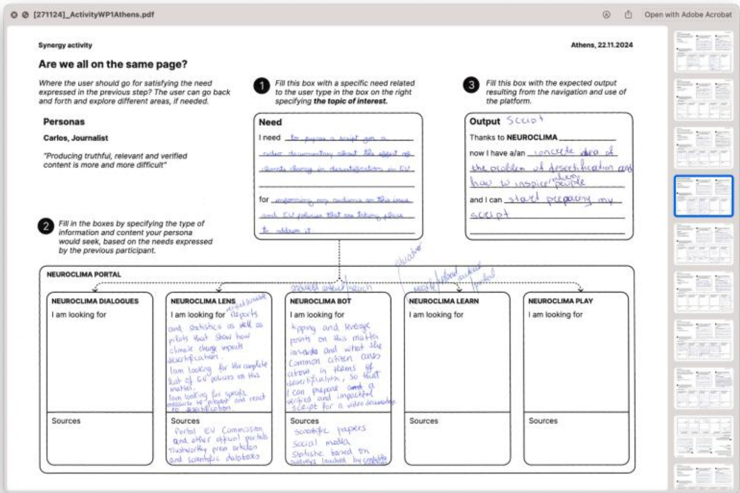


Figure 8. Example of a completed template. (1/16)

We brought all the contributions together and analyzed the results to define specific scenarios for each persona, applied to the various tools available within the NEUROCLIMA Solution. In total, we developed 16 scenarios. Each scenario outlined, on one side, the type of technology required to achieve the identified goals available in the NEUROCLIMA Solution (blue post its below), and on the other side (indicated using green post-its), the type of climate adaptation intervention that was expected to result from using the selected tool. (Figure 9) For instance:

- **Technology:** *"NeuroClimaBot supports journalists in preparing a script for a video documentary on the effects of climate change on desertification in the EU."*
- **Climate Intervention***: "***Informing the general public on the EU Climate Action on Desertification.** *Raising awareness by informing audiences about climate change's impact on desertification in the EU and sharing EU policies to combat this issue through a video documentary."*

Figure 9: A screenshot from the collective Miro Board we used for analysing scenarios of the Neuroclima Integrated Solution and their scaling dynamics.

This information was then used for carrying on a second activity, dedicated to the exploration of Scaling dynamics which involved partners of T1.3 in January 2025. The activity — *"Exploring Scaling Dynamics"* — was designed to reflect on how specific technologies, interventions, or initiatives from the Pilots could be scaled in different ways. Each group was assigned a particular example (they could choose among the pairs above) and asked to analyze its scalability potential across three dimensions: **Scaling Up, Scaling Out, and Scaling Deep**[18]. Participants were invited to brainstorm where their assigned technology or intervention fit within these dimensions. To strengthen our connection with the pilot activities, we asked partners to work in four groups, each dedicated to exploring the scaling dynamics of a specific use case. Each group focused on identifying how their assigned case could scale up, scale out, and scale deep, considering both technological and social aspects. These are the four use cases we are planning to develop as pilots. As described in *D2.2 - Technical, operational and interoperability specifications and reference architecture*, *D4.1* and *D2.3 - Use case requirements definition* , we have identified a set of main users dedicated to each one of our use case: Below (Table 3) are the use cases and the corresponding stakeholders as well as a diagrammatic representation of the tools that we are aiming to combine in our Pilot activities. (Figure 10)

[18] As introduced in Section 1 → Scaling Up focused on influencing policies, systems, or institutional change; Scaling Out involved replicating or adapting the solution in different locations or contexts; and Scaling Deep addressed cultural shifts, values, and long-term behavioural change.

Table 3: Table of pilots and use cases, as described in D2.3

Pilot	Use Case	Description	Target Stakeholder
1	1.1	Measuring the impact of AI monitoring tools and traditional and experimental informational approaches and tools on identifying social tipping and leverage points.	*Journalists and Content Creators*
	1.2	Measuring the impact of AI monitoring tools for policy/decision makers towards identifying and activating social tipping and leverage points for climate change adaptation	*Policy Makers and Citizens*
2	2.1	Implementing behavioural and systemic change through blended learning tools, participatory design and interactive storytelling	*Citizens, students and educators*
	2.2	Participatory design and creative expression as the driving force for the implementation of climate change adaptation	*Citizens and Youth workers*

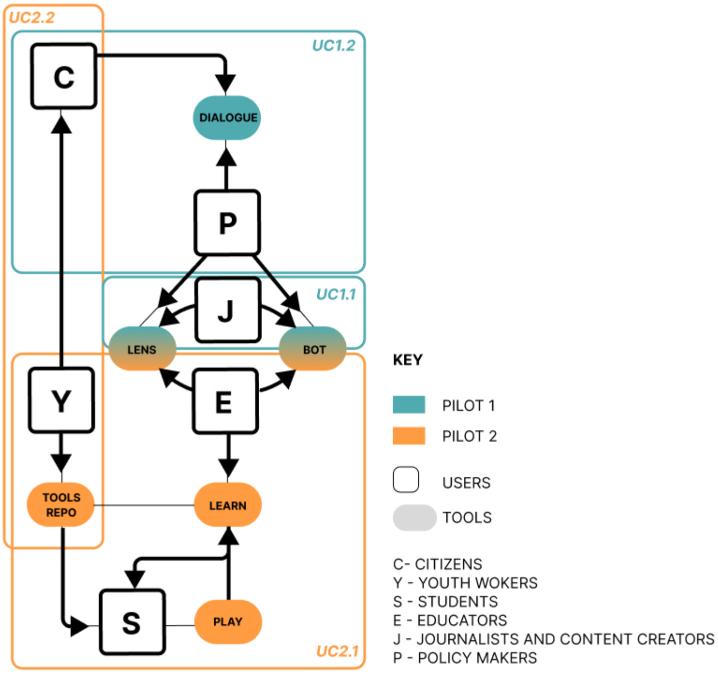


Figure 10: A diagrammatic representation of the Use Cases within pilot activities (Same as FIgure 1 but with Use Cases). Here, all the designed connections among our stakeholders are highlighted, as well as the tools they are testing within the pilot activities.

