PATHWAYS2RESILIENCE

D6.5 – Catalogue of Innovative and Transformative Adaptation Options and Approaches

WP6 – Task 6.2

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Summary

This deliverable, D6.5, part of Work Package 6 (WP6) under Task 6.2, focuses on collecting and cataloguing existing innovative and transformative adaptation options and approaches, designed to address disaster risk reduction, adaptation, and vulnerabilities within Key Community Systems (KCSs). The primary objective of this deliverable is to create a comprehensive catalogue of practical examples of such options and approaches. By focusing on transformative adaptation and innovation, this deliverable aims to inspire regions to implement forward-thinking solutions that enhance resilience against climate change impacts.

The resulting catalogue is the first of its kind and intends to support regional stakeholders in the formulation of regional climate resilience pathways. It offers a structured compilation of transformative adaptation options tailored to the European context, and serves as a central resource for the P2R regions and communities in identifying innovative ways to address diverse climate-related challenges.

To develop this catalogue, we employed a rigorous and iterative methodology, integrating literature reviews, expert consultations, and multi-criteria analyses. The selection criteria focused on three key aspects: effectiveness, innovation, and transformative power. Adopting a flexible multi-tiered selection process, 30 adaptation options were identified from 64 different resources related to adaptation and resilience building. Each of these options was evaluated at various stages using evidence from literature and structured expert judgement. This approach ensured the selection of adaptation options that are not only effective but also innovative and capable of driving systemic change.

This catalogue presents a diverse suite of 30 adaptation options categorized into five key areas: Physical and Technological Measures, Nature-based Solutions, Governance and Institutional Measures, Economic Instruments, and Knowledge and Behavioral Change. These options are applicable at various scales, from local to regional, and address a wide spectrum of climate hazards, including floods, droughts, and extreme heat with different breadth and depth. This illustrates the catalogue's adaptability and applicability to different regional contexts.

This deliverable is strategically linked to the Regional Resilience Journey (RRJ), offering insights and approaches that align with the RRJ's objectives. By providing concrete examples, a systemic approach for building climate resilience, and a methodological framework for identifying innovative and transformative adaptation options, this deliverable supports the three main outputs of the RRJ: adaptation pathways, innovation agendas, and adaptation investment plan.

Overall, this deliverable and its catalogue, serve as important resources for regions embarking on their journey toward climate resilience, encouraging the adoption of innovative adaptation action that can lead to profound systemic change.

Keywords

Transformative Adaptation; Innovation; Adaptation Packages; Catalogue; Synergies

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Abbreviations and acronyms

Acronym	Description
AIC	Adaptation Investment Cycle
KCS	Key Community System
KTM	Key Type Measures
MRD	Multiple Resilience Dividends
RRJ	Regional Resilience Journey
WP	Work Package

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Introduction

Europe faces a confluence of urgent challenges driven by climate change (European Environment Agency, 2024). Rising temperatures, increase in frequency and severity of extreme weather events, and shifting climatic patterns are threatening the sustainability of urban and rural environments (IPCC, 2022). Traditional approaches and options for climate adaptation and disaster risk reduction are no longer sufficient to address the multifaceted impacts of climate change on our regions and cities, currently and in the future (Kates et al., 2012). Therefore, regions in Europe need to think beyond conventional solutions and generate innovative and transformative ways to ensure resilient development.

This deliverable aims to provide an exemplary collection of various innovative and transformative adaptation options specifically tailored to the European context. The systemic approach described later in this deliverable as well as the accompanying catalogue of adaptation options both emphasize the relevance of moving towards more transformational adaptation. Together they highlight the importance of thinking systemically and implementing forward-thinking solutions to build resilient and adaptive urban, rural and regional landscapes.

Within the Regional Resilience Journey (RRJ), this deliverable and its catalogue serve as a supporting resource for those regions seeking inspiration on strategies that are effective, innovative, and transformative. For that, the deliverable introduces an approach to frame adaptation planning and long-term resilience building from a systemic, strategic, and integrated perspective. Also, the catalogue developed within this deliverable is designed to inspire a vast array of regional stakeholders with real-life examples of innovative and transformative adaptation measures and strategies. By showcasing successful cases in other regions, the purpose of this catalogue is to demonstrate the potential of innovative solutions in overcoming climate-related challenges and interrelated issues (e.g., food and water insecurity).

