



NEUROCLIMA

Deliverable D2.1

Ethnographic research review
and Innovation landscape
analysis on social tipping and
leverage points

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ABBREVIATIONS

Abbreviation	Full name
AI	Artificial Intelligence
EU	European Union
GDPR	General Data Protection Regulation
SLP	Social Leverage Point(s)
STP	Social Tipping Point(s)
UC	User Case

EXECUTIVE SUMMARY

The objective of Deliverable 2.1 was to sketch out and explain the **context in which change might take place regarding climate warming**, the **key concepts** that may help this happen, and the **level of policy** but also behavioural change at several levels that could make a difference.

NEUROCLIMA is a project suggesting experimenting approaches to advance some key solutions thanks to a specific understanding of where and how individuals, groups and European territories can act, with all due environment-relevant characteristics, to **produce effective impacts** thanks to significant behavioural changes and with that, a **series of more promising openings against climate warming**.

Within the broad EU Green Deal scheme, key concepts are defined and examined that may be instrumental for the kind of change that this policy framework targets, detailed in Deliverable 2.4. In this document (D2.1), we aim to ensure that it aligns with the deep and systemic changes needed to enhance awareness, and the key actions that can lead to valuable effects. We will also focus on measuring, communicating, and coordinating all that can contribute to positive progress in addressing climate change.

These key concepts are **social tipping points and leverage points**. However, to understand how these notions can help, we must put in place an epistemic landscape of the project, encompassing:

1. the systemic view of the problem,
2. the relationship between social tipping points and environmental tipping points, and
3. pain points as potential leverage points, but even before,
4. how all changing efforts tend to take place in a structural and tensional context.

We are required to reduce our environmental impacts and moderate our consumption, but we are also constantly encouraged to buy things and services which is claimed to contribute to growth and employment. This structural hurdle must be understood to anchor all the communication and pedagogical efforts of the NEUROCLIMA project in its real and concrete context.

Other deliverables propose a functional inventory of stakeholders, but it is also important, beyond just listing them all as part of a general casting. The most usual suspects are easy to identify. Policymakers and administrations, enterprises, communicators and educators, other specialists in the legal and technological domains, researchers and citizens in their various roles and forms of existence. This deliverable has the task to focus on **how these different social actors can participate** in inducing changes, in individual terms or more effectively also, through groups of community-level importance and with the possibility of addressing territorial stakes at city, regional, national or even broader level.

Participatory forms can take place through intermediating groupings that may transform isolated changes into impacts of greater magnitude and persistence, with effects that are possibly scalable or at least worth communicating upon in that perspective.

This mechanism and social change schemes can be prepared and reinforced thanks to specific NEUROCLIMA pilot actions involving efforts and creative approaches of educational and communicational nature, involving upfront or in the background some timely and relevant scientific evidence. In this process, AI is deployed as support technology to identify changing ideas and point out, monitor and re-force their federated effectiveness.

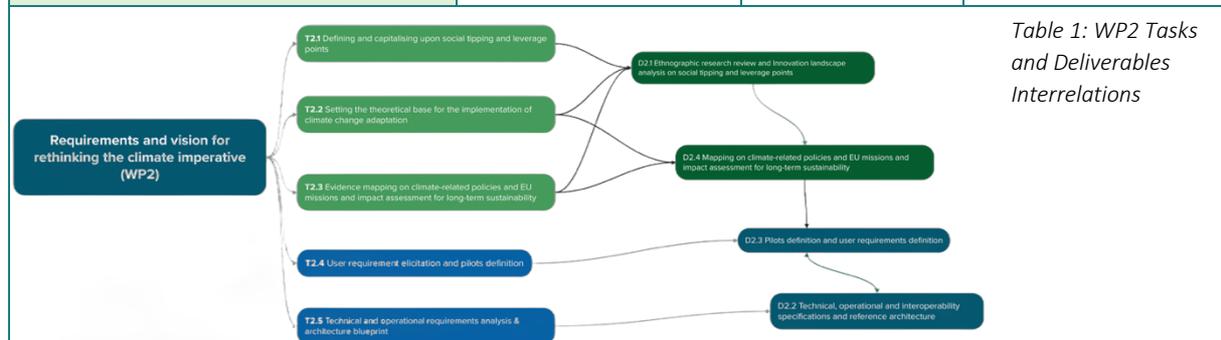
More than just pretend to explain, NEUROCLIMA will thus bet on concrete experimentations, exploring how the tools and concepts envisaged can change the yield of how we relate to climate stress, through two pilots and four examples which will help engage in detection, connection, stimulation and playful education, whose effects will be assessed and measured as part of a collective learning process.

1 About NEUROCLIMA

*NEUROCLIMA is a European project (Jan 2024 – Dec 2026)¹, that aims to raise awareness, provide best practices, and ensure **sustainable use of climate change adaptation and resilience solutions**. **NEUROCLIMA leverages both human and artificial intelligence (AI) to support dissemination and communication strategies**, it collaborates with other EU-funded initiatives, develops viable business models, standardises outcomes, and invests in frameworks and toolkits addressing citizen and stakeholder needs and climate change challenges. NEUROCLIMA's impact through the use, commercial and other, may span well over 2030.*

This deliverable is part of WP2 that aims to establish **a common project vision** that contributes to the project’s SOs through a human-centred approach but also a technically feasible approach. WP2 is focused to developing a thorough grasp of **user requirements and system characteristics** that are critical to the overall strategy. WP2 used a participatory design approach to identify all functional, structural, and technical components of the project, define detailed specifications for use case scenarios, identify and assess user requirements and system specifications, and design the NEUROCLIMA solution's scalable and modular architecture. The table and the diagram below show the structure and interrelation of all the deliverables.

T2.1: Defining and capitalising upon social tipping and leverage points: setting the landscapes	T2.2: Setting the theoretical base for the implementation of climate change adaptation	T2.3: Evidence mapping on climate-related policies and EU missions and impact assessment for long-term sustainability	T2.4 User requirement elicitation and pilots definition	T2.5: Technical and operational requirements analysis and architecture blueprint
The science base behind behavioural change for climate	Knowledge Framework for Climate Adaptation Actions	Lessons learned. Benefits and Opportunities for EU societies	Use-case scenarios. Storyboards and workflow. End user requirements.	Technical Specifications of each system component
D2.1 Ethnographic research review and innovation landscape analysis on social tipping and leverage points		D2.4 Mapping on climate-related policies and EU missions and impact assessment for long-term sustainability	D2.3 Pilots definition and user requirements definition	D2.2 Technical, operational and interoperability specifications and reference architecture



¹ Research and Innovation Action (RIA) funded by the EU under the Horizon Europe program (HORIZON-CL5-2023-D1-01-09).

2 Why NEUROCLIMA is needed

2.1 Climate Change Reality

Although some people deny the existence of climate change or simply reject human conduct as the main cause, the majority recognises that climate change is a structural and systemic problem that worsens with time and has frightening levels of perceivable impacts. This realisation has fostered a series of reflections, awareness moves and since at least half a century, a series of measures of public policy, meant to contain this evolution within tolerable limits.

NEUROCLIMA seeks to contribute to a comprehensive history of analyses and policy interventions, including the recent EU Green Deal, the EU Adaptation Strategy, and the Mission on Adaptation to Climate Change, which aim to translate policies into concrete actions.

There is a deep problem to cope with, concerning current and future generations, for which something must be done, if possible, integrating its systemic nature, with its local and global components, and building on current knowledge, initiatives and participatory engagement of individuals and communities at these different scales. NEUROCLIMA aims to integrate the cohort of people who strive in that direction, while also building the necessary technology tools and support to maximise the desired effect, with a solution precisely tailored to that expectation.

2.2 Key Terms for understanding Climate Change

The academic community and policymakers have generated an abundance of terminology, frequently overlapping, to describe the problem and indicate the policies and instruments aimed at delivering solutions. Nevertheless, this surplus of definitions and vocabulary frequently causes confusion and ambiguities. To address this, we provide a brief but essential glossary, that will help the reader to understand the context better. In the table below we give only some key definitions, you can find the full glossary in the Annex.

Term	Definition
Tipping Points	Critical thresholds in the climate system, that when crossed, small changes can lead to large, accelerating and often irreversible changes.
Leverage Points	Key areas in a system (climate, economy) where small changes can create large, lasting improvements.
Climate Change Adaptation	Adjustments in systems to reduce harm or take advantage of opportunities from climate change.
Climate Change Mitigation	Actions taken to reduce or prevent the emission of greenhouse gases to limit future global warming.
Climate Neutrality	Achieving net-zero greenhouse gas emissions by balancing emissions produced with those absorbed by nature.
EU Green Deal	A set of policies aimed at making the EU climate-neutral by 2050, covering climate, energy, transport, and more.
SDGs (Sustainable Development Goals)	Seventeen global goals aimed at balancing social, economic, and environmental sustainability, adopted in 2016.

We will develop further and in more detail all these concepts, but at this stage NEUROCLIMA needs to identify **social tipping points** and their relation to environmental tipping points, as well as 2) **leverage points**. These concepts are essential instrumental and pivotal resources to make change effective regarding the worrying needs and sense of emergency suggested by climate warming.

Social tipping points, to make it simple, are types of changes that tend to relate, upon the accumulation factors of a problem (of social nature), a «before» (defined by a certain social understanding and configuration) and an «after», radically different, and sometimes irreversibly so. There are all sorts of social tipping points, as the kind of problems likely to fit that pattern can be quite large. *In NEUROCLIMA, we are mostly interested in those social tipping points that may trigger changes regarding environmental issues and even more so, environmental tipping points.* Leverage points, precisely, concern those processes through which citizens and inhabitants may create or engage in concrete change of significant positive environmental effects. Let's acknowledge for the moments, the usefulness of these early yet necessary positioning definitions.

2.3 Main Goals for this Deliverable

				
Define Landscape	Epistemic Base	Knowledge Base	Tech-Enhanced Approach	Theoretical Framework for Pilot

The aim of this deliverable is multifold:

1. **Define the landscape** in which the project takes place with its policy-level reference framework, its stakeholders, its knowledge-building approach, its experiments and tools that aim to help individuals and communities engage in a behavioral change.
2. **Define the epistemic base** likely to trigger behavioural and systemic changes for climate adaptation, building on the drivers and considering diverse types of barriers.
3. **Specify** the way the existing **knowledge base**, and **communicational, educational** and **playful** actions of diverse kinds may positively impact the current situation.
4. Support a **technology-enhanced approach** to relevant knowledge follow up, citizen participation facilitation, and decision-making.
5. **Translate** all these **inputs into user requirements** and system specifications for the diverse hybrid learning initiatives, the technology for enhanced knowledge tracking, participatory dynamics, relevant data acquisition and decision making.
6. Provide the **theoretical framework** for the successful implementation of the **pilot cases**.

It will do so by defining and documenting both theoretical insights and examples on key change monitoring concepts such as social tipping points, leverage points, associated issues and transitional schemes. This involves starting with broad policy-level considerations on how to foster environmental change, including the barriers that must be overcome, and eventually combining specific human actions with sophisticated digital means (cutting-edge AI).

Examining these various positive and negative factors and focused processes, will highlight some of the influential forces at work as potential decisive change channels and as such, define a sound basis for KPIs regarding climate change adaptation.

The defined landscape will lead us to inform other WPs and more broadly all the Consortium through the requirements which will make the project concrete and effective and will help establish NEUROCLIMA as a large-scale impacting platform, tuned to become a behavioral change enabler.

Finally, this deliverable will try to provide insights of not only what may be the **triggers for change and the requirements that the project must comply with**, but offer a **strong analytical underpinning**, with the main debates crossing the fields and topics covered, to make NEUROCLIMA more robust and likely to evolve in its own terms.

2.4 The EU Green Deal and Climate Adaptation Strategy

Over the years, Europe has worked hard to shape a strong set of measures to deal with climate change and its harmful effects, both real and possible. These measures are based on important steps taken to raise awareness and knowledge in the environmental fight, and they are meant to be a strong reference for policymakers going forward. Deliverable 2.4 examines into detail these achievements (see summary below).

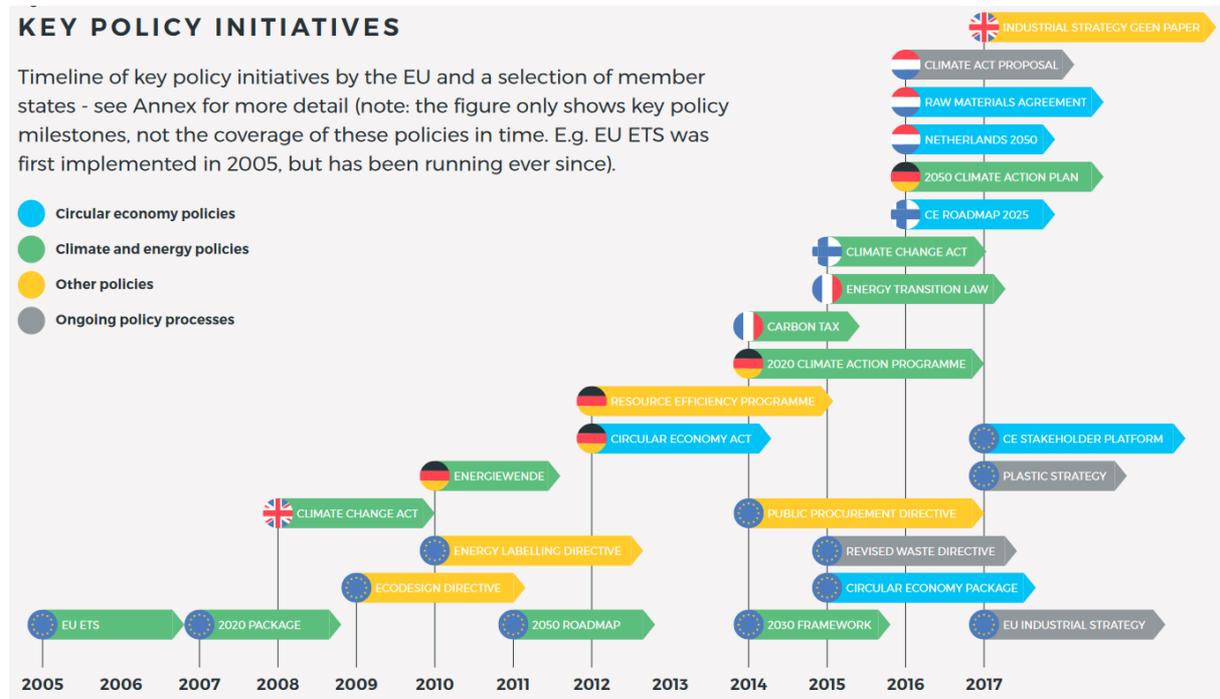


Figure 1: Timeline of circular economy and climate policies in the European Union (<https://www.shiftingparadigms.nl/projects/policy-levers-for-a-low-carbon-circular-economy/>)

These actions evolved in the broader awareness rise, which at a global level, led to the first warnings on planetary limits and their impacts (1970s), to the “Rio Convention”² (1992), and later to the Kyoto Protocol (1997). These landmark events were preludes to a long series of global governance efforts known as COP³ (for Conference of the Parties), which includes all UN member states deciding on what to do and how to do it in relation to climate change.

In this long-term struggle, we should not think of the current efforts as the key EU policy of the Green Deal as just another step in an endless stairway. On the contrary, we need to stress its value as an important action-oriented cornerstone, of high governance and policy-making status. In support of this claim are the facts that the Green Deal is

- **extremely assertive on what the current situation is** and what needs to be done, with the idea to mobilise all stakeholders in an improvement perspective.
- **supported by large-scale research commitments** to both help understand, but also experiment solutions for the efficiency of which we can have measures and evidence-based assessments.
- **connected to policy decisions and constraints**, precisely to escape a paradigm in which economic growth would be the only dominant concern.

² “The 1992 United Nations Framework Convention on Climate Change (UNFCCC)”.

³ Last one (COP28) took place in Dubai in 2023. Next one (COP29) in November 2024, in Baku, Azerbaijan.

A full account of all the steps that have led to the **Green Deal** and the **Climate Adaptation Strategy** can be found in Deliverable 2.4⁴ (D2.4). D2.4 presents a detailed inventory of all the directives that have been enacted so far and the concerns covered by these instruments, a large array of legal specifications ranging from domains' emissions (industry, aviation, construction, etc.) to alternate energy efficiency to carbon bond trading to wrong private company environmental claims, etc.