Groups captured their ideas on sticky notes, then placed in the corresponding sections of a visual framework representing the three scaling dimensions. This activity aimed to not only categorise the scalability potential but also stimulate discussion on how to enhance the reach and impact of each tool. Participants explored specific digital tech tool–intervention pairs and elaborated insights. (Figure 11) Full results of this activity can be found in ANNEX IV.

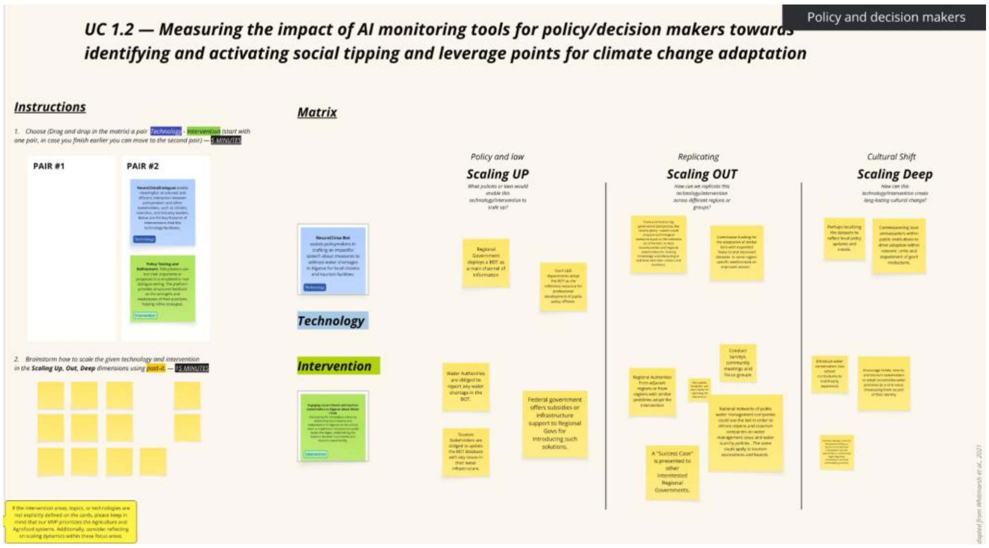


Figure 11: One of the canvas of the activity, showing the potential scaling mechanism for the pair *digital technology* and *intervention*.

As a second step of the activity, we focused on the different NEUROCLIMA tools of the Integrated Solution to identify the **levers and barriers** emerging at each scale—**scaling up, scaling out, and scaling deep**. The goal was to surface both challenges and potential for each tool. All partners involved in Task 3.1 participated in this session. They were asked to map specific levers and barriers corresponding to each short scenario previously developed during the scenario generation phase. (Figure 12)

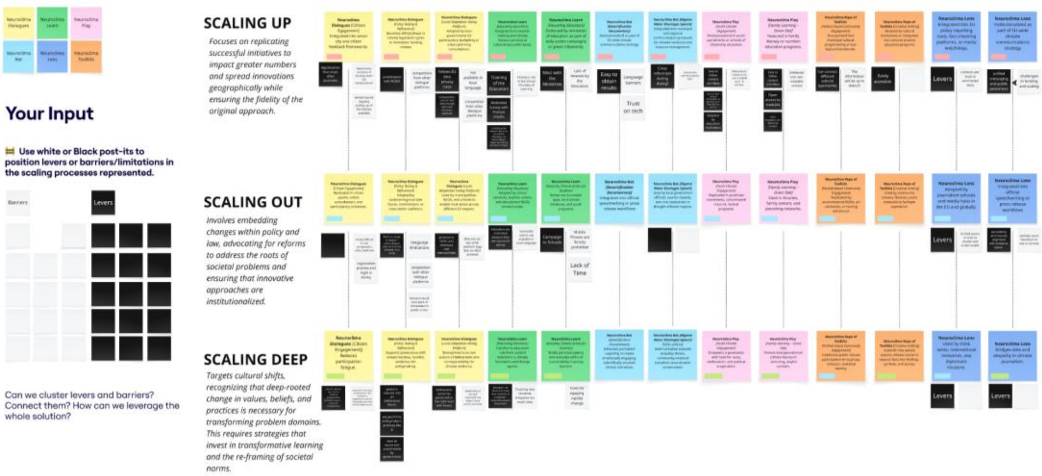


Figure 12: A screenshot from the collective miro board we used for detecting levers and barriers of Neuroclima Integrated solution and their scaling dynamics

4.3. Scaling Mechanism, Levers and Barriers Across tools.

The collaborative work described in the previous section revealed some insights into scaling scenarios, tools, and barriers. Building upon these results, the final section consolidates these findings into the NEUROCLIMA climate-theme sensitive scaling mechanism.

Here we show how NEUROCLIMA ecosystem can support scaling up, out and deep. Each NEUROCLIMA tool—Dialogues, Learn, Bot, Lens, Play, and also the Repository[19] (comprising Participatory Design, Creative Writing, and Cinematography Toolkits) plays a distinct role in this systemic scaling strategy.

While each NEUROCLIMA tool plays a role in its scaling dimension, ***NeuroClimaDialogues*** holds an interesting position within the ecosystem, serving as the **hub for institutional adoption and cultural transformation.** This is because genuine deliberation is the **foundational mechanism for achieving legitimate, sustainable, and equitable socio-technical transitions**, especially in complex and often contentious areas like climate adaptation: it bridges the knowledge-action gap, fosters trust, drives cultural change, and enables inclusivity. Hence, ***NeuroClimaDialogues*** **provides the deliberative arena where this intelligence, cultivated from different perspectives through the other tools, is collectively processed, legitimised, and translated into shared purpose.**

4.3.1. Scaling Up. Institutional Adoption and Policy Integration

Scaling up involves integrating the NEUROCLIMA tools and their results into formal institutional processes and policy frameworks. This ensures that citizen-driven insights and evidence-based solutions inform decision-making at a systemic level. The aim is to achieve broader policy adoption and integration, turning local successes into effective large-scale governance strategies.