This catalogue differs from existing ones by focusing on transformative and innovative adaptation options tailored to the European context. It is not intended to be an exhaustive compilation of all possible adaptation strategies but rather an inspirational source to spark new ideas and approaches based on existing practices. Recognizing that innovation and transformation are context-specific, it acknowledges that some options may not be as novel or transformative in certain regions as in others. Accordingly, this first version of the catalogue will be updated with the experiences and feedback from the P2R regions, and its goal is to provide a starting point for thinking creatively about adaptation, rather than a definitive guide.

This deliverable begins by introducing the need for innovation and transformation in adaptation (Section 1), followed by the methodology used in selecting the adaptation options featured in the catalogue (Section 2). It continues describing how the deliverable contributes to the RRJ (Section 3), highlighting links with the formulation of adaptation pathways (D6.2), innovation agendas (D6.4), and adaptation investment plans (D5.3). An overview of the selected options is presented (Section 4) together with a stand-alone catalogue of innovative and transformative adaptation options (Annex 1), describing 30 different measures. As there is no single measure capable of fully addressing climate risks and triggering profound transformations, we present a conceptual approach to building resilience systemically, consisting of crafting adaptation packages, synergistic and cross-sectoral action, and experimentation and learning (Section 5). The deliverable concludes with a call to action encouraging P2R regions to generate and implement innovative and transformative adaptation strategies, important for an updated version of the Catalogue (Section 6).

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1 The Need for Innovation and Transformation in Adaptation

Conventional approaches to adaptation often fail to achieve the necessary transformative changes needed to adequately respond to profound environmental shifts that climate change is bringing and will bring in the future (Colloff et al., 2021; Folke et al., 2010; Kates et al., 2012; Nightingale et al., 2022; Park et al., 2012; Saxena et al., 2018; Vermeulen et al., 2018). The limitations of these approaches primarily revolve around how these support incremental change rather than more substantial transformation, which inherently brings challenges in addressing the complexities and uncertainties of climate change (Kates et al., 2012; Park et al., 2012; Saxena et al., 2018; Vermeulen et al., 2018). This can lead to improvements that are too marginal to effectively address the scale of climate change impacts. Such approaches often aim at minor adjustments or technical fixes within existing systems rather than overhauling the systems themselves (Kates et al., 2012; Roggema et al., 2012). Moreover, the current implementation of adaptation measures often lacks a flexible management approach capable of adjusting the course of action based on intervention's performance or changes in external changes (Colloff et al., 2021; Meerow et al., 2016; Nightingale et al., 2022; Pelling et al., 2015; Vermeulen et al., 2018). This results in rigid adaptation strategies that are not responsive to new information or changing conditions (Folke et al., 2010; Pelling et al., 2015), or in the worst cases in exacerbating risk conditions (i.e., maladaptation) (Antwi-Agyei et al., 2018; Granberg and Glover, 2014; Piggott-McKellar et al., 2020; Schipper, 2020).

Additionally, conventional adaptation tends to ignore the power relations and dynamics of those involved (decision-makers and affected groups) and the complexity of real-world adaptation scenarios, where different stakeholders have varying interests, positions, values, and levels of influence (Boon et al., 2021; Colloff et al., 2021; Nightingale et al., 2022; Park et al., 2012; Patterson and Huitema, 2019; Rodima-Taylor et al., 2012; Saxena et al., 2018; Vermeulen et al., 2018). In turn, this can lead to the perpetuation of existing inequalities and the failure to address the root causes of vulnerability (Colloff et al., 2021; Meerow et al., 2016; Pelling et al., 2015). Also, conventional adaptation approaches are mainly top-down and science-dominated (Colloff et al., 2021; Saxena et al., 2018), with limited participation and lacking meaningful involvement of local communities and stakeholders (Zuccaro et al., 2020). Thus, these approaches may fail to build the necessary trust, local agency, and commitment for successful adaptation implementation (Boon et al., 2021; Colloff et al., 2021; Nightingale et al., 2022; Park et al., 2012; Rodima-Taylor et al., 2012; Zuccaro et al., 2020). This is particularly problematic in scenarios requiring transformative adaptation, which necessitates significant participation to exert sufficient power to effect systemic change (Colloff et al., 2021).