In a more future-oriented perspective, D2.4 also reports on various key EU policies and regulations:

- *Pathway to Climate Neutrality by 2050*, which lists 15 targets for 2040, as the expression of a large-scale strategy, that are perfectly in line with the kind of positive impacts that NEUROCLIMA aims at generating.
- *Eco-design for Sustainable Products Regulation* (ESPR), Regulation (EU) 2024/1781 and Regulation (EC) No 66/2010 on the EU Ecolabel, indirectly conveying behavioral change,
- *The Corporate Sustainability Due Diligence Directive*, Directive (EU) 2024/1760, directly linked to the behaviour and best practices of key stakeholders,
- *The European Climate Pact*, launched in Dec 2020,
- *The EU Nature Restoration Law, EU Nature Restoration Law*, which may concretely involve participatory forms of community engagement.
- *Water, waste and air quality issues*, as well as *mobility* policies, (we often talk for Smart Mobility which implies a heavy involvement of digital and AI means to help the sector get more efficient and diminish its load of emissions.
- *Biodiversity, cleaner cities and soil*, which are considerable stakes for behavioral involvement and change.
- A key section of the deliverable deals with the *“Farm to Fork” Strategy* concept⁵, which everyone, in our daily habits, can make our own, and therefore apply in all the domains of activity and responsibility. This “Farm to fork” notion, is more concrete than the *Circular Economy* concept which can be a bit more abstract for the citizen. To some extent, we can even envisage the first as a learning field for the second one.

⁴ D2.4 Mapping on climate-related policies and EU missions and impact assessment for long-term sustainability

⁵ https://food.ec.europa.eu/horizontal-topics/farm-fork-strategy_en

2.5 NEUROCLIMA's Approach

In this demanding and challenging context, NEUROCLIMA bets on a complementary series of tools, methods, knowledge processing and supportive technologies to help a large series of stakeholders involved in the communication, education and policy-making implementation strands. Educational and communicational support of traditional nature, but also playful and nudging facilitation for the involved actors of these fields, are combined with AI-supported knowledge tracking of existing social tipping points, pain points, leveraging point initiatives, participatory design, stimulation and accompaniment, as well as help to decision-making.

NEUROCLIMA wants to build on what already exists to strengthen, stimulate and federate the initiatives and learning processes, with a series of complementary approaches that value communication skills, performing arts and on-line learning, hence the concept of “**nervous system**”.

2.5.1 Promoting Behavioral Science

Behavioural change refers to the *modification of human behaviours and actions that contribute to climate change*, with the aim of reducing environmental impacts and increasing resilience to climate risks. In the context of NEUROCLIMA, behavioural change focuses on **promoting sustainable consumption patterns**, increasing climate-informed decision making and supporting community-level adaptation in line with climate change adaptation objectives.

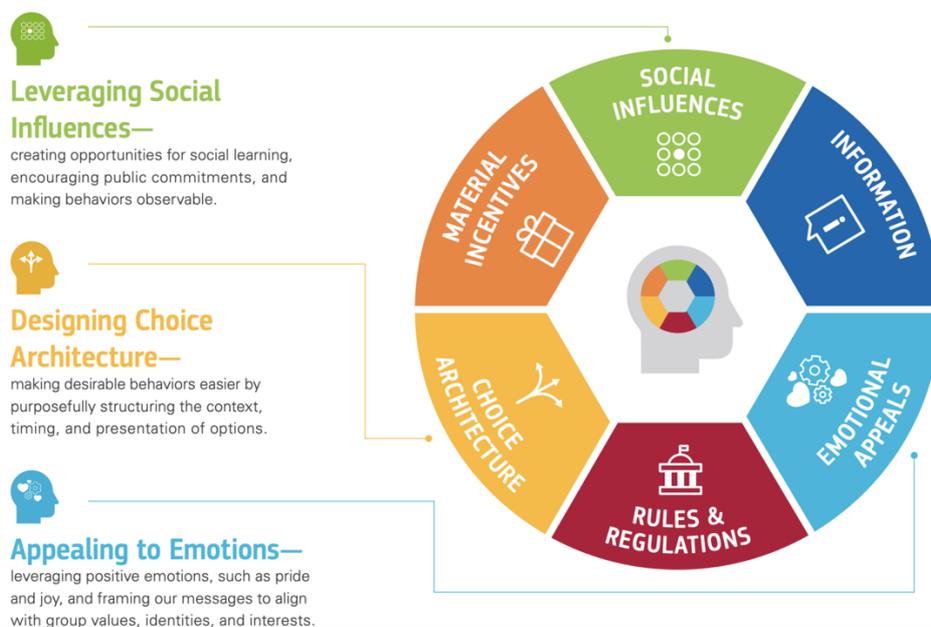


Figure 2: Behavioural Science Insights from the Center for Behavior & the Environment (<https://behavior.rare.org/>)

*Mitigation and adaptation, regarding climate change are both legitimate reference concepts. However, there is a difference. **Adaptation** should be considered of a superior order as it involves the idea of a significant shift and possibly of a different cause to effect relation concerning what changes, likely to get us closer to, if not solving, at least really addressing the terms of the problem. **Mitigation** only suggests a relative and minor alteration in the deployment of a problem, not radically modifying its rationale and root issues. Envisaged in those terms, *climate adaptation is the objective*; but mitigation should not be despised as it may also trigger first awareness and learning opportunities when it comes to behavioural change. It is simply not the deep objective nor even a sufficient alteration threshold to target.*

Policy can introduce stringent directives that restrict individuals, groups or organisations from adopting a targeted change, especially when security and high risks are involved. However, before we reach that level of constraints, there are many possible social and knowledge awareness dynamics that need to be understood and considered, should we want to foster behavioral change in a more climate-sensitive perspective.

If everything was ideal and simple, there would be a direct and fast learning relationship between the problem we identify (climate warming and its root problem linked with lifestyle and all its underpinnings) and the expected change solving it: we analyse the problem, identify the cause, advocate a change likely to suppress the cause and explain to all stakeholders why it happened and how to change to obtain the desired result. Of course, reality is much more complex, and we must understand what may induce change in people's behavior or not, and what are the possible triggers and underlying forces that change possible.

In the next section, we will examine in detail these triggers. Even if we understand the hardship of reality and are ready to deal with it, we need to keep learning, foster engagement, and not just good explanations, and innovate to create novel approaches. This approach will help citizens, users, inhabitants and any stakeholder to go beyond their comfort zone.

2.5.2 What Needs to Change

In other words, if people do not change, it is not (only) because they do not know the truth about climate warming and what may bring change, but also because they may be trapped in the middle of contradictory incitements or/and facing too complex hurdles to overcome. NEUROCLIMA believes in a proactive assertion that knowledge helps, but also considering the factors that have created the problematic situation. There is on the one hand the knowledge about climate warming, the knowledge about initiatives that may bring changes, but there is also a needed knowledge to share about the difficulties that may hinder or slow down our efforts and how to take them into account in the learning process.

Part of the solution to these challenges is to value participatory and deliberative processes in which people can experiment, learn, interact, and feel empowered. Technology is not meant to be a substitute for human decision but a helping toolbox to expand upon positive human actions, in complementary manner with educational, communicational activities taking the path of already existing channels.

In this complex setting, NEUROCLIMA advocates for moving forward and creating positive change conditions from multiple connected perspectives or areas of interest. A first key aspect is to assess the factors and motivations that have led us to where we are and are likely to play some a role that we are not yet aware of.

This positive but also realistic standpoint requires some detour towards some of the barriers that experimenters, educators and communicators may encounter, to understand and hopefully overcome these forces.

2.5.3 Challenges and Obstacles to Change

The NEUROCLIMA project has integrated a PEST analysis of potential barriers that may hinder the project's impact, over which the consortium members may have little effect, with barriers of economic, political, social and technological nature, in total with 17 such factors inventoried, which could constitute a demotivating field force. Key problems mentioned were unequal access to technology and digital resources, digital divide, language diversity, reluctance or too low capabilities of educators to play a strong role in that change expectation, reluctance of some authorities to foster

change processes, especially when they involve participatory actions, economic competition, but also technology-linked difficulties like, for the implementation of AI-supported solutions, data heterogeneity and data confidentiality.



Figure 3: Image taken from “The Ability-Motivation-Opportunity Framework for Behavior Research” (Hughes, 2007)

Beside these most obvious hindering factors, we have a series of hurdles to consider that also belong to the kind of knowledge to be acquired, federated and AI-supported within the NEUROCLIMA framework.

- The **difficulty to relate to problems of global nature** in terms of behavioral change and believe that you can make a difference. Such as the acidity of the oceans, the threat on the Great Coral Reef, the depletion of the tropical forest, the diminishing biodiversity, etc.
These problems are little visible, are not felt as such and their processes are taking place at a super slow speed or a scale beyond human perception. No one can really see it outside the scientific community. Even with phenomena such as temperature rise, sea level rise, the ozone layer depletion, the influence of hormone-interfering substances on health, etc. it is hard to see how they have evolved (and how they will continue).
- The **difficulty to relate to some of these global problems as Common**: Switzerland and Austria do not have direct access to the ocean, but the ocean is vital for everyone, making its pollution a common problem.
The ice shelf melt, be it in Greenland or in the Alps, concerns a type of change upon phenomena that have taken thousands of years and become part of the systemic stability that is today threatened. This broader time and space perception of what affects us, regardless of our immediate perceptive capacity or proximity to a particular problem is fundamental as it touches essential factors of the climate regime. Similarly, what happens to the tropical forest, the Great Coral Reef or in the higher atmosphere have a global common impact for everyone on earth and people should get accustomed to realising this substantial relation.
- the **disappointment of individuals willing to change when they experience policymakers approving disputable measures** regarding the environment to please particular lobbies.
- the complexity of the environmental and social interrelationships to demonstrate **clear cause to effect evidence**. It’s not always possible, even with scientific support, to demonstrate cause-to-

effect evidence; there are legitimate debates in the science arena, with open-ended issues and even some dilemmas and paradoxes, that further confuse the public.

An example of a dilemma is the positive re-classification of nuclear energy by the EU as an acceptable transition technology. An example of a paradox (quite famous) is the cooling system one: you are warmer and warmer and therefore you need to mitigate the stress you have to bear by cooling the air around you; by doing so you increase the warming. Another serious type of paradox is linked to sea water desalination of sea water, for which Spain is now becoming world champion. Climate change is generating a temperature increase and therefore drying the air and producing severe droughts, threatening agriculture by lack of accessible water. Desalination can help solve the problem, but by doing so, one contributes to spend increasingly more energy, amplifying the local conditions of the global problem at the root of the water shortage triggering the desalination need.

Even an informed citizen can be confused by the media or policymakers' proposals; Science may be sometimes contested, while some specialists have the habit to promote a "silo thinking" style, based on relevant expertise, rather than a systemic approach.

It is natural that tipping points of higher concerns are the ones we can perceive from our everyday perspective and engage thereupon in behavioral change on those problems in priority. For a local community, the problems that impact it locally will be envisaged as more important. For a professional community, some aspects of the environmental challenges will appear more central. The scientific community, characterised by a high degree of specialisation, does not always score well on this issue.

- the **economic and political forces that are averse to change if a situation is favorable to them**; some political and economic leaders may even deny that the situation is alarming, privileging a business-as-usual approach (and for some, betting on the continuation of fossil energy consumption).
- the **averse narratives promoting a different view of what is happening, why it is happening and what should be done**. The conspiracy theory sphere is active and producing an intense misinforming message.

The above hurdles are maybe understood better through the voice of the citizen:

					
I can't make any difference	Not my problem. It can't affect me.	Politicians are all corrupt. Nothing will ever change.	We can't be sure how critical it is.	Corporations will never let things change.	No matter what we'll do we can't stop it.

The biggest challenge we face is a contradiction in our society. On one hand, we're asked to protect the environment. On the other hand, our culture and advertising encourage us to consume more - to buy things and throw them away. Many economists believe this consumption is necessary for a strong economy. This puts us in a difficult position every day, as we often don't know how to choose between these conflicting messages about what we should do.

3 NEUROCLIMA Stakeholders & Policies

3.1 Key Stakeholders in Climate Action: Roles, Engagement, and Collaboration

In principle every individual, group, community, institution, private or public organisations and states are stakeholders of a relationship with the climate which must absolutely improve. The quality of life of humans today and that of those who will come depend on how effective this improvement will be. However, within this general assertion regarding the status of “stakeholders”, some distinctions and assignments may be proposed.

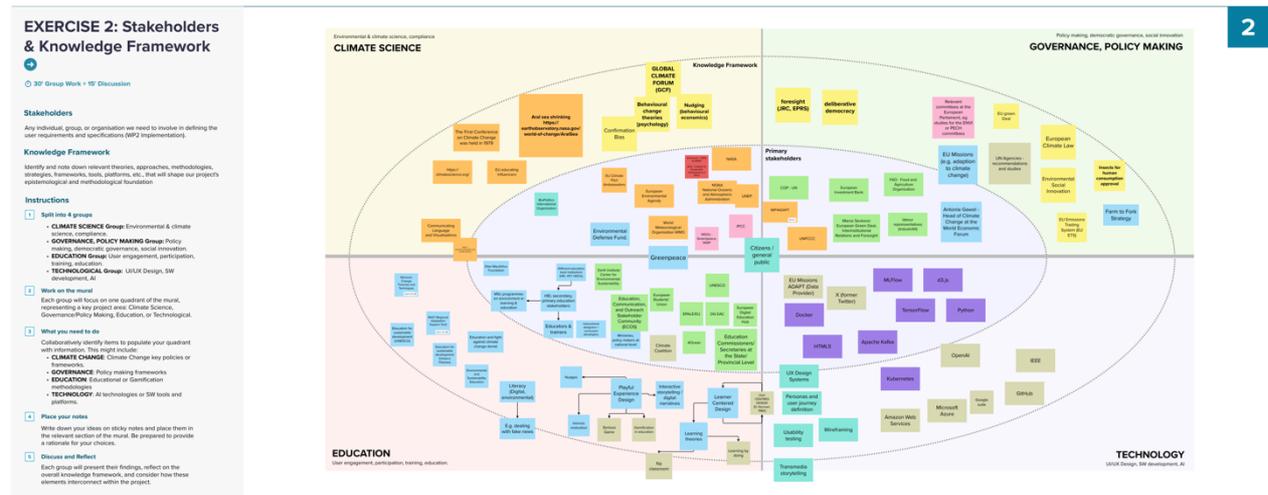


Figure 4: Stakeholders Mapping and Knowledge Framework. Exercise from Online Workshop (Mar 2024)

Two interactive workshops with the participation of all partners helped us map the stakeholder landscape and showed a spectacular variety of influencers of one kind or another (personas). For the purpose of this deliverable, it is important to stress the central roles of specific stakeholders:

- **Governments and policymakers** as the ultimate audience of our project, in particular at EU level but also the diverse Member States and even more so the city levels: these urban decision makers and specialists have an optimal proximity with citizens and inhabitants and most often, with some leeway and budget to engage in relevant environmental initiatives.
- **Economic actors of various kinds**, with an emphasis on technological actors (there is of course a wide range of such players). They are often neglected as if they were in all cases not reliably concerned by the environment, but in reality, upon their organizational transformation and process conduction depend, some important changes.
- **NGOs, communities of practices, associations of citizens, inhabitants** engaged in climate change processes of some sort. This level of actuation is what most often allows for overcoming the difficulty of building on individual choices only and motivated to interact in a multiplicity of ways and topics.
- **Education professionals and their institutions**. These actors have an essential role of explaining, sensitizing, connecting, enlisting individuals.
- **Academic and specialized institutions dedicated to research**. Their educational role is both broader and often more indirect than the previous category, but as essential to propagate a “reference framework” kind of understanding and measuring the evolution of our environment.
- **Communication specialists** both in traditional and digital media. Like educators but within a broader variety of means, channels and communicating modes, they must ensure the

permanence and even the redundancy of messages it takes to produce mental maps and imprints.