Table 5: NEUROCLIMA tools' roles, levers and barriers in scaling up

Component	Role	Levers	Barriers
Dialogues	It will institutionalise citizen engagement in climate adaptation, integrating it into policy-testing and smart-city frameworks to directly inform policy with deliberative insights.	Uniquely capable of building trust and legitimacy in policy-making through structured public deliberation; compatibility with existing European and national networks (mini-publics, climate assemblies) accelerates uptake.	Significant legal and regulatory fragmentation across jurisdictions; lack of interoperability with other digital systems hinders administrative integration. Overcoming these requires strategic policy harmonisation.
Lens	Serves policymakers and institutional analysts to map public sentiment, emerging discourses, and value-based framings for climate adaptation policies. Supports real-time narrative tracking for communication strategies and agenda-setting.	Interoperability with other NEUROCLIMA tools (Dialogues, Bot); ability to synthesise large volumes of text for policy insights.	Reliance on NLP models requires continuous tuning; lack of institutional data-science capacity and language resources; difficulty translating semantic outputs into actionable insights; need for rigorous validation and transparency for institutional trust.

[19] While the Neuroclima Digital Solution has already been defined and the MVP will be released by M18 as described in D4.1., the design of the Neuroclima Repository of toolkits is still in progress (T3.3, T3.4, T3.5, T5.1).

Bot	Leverages the "democratised" nature of AI interactions to facilitate institutional adoption, aligning AI agent interactions with public expectations.	Builds on existing public familiarity with AI agents; cultural and technological acceptance.	Strict regulatory and ethical requirements (data protection, accountability); need for explainability and transparency in AI outputs; risk of misaligned logic with public-accountability standards.
Learn	Aims for integration into formal education systems through national curricula and teacher-training initiatives. Fosters a collaborative, transnational educational ecosystem.	Modular architecture for diverse content; fostering co-creation among educators.	Language accessibility (local/minority languages); lack of teacher training in participatory climate education or AI-enhanced digital tools; resistance to new pedagogies.
Play	Acts as a bridge between institutional outreach and public communication, supporting large-scale awareness campaigns and education partnerships.	Accessibility and emotional engagement across age groups; customisation for specific contexts and demographics.	Difficulty positioning within rigid administrative frameworks (where formal education is prioritised); lack of clear institutional mandate or evaluation mechanisms; challenges in quantifying long-term impact.
Repository (Toolkits)	While not a direct policy tool itself, the Repository of toolkits underpin the methods required for successful institutional engagement and policy integration across the NEUROCLIMA ecosystem, providing resources for effective deliberation and communication in official contexts.	**TBD T3.3, 3.4, 3.5*	**TBD T3.3, 3.4, 3.5*

4.3.2. Scaling Out. Cross-Context Replication & Institutional Diffusion

Scaling out focuses on expanding the NEUROCLIMA ecosystem across diverse geographical and institutional contexts, encouraging widespread citizen-led adoption and knowledge sharing. The aim is to ensure solutions are disseminated and adapted successfully, enabling more communities to benefit from NEUROCLIMA's tools and resources.

Table 4: NEUROCLIMA tools' roles, levers and barriers in scaling out

Component	Role	Levers	Barriers

Dialogues	Role in enabling citizen-led uptake across contexts. Its structure and features are compatible with existing deliberative mini-public formats.	Transferability due to compatibility with established deliberative formats; “ready-to-deploy” alignment with policy standards; direct support for both in-person and digital public engagement.	Bureaucratic resistance; lack of multilingual infrastructure; incompatibility with local digital systems; complex registration processes; competition with existing platforms; slow pace of public-sector innovation. Requires active facilitation to bridge digital/cultural divides.
Lens	Analyses narratives and data in diverse communities (academic, scientific, policy) to support messaging for different contexts and guide replication of successful interventions.	Capacity to analyse diverse narratives; web-based accessibility; ranking system for insights.	Contextual sensitivity of source data (bias, lack of regional diversity); language/cultural translation gaps; analytical accessibility (interpreting “social tipping points”). Requires explainability measures.
Bot (LLM)	Lightweight, conversational interface enables informal deployments. Can support regional adaptation and the use of Social Tipping Points.	Familiarity with LLM-based tools; lightweight architecture; customisable datasets.	Structural incompatibilities with local IT systems; data-privacy concerns; limited trust in AI-generated content; language/multimedia costs; non-scalable components (e.g. data-source dependence); false positives; selection bias.
Learn	Modular architecture allows educators to fill the platform with culturally and linguistically diverse content; fosters collaborative, transnational education.	Open Educational Resource (OER) compatibility; ease of sharing/reusing content; success stories.	Language barriers; limited regionally relevant stories; varying digital access in schools (e.g. mobile-phone bans); content-creation burden for educators.
Play	Interactive, culturally adaptable, and modular, making it easier to integrate into diverse outreach formats.	Narrative flexibility; cultural adaptability; modular design; low barrier to entry.	Balancing generality with contextual relevance; risk of superficial engagement if too generic; need for locally grounded materials; potential perception as trivial without follow-up; difficulty quantifying long-term impact.
Repository (Toolkits)	Supports local adaptation and championing of insights through participatory methods, artistic interventions, and cinematographic storytelling.	**TBD T3.3, 3.4, 3.5*	**TBD T3.3, 3.4, 3.5*

4.3.3. Scaling Deep. Long-Term Cultural and Normative Change

Scaling deep aims to cultivate lasting cultural and normative shifts by embedding climate awareness, democratic practices, and collective values into societal behaviours, mindsets, and educational ethos. This dimension goes beyond mere adoption or policy integration; it seeks to foster intrinsic motivation and a shared sense of responsibility for climate action, leading to profound and sustained societal transformation.