These limitations make conventional adaptation approaches insufficient to tackle today's climate challenges in the depth, scale, and speed required (IPCC, 2022; UNEP, 2022). While in some regions conventional adaptation measures can contribute significantly in terms of resilience, the current climate crisis involves unprecedented levels of complexity and uncertainty, which incremental adaptation measures are not equipped to fully handle (Kates et al., 2012; Roggema et al., 2012). These measures typically rely on past experiences and predictable changes, whereas today's climate challenges are characterized by unpredictable, non-linear interactions within social-ecological systems (Pelling et al., 2015; Roggema et al., 2012). Lacking the flexibility and foresight to adapt to these unpredictable changes, there is an urgent need for new ways capable of triggering the necessary changes that build long-term resilience effectively, sustainably, and systemically.

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Box 1. Understanding of Innovation and Transformation in this Deliverable

Innovation for climate adaptation refers to the development and application of new ideas, practices, technologies, and approaches that address climate risks in novel or improved ways **(Patterson and Huitema, 2019)**. It involves leveraging scientific advancements, technologies, and creative problem-solving to enhance the effectiveness of adaptation measures. ***Innovative adaptation*** often involves integrating diverse types of knowledge (Boon et al., 2021; Colloff et al., 2021; Faivre et al., 2017; Folke et al., 2010; Nightingale et al., 2022; Patterson and Huitema, 2019; Rodima-Taylor et al., 2012; Zuccaro et al., 2020)—scientific, traditional, and experiential—to generate new insights and practical solutions that are contextually relevant. Examples include the use of big data and artificial intelligence for better early warning systems or the implementation of climate-smart agricultural practices that improve adaptive capacity.

Transformation in the climate change adaptation context—refers to fundamental changes in the structures and functions of systems (social, ecological, economic, technical, and governance) to enhance their resilience to climate change (Colloff et al., 2021; Folke et al., 2010; Park et al., 2012; Pelling et al., 2015; Roggema et al., 2012)**.** This implies that transformation is both a process (undertaken through ***transformative** adaptation*) and an outcome (also called ***transformational** adaptation*), dynamically reframing underlying values, rules, and knowledge that shape decision-making contexts (Colloff et al., 2021; Gillard et al., 2016; Park et al., 2012; Vermeulen et al., 2018) that lead to profound changes in the system (Gillard et al., 2016; Roggema et al., 2012). Transformative adaptation actions address the root causes of vulnerability (Boon et al., 2021), such as social inequities and environmental degradation, leading to more equitable and sustainable outcomes (Colloff et al., 2021; Gillard et al., 2016; Pelling et al., 2015; Saxena et al., 2018)**.** In practice, transformational adaptation can involve shifts in land use, economic systems, and community planning, such as transitioning from traditional agricultural practices to diversified production systems, or redefining urban planning to prioritize green infrastructure and well-being.

Inducing transformation is a daunting task for the adaptation community, where fostering innovative approaches can aid in achiving this goal . Innovation can enable regions and communities to better prepare for and respond to climate impacts (Faivre et al., 2017; Folke et al., 2010; Park et al., 2012; Patterson and Huitema, 2019; Rodima-Taylor et al., 2012; Zuccaro et al., 2020), for example, through new technologies that improve common practices such as early warning systems, climate-resilient infrastructure, and climate-smart agriculture. New developments like big data, artificial intelligence, and advanced analytics can improve the prediction and understanding of climate trends (Zuccaro et al., 2020). This information can facilitate informed decision-making and guide timely interventions to manage risks more effectively.