To go beyond this general casting view, two contributions provided by other Deliverables are worth mentioning:

- The **Stakeholder theory on influential roles** presented in D2.4, with a table inventorying what can be envisaged (what kind of interaction for change), with whom (which stakeholder) in the climate stake landscape.
- The **Stakeholder Engagement** covered in D2.3, presenting how NEUROCLIMA can build its value-added contribution with these different stakeholders, in particular examining how to pass from a stakeholder perspective to a user group empowerment, a prelude to the specifications implied by these stakeholders-users expressed in terms of requirements.

The D2.3, presents the **stakeholders’ engagement plan**, meant to structure the way stakeholders will be handled and valued in the pilots’ deployment, with the following characteristics. Four categories of stakeholders are envisaged.

			
Policymakers and Decision Makers	Journalists and Content Creators	Citizens and Community Groups	Researchers and Academics

In this casting, the designers of the pilot requirements assembled several categories we had distinguished anchoring with policymakers, citizens with associative groupings and communities. Moreover, decided not to include economic sector players. Altogether, this simplification will help the pilot to be more effective, concentrating the efforts rather than dispersing them. This is the difference between an analytical list of stakeholders and a practical way of handling them for concrete purposes.

Beyond the identification of stakeholders, the engagement plan considers the following objectives:

- Ensure stakeholder needs and perspectives are integrated into the pilot design and implementation.
- Facilitate continuous feedback loops to improve the tools, methodologies, and educational resources developed.
- Foster collaboration and shared understanding among stakeholders.
- Enhance the relevance, usability, and impact of the project outcomes.

3.2 Engaging Stakeholders Through Pilots: Driving Change and Measuring Impact

Specific strategies meant to support these objectives are encompassing the following interactions: Communication and Outreach, Active Participation and Collaboration, Active Participation and Collaboration. Then, each pilot is designed to build on a specific type of engagement, the whole creating a large array of explorative and experimenting involvement.

- **Pilot 1: “Capitalising on Social Tipping and Leverage Points for Behavioural Change”**, is targeting the category of Policymakers, Journalists and Content creators, to:
 - hold workshops to train stakeholders on the use of AI monitoring tools and methodologies,
 - foresee feedback sessions to discuss the effectiveness of the tools and gather suggestions for improvement, and
 - involve stakeholders in pilot testing the tools in real-world scenarios and collect their experiences and insights.
- **Pilot 2: “Cultivating Climate Literacy and Citizen Engagement”**, is targeting the category of Educators, Students, and Citizens, to:
 - provide training sessions for educators on using the digital learning tools and resources,
 - Conduct participatory design workshops where students and citizens can contribute to the design of educational content and creative expression activities,
 - organize workshops focused on creative writing, cinematography, and performing arts to engage citizens in climate-related discussions through these ludic channels of expression.

There is however not only the need to generate engagement but also to:

- **measure it**, therefore developing metrics to track engagement levels, such as the number of participants in workshops, feedback received, and the frequency of stakeholder interactions, with regular engagement reports summarizing activities, feedback, and how stakeholder input has been integrated into the project,
- **adapt the modus operandi and objectives to lessons learned**, including evolving needs, and ensuring, all along transparency, on how feedback is used, providing stakeholders with clear explanations of changes made as a result of their input.

The Pilot cases are extensively covered in D2.3 Pilots definition and user requirements definition.

4 Challenges in Environmental Policy and Public Engagement

4.1 The Role of Governments in Environmental Progress: Policy Inconsistency and Backtracking



In this initial stakeholder casting, **governments should take a more proactive role in advancing environmental policies** by conducting studies, interacting with science, and promoting regulatory measures. These actions can truly help advance a more environmentally friendly society along strategic EU commitments, deploy what is required at the city, regional, or national level, and actively participate in governance efforts on a global scale.

In principle, the environmental battle should be about improving the situation, with each step aiming to improve efficiency on how to fight climate warming. However, on the one hand, in spite of a general agreement “to act” in the direction of mitigating the effect of this problematic environmental evolution, there are different viewpoints and interests at stake.

This explains why **policy implementation is often delayed**, and states or the EU as a whole may have to reconsider or slow down the adoption agenda. We will have to take stock of these moves as a means to better understand how behavioral change can concretely take place at the citizen level. On the other hand, at the global scale, climate-skepticism is always there, advancing in various types. This misinformation dynamic goes beyond the struggle between truths and lies. Governments have to arbitrate, sometimes negatively for the environment, policy decisions between various and partly contradictory influences.

We should be aware and vigilant regarding the first issue, but also understand that this may happen. This domain of retro-peddling messages or measures may take many forms. Sometimes, agriculture upheavals push governments to back up on the prohibition of hazardous substances. On other occasions, the energetic pressure rehabilitates the status of nuclear energy. On other occasions, governments simply lack the means to control everything, until a problem comes to the general public's attention. Then, there are also less visible issues (sugar and meat consumption, sand exploitation, for which measures are necessarily complex). The most obvious in this category is the carbon footprint and the pollutive effect of digital technology development and consumption, particularly rising with video and music streaming, cryptocurrency blockchains, and now the explosion of AI applications with Large Language Models (LLMs).

Progress towards a more environment-friendly society is not a linear and crystal-clear pathway. Of course, when it comes to convincing people to change their behavior, meaning they must do a personal effort against the attraction of buying goods and services as an obvious and respected conduct, these hesitations and even more so retro-peddling measures of governments, especially in countries that claim to be leading the environmental cause, create unfavorable conditions for behavioral change. Still, **this non-linear and hurdle-plagued perspective is part of the game**, and we need to integrate it as a requirement for any change-minded project to deepen its understanding and implementation.

4.2 Disinformation and Conspiracy Theories

The second issue is more problematic in the sense as it is now part of a world-scale culture, to a large extent not generated but amplified by social media and nurtured by the trolling efforts of agents supported by specific states so as to weaken or divide their opposing countries.

Disinformation and conspiracy theories are flourishing on the one hand thanks to a multiplicity of narratives, in which science and

policy efforts such the ones the Green Deal proposes is only one of the options. On the other hand, the capacity of some nations to use AI and cybersecurity weaknesses to increase the level of confusion we have to cope with. Just the same, this seems now to be the new normal, and the nobility of the fact-checking endeavors of several indispensable NGOs does not seem to suffice to catch up with the overall trend. This means that NEUROCLIMA is not only compelled to explain and educate but also struggle in a minefield. Hence the importance, for the pilots and the use cases, of connecting efficiently:



- the **explanatory and educational level of the climate crisis** (with the variety of expressive channels NEUROCLIMA is proposing) and the type of change we can be actors of, with
- the **participatory and deliberative support** we can provide to community initiatives and experiments linked to concrete and specific environmental stakes, for which the learning taking place, based on real life observation and results, may make a clear difference against disinformation endeavors.

4.3 The Role and Challenges of Science in Environmental Understanding

Measuring, Modeling, Communicating, Advising is not always easy

Another stakeholder plays a central role in our casting. Science is generally recognised (there are of course exceptions) as an authority when it comes to explaining why environmental problems, and even more so, global warming, take place, at what speed, and how it may evolve in the future. There are recurrent phases of distrust, however, and the recent COVID episode showed partly one such moment, but globally speaking, we do not have much other choice than pursuing with the option of chasing good data and modeling them for action, which has guided us so far. There are ambiguous aspects in that reference framework and status.

1. First of all, country-specific or even **private interests may be interfering** with the universalistic nature of science (against their religious beliefs or their political interests).
2. Second, in the environmental domain, **science is more often conveying alarming messages** or even bad news than being capable of advocating what to do and how to do it.
3. Third, with the advent of some technologies like nanotech, genetic editing, AI, and neuro-digital implants, there may be **important discrepancies between the opinions of some scientists** or groups and others.⁶

⁶ The deterministic (or now solutionist) approach and the constructivist approach have been a source of disagreement between scientists and developers for the past 50 years. We will not get into those arguments here. However, there is a big difference in how the two groups see how science is built and developed, as well as the epistemic foundations of each. There are also

4. Fourth, finally, the environmental challenges pose problems of a level of complexity that no one, even cutting-edge science, can master completely. For science also, the fight against climate warming is a learning process.

Having said that, science is of course playing a central role in monitoring, measuring, modelling, explaining, alerting in whatever climate-related domains and level of threats we may have to consider, and it is important, with due precautions, that we keep using technology and science with the knowledge and the tools we need to support the change we need to advance.

We just need to consider it is a reference baseline, a knowledge framework itself in constant evolution, even if on topics like climate change there is a solid continuity of argument. To alert, document, and model what we need and hopefully contribute, with the relative authority that science is enjoying, to explain and suggest drastic changes in behaviors and regulatory framing of these behaviors.

4.4 The Requirements for the Project Deployment

The deliverable's mission is also to define a series of broad yet specific requirements for:

- the educational and communicational approach, including those conveying game playing and art performing, for the pilots and
- the technology enhancing toolbox likely to boost NEUROCLIMA effectiveness, including data issues,

All these factors constitute the various yet complementary components of the NEUROCLIMA solution, we can say that all the landscape description (Tasks 2.1, T2.4), the specific concepts' analysis (social tipping points, leverage points, etc.), the barriers, and the explanation concerning the educational and communicational support actions are the building blocks of the sequence conducive to the requirements needed to advance the project. The following sections will therefore bring these different building elements to our attention so as to recall, support and detail, at the end of this deliverable, the different requirements' claims.

differences in how they see environmental problems. The most radical environmentalists believe technology is a root problem, while more moderate ones acknowledge that without technologies, we cannot measure and understand global and local changes. There is also a debate between those who believe that technologies will solve the problems that technological development has created and those who believe that, as history has shown, technologies alone do not convey that capacity and may create new problems. These clues are just a few of the scientific community's disagreements.

5 Defining Social Tipping and Leverage Points

5.1 Below the surface: a structuring force shaped by and shaping lifestyle

This section proposes a comprehensive and motivating perspective to work with, comprising points of attention that may make a difference as well as levers allowing us to act. In this process, spousing the European Union views, especially regarding environmental challenges, including how all the stakeholders' interests and actions must be dealt with. Then, of course, through the cases, pilots, and technology tools experimented, there is the objective of helping learning participation take place and federate promising community efforts to not only alert on threats and risks but also build game-changing tracks, gradually establishing a neural network of nodes and engaged socio-economic agents. However, before tackling the social tipping point and leverage point issue, it is fundamental to understand in what type of setting these enabling landmarks take place and what makes them so valuable.

5.1.1 Economic and environmental concerns have failed to converge so far

The main hypothesis we are confronted with regarding climate change and how difficult and yet indispensable it is to understand how complex the situation may be, is that if we have reached that level of threat and even real-life problems, it is because for decades, we have constructed it, with dedication and "efficiency": *we have been very efficient in developing society's wealth at the cost of harming our livelihood conditions.*

The general underpinning of this evolution is to be found in particular in the overall political-economic narrative of our society. All economic factors are organized in such a way as to produce a level of wealth, keeping the economic engine performing. While this takes place, it is hopefully supposed to distribute some of this wealth to many, if not all, as a means to keep all sectors of society tacitly or explicitly, consenting to this overall deal. In theory (but it is also a narrative that can be disputed), this economic scenario generates a pervasive leitmotiv stating that all citizens and inhabitants can be seduced and satisfied by what is produced and thereupon enticed to buy and consume it, in the strict sense (eventually: destroy it). Economists of the various dominant schools of thought have brought their contribution to explain how this was the way towards collective progress. In the globalised capitalistic strand, this has implied the "trickle-down" idea, i.e., *"if we produce enough, there will be, by dissemination down the social ladder, enough for everybody."*

Some tend to simply attribute this to capitalism, which is striving to exacerbate competitiveness, innovation, and economic growth as goals. Although we can observe that alternate experiments, so far (some 70 years of socialist endeavors as a reference for that, for instance), have not demonstrated environmentally more responsible results than the capitalistic strand. Without entering too much into this debate, let's accept for the moment, that there are various ways of neglecting the environmental factors regardless of the economic or social model.

Politicians have to arbitrate and choose, depending upon the countries and their regimes, between privileging production and entrepreneurship against a more social balance, or, on the contrary, towards a more redistributive scheme, but without giving up entirely the needs associated with productive stakeholders and their ownership over the productive infrastructure.

In spite of the fact that this long-standing commitment towards economic growth has generated a voracious energetic race and a predominant neglect for environmental damages, a more frugal and

environmentally sensitive set of measures, possibly not aligned with economic growth and business as usual, created a new tension.

NEUROCLIMA’s objective to intervene as a change actor in this situation lies exactly in the middle of this difficulty. On the one hand, in 2024, more and more people have understood the fact that climate is changing in an undesired way. With higher risks ahead of us and with the correlated knowledge we understand that each one of us, and all of us together, need to do something about it. “What to do” is still not clear. On the other hand, even with all the regulatory efforts engaged, we are still enticed to spend nice holidays away from home, buy new clothes according to seasons and fashion suggestions, renew periodically our belongings, from smartphones to cars, as if it would not be related to the previous statement and not bound by planetary limits.

Our task is precisely to take stock of this contradictory situation, away from any naive thinking that solving that problem is simple (we just have to change our habits) and identify the points where it is possible to act, shaping the conditions, helping people exert a concrete pressure, even if small, on this force field, and thereupon make it evolve in a more acceptable and promising direction. This historical tension, in which NEUROCLIMA intends to bring positive options, can be represented in the following diagram.

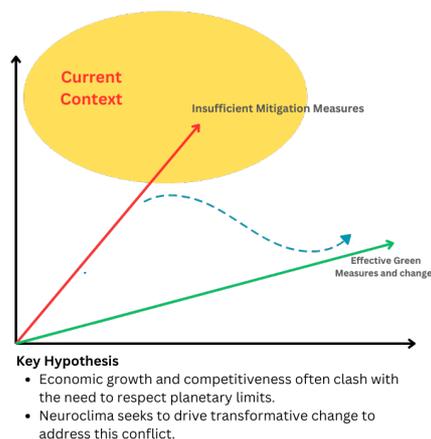


Figure 5: Starting and arrival points for Neuroclima effectiveness

This situation is largely due to the long-standing habit of linking social and economic welfare with economic growth. This mindset encourages constant consumption and measures progress by macroeconomic indicators. The visible damage and the potential for worse outcomes have led many countries to adopt policies aimed at mitigating, slowing, and even reversing these trends. However, these efforts have faced significant challenges, often hindered by conflicting interests. To bring about real change, especially in behavior, we must understand and address these contradictions.

NEUROCLIMA aims at clarifying and helping use the different levers at our disposal to push changes in the right direction (improvements towards a more sustainable quality of life), within a collective learning perspective, and support policy orientation to do so in the most impacting manner.

5.1.2 What is likely to make change possible and effective?

A naive approach would suggest that to trigger behavioral change, you just need to explain well what the problem is and how to improve upon it in different ways, all improvements being good anyway. A less naïve approach consists of thinking that to trigger behavioral change, you need to explain well what the problem is and how to improve upon it in different ways, but in addition, taking simultaneously care of 2-3 co-factors of different nature to keep being aligned with the objective, in

spite of hurdles. We will gradually learn how to make good use of this “7-errors game”⁷ between the two sentences. The good news is that NEUROCLIMA can build upon several types of levers, in particular:

- **Social tipping points, pain points** and **leverage points** must be considered as the many factors triggering a series of changes (production mindset, lifestyle, citizen implications, and policy coherence).
- **Participatory dynamics**, with a large variety of communities and territories.
- **Narratives**.
- **Educational** support (WP3).
- **Communication channels** (WP7).
- **Policy recommendations** at EU and MS levels, with also future-oriented governance endeavors at local as well as international level.
- A mix of **knowledge sourcing and decision-oriented capacities** of human expertise and AI-based support (the innovative tool-minded orientation of our project).

The objective of our work has been to examine and evaluate the potential as well as the limits of these various levers and channels. Part of the result is the possibility to combine these factors for the neural construction that NEUROCLIMA ambitions to establish.

NEUROCLIMA bets on key concepts such as **tipping points to shape an alert system, similar to the human nervous system** and aims at building possibilities and motivations **towards positive change to trigger what is called leverage point** as a concrete means of deploying its policy recommendations.

It does so by combining at best:

1. **Policy objectives**, which intend to guide collective action at the most effective level and
2. **Participatory action at community or territorial level**, as the many nodes of the nervous system **to stimulate, support, or revive citizen involvement**, and as the means of expressing perceived needs for change and experimenting necessary modalities for that, and with
3. **the supportive enhancement of AI-monitored collective knowledge processes**.