Table 6: NEUROCLIMA tools' roles, levers and barriers in scaling deep

Component	Role	Levers	Barriers
Dialogues	It fosters a lasting culture of democratic engagement and collective climate reasoning. Normalises active participation in adaptation strategies and builds shared responsibility through deliberative practice.	It helps people learn and create solutions together. It boosts climate understanding, shared responsibility, and builds community trust. It also helps grow the next generation of active citizens.	Risk of consultation fatigue if contributions are perceived as ignored or tokenised; requires robust continuity mechanisms and institutional feedback loops; if a culture discourages people from disagreeing, it can stop open and honest discussions from happening.
Lens	Influences how institutions and communities perceive climate knowledge, fostering epistemic humility and acceptance of diverse worldviews.	Facilitates critical reflection by visualising discourse; enables more responsive and inclusive institutional processes.	Risk of passive consumption or misinterpretation if insights are not actively framed or facilitated; bias in source data may reinforce cultural blind spots.
Bot	Reshapes how societies understand and seek climate information, normalising access to nuanced AI-supported knowledge and combating misinformation.	Fosters informed, inclusive and reflexive public discourse; normalises transparency and participation expectations.	Fragility of user trust; risk of algorithmic framing reinforcing dominant narratives; potential over-reliance on automated tools at the expense of critical thinking.
Learn	Embeds climate adaptation into the identity and mindset of young learners and educators, evolving curriculum content and pedagogical values.	Promotes co-created learning, critical inquiry and active participation; builds cognitive connections between personal and systemic challenges.	Dependence on institutional willingness to embrace participatory pedagogy and long-term investment; cultural resistance to emotional or values-based education; lack of time and training for educators.
Play	Embeds play-based, emotionally engaging formats into everyday culture, offering a unique channel for intergenerational and affective learning.	Cultivates empathy, agency and systems thinking through co-creation and storytelling; appeals to informal learning spaces; sparks curiosity and commitment through joy.	Risk of being perceived as trivial without meaningful follow-up; difficulty measuring long-term effects (vulnerability to defunding); cultural norms undervaluing play as civic participation.
Repository (Toolkits)	Indirectly contributes by providing foundational toolkits (e.g. for participatory methods and creative expression) that enable cultural embedding and normative shifts facilitated by other NEUROCLIMA tools. It helps foster the "how" of deep	*TBD T3.3, 3.4, 3.5	*TBD T3.3, 3.4, 3.5

	engagement within communities.		

4.4. Challenges to Scaling Mechanisms and AI Implementation in NEUROCLIMA

This table summarises the key challenges identified in the text so far, which relate to the implementation and scaling of AI-driven climate deliberation within the NEUROCLIMA framework. These challenges cover various crucial areas, from technical and data-related matters to political, governance, ethical, social, environmental, and the inherent complexities of climate change itself.

Table 7: pitfalls and strategies for the NEUROCLIMA climate theme Sensitive Scaling Mechanism

Pitfalls	**Suggestions / Strategies to overcome**
Technical & Data	
Lack of model transparency and interpretability	Design and develop explainable AI techniques and implement specific explainability metrics that illustrate how the AI and the concept of Social Tipping Points (STPs) work. Design explanation mechanisms to make the AI's internal processes readable, traceable and trustworthy for users.
Data quality issues and fragmentation	Invest in data management and interoperable infrastructure. Apply FAIR principles (Findable, Accessible, Interoperable, Reusable). Tailor datasets to reflect local policy updates
Data and recommendation bias (i.e., hallucinations, inaccurate suggestions)	Develop community-informed AI frameworks where local knowledge and needs shape model parameters and evaluation metrics. Involve marginalised communities in AI design and monitoring.
Difficulty translating complex digital outputs into actionable insights for non-expert users; misinterpretation of visuals	Use AI to translate complex climate data into accessible formats. NeuroclimaLens guides policymakers, content creators, journalists and educators in communicating systemic impacts, providing summaries and the knowledge graph. NeuroClimaLearn delivers clear, engaging education.
Political & Governance	
Coordination difficulties among stakeholders	Position NEUROCLIMA as an interconnected ecosystem that links individual behaviour change with collective and institutional processes, supporting coordination. Integrate NeuroClimaDialogues into policy-testing environments and smart-city frameworks to institutionalise citizen engagement.
Slow public-sector innovation; legal and regulatory fragmentation; lack of interoperability with existing digital systems	Leverage existing European and national deliberative networks to accelerate institutional adoption.
Ethical & Social Risks of AI	
Concerns about individual autonomy and "nudging" pro-environmental behaviours	Emphasise deliberative engagement where individuals and communities actively reflect on values and trade-offs rather than relying solely on automatic nudges.

	Use NeuroClimaDialogues to support structured discussion, shared learning and reasoned argumentation.
Exclusion of marginalised communities (digital divide, lack of accessibility)	Ensure inclusivity through targeted recruitment strategies and accommodations (alt-text, interpretation services, accessible venues). Design digital platforms to expand participation opportunities for underrepresented groups and provide accessible digital entry points.
Risk of personal data exposure	Apply responsible AI design attentive to power, representation and justice, and adhere to strict regulatory and ethical data-protection requirements.
Environmental Impact of AI Itself	
High environmental cost of AI	Promote transparent, open-source assessments of AI technologies' environmental footprints.
Barriers to Democratic Deliberation & Scaling	
Technology used mainly for interaction or information—not deep deliberation	Design NeuroClimaDialogues specifically to support structured discussion, shared learning and reasoned debate. Use AI/ML to structure debates, summarise contributions and detect emerging themes.
Replicability and contextual sensitivity	Ensure NEUROCLIMA tools are built for cross-context replication: Lens analyses narratives across communities; Bot customises STPs; Play offers narrative flexibility and modularity for cultural adaptation.
Institutional resistance and "participation fatigue"	Promote institutional integration and political buy-in. Ensure users see their contributions valued through continuous feedback mechanisms (local initiatives, institutional responses). NeuroClimaDialogues aims to strengthen social trust.
Cultural resistance and perception of triviality	Cultivate collective awareness of how individual and group actions connect to Social Tipping Points (STPs). Embed emotionally engaging, game-based formats into everyday culture (NeuroClimaPlay) with meaningful follow-up and integration into broader engagement strategies.
"Science of Scaling" Challenges	
False positives in pilots (misleading signals, insufficient statistical power)	Conduct systematic replication: run three to four independent pilots with similar populations.
Audience heterogeneity and selection bias (differences between early adopters and general population)	Ensure sample representativeness through randomisation. Test in at least three distinct demographic/cultural contexts. Use adaptive scaling strategies with market-specific customisation.
Implementation drift and fidelity loss	Explicitly define core (non-negotiable) versus adaptable components. Design for compliance from the outset using choice-architecture principles. Establish real-time fidelity-monitoring systems. Test under realistic conditions. Mitigate drift via ongoing localisation and fidelity checks.
Spillover effects (unintended impacts when interventions reach critical mass)	Map potential spillover channels during pilots. Use empirical strategies such as cluster randomisation.