Furthermore, innovation can provide solutions that go beyond the application of technology. Innovative approaches emphasize the co-production of knowledge, integrating scientific, traditional, and experiential knowledge (Boon et al., 2021; Colloff et al., 2021; Faivre et al., 2017; Folke et al., 2010; Nightingale et al., 2022; Patterson and Huitema, 2019; Rodima-Taylor et al., 2012; Zuccaro et al., 2020). This involves generating new insights and practical solutions that are not only scientifically sound, but also contextually relevant. Accordingly, innovation can also be seen as bringing together groups or sectors that usually don't interact or work together, for example, through Climate Adaptation Partnerships that bring together government, business, research and civil society to facilitate climate adaptation; or when solutions are used in a new way that harness their capacity to generate positive impacts, such as utilising public procurement power to induce climate adaptation considerations; or turning climate challenges into new opportunities, similarly as many companies are reinventing their business models to gain competitive advantage under an uncertain climate future.

In addition, combining approaches for building resilience in a more comprehensive and sustainable manner can be considered another form of innovation. For instance, integrating

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incremental and transformative changes allows for addressing the most urgent adaptation needs while setting the stage for systemic adaptation in the long run (Colloff et al., 2021; Meerow et al., 2016; Park et al., 2012; Vermeulen et al., 2018). This integration creates more holistic and context-specific adaptation strategies that are more likely to succeed in diverse settings.

By fostering a culture of learning, innovation can open new avenues within the adaptation community (Boon et al., 2021; Folke et al., 2010; Park et al., 2012). For example, innovation can create new economic opportunities that encourage investments in resilience-building activities and reduce vulnerability to climate impacts by developing markets for products or services, such as payment for ecosystem services, parametric insurance, or climate-resilient crops (Faivre et al., 2017; Pelling et al., 2015; Vermeulen et al., 2018). Innovation, thus, can introduce the transformational lens needed in current adaptation efforts.

In the context of this deliverable, innovation for adaptation involves developing and applying new ideas, practices, and approaches to address climate risks (Patterson and Huitema, 2019). It emphasises the ability to find novel solutions to local challenges emerging from the changing climate—solutions that can manifest in various forms. Examples are the application of new technologies and tools (e.g., ai for early warning systems, building information modelling for resilient infrastructure, or advanced sensor in climate-smart agriculture) (Faivre et al., 2017; Zuccaro et al., 2020), governance structures and arrangements (e.g., power decentralisation, multi-stakeholder partnerships, community empowerment) (Bauer and Steurer, 2014; Bellinson and Chu, 2019; Patterson and Huitema, 2019), economic and financial models (e.g., new marketable products and services, business models for payment for ecosystem services, climate finance mechanisms) (Colloff et al., 2021; Faivre et al., 2017; Fleming et al., 2015), and people's behaviour and decisions (e.g., consumption choices, land management decisions) (Bauer and Steurer, 2014; Fedele et al., 2020; Patterson and Huitema, 2019).

Transformational adaptation rethinks and restructures the fundamental aspects of socio-ecological systems by addressing the underlying causes of vulnerability and risk (Nightingale et al., 2022; Park et al., 2012; Pelling et al., 2015; Roggema et al., 2012; Saxena et al., 2018; Vermeulen et al., 2018). This often involves challenging and changing entrenched norms, values, and power dynamics that contribute to systemic issues (Boon et al., 2021; Nightingale et al., 2022; Park et al., 2012; Pelling, 2011; Pelling et al., 2015). By identifying those points where adaptation measures can leverage and catalyse profound changes in the system, the focus of adaptation action shifts from incremental to transformational. For example, by targeting power imbalances (Colloff et al., 2021), redistributing adaptation benefits equitably (Nightingale et al., 2022; Saxena et al., 2018; Vermeulen et al., 2018), and facilitating collective action and collaboration among multiple stakeholders (including governments, NGOs, local communities, and the private sector) (Boon et al., 2021; Folke et al., 2010; Nightingale et al., 2022; Rodima-Taylor et al., 2012; Zuccaro et al., 2020), adaptation strategies are more likely to drive systemic change while reducing risks more effectively. Within the complexities and uncertainties of climate change, adaptation actions hence need to address these leverage points so they can enhance resilience across multiple sectors and scales (Kates et al., 2012; Meerow et al., 2016; Nightingale et al., 2022; Zuccaro et al., 2020).