⁷ The game of the 7 errors consists of finding the 7 errors on an image for example.

5.2 Conceptual tools to conceive, evaluate, measure and prioritise most needed changes

5.2.1 Social tipping points and environmental tipping points

Understanding the Concept of Tipping Points

Before examining what, social tipping points are and their relationship environment, let's explain the root notion of “**tipping point**” and what it can provide to our NEUROCLIMA needs. Everything changes all the time, but for adaptation purposes, we learn from childhood how to detect within our constantly changing environment, some stable elements on which to rely and understand what is taking place, act in a manner that is efficient in our own terms and gradually too, which can be recognised as such by others, parents, friends, and even unknown individuals. Thus, although change seems to be the rule, we perceive and organise our perception in a way that tells us that eventually not everything changes all the time. «Non change» may be temporary or last. *Some aspects of our lives seem stable, while others seem less, making us learn that life and society are complex notions.* We also discover that although we may have the impression that our environment is stable, there are some subtle forces at work that at some moment of time modify the situation and our perception of it, all of a sudden making us realize that something has changed. In fact, both impressions of changes and stability have their relevance, and identifying the underpinning factors of that difference is an important dimension of human expertise.

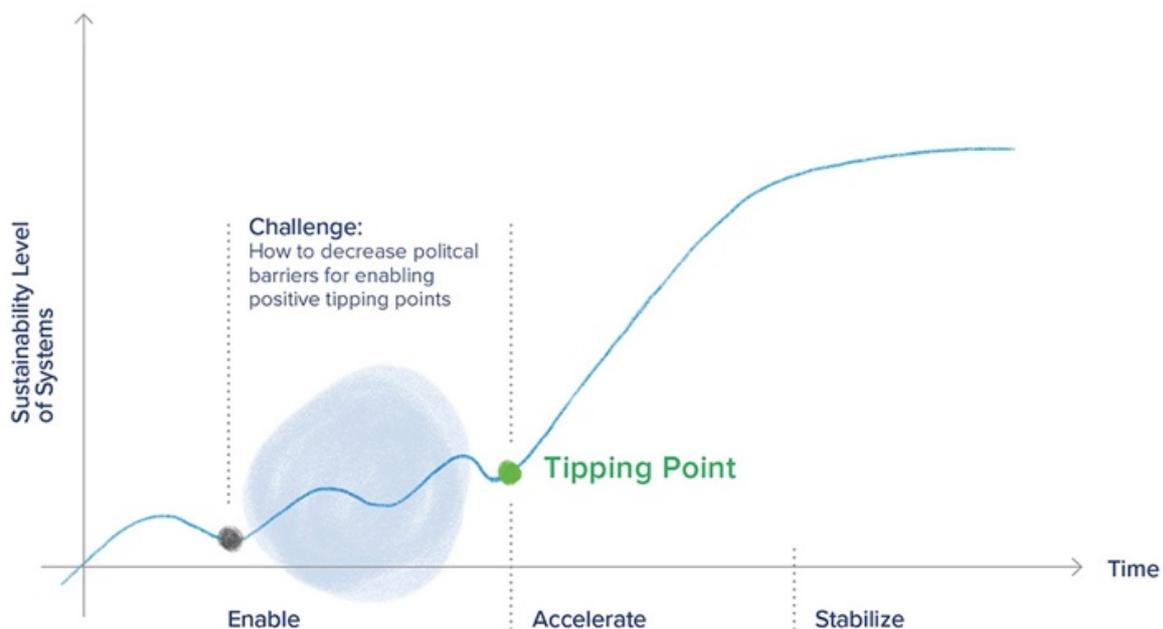


Figure 6: Enable positive tipping points to accelerate the transformation of sociotechnical systems in line with the SDGs (Fesenfeld et al., 2022)

We use for that, as helping factors, some common sense (personal, but also culturally learnt), from our own experience, enhanced by the possibility of exchanging impressions with others, and as supportive influence, the role of science, an “institution” that has dedicated itself to explaining physical and human processes in formal and peer-verified principles. This hybrid framework of knowledge components guides us to navigate changes as a normal pattern of life.

Types of Change and the Emergence of Tipping Points

However, there are **different types of change**. That, too, we learn from childhood. The seasonal sequence, the growth of living organisms, to which we get accustomed, but also deaths, disease, separations, geographical moves which define types of transformation of greater magnitude and also of more sudden and dramatic expression. Change is therefore a generic term to hint at a large variety of phenomena and the words of equivalent status or near to it are quite numerous⁸.

Among all the possible kinds of changes one can envisage, there is a type which draws the attention. It may represent a more or less sudden phenomenon, but has nevertheless enough track record to be followed as an evolving scheme with, as key characteristic, a point of time after which the overall context and underpinning factors create a new situation, more or less understood as such (it may take time for all stakeholders to converge) and with possible changes of irreversible nature as compared with the previous phase. Let's follow those who have proposed a formal definition for the kind of change we call **tipping points: "the critical point in a situation, process, or system beyond which a significant and often unstoppable effect or change takes place"**⁹.

Historical Perspectives on Tipping Points in Systems Thinking

Historically speaking, tipping points have been conceptualised and studied with great attention by the systems' approach schools, since the 40s and 50s. The most interesting aspect, regarding that tradition, which involved some core concerns but also quite diverging models and theories, including up to the present days, is that quite early two diverging paradigms were developed:

- one considering that **systems tend to predominantly stable** (or homeostatic) arrangements of parts, within which or against which (from the outside) some alteration process could take place, with an impact or more or less changing magnitude, ranging from absorbable to destabilizing.
- another one considering on the contrary that **instability is a normal regime** but that temporarily and under some cohesive force effects may appear as stable, until internally or externally dissolving factors take over.

This nuance may seem minor or a specialists' problem; but when it comes to project oneself (as individual, as group, community, territory or as policy-maker), as the actor of a desirable change, with the possible identification of what may play the role of urgency signal (tipping points) or facilitating support dimension (leverage point, as we shall see), this can make quite a big difference.

In fact, this issue is linked to the epistemic foundation of the explanatory propositions, either thinking systems as "things" and then, "things of things", which can be analysed and even simulated in a problem-solving perspective, as it has been for instance advocated since the 50s by the *System Dynamics* school¹⁰ or as the representational construction, but conveying some pragmatic value, of a complexity approach.

In the systems' thinking history, this was mainly initiated by the Complex Adaptive System (CAS) approach; but in the last 50 years, many scholars have proposed their particular view on what complexity may mean¹¹. This can be:

⁸ Bifurcation, mutation, transformation, transition, alteration, modification, metamorphosis. It is an interesting game to try to make this list as long as possible, with dozens of near equivalents, as well as concepts that suggest specific types of changes (like revolution for instance).

⁹ From Merriam-Webster. Cambridge dictionary adds: "the time at which a change or an effect cannot be stopped"; There are many near-equivalent words, such as "turning point" or more specific ones that suggest additional variables or consequences, including «extreme» or «abrupt» shifts.

¹⁰ Derived from the cybernetic model formalised in the 40s, Forrester (1968) proposed a more ambitious methodology he called systems' dynamics, a school of thought that became extremely important in the engineering profession, worldwide.

¹¹ See (Wells, 2012) which is in addition tightly linked to our NEUROCLIMA concerns.

- **reductionist** and therefore of relative status,
- **depending on the system** constituted by the observer, which cannot entirely escape impacting their findings under the effect of their own observation of the system.

This is typically the line of thinking of those who have developed *constructivist approaches*¹². However, to understand the root problem in which NEUROCLIMA will have to deploy its talents and effects, we need to consider the fact that *people explaining to others what to do regarding the environment are also, themselves, implied in the problem they explain*¹³.

Epistemological Foundations and Complexity

This complexity effect does not mean that we cannot say anything relevant, but that we are making proposals that are themselves systemic influences transforming the landscape, which we try to understand and if possible, to be an actor of. This approach was developed by Edgar Morin in his multi-volume explanation of what it means to be acting in a complex world, with the epistemic figures that shape complexity for him: *dialogic, hologram* and *recursivity*, which add themselves to a principle more or less common to all complexity thinkers: *the notion of emergence*¹⁴. Greene et al (1993) and Banathy (1996), have been designing ways of supporting this actor perspective across complex systems for the last 30 years, and also the scholars of the agent-based modelling of social systems (see for instance Van Dam et al. 2013).

However, in the middle of this epistemic gap, emerged a school of thinking, out of the Santa Fe Institute¹⁵ and belonging rather to the second type of system’s thinking schools («order out of chaos»), proposing the concept of *Complex Adaptive Systems (CAS)*, with concrete linkages to social reality applications¹⁶ and a focus on the adaptive and learning capacities of human beings upon their experience.

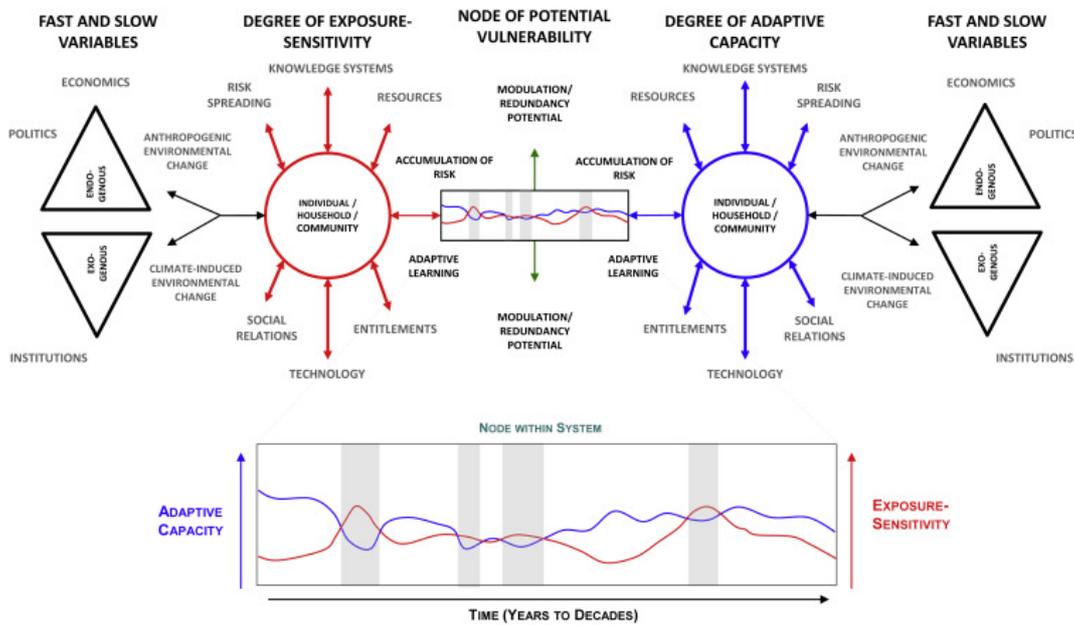


Figure 7: Conceptualizing Climate Vulnerability in Complex Adaptive Systems (Naylor et al., 2020)

¹² A large and little cohesive group of scholars with such figures as Luhmann, Varela and Maturana, etc.

¹³ See Von Foerster (1981, 2003), who has developed what he called “second-order cybernetics” or how the observer’s system interacts with the observed system.

¹⁴ Also linked to the works by (Maturana & Varela, 1987), (Luhmann, 1996) and others on self-organising capacities.

¹⁵ Complexity Explorer. | Santa Fe Institute

¹⁶ CAS concept emerged at the Santa Fe Institute in the 80s. The amount of work done is quite abundant, so it is worth relying on meta-analyses such as the one proposed by Dodder and Dare (2000).

The NEUROCLIMA Approach to Tipping Points

NEUROCLIMA is not a theoretical debate, **but a project to generate more climate-positive behavioral conditions**, which we aim to reach using a more concrete concept of the tipping point notion: the clear distinction between social tipping points and environmental tipping points. We will see further that regarding this relationship there are two different ways to understand and apply it. At this stage we need to define our concepts more precisely.

Defining Social Tipping Points

Social tipping points are moments of important junction in a life cycle, process or evolution involving the understanding of, and possible participation in a change taking place, of a large number of social actors, individuals, groups, communities, etc. To better substantiate what we are talking about, let's take an example of social tipping point which has little or nothing to do with the environment.

During decades, in many social and professional milieus, inappropriate behavior (to say the least) from masculine figures in their interaction with women, but also men, have taken place, yet without creating the rebelling effect that the sufferance encountered by the victim side would have let suppose. It took years, the courageous action and the resonance of media which may have had other objectives themselves than the sole pursuit of moral justice, to generate a snowballing process that made it not only possible for more women or men to express what they had experienced but to some extent revert the status of social significance of the offenders' behavior. We will not here enter in the debate of whether media and also social media are overpassing their legal prerogatives, but only to emphasize a process involving the emergence of a tipping point after which things became perceived and treated differently regarding the reference issue.

Social tipping points are processes in which a sufficient number of individuals or groups (a number which can vary greatly from one problem to the other, however) is acting upon a particular problem, in a way that concretely creates a changing mindset, and thus opening the way for this problem to be, from then on, treated differently. It may concern demographic pressure, educational stakes and organisation, migrations to be handled on both ends, gender issues, poverty measures, social benefit conquests, traditional family pattern explosion, territorial criminality due to drug taking, changes in professions and careers due to the digital transition, etc., the bandwidth of social tipping points is quite wide and their positive value is also manifold: it can trigger the understanding that change may be the solution, n stimulate a desire for change, accelerate individual or collective behavioral change, and even catalyse unlikely change to take place, as non-linear processes seem to be more often the rule than plannable agendas in these dynamics.

Environmental Tipping Points and Their Relationship to Social Tipping Points

While there are myriads of social tipping points, **in NEUROCLIMA, those we are interested in are social tipping points tightly linked to environmental phenomena, and even more precisely to environmental tipping points¹⁷.**

Let's specify at this stage that this relationship can be envisaged in two different manners.

- The most obvious and simple, and by the way the one which has been taken up by D2.4, is merely focusing on those social tipping points that have a clear environmental impact. Plastic saturated environments and oceans generated the first bans.
- The less obvious one, which does not deny the value (on the contrary) of the filtered proposal envisaged in the first approach, tends to contextualise the perception of pain or saturation

¹⁷ Environmental tipping points are defined simply by IPCC as « critical thresholds in a system that, when exceeded, can lead to a significant change in the state of the system, often with an understanding that the change is irreversible.» (IPCC, 2019)

regarding a certain factor within a broader social learning framework, involving often several factors and associated with a variety of social actions possibly involving environmental tipping points.

As Deliverable 2.4 presents the first one of these approaches, with due references¹⁸, we will document and give some substance to the other approach, likely to put forward a larger variety of social tipping points of environmental value.¹⁹

These last 30 years, thanks to international organisations as well as the contribution of science and local studies, a lot of such tipping points have been coined. All IPCC reports, for instance, are full of reference tipping points, regarding temperature increase and green-house effects, but also underpinning factors or major turning points at planetary level²⁰.

These major turning and possibly tipping points near us, or already “activated” (ongoing), are often complex systemic interdependencies of very large factorial influences, and as the IPCC produces reports that are often slightly indigestible, many organisations are engaged in emphasizing their main elements or risks to consider. These large tipping points, according to a summary produced by Earth-Org²¹, are typically concerning such planetary processes as the melting of the Greenland Ice Sheet, the warming of the Permafrost, a change in the Atlantic Meridional Overturning Circulation (AMOC), the monsoons’ regime, the decrease of tropical rainforest, the melting of the Atlantic ice sheet, the Coral reef die-off, etc²².