Economic sustainability	Accept that "perfect is the enemy of scale" and pursue "satisficing" solutions. Apply marginal analysis rather than averages for resource allocation. Develop scale-sensitive cost models. Balance cost, complexity and participant burden.
Cognitive biases	Implement independent evaluation mechanisms. Form teams dedicated to "disrupting" biases
Misaligned partner incentives	Align partner incentives with long-term objectives rather than short-term gains or appearances.
Designing for ideal rather than median conditions	Build for median available conditions, not just optimal environments.
Intrinsic Complexity of Climate	
Climate change complexity	Provide reliable information and facilitate behaviour-change processes by linking data sources to collective capacity for action. Integrate responsible AI and deliberative democracy to support understanding of complex data and nuanced decision-making.
Cognitive dissonance and trade-offs among divergent policy constraints	Use NeuroClimaDialogues to support more informed, consensus-based decision processes. Leverage AI for systemic simulation and environment monitoring, fostering co-creation and institutional alignment.
Evolving issues and new evidence that can shift perceptions	Cultivate a shared sense of purpose and belonging through the NEUROCLIMA ecosystem, bridging individual contributions and collective action to adapt to emerging evidence and shifting narratives.

5. NEUROCLIMA, an Integrated AI Ecosystem for Scalable and Systemic Climate Adaptation

As NEUROCLIMA enters its pilot phase, the insights gathered will be essential to support the experimental activities: the literature review has already underpinned both the development of the NeuroClimaDialogues platform and the ongoing research in Deliverables D3.2, D5.1, and D5.2—belonging to tasks that bridge WP3 and WP5—and many of the partners involved in T3.1 are also active in the pilots and in Task 6.1, ensuring effective knowledge sharing.

The reflections on behavioural change, individual and collective contributions, and the emerging sense of togetherness will take concrete form first in the outputs of WP5 and then, naturally, during the pilot itself. Grounded behavioural theories and a rigorous "science of scaling" methodology, NEUROCLIMA, among others, anticipates and mitigates common pitfalls. To manage the risks inherent in scaling, NEUROCLIMA can mitigate **pilot bias** through independent evaluation and adaptive design, control **implementation drift** via continuous localisation and fidelity checks, and address **engagement fatigue** by carefully balancing cost, complexity, and participant burden.

Hence, NEUROCLIMA is not a single innovation but an interconnected ecosystem of tools—Dialogues, Learn, Bot, Lens, Play, and Repository—that makes climate adaptation scalable, systemic, and context-sensitive. These technologies are designed to be scalable: replicable across cultures and geographies, integrable within formal institutions, and capable of catalyzing deep cultural shifts in how we think, learn, and act on climate risk. Hence, NEUROCLIMA supports three interconnected modes of scaling: out, by expanding its geographic and sectoral reach; up, by influencing policies and institutions; and deep, by shifting mindsets and behaviours at their roots.

The **STP framework** distinguishes between **reactive STPs**, which leverage reference events (for example, floods) to reinforce lessons learned, and **proactive STPs**, which experiment with new leverage points for systemic transformation—while NEUROCLIMA's AI system continually recognises analogies across different cases and recommends proven interventions tailored to each context. With time and constantly reinforced learning potential, NEUROCLIMA will be more and more capable of emphasising meta-features or systemic properties of STPs, allowing scaling up with customised and fine-tuning options, themselves as many triggers of other types of scaling dynamics, i.e. likely to involve more economic types of stakeholders, interested in the value-added of NEUROCLIMA for a diversity of reasons and perspectives beyond the ones motivating the core targeted users of the solution.

The methodology for defining datasets and scaling data—outlined in D1.5 - Data Management Plan 2 and D4.1—will continue to advance so that all interested partners are fully engaged; this will enable us to scale our MVP (due M18, initially focused on the agrifood topic) to additional themes and integrate more diverse data sources and documents.

Looking ahead, we acknowledge that while much can be achieved during the pilot phase, NEUROCLIMA is also opening new horizons for dialogue and research around hybrid and e-deliberation, public participation and scaling mechanisms.

This field continues to evolve, and not only does our NEUROCLIMA ecosystem foster an ever-stronger sense of belonging and shared purpose—bridging the gap between individual contributions and collective action—but so do all the complementary tools and activities we've outlined in previous chapters. Beyond subject-matter expertise (for example, on climate change), there is a crucial meta-dimension to work upon: helping participants develop their own "sense of being part of a learning environment." In other words, while engaging in civic action around a given issue, the group simultaneously builds capacity by learning how to participate effectively in a structured, deliberative process. We should avoid idealizing face-to-face and territorially anchored participatory processes, especially given the constraints of limited time and other various challenges. However, online applications can be designed to address certain subtle qualities, often more easily accessible and exploitable in in-person settings.

Here, we can outline at least three valuable objectives for online participation, framed as questions that also highlight the challenges involved, and the subsequent supportive comments:

- How can we foster effective collective learning processes that are perceived and experienced as such? This includes learning how to learn, potentially through experiments, evaluations, multi-session sequences, and the retention of intermediate insights gained along the way.
- How can we cultivate a sense of belonging—whether to a territory, a group, or a cause—and foster a feeling of "togetherness" that might enhance resilience and motivation? Such a sense of community could support rebound capacity when shifting from one topic to another.
- How can we develop genuine democratic substance through the creation or strengthening of coalitions that express diverse viewpoints to further confronting them? This involves moving beyond simply voicing opinions, voting, ranking, or selecting options, i.e. towards deeply nurturing the building processes that are necessary for meaningful deliberation.

To conclude, it is also worth stressing the stimulating link that exists and will be constantly nurtured, between the reflection developed in this deliverable on the channels to effective scaling, and the work engaged in Task 7.2 (with a formal Deliverable due at the end of the project), currently in progress and which has to do with the building and exploitation of a commercial perspective for the NEUROCLIMA solution, also a form of scaling dynamic, with which the socio-cognitive scaling examined in this document will have to bridge.