Like climate adaptation, transformation is a moving target. This implies that transformation is both a process and an outcome. This dual nature highlights the dynamic nature of transformational approaches and the importance of sustaining transformative efforts over time. As a process, transformation is seen as an ongoing, iterative cycle of engagement, learning, and

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reframing underlying values, rules, and knowledge that shape decision-making contexts (Colloff et al., 2021; Gillard et al., 2016; Park et al., 2012; Vermeulen et al., 2018). On the other hand, as an outcome, transformation implies fundamental changes in the system's structure and functioning, reconfiguring new development trajectories (Gillard et al., 2016; Roggema et al., 2012) and enabling communities and ecosystems to sustainably thrive under new conditions in the long term. Thus, transformation can be understood as a dual concept where the transformative process and transformational outcomes are deeply interconnected. The iterative process of engaging stakeholders, co-producing knowledge, and re-framing decision contexts leads to fundamental changes that constitute transformational outcomes. These outcomes, in turn, feed back into the process as new information along with associated emerging challenges in the system's state, triggering therefore a new series of transformational actions (Park et al., 2012). This element is crucial for understanding how systemic change and resilience building are achieved.

In this deliverable, transformational adaptation refers to approaches that seek to fundamentally change the structures and functions of social-ecological systems to enhance system's resilience to climate change (Colloff et al., 2021; Folke et al., 2010; Park et al., 2012; Pelling et al., 2015; Roggema et al., 2012). Hence, transformational adaptation options aim for deep, systemic changes that limit current or future risks (Meerow et al., 2016) by addressing the root causes of vulnerability (Boon et al., 2021) and building new capacities for better anticipate, respond to, and recover from the climate change effects (Meerow et al., 2016) . This includes adaptation responses targeting changes in norms, values, rules, and practices towards more equitable and sustainable outcomes (Colloff et al., 2021; Gillard et al., 2016; Pelling et al., 2015; Saxena et al., 2018). Acknowledging the inherent uncertainty and complexity of climate change and the interconnectedness of social-ecological systems, transformational adaptation promotes continuous learning and adjustment to new information and circumstances (Bellinson and Chu, 2019; Colloff et al., 2021), interventions at multiple temporal and spatial scales (Folke et al., 2010; Meerow et al., 2016; Park et al., 2012), as well as sustainable practices that redefine the relationship between human and natural systems (Pelling et al., 2015). Central to transformational adaptation are processes that reflect diverse views, interests, and knowledge systems in adaptation strategies (Colloff et al., 2021); re-evaluate and change the underlying values, rules, and mindsets in the adaptation decision-making (Colloff et al., 2021; Pelling et al., 2015); address power imbalances and challenges existing power structures that drive inequality (Colloff et al., 2021; Nightingale et al., 2022); and empower marginalised communities with capacity and agency to take an active role in adaptation planning and implementation (Colloff et al., 2021; Gillard et al., 2016).

As it will be showcased in this deliverable, transformational adaptation manifests differently across various social-ecological systems depending on local conditions, needs, and capacities. For instance, in the French Alps, transformation may involves broadening the tourism packages from winter sports to other activities, as well as a shift from traditional pastoralism to diversified agricultural production consisting of novel crops, horticulture, and traditional farming revival to face changes such as shorter snow seasons, glacial melting, and variability in the precipitation patterns (Colloff et al., 2021). Differently, in the city of Lisbon in Portugal, transformation may encompass a set of actions for urban regeneration such as expanding green areas, establishing natural corridors and urban agriculture to address flooding, heat islands, and air pollution while prioritising human well-being (Faivre et al., 2017). Therefore, for adaptation options to be transformational, they must be tailored to the local context, enabling communities and regions to effectively address their specific environmental and socio-economic challenges raised by climate change.