However, environmental tipping points are of very different nature, scale and impact levels and one of the problems is to make sure that small steps are no excuse to avoid confronting major challenges (“ordinary green washing”?). This requires research to continue its knowledge quest and also a constant educational pressure to diffuse a more holistic understanding of how regarding climate warming, with the near and the far away, the local and the global, being conjunctively important to deal with. Research is needed, for explanatory but also instrumental reasons. It helps measure the modifications of the ocean’s elevation, difficult to appraise globally otherwise; it helps spot the loss of tropical forest, it can monitor flows or gases and liquids or semi-liquids (glaciers for instance) which would be impossible without scientific instruments and satellites. For the explanatory strand, it has to do with the permanent quest for better theories, but also the debates and modeling issues that support them. The understanding of why and how things change is indeed regularly updated, and if necessary, modified. *Complexity is most often the rule, reality cannot be captured so easily.*

The Role of Research and Science in Understanding Tipping Points

The number of individuals under the eyes of whom a given species is likely to disappear varies considerably and sometimes, we detect it too late. When the last glacier for the Northern Andes disappeared, in Venezuela, recently, it may have looked negligible as compared with the Greenland ice shelf melting for instance; but the understanding that other glaciers will also melt may constitute a more perceptible chain-like impact, as it is already the case in the European Alps for instance. To take

¹⁸ "Social tipping processes for sustainability: An analytical framework." (Winkelmann et al., 2020). The important features emphasised by this approach when attempting to differentiate social and environmental tipping points, are 1) human agency, 2) the complexity of social network structures, and 3) the different spatial and temporal scales at which these processes occur.

¹⁹ The work of some authors can be claimed by both approaches, as for instance (Bretschger & Leuthard, 2024).

²⁰ One example, shows the importance of satellite observation and measuring, associated with explanatory follow-up models, of course, the “ESA understanding of what a tipping point is for climate change”, (ESA - Understanding climate tipping points).

²¹ Explainer: The Tipping Points of Climate Change | Earth.Org

²² For the examination of climate-induced tipping points, see for instance the review of (Van Ginkel et al., 2020).

another example, traffic nuisances at respiratory level present a quite different problem as it depends on the amount and also the spatial density of vehicles, as well as the geo-physical configuration in which they are flowing. Tipping points, in all our examples, differ obviously from one case to the other, often with cross-lessons that only specialised individuals or organisations can relate into significant categories of evidence, and therefore entering into a collective learning process. However, whatever the complexity to be coped with and the distance that may exist between specialists and ordinary citizens, the role of science in the context of climate warming, is fundamental.

Still, research is not enough, other types of specialists have to translate, explain, demonstrate, exemplify the scientific messages, for more people to be capable of understanding and possibly being influenced, and turn themselves into educational agents of one kind or another.

NEUROCLIMA's Perspective on Social and Environmental Tipping Points

In our 2024 Lisbon workshop, NEUROCLIMA members inventoried a diversity of such communication and educational agents. The project will beyond doubt give this large variety of players a role and shed light onto how they will emerge as cooperation and federating (f)actors in the years to come. That is one of NEUROCLIMA's objectives.

We will see how these stakeholders may boost participatory dynamics involving users, inhabitants and communities of practice concerned with environmental change. This is where NEUROCLIMA intends to be useful. And to support the idea that beside the environmental filtering of social tipping points there is a valuable framing worth considering and also interesting for NEUROCLIMA, we can emphasize the fact that a lot of social tipping points involve multi-dimensional issues and may focus, after a maturation time, into an environmental focus. The fact that a social tipping point does not start with an environmental goal to start with, in many problems dealing with traffic saturation, transport investment, healthcare access, food quality, security, may involve at some point of time a bifurcation in which an environmental component becomes a key focus and the start of a potential leveraging dynamic. Let's not forget that grassroot initiatives, opposition projects and change initiatives often take the form of a **social learning process** in which people are capable of transferring, applying and progressing in the way they can express themselves and focus on essential elements over time. In this sense, we can acknowledge that numerous problems involve, embedded, environmental stakes that may eventually prevail. Cases of this kind are valuable to keep track of and should not be discarded.

To come back to our previous dilemma, for all tipping points, we can ask ourselves the following question: is there a stable situation in which we can initiate a change or should we rather consider that we are confronted to a permanently changing landscape in which we have to detect some factors we can act upon, as an expression of change need, desire or potential? We will see that there are different types of participatory processes that borrow their value to one or the other of these strands.

It is clear that large-scale processes, such as the ones mentioned in the Earth-Org list (and therefore in the IPCC report it comes from), are difficult, for individuals, groups or even specific states, to relate to efficiently, with the sole criteria of changing one's everyday behavior. However, and the problem is precisely «there»: even these large-scale phenomena are depending, ultimately, of everyone's everyday behavior. It is within the goals of NEUROCLIMA, through diverse means like the « neural networking » and the creative educational stimulation, and their supportive technologies to help individuals and communities engage towards behavioral change with both local and global impact regarding climate concerns.

Transition Theory and Alternative Approaches

Let's oppose to this ambitious tackling of the complex world and the level of challenging efforts it will take to cope with its most problematic effects, the more obvious and solid approach developed in the transition theory school, in particular by: (Geels, 2002; Geels & Schot, 2007, 2010)

Their working concepts suppose:

1. a **stable landscape** (that eventually may be less stable than envisaged, of course, but it constitutes a starting point), encompassing both intangibles such as social values, political beliefs and worldviews, and tangibles such as climate or physical landscape;
2. **regimes** (which include forms of government, sets of rules, cultural and social norms, physical infrastructures, professional practices);
3. **niches**, which are spaces or labs where new ideas can be tested, experimented, prototyped.

Given the way reality is broken down here into simpler and workable "bricks" and given also the complexity of the challenges at stake, there is obviously an arrow of epistemic work going from point 3 to 2 and then to 1 in all the actions that can be envisaged regarding a changing perspective.

Now, let's stress that there is no right or wrong, each perspective has its advantages and inconvenience. The Geels perspective has the merit to pose the human actor as a starting point who, layer by layer, step by step, can expect to make some changes happen. It is a motivational perspective. In other words, if the world is unstable and changes, why some humans would not take the opportunity to navigate these multi-change configurations and become relevant players in their own terms. The inconvenience is that the upper layer represents complex and perhaps inertial forces against which the niche innovation may be considered negligible (until it grows to a sufficient threshold, but this is another story), meaning success is not obvious against global forces. Indeed, opposed to that opportunistic interpretation of tipping points, the complexity approach is probably more realistic, but also perhaps a bit demotivating, as the level of problems to be tackled, the remoteness of some of them too, may help consider vain any change attempt.

In between these two strands, we can envisage a strong rationale combining 1) tipping points (not all change objectives are at stake, some of them matter more, with more proximity and urgency), 2) leverage points (ways of establishing promising niche efforts) and possibly also 3) pain points, as we will see further (how to evaluate, learn and change from bad experience), as a pragmatic handling of those different factors, criteria and overall perspectives.

Integrating Tipping Points, Leverage Points, and Pain Points

Whatever the initial configuration and the approach, in this large scope and not upfront filtered perspective (in which only those social tipping points having a clear and immediate environmental relevance are identified), motivational factors such as proximity, emotions for endangered species, the thrill of collective learning dynamics and the possibility of personal and sense-making implication can make a large variety of social tipping points the triggers for more: health problems, mobility saturation, urban planning policies, migration issues, educational programs may involve social tipping points, and be also the entry into the perspective to become actors regarding relevant environmental tipping points.

We will have to come back to these differences: the topical filtering approach vs. the broad social understanding of how these different tipping points (social and environmental) may relate to each other, when we will examine the participation issues.

In all cases, tipping points (or rather said, social tipping points linked to environmental tipping points), in the NEUROCLIMA mindset, are important processes to pay attention to, as they can be conducive

to change more easily than what stable situations may offer, as they can allow us to experiment alternatives, conduct and evaluate trials, learn and share experience, quite a promising programme.

5.2.2 Leverage points, small and big

If tipping points have been examined with such detailed explanations and a few detours to make sure we were handling the situation with the level of theoretical and historical requirements they convey, should one wish to avoid too naive proposals and clues, leverage points are much simpler to understand. In systems analysis, leverage points refer to specific places within a complex system where small adjustments can lead to significant and lasting improvements. These points act as “levers” that allow us to influence the system’s behavior and imagine them as strategic intervention points, thanks to which minor changes can yield major results²³.

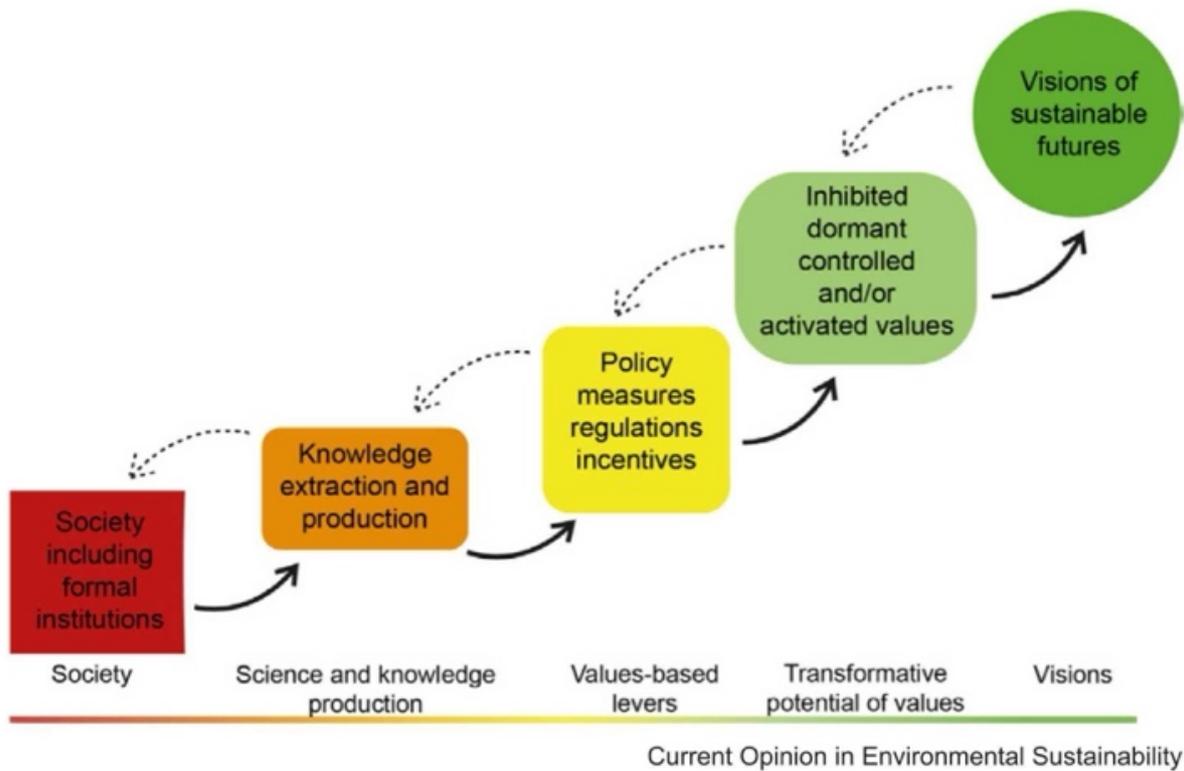


Figure 8: A pathway for engaging with values as leverage points.(Horcea-Milcu, 2022)

However, there is probably no better way to clarify the notion of leverage point than making reference to the definition proposed by Meadows at al. in their foundational report²⁴ to the Club of Rome («Limits to Growth»). For these scholars, leverage points are «..places within a complex system (a corporation, an economy, a living body, a city, an ecosystem) where a small shift in one thing can produce big changes in everything»²⁵.

The good news is that Donella Meadows, the lead author of the above-mentioned report, also proposed, later, a list of concrete tracks to consider effective leverage points. Here they are as she suggested them:

²³ For a broad review of this notion, see in particular Abson et al. (2016) and Dorninger et al. (2020).

²⁴ We are well aware that this 1972 study, largely based on system dynamics, has been revised and updated, and also criticised over a dozen times since then, but it represents a social tipping point in its own terms.

²⁵ Meadows Donella: Leverage Points: Places to Intervene in a System - The Donella Meadows Project.

PLACES TO INTERVENE IN A SYSTEM (in increasing order of effectiveness)

12. Constants, parameters, numbers (such as subsidies, taxes, standards).
11. The sizes of buffers and other stabilizing stocks, relative to their flows.
10. The structure of material stocks and flows (such as transport networks, population age structures).
9. The lengths of delays, relative to the rate of system change.
8. The strength of negative feedback loops, relative to the impacts they are trying to correct against.
7. The gain around driving positive feedback loops.
6. The structure of information flows (who does and does not have access to information).
5. The rules of the system (such as incentives, punishments, constraints).
4. The power to add, change, evolve, or self-organize system structure.
3. The goals of the system.
2. The mindset or paradigm out of which the system — its goals, structure, rules, delays, parameters — arises.
1. The power to transcend paradigms.

We will of course have to learn, upon that list of suggestions, how to develop our own reference framework concerning leverage points, but we have at least a practical starting ground. Donella Meadows, in the intervention in which she made this proposal, added that in order for this to be fully understood, she needed to explain more in-depth parameters, stocks, delays, flows, feedbacks, etc. Her approach stays within the system dynamic paradigm, but it offers a lot of concrete reference to conceive leverage points for climate-positive action.

Let's mention however, that scholars, more recently, have re-categorised Meadows points, translating the 12 clues in four broad areas of concerns for action (Leventon et al., 2021), (Dorninger et al., 2020).

Above all, we have to consider in NEUROCLIMA deployment:

1. *leverage points* on which people and communities can engage in behavioral change as a means to «leverage» the problems they are tackling in favor of climate-positive objectives,
2. how some leverage points may represent more *ambitious challenges*, even if remote and broader problems to cope with than proximity concerns, and
3. how to *facilitate behavioral change, participatory dynamics* and the *learning* that may go with them to possibly address these two dimensions: what is near, concrete and accessible, but also what is critically important although sometimes of a level of magnitude difficult to grasp or too remote to feel effectively concerned, in other words «**Environmental Commons**».

This is a fundamental “learning tipping point”. When people from countries which have no ocean, no glaciers, no tropical forest, no endangered mammals, no coral reef die-off, etc., will understand and accept as a commonality impacting their life those extra-territorial stakes, and integrate in their behavioral change reasons also linked to these more seemingly distant issues, we will have made a huge progress. There are cross-cutting factors connecting the dots (including for worse), as for instance plastic rejects in the ocean, finishing as micro-plastic pieces in each one's stomach.

Beyond that already substantial menu, there is of course the need to consider how social tipping points of environmental relevance may represent promising leverage points. Part of the educational game NEUROCLIMA aims at deploying will revolve around that challenge.

5.2.3 Pain Points: Catalysts for Change and Challenges in Environmental Awareness

Past failures and memorial resistance

In the NEUROCLIMA proposals, in spite of the fact that the focus for change are indeed social tipping points and leverage points, the notion of pain (point) appears 21 times, a therefore important complementary notion to the first two ones.

Understanding Pain Points in Environmental Change

One reasonable way to use these factors (tipping and leverage “points”) to trigger action would seem to build motivation out of the negative effects that environmental change is generating, that may severely impact the quality of life and even the livelihood of some populations. We suggest here that, directly or indirectly, there are consequences linked with climate warming and its co-processes that create perceptible, measurable, lasting pain feeling or physical damage to humans that can be associated, without too much complication, to their causes (in which the human beings who are impacted can in principle blame their own behavior as being part of the problem, let’s not forget that aspect of the problem). The range of cases of the kind is quite broad and some are even directly damaging, in the sense of time and space immediateness between the damaging effect and the root problem.

Let’s consider for instance the droughts that are now hitting every year, some parts of Southern Europe (and even beyond, to the North). Every year, the number and the impact of fires, intentional or not, are increasing, causing dreadful ravages. In addition, for the regions who live upon their agricultural resources for their prosperity, the lack of water (with ineluctable water disputes) is threatening their economic regime. These situations are typical of evolutions that are going towards the worse and where some tipping points are not only environmental but become social and felt as local yet collective pain points.

In these cases, it takes time and several rounds of «pain», until the attribution of the problem ceases to be denied, or simply put on the shoulders of incompetent public authorities, and gradually associated with collective consuming choices, everyday behavior and part of broader problematic stakes of socio-environmental nature.

It is even more the case with indirect relationships. An example of that can be found for instance in the respiratory difficulties linked to temperature increase, pollution and air dryness. As this does not strike a homogenous group, spatially speaking, but the most vulnerable individuals, who may be scattered, it takes time until the healthcare system spots the root cause with enough documented evidence, formulates an explanation, if possible, with some defensive precautions to adopt, with the aura of science and commonly agreed upon observations²⁶. Thus, in this type of example, denial may be easier or even stay unnoticed, and most of the time, the relation of the problem with one’s own behavior and responsibility is even more difficult to establish and therefore understand as a starting point for behavioral change.