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NOTES: In this report, we adopt the term "citizen" for simplicity, while acknowledging its limitations and the risk of exclusion it entails. Individuals such as migrant workers, asylum seekers, and refugees—who may lack formal citizenship status—are often left out of participatory processes, despite having a legitimate stake in the decisions that affect their lives. The terms "citizens' assemblies" and "citizens' juries" can therefore be misleading, as participation in such forums should not be restricted to legal citizens alone but open to all members of the community.

ANNEX I

In NEUROCLIMA we recognise that AI is not only a computational tool but also a socio-technical and governance instrument. Here we propose a classification of some of the roles that AI can play in the context of Climate Adaptation, looking at Individual Climate Action and Collective Decision Making. Roles with "*" apply mainly to the NEUROCLIMA approach.

Table 8: The role(s) of AI in climate Change Adaptation. AI

AI Role	Individual Climate Action	Collective Decision Making on Adaptation
AI as a watchdog	AI tracks personal emissions (energy, waste, water) in real-time, providing feedback for sustainable choices. (Evans & Gao, 2016; Mucci 2016; Nam and Pardo, 201; Rolnick et al., 2023)	AI monitors industrial emissions, land use, and policy adherence, identifying inefficiencies for targeted interventions. (Salam, 2020)
AI as a predictor	AI predicts the impact of personal actions (e.g., switching to EVs, reducing consumption), helping individuals plan sustainable lifestyles. (Bibri S.E. et al., 2024)	AI models climate trends and policy outcomes, enabling governments to prepare for risks and create effective strategies. (Mardani et al. 2020; Wei et al. 2018; Cowls et al., 2023; Abrell et al. 2019) *
AI as a translator	AI simplifies complex climate data into visuals and summaries, making it easier for individuals to understand their impact and take action. (Rolnick et al., 2023) *	AI helps communicate complex climate policies to the public, ensuring accessibility and encouraging informed participation. (Rolnick et al., 2023)*
AI as a knowledge Co-Creator	AI accelerates learning by providing personalised climate action tips, making it easier for individuals to adopt sustainable behaviours. (Cowls et al., 2023)	AI synthesises climate research and identifies knowledge gaps, speeding up the development of climate solutions and informed policies. (Cowls et al., 2023)*
AI as an optimiser	AI optimises personal energy use (e.g., smart home systems), helping individuals reduce their carbon footprint. (Evans & Gao, 2016)	AI optimises energy grids, transportation systems, and industrial processes, enhancing efficiency and minimising emissions at scale. (Cowls et al., 2023)

ANNEX II: Deliberative democracy and Climate Change Initiatives Using Digital Technology According to *Participedia*

Table 9: cases of deliberative democracy retrieved from Participedia in March 2025, filtered to include only those involving digital technologies and addressing climate change adaptation-related issues.

Project	Location	Scope	Topic	Use of digital technology	Method
Adur and Worthing Climate Assembly	Adur and Worthing, England, United Kingdom	Council	Emission reduction, adaptation	Fully online; used Zoom, Miro, Google Docs, Jamboard, Google Sites, SurveyMonkey, Slido; interactive website; sortition algorithms; technical support; online deliberation.	Citizens' Assembly
Bristol Citizens' Assembly	Bristol, England, United Kingdom	Council	Climate change and housing, transpor, Health and social care	Online sessions; stratified random sample; used general tools for discussion/deliberation.	Citizens' Assembly
Camden Council's Citizens' Assembly on the Climate Crisis	London, England, United Kingdom	Council	Climate action at home, in the neighborhood, and in the city council	Mixed mode (face-to-face and online); used online consultations; sortition.	Citizens' Assembly
Climate Assembly UK and the COVID-19 Crisis	United Kingdom	National	Net-zero target, green recovery	Transitioned to online deliberation mid-process due to COVID-19. Used video conferencing, digital documents, and online collaborative tools to complete final stages. Online platform ensured continuity.	Citizens' Assembly
Collaborative Online Lawmaking: Brazil's e-Democracia	Brazil	National	Legislative participation	Online portal; ICT, online consultations, social media, crowdsourcing; Wikilegis; video chat, forums, polls; hybrid modes; outreach via	Online consultation

				email, SMS, radio.	
Geraldton 2029 and Beyond[20]	Geraldton-Greenough, Western Australia, Australia	Council	Sustainability	Mixed mode; online deliberation, social media, ICT; used IStorm software; social media for deliberation support.	Deliberative democracy
Global Assembly on the Climate & Ecological Crisis	Global	Global	Actions for the climate and ecological crisis	Conducted online; stratified random sample; technical support; video presentations; online discussion/deliberation.	Citizens' Assembly
Herefordshire Citizen's Climate Assembly	Herefordshire, England, United Kingdom	Regional	Climate change challenges	Online; stratified random sample; online deliberation and Q&A; video and online documentation.	Citizens' Assembly
IDEAL-EU Social Networking Platform	Europe	European	Climate change awareness and energy	Social networking platform; mixed mode; social media; moderated online discussion with interactive features; new media for outcomes.	Online discussions
Leeds Climate Change Citizens' Jury	Leeds, UK	Council	Achieving zero carbon emissions	Face-to-face; sortition; citizens' jury and Q&A.	Citizens' Jury
Morris Area Rural Climate Dialogues[21]	Morris, Minnesota, USA	Regional	Addressing extreme weather and climate change	Face-to-face; sortition; citizens' jury and Q&A; no specific online tools.	Citizens' Jury

[20] Even though it is based in Australia, we included in our analysis because they used Social Media in an original way.

[21] Even though it is based in the USA, we selected it due to the significant number of actions implemented and the innovative use of technology, especially considering that the initiative dates back to 2014.