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2 Methodology for selecting adaptation options

To develop the catalogue, we opted for an agile and iterative approach, consisting of multiple selection stages guided by the overarching question: *What are the most **promising** innovative, transformative adaptation **options** and strategies for improving climate resilience in different **Key Community Systems (KCS)**[1] **in Europe**?* We integrated various methods, applied differently throughout the selection process, including literature review, multi-criteria analysis, expert structured judgement, survey, and focus group discussion. Figure 1 summarises the methodological approach for developing the Catalogue, which is further described in this section.

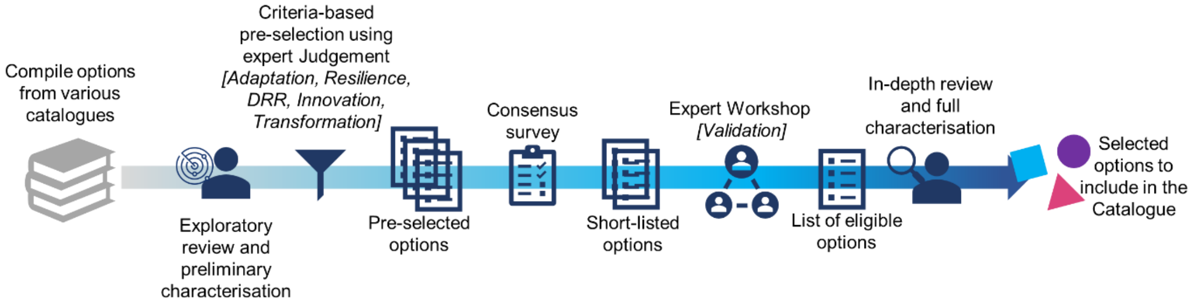

Figure 1. Methodological approach for developing the catalogue.

- **Compiling Material**

To leverage the diverse knowledge and experience of the multi- and interdisciplinary partners involved in the consortium, we compiled various resources related to adaptation measures (*see Annex 2)* through an open call for contributions to consortium members—a total of 64 resources. The compiled material included existing catalogues, case studies, and ongoing European adaptation projects, as well as links to relevant platforms, online databases, knowledge hubs, and organizations working on adaptation. This compilation was facilitated through an online collaborative tool, Padlet, which served as a repository of resources. The catalogues focused on different types of interventions and adaptation approaches at various spatial scales and governance levels, designed to address climate-related challenges in different KCS across multiple geographies (Figure 2).

[1] The European Union Mission of Adaptation to Climate Change defines six KCS, namely: (i) Nature-based Solutions and Ecosystems, (ii) Water Management, (iii) Land Use and Food, (iv) Critical Infrastructure, (v) Health and Well-being, and (vi) Local Economy.

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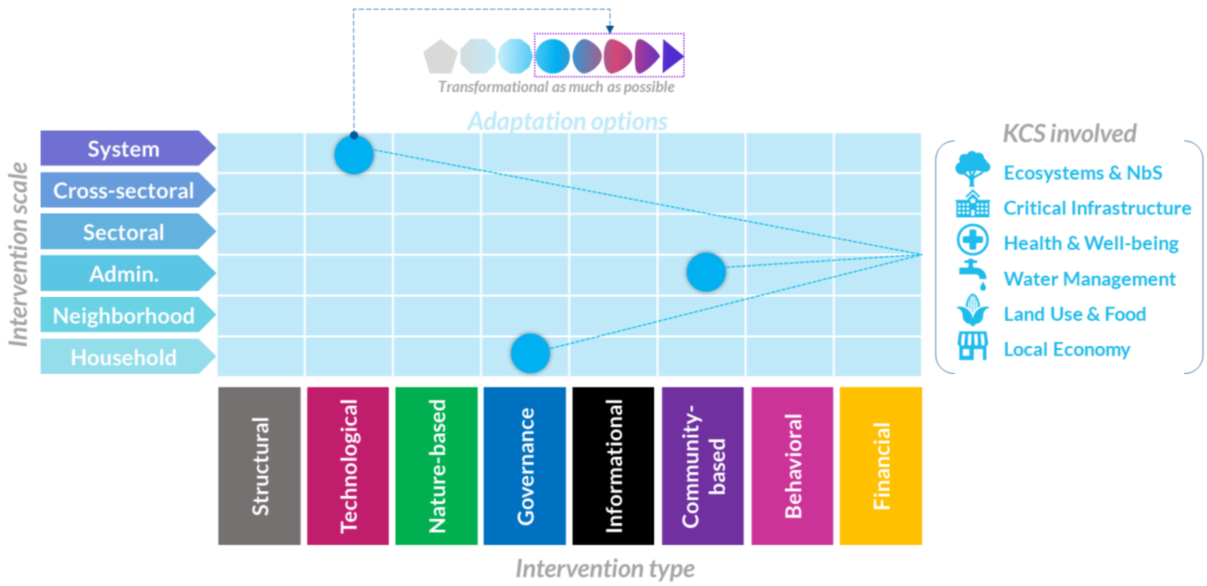