NEUROCLIMA's Approach to Pain Points

For NEUROCLIMA, there is therefore an imperative to deploy effort towards understanding these different levers, documenting cases and providing communication contents (with, as well as without AI-aided support) to exert a proactive didactic effect along the communication value chain and the community of usages and practices already engaged in changing their situation.

²⁶ We will see that there are groups and even political parties, on the European continent, that are playing a quite disputable disinformation game, for instance complaining that weathercasts are too negative.

Another example is provided by the recent decisions of some touristic cities to put a halt to their attractiveness in terms of the number of tourists they welcome. For some places like Venice, this implied to limit the overflow of tourists not only to preserve a minimum quality of life, but also to diminish erosion and even medium-term survival of their city; for others, like Barcelona, this limitation was meant to make sure the local needs in water would be satisfied. These cities live to a great extent thanks to tourism, but the risks become so high that they have to limit or even in some cases (Capri Island this year) to forbid the access of their resorts to tourists.

Another example is given by the ozone layer depletion of the 80-90s, which provoked an increase of skin cancers in the Southern hemisphere and a public scare associated with that factor. The measurement and the public policy directives of those governments most heavily involved in the release of the damaging gases into the atmosphere, gradually helped diminish the depletion, almost reaching a pre-depletion state²⁷. In that case, it is sufficiently remarkable to emphasize it: the level of scientific and public-policy governance (a result of the Montreal Protocol) has been efficient enough to generate a salutary change, at least according to the currently agreed upon explanation²⁸.

Varied Responses to Environmental Pain Points

Thus, we have several examples which show how the local «pain» felt may induce a series of complaints and perhaps negotiation rounds with political authorities varies considerably. In the first case, with the drought threatening agriculture, the negotiation took place mainly between the principal economic players and the local or regional political power, with the monitoring collaboration of science. In the second case, involving a respiratory risk, it took time, the population was mainly informed but did not participate much in the deliberations leading to policy measures; science, the healthcare sector and insurance companies were at center stage. In the touristic issue, on the contrary, a lot of participatory dynamics took place with probably a more impacting learning process for all the inhabitants-citizens of the concerned touristic locations. In the last example, of the ozone layer depletion and remediation, it took mostly place, like in the respiratory problem, between a small number of specialised stakeholders, but with a good level of communication to the grand public.

The Role of Pain Points in Stakeholder Engagement

The value of “pain points”, although the previous lines demonstrate that there is no one-size-fits-all configuration, tends to appear and become negotiable when the problem is so acute that an effective participatory interplay can take place between the different stakeholders, and in particular between the population possibly suffering from a problem (but also indirectly responsible for it, as we have seen) and the policy-making or political (executive) decision makers. Thus, the possible value of “pain points” is most of the time a multi-round and under-rational game of conflicting interests and viewpoints, but with time, across the combination of tipping, leverage and pain points, it can lead to some results and benefits, in particular under the persistent action of scientific messaging and communication specialists’ engagement.

²⁷ In this case, it opposes the irreversibility clause often attributed to tipping points. In fact, there are many other interesting examples of the kind. The revival of forests, the marine sanctuaries allowing for many species to recover, the cleaning of lakes and rivers by rejecting less pollutants, etc. are of that kind.

²⁸ World Meteorological Organization (2022).

Working on « pain « points »: a typical hurdle race

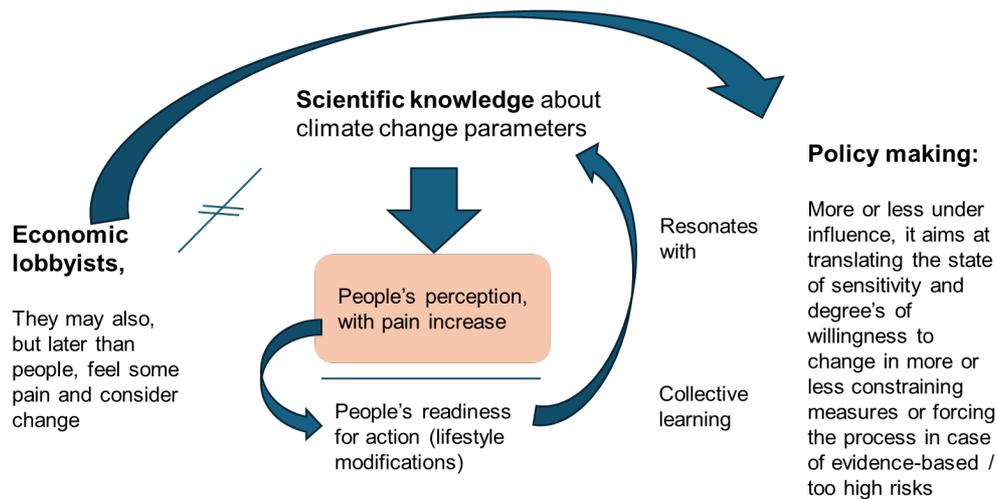


Figure 9: the most likely life cycle of pain points, social tipping points and leverage points

In this diagram, we suggest that the pain felt by a specific population and the possible change dynamic it can trigger may often have to pass through several stages to end up involving, at some point of time, the interplay of the concerned population and other key stakeholders (science, economic players, civil society organisations), with public authorities at the most appropriate political level and with a chance of conveying some expected effect.

Pain Points as Part of a Broader Change Strategy

One may ask, at this point of our analysis: is the “pain” evidence a necessity to foster change? The answer is obviously “no”, there is also a rationality which may be understood and shared, well enough to generate genuine behavioral change spontaneously. However, we should just not count on that possibility alone to turn tipping and leverage points into effective changes. Inertias, complexity expressions of how systemic linkages may be dealt with, paradoxes, conflicting interests are also part of the landscape we want to work upon. “Pain” points are just part of the interactive game between social tipping points, their environmental incidence and the potential to leverage something positive out of it.

To finish this section on the awareness of and subsequent steps to suffering a “pain” or a form of direct and hurting damage from climate warming, with the possible evidence of having to change habits and consuming behaviors, should one want to get away from it, let’s stress two more factors to consider.

Challenges in Addressing Pain Points

Economic Stability vs. Environmental Change

The first point for all educational and communication actions, as it is a primary concern for NEUROCLIMA, is that while we are concerned by change, the economic system continues to remain stable and prosperous, with its mainstream propensity to encourage people to consume and contribute with this behavior in the growth competition and marketplace solidity. This means basically that while at some critical points, groups of individuals or communities may suffer from climate change, directly or indirectly (the « pain » feeling), the idea that they would have to change their behavior to mitigate or stop this damaging effect enters in competition with the pain of having to give up the need fulfilment, but also, especially in the OECD countries, some of the pleasure and even the addiction possibly associated with consumption, including fancy holidays, smartphone or car automatic renewable, etc. Two types of pains, to maintain our vocabulary simple at this stage, are in

balance and it takes a substantial overweight in favour of the environmental one for any didactic communication to get through²⁹.

Social Disparities in Pain Point Distribution

The second aspect worth taking into consideration is the social divide. «Pain», whatever is the reality which may be associated with it as a consequence of climate warming, is not evenly distributed, socially speaking. The UNDP and even IPCC reports stress the importance of how environmental evolution impact the most vulnerable people, the poor (people with less means and a lower education have more difficulties), seniors, for obvious reasons, but also women in their special phases of pregnancy or menopause, and children combining several vulnerable factors, too. Territorially speaking, similarly, it is also well known that the regions suffering most of climate warming are not necessarily those being the highest energy consumers and greenhouse gas emission producers. Let's take just one example: every year in the world, the equivalent of Manhattan is built and for that, there is a constant need of sand. Aerolithic sand, from the desert, is not good for construction. It is therefore the sand of coasts of Southern countries, which serve as mining spots, which is exploited, producing erosion and of course all sorts of illegal associated traffic and almost needless to say, generating severe damages at the level of local biodiversity.

Implications for Environmental Education and Communication

In other words, and it should be part of any educational programme, a responsible communication approach consists in enlarging the scope of cause-to-effect relationships in which change is envisaged, especially considering that the « pain » may not be, in many cases, perceived or even understood as being part of the problems.

²⁹ A good example of the difficulty that individuals have to confront their addictive pain in order to possibly diminish the environmental impact is given nowadays by the obesity issue. Over one billion persons in the world can be considered obese, but the approach which prevails in OECD countries and also in China (a huge market), is to take pills or even anti-obesity medicine injections, as a means to maintain behaviors « as usual », rather than striving for change in terms of nutritional and life-style habits.

5.3 The NEUROCLIMA Approach: Nervous System Metaphor

Integrating Issues, Learning, and Communities through a Neural Network Model

Addressing Root Causes vs. Effects in Behavioral Change

WITH THE SAME MINDSET, there are problems which are effects of some causes and to be considered of different nature than the causes themselves. However, to impact causal processes by one's own behavioral change is much more difficult than changing the level of effect. For instance, we can try to consume less energy at some moments of the day, buy more energy-efficient equipment, optimise our travelling style towards a lesser carbon footprint; but to change the way publicity is made to make us buy and constantly change clothes, electronic devices or cars, either to make them more lasting upfront (by forcing manufacturing processes to go in that direction, or to regulate the programmed obsolescence of big brands to entice us to make the changes that is useful to their business) is of course another story. In the types of **tipping points**, **leverage** and **pain points** we are using for alerting and discussing towards behavioral changes, we should be paying attention to focus not exclusively on mitigation efforts but also on root issues and the policy-making lobbying activity and organisational pressures that can raise causal stakes being as important to tackle and communicate upon.

The Role of Circular Economy in Connecting Issues

Circular economy is typically something connecting the two types of issues, diminishing the causes, and mitigating some aspects of higher proximity to each one to start with, as a direct effect but also as a learning pathway to share and translate in a participative endeavor.

NEUROCLIMA's Neural Network: From Metaphor to Effective Action

NEUROCLIMA is based upon the idea of creating a sort of network of communication and participative action, i.e., a neural network in its own terms, to increase behavioral change effectiveness. The various point that has been dealt with in the previous paragraph, not only on social tipping points and leverage points but also on pains, dilemmas, paradoxes, Commons, visible and less visible phenomena, mitigation or root problems' tackling, locally and globally, are part of the challenge to make this neural network effective and not just metaphoric.

Behavioral change should target both individual and collective levels. At the individual level, it involves changes in everyday life and lifestyle choices, with the awareness to turn these changes into new reference habits. Beyond this narrow, additive perspective, behavioral change should also aim for more effective and collective forms of change at the community level, and potentially trigger climate-relevant institutional effects. The ultimate goal is to trigger real and effective climate adaptation dynamics through these complementary individual and collective forms of change.

6 Building NEUROCLIMA's Knowledge Framework

6.1 Strategies for Fostering Behavioral Change: Communication, Education, and Engagement

Effective dissemination of climate change clues and explanation is essential for fostering public awareness and promoting behavioral change. To achieve this, it is crucial to explore the role of scientific communication, understand psychological perspectives on climate change adaptation, and recognize the role of educational approaches and narratives in enhancing climate awareness and encouraging action. These elements work together to bridge the gap between complex scientific data and public understanding, ultimately promoting more effective engagement with climate-related issues. (Loy & Spence, 2020). The following sections will detail these functional needs.

Visualizing Climate Data: The "Climate Stripes" Example

The success and impact of scientific communication within the frame of climate change adaptation, particularly in conveying climate change effects and climate predictions, depends on the ability to make complex data accessible and understandable to the general public. One widely recognized tool for visualizing climate change is the "climate stripes" visualization created by Ed Hawkins³⁰ (2018).

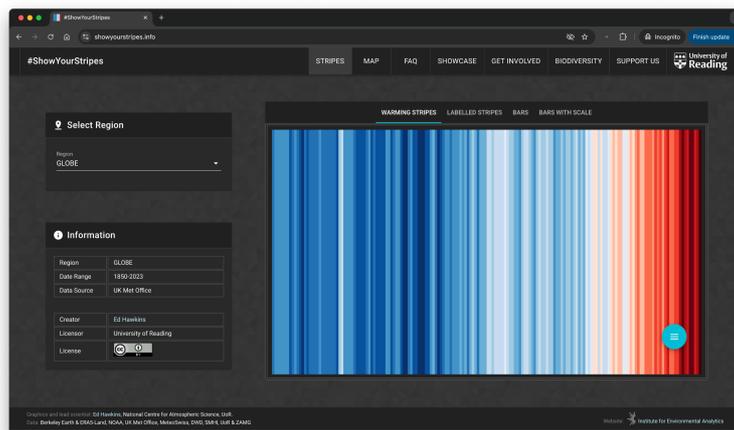


Figure 10: The Warming Stripes and the Climate Book

This simple graphic illustrates the rise in global temperatures over time, helping to convey the urgency of climate change in a clear, visually accessible format. Visual tools like the climate stripes enhance public engagement by making abstract climate data more relatable and easier to understand, bridging the gap between scientific complexity and everyday awareness. The visual has become iconic, even featured on the cover of Greta Thunberg's book (2022), symbolizing how data can be effectively communicated to the public in a way that is easy to interpret.

Challenges in Accuracy and Public Trust

However, the challenge lies not only in making this data legible and understandable but also in ensuring accuracy. For instance, old research from 1994 on climate change news coverage in New Zealand revealed that over 80% of news stories were rated as no worse than slightly inaccurate (Bell, 1994; Boykoff, 2008). (Boykoff, 2008) explored how media representation practices shaped international science communication: media coverage of climate science is influenced by various journalistic, political, cultural, and economic norms, which in turn shape public discourse at the

³⁰ <https://showyourstripes.info>

intersection of science and policymaking. Moreover, research indicates that clear communication of these uncertainties can significantly enhance public trust and engagement. For instance, (Howe et al., 2019) found that *acknowledging uncertainties in climate predictions can increase public trust in scientists*, thereby improving the acceptance of climate messages.

The Role of Machine Learning in Climate Communication

Machine Learning can further enhance this process by refining data linkages, checking consistencies and improving predictive capabilities, allowing for more precise and transparent communication over uncertainties. As highlighted (Huntingford et al., 2019), *integrating ML in climate science not only helps in reducing uncertainties but also makes complex climate data more actionable for the public*. Accuracy, in turn, involves several types of contribution: good data to start with, good data stewardship to handle and transfer data to the final users verifying quality and solving possible issues at that level, and finally the deontological attitude of the journalists making use of these data, capable of also verifying and even double checking is necessary at the end of the value chain. Machine learning needs those requirements to be matched, to avoid being trapped into the “*trash in - trash out*” risk.

6.2 Psychological Perspectives

Key Factors Influencing Individual Adaptation Behavior

Psychological factors play a pivotal role in how individuals perceive and respond to climate risks. Understanding these psychological dimensions is critical for designing communication strategies that effectively promote climate adaptation. According to studies, *the strongest predictors of individual adaptation behavior are outcome expectancy, self-efficacy, and emotional reactions to climate change*. The study suggests that enhancing individuals' beliefs in the effectiveness of adaptive actions and their ability to carry them out can significantly improve engagement in adaptation behaviors (Bechtoldt et al., 2021).

The Concept of Psychological Distance in Climate Change Perception

Moreover, the concept of psychological distance—how distant people perceive the impacts of climate change to be from themselves—also affects their engagement with climate adaptation. Gubler and colleagues found that reducing the perceived psychological distance of climate change increased concern and motivation to act, particularly among adolescents (Gubler et al., 2019). This highlights the importance of framing climate change as a local and immediate issue to foster a stronger sense of urgency and responsibility.

6.3 Educational Approaches and Narratives

Multidisciplinary and Place-Based Education Strategies

Educational approaches incorporating multidisciplinary perspectives grounded in well-designed narratives are essential for enhancing public understanding of climate change and fostering behavioral change. An effective multidisciplinary approach to climate change education (CCE) should encompass environmental and social issues, disaster risk reduction, sustainable consumption, and the creation of resilient educational environments (Anderson, 2012). It should also integrate humanities and arts with the sciences (Bist & Mayberry, 2022).

Connecting Climate Change to Students' Everyday Experiences

Sustained, active learning activities focusing on personally relevant and meaningful information can improve climate change literacy. This includes using integrated, cross-discipline curricula and if needed, a variety of expression channels. To make the 'distant, global, and nebulous threat of climate change personally relevant,' place-based education that connects climate change to local and observable impacts has proven effective (Monroe et al., 2019).