Participatory Redesign of Tempelhof Airport (Berlin)	Berlin, Germany.	City Airport	Airport area redesign	E-participation project; online moderated discussions integrated with offline; interactive features (comments, uploads, ratings); mixed mode; new media for outcomes.	Online discussion
Public Debate Termoli 2020	Termoli, Molise, Italy	Council	Urban redevelopment	Face-to-face; online registration; archived website.	Public Debate
The Brighton and Hove Climate Assembly	Brighton and Hove, England, United Kingdom	Council	Reduction of carbon emissions from transport	Fully online; online deliberation and Q&A; stratified random sample.	Citizens' Assembly
The Southwark's Citizen's Jury on Climate Change	Southwark, England, United Kingdom	Council	Addressing the climate emergency		Citizens' Jury
Uster Citizens' Panel for More Climate Protection	Uster, Zurich, Switzerland	Council	Climate protection, conscious consumption, waste reduction	Face-to-face; sortition; no specific online tools.	Citizens' Panel

ANNEX III: The 10 Highest-Rated E-Deliberation Platforms According to *People Powered*

Table 10: The ten highest-rated e-deliberation platforms, as identified by PeoplePowered, highlighting the digital technologies they employ and the range of participatory processes they support beyond deliberation.

Platform	YEAR	Use of Digital Technology	Type
Your Priorities	2008	Idea generation, user assistance, moderation, and analytics. AI supports consensus-building among diverse groups, **aggregating results into unified decisions.** **Helps citizens draft proposals to the government with subject-specific information.**	Participatory Budgeting; **Deliberative processes;** Participatory Policymaking; Citizens' Assemblies; Public Consultations
Consul	2016	It offers a wide range of features, including debates, citizen proposals, voting polls, participatory budgeting, collaborative legislation, and support for sustainable development goals. Additionally, the platform supports multi-tenancy, enabling versatile and inclusive engagement.	Participatory Budgeting; **Deliberative processes;** Participatory Policymaking; Citizens' Assemblies; Public Consultations
Decidim (n 2015, a fork of Consul)	2015	Supports these processes (mentioned in 'Cases') for groups and cities by serving as a comprehensive infrastructure for collaboration. It provides tools like proposals, meetings, sortition, voting, participatory texts, comments, and results, as well as features such as conferences, pages, blogs, surveys, newsletters, and notifications, all underpinned by a robust legal framework and community-driven design.	Participatory Budgeting, Citizens' Assemblies, Participatory Policymaking, **Deliberative processes**
LiquidFeedback	2010	AI only to the extent that it is auditable by participants, and the process of developing proposals remains reproducible	**Deliberative processes,** Participatory Budgeting, Citizens' Assemblies
LOOMIO	2012	Web-based, Open-source; screen reader compatibility; voice recording; analytics; collaborative tools	Consensus Building, **Deliberative Processes**, Citizens' Assemblies
GoVocal	2015	Open-core platform with AI-driven analytics, text summaries, and moderated discussions	Participatory Budgeting; Participatory Policymaking; Participatory Planning; Consensus Building; **Deliberative processes**; Citizens' Assemblies

adhocracy+	2020	Enables collaborative engagement through three main phases: defining topics using tools like brainstorming, spatial brainstorming, and polls; fostering discussion through text reviews, debate modules, and interactive events; and driving decision-making with mechanisms such as idea challenges, spatial idea challenges, and participatory budgeting.	Citizens' Assemblies, Participatory Budgeting, Participatory Policymaking, **Deliberative processes**
CapCollectif	2014	CapCollectif is a debate tool that is highly rated for its capacity requirements, ethics, and transparency functionalities and features. The tool can be used to highlight different parts of the discussion and facilitate the exchange of opinions. It offers users most of the features listed in our methodology, as well as the possibility to use a basic version via Purpoz.	
POL.IS	2014	Powered by advanced machine learning and statistical analysis, it allows users to provide insights in their own words while offering features such as commenting, voting and detailed analytics. Polis generates custom reports tailored to user needs, examines datasets for meaningful patterns and insights, analyzes subtopics, and explores demographic information within samples to deliver comprehensive understanding.	**Deliberative processes**; Consensus Building; Participatory Policymaking; Citizens' Assemblies
Consider.it	2010	Web platform with data analysis and visualization, storytelling tools, moderation controls, and encryption	**Deliberative processes;** Participatory Planning; Public Consultations
Ethelo	2011	Strong in the final stages of decision-making, where it supports aggregation, convergence, and closure. While earlier phases—such as conflict, ideation, deliberation, and synthesis—help generate and refine ideas, Ethelo excels at bringing diverse inputs together, identifying consensus, and guiding groups toward ratified, collectively accepted decisions.	Participatory budgeting, **deliberative processes**, policymaking, consensus building

ANNEX IV: Findings from the "Exploring Scaling Dynamics" activities

Table 11: Here, we present the findings from the Scaling Dynamics activities—an illustrative example designed to guide pilot experimentation.

UC		Scenario	Scaling UP *What policies or laws would enable this technology/intervention to scale up?*	Scaling Out *How can we replicate this technology/intervention across different regions or groups?*	Scaling Deep *How can this technology/intervention create long-lasting cultural change?*

1.1	**Digital Tech**	*NeuroClimaBot supports **journalists** in preparing a script for a video documentary on the effects of climate change on desertification in the EU based on social tipping points.*	• Rules on **AI Liability** • **Standards** for Generative AI (AI Act)' • Implementation of **Data Governance Act** • **Digital Services Act**	• Ensure accessibility via multilingual interfaces • Address non-scalable components (data source dependencies) • Beware of false positives when generalizing • Consider costs of multilingual and multimedia adaptation • Mitigate digital divide (uneven access)	• Address long-term trust in AI-driven journalism • Use open tools to build transparency and editorial integrity • Embed climate storytelling in journalism training programmes
	Climate	*Informing the **general public** on the EU Climate Action on desertification: NeuroClimaBot supports climate change reporting in Europe by helping journalists to prepare scripts of documentaries on the issue and spread it via video documentaries.*	• European media freedom act (**EMFA**) • European democracy action plan. • **LIFE programme** (EU) 2021/783 • Release Climate Reporting Standards using more friendly platforms.	• Partner with local and regional media networks • Rotate messaging themes to avoid audience fatigue • Design campaigns with measurable outcomes (track views, sentiment, reach) • Mitigate selection bias by testing across different populations	• Test and refine narratives that resonate across diverse audiences • Promote human-centreed climate narratives • Encourage journalism that connects policy to lived experience
1.2	**Digital Tech**	*NeuroClimaBot assists **policymakers** in crafting an impactful speech about measures to address water shortages in Algarve for local citizens and tourism facilities.*	• **Regional Government** deploys a BOT as a main channel of Information • **Gov't L&D** departments adopt the BOT as the reference resource for professional	• Commission funds replication of similar bots with localised datasets • National networks (e.g., water authorities) adopt and distribute the bot model • Create implementation toolkits and "success case" briefs for other regions	• Embed the bot in long-term water management systems and citizen participation platforms • Use trusted community figures (e.g. ambassadors) to drive legitimacy • Build trust by linking the bot's outputs with real, local

			development of public policy officials.	● Customise datasets to align with local policy updates and trends ● Train local ambassadors in institutions to lead adoption and support	improvements in water use awareness and behaviour.
	Climate	*Engaging **local citizens** and tourism stakeholders in Algarve about the Water Crisis. Advocating for immediate action by addressing local citizens and stakeholders in Algarve on the critical need to implement measures to tackle water shortages, emphasizing the balance between local needs and tourism sustainability.*	● Water Authorities are obliged to report any water shortage in the BOT. ● Tourism Stakeholders are obliged to update the BOT database with any issues in their water infrastructure. ● Federal government offers subsidies or infrastructure support to Regional Govs for introducing such solutions.	● Regional Authorities from adjacent regions with similar problems adopt the intervention ● A "Success Case" is presented to other interested Regional Governments. ● Conduct surveys, community meetings and focus groups ● The same could apply to tourism associations and boards.	● Introduce water conservation into school curricula to instil early awareness ● Encourage hotels, resorts and tourism stakeholders to adopt sustainable water practices ● Provide training courses to the people working on tourism or to the ones interested in tourism specifically in coastal areas regarding water conservation and best sustainability practices
2.1	**Digital Tech**	***NeuroClimaPlay** offers interactive storytelling tools, games, and activities designed for festivals. These tools make climate education engaging and fun, fostering inclusivity and participation. The activities align with sustainability goals and are customizable to reflect the*	Ministries of Education and Culture co-fund and mandate the creation of a **centralised, multilingual database** of **certified interactive climate learning tools,** integrated into formal and informal education systems.	● Adapt and deploy NeuroClimaPlay in multiple European countries, ensuring translation and alignment with local educational standards. ● Distribute **open-source toolkits and templates** to allow schools and municipalities to customise games for regional challenges.	● Ensure open-access, youth-oriented gamified platforms that support long-term engagement and climate literacy. ● Develop localised games based on real-life environmental issues to increase emotional resonance

		community's identity.			and relevance.
	Climate	*Activities such as games, interactive storytelling sessions, and collaborative workshops during a community festival. These tools create a fun and inclusive environment that encourages attendees of all ages to engage with climate themes.*	Include interactive community-based climate events in national environmental education strategies, with dedicated funding streams and municipal support.	• Organise EU-wide school competitions and storytelling festivals to encourage cross-country participation and knowledge sharing • Partner with Ministries of Education, NGOs, game developers, and youth organizations to co-host regional game-based learning events.	• Empower youth as co-creators through storytelling labs and participatory design workshops. • Institutionalise annual climate festivals and community exhibits to build shared traditions and deepen public climate awareness. • Create youth-led climate councils that advise on public engagement activities and co-develop educational content.

2.1	**Digital Tech**	*The* ***NEUROCLIMA Repository of Tools*** *integrates advanced artificial intelligence to enhance participatory design and creative activities. It offers tailored resources, such as templates, guides, and interactive AI features, enabling citizens and youth workers to collaborate effectively on climate adaptation projects. The AI provides real-time insights, generates suggestions, and synthesizes inputs, streamlining the process and ensuring that solutions are data-driven and actionable*.	• Develop an EU-wide certification scheme for participatory climate tools used in youth engagement. • Adopt a directive to harmonise national guidelines for the use of AI-supported participation platforms across youth sectors. • Encourage national legislation to support the certified use of AI tools in formal and non-formal education environments.	• Create localised versions of the platform in multiple EU languages. • Develop quick-start kits for municipalities or schools to launch it. • Partner with school networks to integrate it into digital literacy programmes.	• Open-source the platform and allow communities to contribute new tools. • Create a youth advisory board to guide its evolution. • Build a badge or recognition system for active use.
	Climate	Facilitate participatory design workshops where citizens and youth workers co-create climate adaptation solutions. The intervention prioritizes collaboration, creativity, and actionable outcomes, using AI to enhance the efficiency and impact of the process.	• EU-level inclusion of the model in **Erasmus+ training modules** for facilitators • National youth agencies formally adopt facilitation standards for climate-themed workshop	• Partner with international NGOs (e.g. WWF Youth) to run workshops in different contexts. • Use Youth Climate Hubs or EU delegations to disseminate the tool, showcase examples and build demand	• Make it a yearly climate action week in schools across Europe. • Involve parents or local leaders to root it in community culture. • Allow youth to co-lead or adapt future workshops.


Journalists and content creators
UC 1.1 — Measuring the impact of AI monitoring tools and traditional and experimental informational approaches and tools on identifying social tipping and leverage points.
Instructions
Matrix
Policy and law
Scaling UP
Replicating
Scaling OUT
Cultural Shift
Scaling Deep
PAIR #1
PAIR #2
Technology
Intervention
Policy and decision makers
UC 1.2 — Measuring the impact of AI monitoring tools for policy/decision makers towards identifying and activating social tipping and leverage points for climate change adaptation
Instructions
Matrix
Policy and law
Scaling UP
Replicating
Scaling OUT
Cultural Shift
Scaling Deep
Technology
Intervention
Citizens, students and educators
UC 2.1 — Implementing behavioural and systemic change through blended learning tools, participatory design and interactive storytelling
Instructions
Matrix
Policy and law
Scaling UP
Replicating
Scaling OUT
Cultural Shift
Scaling Deep
Technology
Intervention
Citizens, youth workers
UC 2.2 — Participatory design and creative expression as the driving force for the implementation of climate change adaptation
Instructions
Matrix
Policy and law
Scaling UP
Replicating
Scaling OUT
Cultural Shift
Scaling Deep
Technology
Interevention