For instance, Anderson found that *a place-based climate change education program significantly increased high school students' understanding and behavioral intentions*. Focusing on local impacts and behaviors that individuals can address, like in a drought-prone area where students learn about water conservation, enhances the understanding of climate change and promotes water-saving behaviors at home and in the community (Anderson, 2012). (Hallar et al., 2011) also reported success from a three-day school program in Colorado, where students engaged in educational activities by interacting with scientists at a nearby laboratory to study weather and climate effects on a local mountain and collect data thereupon.

A study found that *students who view climate change as relevant to their lives are more willing to act*, especially when they perceive mitigation strategies as relevant to their everyday behavior (Anderson, 2012). Teacher education is also crucial in improving student education on climate change. Teachers view behavioral change in students as a significant outcome of climate change education, aligning with the emphasis on connecting individual behaviors to environmental impacts (Richter-Beuschel & Bögeholz, 2020). According to Anderson schools and educational centers themselves play a role in climate education by adopting sustainable practices (i.e., aiming at carbon neutrality, energy efficiency, and reducing their own ecological footprints). Educational initiatives that integrate sustainability into schools, including sustainable building design and site management, have been shown to enhance students' understanding and engagement with environmental issues (it works!).

The Role of Schools and Teachers in Climate Education

Hence, *educational approaches that connect climate change to students' everyday experiences, places and spaces make the subject more relatable and actionable*. A study found that students who view climate change as relevant to their lives are more willing to act, particularly when they perceive mitigation strategies as relevant to their everyday behavior. Teacher education is crucial to improving student education on climate change. Teachers view behavioral change in students as a significant outcome of climate change education, which aligns with the emphasis on connecting individual behaviors to environmental impact.

According to Anderson, schools and educational centres themselves play a role in climate education by adopting sustainable practices (i.e., aiming at carbon neutrality, energy efficiency and reducing their own ecological footprints). Educational initiatives that integrate sustainability into schools, including

sustainable building design and site management, have been shown to enhance students' understanding and engagement with environmental issues.

Narrative Techniques and Visual Imagery in Climate Education

Narrative techniques and visual imagery have proven effective in helping students grasp complex scientific subjects, such as climate change (Anderson, 2012). These tools not only make the intricate dynamics of global climate more accessible and engaging but also play a crucial role in shaping students' attitudes and their readiness to adopt new behaviors. This underscores and expands the broader challenge in scientific communication introducing this section: how best to convey complex information in a way that is both understandable, reliable and motivating³¹.

³¹ A deeper analysis of the literature will be provided in Deliverable 3.1 (M18).



6.4 AI In the picture: A Decisive Knowledge Sharing and Building Step

“A new marriage between the Green of our habitats natural, synthetic and artificial, from the biosphere to the infosphere, from urban environments to economic, social, and political circumstances—and the Blue of our digital technologies, from mobile phones to social platforms, from the Internet of Things to Big Data, from AI to future quantum computing”.

The role of Artificial Intelligence in combating climate change is increasingly significant. Projects utilizing AI to address the **UN Sustainable Development Goals** have already demonstrated impact in various domains, such as weather forecasting, disaster anticipation, and phenomena prediction. In fact, AI is already more used in a variety of environment-relevant domains, e.g. to monitor energy consumption across industries and assess the sustainability of food production. A recent review demonstrates how AI technology could be leveraged to promote sustainability over the food supply chain, from precision farming to the analysis of consumers’ experiences (Ta et al., 2024). NEUROCLIMA could become an interesting observatory of impactful cases of the kind, in many domains, in its own terms.

In policymaking, AI tools can help predict the viability and outcomes of large-scale policies, helping to shape them more effectively. For instance, by predicting carbon dioxide emissions focusing on energy consumption and economic growth in 20 countries leveraging Artificial Neural Networks (Mardani et al., 2020). Major institutions and large-scale initiatives illustrate the growing influence of AI in climate action, such as ELLIS³², ESA - Digital Twin³³, and numerous HE-funded projects and NGOs.

The NEUROCLIMA project aims to *bridge the gap in deliberative democracy*, making the effects of large-scale policies more comprehensible and democratic, while also offering educational toolkits. As we shall see, in this perspective too, AI can play an effective role and NEUROCLIMA aims at being an explorative platform for that.

However, the deployment of AI in this field is not without risks, including that, among others, training and supervising AI models can introduce *unintended biases* into the technology systems as well as *malicious disinforming or polluting intrants*. This challenge is compounded by the fact that when dealing with multi-regional platforms (such as the NEUROCLIMA project) data and confirmation biases can vary, but also that we live in a dangerous world concerning disinformation and cybersecurity³⁴.

The potential erosion of human autonomy also leads to questions about how AI can balance large-scale coordinated actions with individual behavior changes, while privacy concerns arise from the combination of nonsensitive and personal data, which could reveal political behaviors. This raises the question of how current trends of digital development, AI included, are building a surveillance society. Moreover, the carbon footprint generated by AI, contributed to 1.4% of global greenhouse gas emissions in 2015, though AI systems, when implemented in production environments or on edge devices, may offset energy usage and emissions (Cowls et al., 2023; Malmodin & Lundén, 2018).

In spite of these risks, we have to learn how to make the best use of this emerging potential and in this sense. NEUROCLIMA will both deploy solutions as well as pay attention to biases and risks. It is in particular clear that in the fight against fake news, in the detection of inappropriate speech and forms of expression, in the whole educational arena, generative AIs become the center of a debate, but not

³² <https://ellis.eu/news/combating-the-climate-crisis-with-ai>

³³ <https://climate.esa.int/en/news-events/esa-digital-twin-earth/>

³⁴ AI is of course also used by offenders to reach their goal, including in studying how a platform is using AI to defend itself. It seems today to have become an endless game. In this sense, the EU effort such as the AI ACT are pioneering what needs to prevail in terms of digital governance

to the point of stopping its wide adoption and co-development (*LLM learn with us!*) and they will most likely accompany us during the whole project and even beyond.

Careful consideration is warranted regarding the energy consumption associated with AI model training, which is rapidly increasing. While maintaining a constructive outlook, it is important to stay aligned with ongoing research in this area, as the landscape is shifting quickly and not necessarily for the better.

Environmental impact of AI development

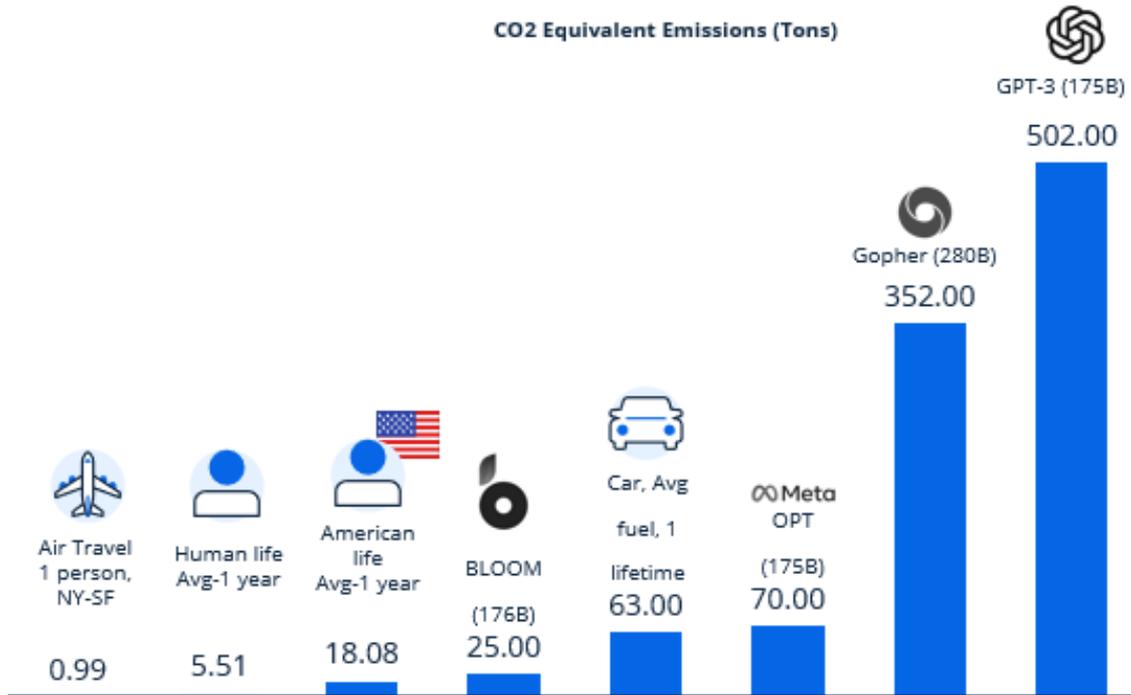


Figure 11: Environmental costs of Generative AI (<https://www.statista.com/site/insights-compass-ai-generative-ai>)

Although technology increasingly consumes more energy due to intensive computational processing, AI systems can offset part of their own energy use and greenhouse gas emissions when implemented in production environments or edge devices. The European Commission's Horizon 2020 programme has also invested in AI projects aimed at improving energy and resource efficiency in multiple sectors³⁵ (FUDIPO³⁶, MATRYCS³⁷, ODYSSEE-MURE³⁸, SOCIO³⁹). However, the critical challenge remains balancing AI's energy consumption against its potential for energy efficiency gains, urging the AI industry, particularly at the EU level, to develop greener data infrastructures and open-source assessments of AI technologies.

The idea that AI can offset its own energy use as a justification, is an ongoing and unresolved debate. This is especially relevant given AI's rapid expansion, similar to the energy-intensive trends in other digital sectors like streaming and blockchain. It is important to note that this concern is actively being studied through current research and modeling.

³⁵ <https://cordis.europa.eu/article/id/415798-using-ai-to-improve-energy-and-resource-efficiency-in-various-industries>

³⁶ <https://cordis.europa.eu/project/id/723523/result>

³⁷ <https://matrycs.eu/>

³⁸ <https://www.odyssee-mure.eu/>

³⁹ <https://socio-bee.eu/>

6.5 Empowering: the participatory challenge

Evolution of Participation Theory: The Arnstein and Rocha Ladders

For several decades now, most practitioners and scholars working in participatory activities have been referring to the Arnstein ladder. Sherry Arnstein proposed it in 1969, with 8 levels, combining the intensity of participation, the degree of involvement of participants in public affairs, separating on the two extremes:

- **Participatory democracy** (8 - Citizen Control with authentic and effective participant mobilisation)
- **Participatory demagoguery** (1 – Manipulation, Alibi operation).

Others have tried to enhance her ladder adding more degrees, to refine it with more participatory nuances, while others have displaced the focus toward empowerment (the Rocha ladder).

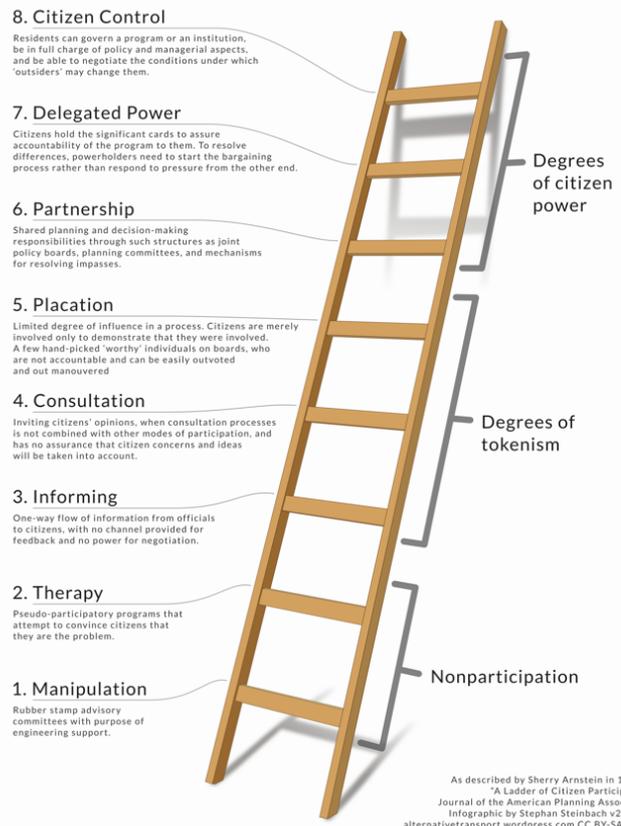
The Arnstein ladder was a tool for monitoring the evolution of the process of involvement and appropriation of a project by the inhabitants, an evaluation tool, for understanding requests and responses and the significant levels of participation involved, as well as a tool for dialogue around the notion of participation; but in all cases, it was meant to be a tool to measure the degree and the quality of citizen participation.

Not too different, but less general with her own ladder proposal, Rocha’s primary audience was professional “public planners” such as local-government officials, but her model was based on cross-disciplinary research and could be directly applied to issues in education-organizing projects and engagement of diverse forms, ranging from individual empowerment to collective... to political empowerment, with, in the middle, mediated empowerment.

Origins and Dynamics of Participatory Processes

These two ladder attempts raise another issue: how did it start in the first place? Are we dealing with processes originated by grassroots players trying to create their own space and change project, who at some point of success have to negotiate with other groups and possibly, too, with authorities and their specialised representatives to get attention, and maybe bring about a real change capacity? Or are we confronted with a city, regional or national plan to change things from the top, that at some point of time has to be discussed and possibly endorsed by citizens? Or something in between? In the multiplicity of contexts and issues in which citizens, inhabitants, users, consumers, etc., may consider that something needs to change, in particular regarding environmental issues, the way the process starts either as a rather spontaneous dynamic but sooner or later forcing public authorities to do something about it, or as a movement initiated and supported by some authorities. In the duration, tends to define how citizens can be actors in the full sense, or not, of these initiatives. Things may change along the way, but the history of the participation process may leave imprints in the mindset,

Arnstein's "Ladder of Citizen Participation"



collaborating habits or flexibility or on the contrary rigidity of the objectives, and of course, too, on the motivation to stay in the change process beyond the hurdles to be coped with. This means that the way social tipping points are envisaged, but also the type of social tipping points that may have triggered initiatives, public attention and participation of one kind or another also have to do with how much citizens and inhabitants have to struggle to make their voice listened and be concretely involved in change, not only behavioral, but behavioral AND policy-resonant; how the social dimension of the environmental issue came into the picture may matter; how environmentally-resonant a broad social issue generating a tipping point may become a leverage point for changes of climate-sensitive nature has to do with the history of each process, to a certain extent.

Challenges of Digitally Enhanced Participation

In addition, the most important point is to stress that digitally enhanced participative and deliberative dynamics do not escape, as if the digital framing, including with AI, were a kind of magic, the large variety of processes and evolutions involved in this type of interactive configuration. In other words, supporting and facilitating participation thanks to digital means and AI supported guidance does not mean that traditional social experience of what we call participation is all of a sudden solved and communication hurdles irrelevant. Conflictive viewpoints and divergences of interests, communication difficulties, gaps between expert and lay knowledge, the need from expert to defend their professional expertise and identity, vs. common interest, etc., the way to advance into complex and multidimensional issues, all these typical items of the participatory and collective decision-making agendas will also be on the table, and eventually to be coped with.

The Persistent Need for Human Mediation in Digital Participation

This means that beside the technology specialists, to make sure that the ecosystem functions, there is, as always before, the need to have mediators or participation specialists. We have explained enough how environmental issues were complex and often misinformed to make clear that technology alone will not make these social asperities disappear, On the contrary, technology may magnify the role of these more traditional experts, allowing them to manage leverage point dynamics at a scale and at distances unknown so far, with the help of efficient learning-oriented tools.

Digital Divide: A Consideration for Inclusive Participation

Finally, a last point deserves to be evoked: digitally-facilitated communication may be an enhanced and scalable way to foster the conditions of change in the climate sensitive issues, bringing about a number of advantages worth experimenting; but let's not forget that just entering in this type of environment may leave on the side categories of digitally illiterate people (it is not just a question of inclusive UI, although it of course plays a role) and any innovative attempts in this direction should take a time to evaluate how this digital divide could evolve in the years to come.

How can tech-aided participation help overcome some known participatory limits

The technology components of NEUROCLIMA are presented in D2.2. They comprise an impressive arsenal of tools and resources to engage in the targeted processes (pilots, use cases). NEUROCLIMA system will be capable to:

- analyse and enhance communication, a **knowledge composition application**⁴⁰ will support all participants in their needs and navigation options
- provide a **chatbot** to facilitate user-platform interactions,

⁴⁰ A Knowledge Composition Application refers to a framework or system designed to combine and utilize different pieces of knowledge from various sources or modules. This concept is particularly relevant in fields like Natural Language Processing (NLP) and machine learning, where models need to integrate knowledge from multiple domains to perform tasks effectively.

- build an **on-line deliberation tool** will accompany and support participants with possibility of helping with high-level ethical and democratic requirements (structuring discussions, checking on equitable time and access, detecting abuses and biases, providing real time and deferred time analytics and also, multilingual support⁴¹)
- provide an **eLearning tool**, allowing access from anywhere and self-paced, as a minimum engaging in interactive content of learning kind, with performance follow up and feed-back and collaborative features.
- design and provide educational games or rather said **Playful interactive storytelling learning modules**
- provide an **Automatic data composing and dialogue generation**
- build its strength on a **Knowledge-Graph semantic** enrichment provision,
- NEUROCLIMA AI analytical sub-system (in the background).

The main point here is to make sure this supportive power remains accessible, learnable by a large number of (types of) users, thanks to its intuitive UI, the data management and verification options, the content creation and collaborative options and even, hopefully, with participatory design implications, and of course with a direct access without download, so as to define a user-friendly platform in the first place.

⁴¹ A well-known example of that type of tool is the Stanford Online deliberation platform (<https://deliberation.stanford.edu/tools-and-resources/online-deliberation-platform>).

7 Requirement for Pilots, User Cases and Scenarios

Although a full deliverable (D2.3) is dedicated to the description of the Pilots, this document, based on the R&I landscape analysis provides a brief definition of the Pilots and User Requirements to help inform the final requirements and overall system's architecture. The text and comments below will inform the final D2.3 which will be the final Implementation guideline on the Pilot Studies.

7.1 Pilots and use cases: a full-fledged grid of action channels

The starting point for the pilots goes as follows (D2.3 excerpts):

The NEUROCLIMA project will deploy two pilots to evaluate the impact of its proposed innovations and their applicability across various domains. These pilots will utilize the project's monitoring infrastructure, frameworks, and engagement mechanisms to test and demonstrate the effectiveness of the EU Adaptation Strategy and the Mission on Adaptation to Climate Change. Although each pilot has different objectives and users, they share the ultimate goal of increasing citizen literacy in climate change phenomena, policies, and adaptation strategies. Each pilot will explore two key areas:

- the *application of services* and approaches by researchers and citizens, and
- the *promotion of climate adaptation* through participatory design, creative arts, and democratic engagement.

The pilots will feature two representative use cases each and will involve diverse stakeholders through workshops and activities across multiple sites. The pilot study will be organised in different phases, in order to promote and encourage an iterative process of deployment, assessment and validation.

The verification methods include training sessions, engagement with policymakers, researchers, students, and educators, and the creation of datasets on learning analytics related to democratic participation. Our goal is for at least 70% of participants to gain new climate literacy skills.

7.1.1 Pilot 1: Testing the efficiency of AI Monitoring Tool

Pilot 1 will test the efficiency of the AI monitoring tool in finding social tipping and leverage points for climate change adaptation. The pilot will work with two types of users: (i) journalists and content creators, and (ii) policy and decision-makers (...). With this Pilot, the AI monitoring tool will be revised and finalized, according to user feedback. As suggested in the following diagram:

It will be deployed in five "NEUROCLIMA" countries and run during eight months.

The first step includes finding valid and trustworthy online sources on climate change and respective policies and adaptation strategies and organising this data in different categories (discourses/speeches, policies, actions, initiatives, scientific data, news, EU policies, etc.) that will form the foundation of the project AI monitoring tool. To that end, the consortium has prepared a joint document on "Data Resources" with these categories. This resource is crucial for the technical partners in developing the tools required for the project.

To identify social tipping points, leverage points, or pain points related to environmental challenges, the project should conduct an inventory of relevant processes and analyze the semantics across a few reference languages. This will help teach the AI system to detect and accumulate the necessary learning experience to identify these key patterns.

Pilot 1 is about capitalising upon social tipping points and leverage points for behavioural change towards climate change adaptation” and will comprise two use cases:

Information approaches and tools on identifying social tipping and leverage points

The implementation of NEUROCLIMA’s proposed AI monitoring tools will be tested by journalists and content creators to identify societal expectations, needs, pain points, and social tipping and leverage points about climate change. The pilot will proceed with participatory learning groups and workshops.

The inventory used to teach the AI will pay specific attention to the variety of tipping points or leverage points, including local/global, sectoral, sudden/slow, those linked to participatory impact or policy implementation, and those supported by technological innovation or cultural behavior awareness.

Measuring the impact of AI monitoring tools for policies/decision makers towards identifying and activating social tipping and leverage points for climate change adaptation

A meta-assessment should take place to follow up the way target processes (social tipping points and leverage points) are detected, what are the markers involved, what the AI recommends, what activation takes place thereupon validating the effectiveness of the NEUROCLIMA approach.

The implementation of NEUROCLIMA’s proposed AI monitoring tools will be tested by policymakers and decision-makers via workshops to assess the usefulness of the tools in getting acquainted with climate change and climate change mitigation and adaptation strategies. The use case will investigate the usefulness of the tools throughout the policymaking cycle and at local, regional, and national levels.

Policy-making cycles, including the effect of the policies, their assessment or measurement, takes time and may in several cases lead us beyond the timeline of the NEUROCLIMA project, hence the need to pay attention to an early signal semantics waving potential effect that might occur in a longer lapse of time. The long waves of change are not necessarily the least interesting, especially when they touch a systemic inertia and open breaches into these established references.

Comments concerning the requirements

Two main strands are to be considered:

- The description of the pilot and the use case level is precise and efficient. Consent, transparency of the acquisition process including feed-back or possible verification provisions from users (who in this case are professionals accustomed to make this kind of verification), actually used or not but explicitly available, are part of the ethical code typical of this type of information collecting process.
- The accuracy (and related trustworthiness) of the data collected is a key principle, mentioned at large in section 3 of this deliverable. The collecting and formatting capacity of the system allows for capturing structured as well as non-structured information, but a particular checking step or mechanism should take place on the quality and value of the captured information, with either some probe or criteria for entrance. It is planned (D2.3, section 6.1) but it is nevertheless important to stress. *Accuracy is not the only criteria to value in this process, the communicational usage of the data, the innovative pedagogical and educational channels that NEUROCLIMA will deploy, is as important to construct trustworthiness.*

7.1.2 Pilot 2: Climate Literacy and Informing citizens

Pilot 2 is about “Cultivating climate literacy and informing citizens about the impact of initiatives for the green transition through blended learning experiences and creative expression for the implementation of climate change adaptation” and will also comprise two use cases.

It will focus on the impact of different tools for participation, information, engagement and education of citizens and students for the implementation of behavioural and systemic change in the scope of climate change adaptation.

From one side, information and education tools will be assessed, while, on the other hand, toolkits for creative expression around the climate imperative proposed by the project (platform) will be presented, applied and assessed through participatory activities. The objective is to evaluate and foster the level of engagement of the stakeholders in the engagement process thanks to the playful and creative experiments proposed, with tools of both human face-to-face and digital nature.

Assessing the potential or actual effects of these educational tools, including any early signs of change processes they generate, may gain relevance if they are linked to social tipping points and leverage points.

It will be conducted in five “NEUROCLIMA” countries and last eight months. The two-use case will bear on the following themes:

Implementing behavioural and systemic change through blended learning tools, participatory design and interactive storytelling

This use case examines the impact of innovative engagement and learning approaches, such as gamification, game-based learning, interactive storytelling, and hybrid and blended learning, by integrating digital tools into climate literacy education.

These tools have the potential to activate social tipping points and leverage behavioural change towards climate change adaptation. By offering playful experiences and tailored hybrid learning tools, the project seeks to achieve two main objectives: (i) inform educators and students about how adaptation efforts affect their lives, and (ii) educate them on the broader impacts of the green transition, climate change, and other key sustainability themes. The partners recognize the need to test these educational tools developed in earlier project phases to evaluate their effectiveness with the target groups.

It would be interesting if NEUROCLIMA analysts used a comparative methodology to determine whether the storytelling and playful/artful approach is more effective than other methods in raising awareness and promoting evident behavior change. Alternatively, the analysis could examine why this approach may not be the most effective or identify the markers that suggest which channel of climate literacy interaction is most appropriate.

Participatory design and creative expression as the driving force for the implementation of climate change adaptation

This use case will explore how various forms of citizen expression, such as creative writing, cinematography, and performing arts, influence citizen engagement, participation, and investment in decision-making and the enforcement of new measures within the green transition framework. By utilizing citizen expression as a versatile communication tool across different media, the use case includes the implementation of diverse workshops in each country.

These activities will encourage citizens and students to reflect on the challenges and opportunities presented by current and new initiatives in the green transition, as well as their societal impacts.

Comments concerning the requirements

Two main factors are here at stake:

- As the first use case is about promoting and disseminating with concrete stakeholders’ key explanations and models of why climate change is an issue needed to be taken care of and how this can lead to effective change patterns, forms of qualitative and quantitative measurement of

effects of these framing-explaining tasks will have on the stakeholders. KPIs are planned for each use case in terms of numbers of persons involved. However, more criteria may be needed to appraise to what extent the use case and the application of all the tools and resources will really impact these stakeholders. As explained in section 3.5 of Deliverable 2.3: to monitor progress, feedback will be collected (or rather said: gathering “in-depth, qualitative insights from key stakeholders”), and to evaluate the outcomes of the pilots, AI tools and learning analytics will be instrumental. But even with AI, some sort of clues, criteria or progression evidence towards behavioral change will have to be identified and valued, clustered different ways depending maybe upon the type of stakeholders (as the pilot envisages to collect information on user needs, preferences, and challenges).and type of impacts; in other words, AI may do wonder but should be supported by human oversight concerning the essentials of what NEUROCLIMA can do in terms of behavioral change.

Human oversight is crucial not only for ethical and moral reasons, but also to ensure the robustness and explainability of how the AI system operates. This allows human actors to continue intervening in the teaching and learning process.

- In the second use case, some more refined evaluation criteria concerning stakeholders’ awareness and progression towards behavioral change should include differentiation options valuing the different types of tools or forms of support channels used (playful and artful supports but also collaborative discussions and co-design activities) meant to stimulate the stakeholders, with distinction or clustering options of the data to be evaluated concerning the type of stakeholders or the country.

7.2 Comments concerning the requirements for both pilots

There is a lot of detailed specifications on the pilots and use cases in Deliverable 2.3, which should suffice to conduct these decisive experiments to the safe side. However, some concerns may be useful to recall.

An extra requirement concerns also both pilots, the UI facilitating characteristics of all digital tools involved should be designed and tuned and with feed-back and trials improved upon, so as to avoid having only geeks in the cohorts and on the contrary be able to demonstrate that NEUROCLIMA stands for a universal access.

Engaging only a fraction of highly digitally literate and young citizens would be counter to the project's objectives. Therefore, it is crucial to integrate a diverse perspective on participatory dynamics, as outlined in this deliverable. This should move away from viewing AI as a magical solution, and instead leverage AI to support diverse forms of engagement and participation across a wide range of citizens and citizen groups. Importantly, this approach should maintain alignment with the project's methodology, including relevant connections to social tipping points and leverage points.

Another way to formulate this requirement would be to establish specific criteria to define expectations for climate literacy, a generic yet effective concept that needs to be clearly defined to avoid remaining vague and unassessable. All this is already well planned (see for that section 6.2 and with even more details in section 6.3 of the Deliverable 2.3, but it was of utmost importance to recall.

This document is crucial to define and clarify key concepts and requirements for the NEUROCLIMA project. The specific cases to be developed will likely emerge later and cannot anticipate the concrete details of the pilots. It is a complex, iterative process. However, we hope that the project will identify and leverage tipping points and leverage points through concrete territorial dynamics, involving both behavior change and policy changes, to drive social awareness and community action in areas like water management, waste, energy, food, and transportation. The guiding value is in the conceptual

framework and the sequencing of addressing issues, building awareness, and promoting behavioral change.

Finally, whenever needed, but often, 1) training sessions should be offered for all user groups to ensure they can effectively use the tools and systems; explain how the system uses to produce its search results / recommendations and as a permanent service, 2) the Pilots should provide ongoing technical support and resources, such as user manuals, FAQs, help desks, and/or Chatbot, to assist users as needed.



8 Conclusion

Requirements for the solution, work in progress

The Deliverable 2.2 is still “work in progress” and “*the chicken or the egg*” issue which we have already evoked is an open question. The Deliverable 2.2 is a task for specialists and no other types of experts should put themselves in their shoes. The description we have of the architecture (section 5) and some of the systems (e.g. in section 6.1.1.2 and 6.1.1.4, the Knowledge composition application, as well as in the section 6.1.5, the “Playful interactive storytelling learning modules”, both already presented in this deliverable), including of the validation and priority evaluation methods, are of that nature. They seem, from a non-expert perspective, to comprise all the needs and details necessary to move on in the project and the only requirements, just to be recalled, concern the ethical issues and the inclusiveness problem (a good UI is necessary but may not suffice, training sessions and before that general presentations of goals and methods are necessary). An internal workshop can help work on this issue: how to ensure that all contributing parties converge and reach a satisfactory yet complementary concept, involving the technological specifications but also some of the interdisciplinary provisions.

Beyond this preliminary remark, most of what we can say regarding the technological specifications can be found in this deliverable in section 3.6.2, meaning that they are intended not to evaluate or advocate what such requirements should be in general, but regarding specific NEUROCLIMA objectives. Participation, collaboration, deliberation activities enhanced by digital tools and AI in particular, regarding tipping or leverage points, are of the kind, hence their treatment in that section.

No serious nor complete conclusion can be proposed as this document will go through several rounds of improvement and smoothing, compatibilizing with the other WP deliverables with which it shares a few overlaps, designed that way upfront and complied with by everyone. However, it seems important to stress that the methodology consisting not in delivering a final message once and for all, but a framing and supportive knowledge base from which to design and build the solution, with a series of key requirements coming from this general appraisal, and then back from the development and testing of the solutions to the epistemic foundations and associated references, by definition likely to evolve with the external environment, and not as if NEUROCLIMA was an closed and sufficient world in itself, seems a fruitful concept to preserve over time.

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10 ANNEX 1: GLOSSARY

Term	Definition
Tipping Points	Critical thresholds in the climate system, that when crossed, small changes can lead to large, accelerating and often irreversible changes.
Leverage Points	Key areas in a system (climate, economy) where small changes can create large, lasting improvements.
Climate Change Adaptation	Adjustments in systems to reduce harm or take advantage of opportunities from climate change.
Climate Change Mitigation	Actions taken to reduce or prevent the emission of greenhouse gases to limit future global warming.
Climate Neutrality	Achieving net-zero greenhouse gas emissions by balancing emissions produced with those absorbed by nature.
Circular Economy	A system that minimizes waste by reusing materials, aiming to restore and regenerate natural resources.
EU Green Deal	A set of policies aimed at making the EU climate-neutral by 2050, covering climate, energy, transport, and more.
Resource Efficiency	Using resources in a way that maximizes value while minimizing environmental impacts.
SCP (Sustainable Consumption and Production)	Practices that ensure resources are used and produced in a way that supports long-term environmental sustainability.
UN Agenda for Sustainable Development	A global plan adopted by all UN countries to end poverty and achieve sustainable development by 2030.
SDGs (Sustainable Development Goals)	Seventeen global goals aimed at balancing social, economic, and environmental sustainability, adopted in 2016.
Agenda for Change	An EU policy to promote a green economy by focusing on sustainable development in international cooperation.
Farm to Fork Strategy	EU strategy to make the food system sustainable, reducing environmental impact while promoting healthy diets.
Europe 2020 Strategy	EU's plan for smart, sustainable, and inclusive growth, aiming for high employment and social cohesion.
GPGC (Global Public Goods and Challenges Programme)	An EU program supporting sustainable development globally by promoting good governance and stability.
MIP (Multi-Annual Indicative Programme)	EU cooperation programs that set priorities for international collaboration at different levels.