Figure 2. Conceptual model of the content of the Catalogue.

- **Setting Selection Criteria**

Before reviewing the compiled material, we defined criteria to identify effective, innovative, and transformative adaptation options in the context of P2R and Europe. Since no existing catalogue or methodology with an explicit focus on identifying innovative and transformative adaptation options was found, we developed a fit-to-purpose criteria set. Table 1 describes the selection criteria, including associated sub-criteria. Additionally, we adopted a three-tier selection approach, where compliance with the criteria (and its associated sub-criteria) at the first tier allowed progression to the next selection level, and so forth (Figure 3). This facilitated a pragmatic and rapid filtering process, reducing the number of options significantly while simplifying the review and characterisation of the options.

Table 1. Description of the selection criteria and sub-criteria

Criteria	Sub-criteria
C1. EFFECTIVENESS: **Refers to the ability of measures to achieve intended objectives or outcomes successfully, addressing the identified needs or problems timely and adequately**	• **C1.1. Relevance**: applicability or suitability of the actual measure implementation and use in a given context, considering the existing needs, problems, or demands of the target area/users. It takes into account how well the measure addresses real-world challenges and meets the expectations of its target users, including ability to minimize potential hazards, uncertainties, or vulnerabilities. • **C1.2. Sustainability**: refers to the capacity of a measure to operate without causing significant harm to the economy, environment or society, while maintaining its performance over the long term. • **C1.3. Applicability**: feasibility of adopting or implementing a measure in a given context, considering factors such as resources, local capabilities, norms, culture, institutional arrangements and governance (regulations, policies, etc.). It looks at how much a measure adequately fits in the contextual conditions and dynamics.

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Criteria	Sub-criteria
C2. INNOVATION: Encompasses existing practices, techniques, measures or products that approach or address challenges in new or improved ways, leading to better outcomes, more efficient solutions, or positive changes while meeting the evolving needs and demands of the targeted entity (individuals, regions, systems).	• C2.1. Novelty: originality, differentiation, and uniqueness of the measure in relation to existing ones in the field. It refers to the features, attributes, functions, application or benefits of the measures provide. It could even be an application in a new sector or under another approach. • C2.2. Adaptability: capacity of a measure to adjust, evolve, modify or respond to changing circumstances, needs, demands, new information, or emerging challenges, while still functioning. • C2.3. Scalability: capacity of a measure to be expanded or extended to a larger scale; how well a measure can grow and meet broader needs or address issues on a larger scale.
C3. TRANSFORMATIVE POWER: The extent to which a measure brings significant and lasting changes or reconfigures existing systems, processes, or practices within a given context.	• C3.1. Synergism: the ability of a measure to trigger or amplify changes via spill-over and cascading positive effects across the system. • C3.2. Low-regrettable: the degree to which a measure minimizes risks of counterproductive irreversible changes that lead to pathway dependencies, critical trade-offs, lock-ins, and positive feedback loops. • C3.3. Replicability: refers to how easily a measure can be duplicated, transferred or applied in different contexts or settings, meaning that the measure's performance can be reproduced in a similar fashion in other areas, providing similar results in terms of benefits.

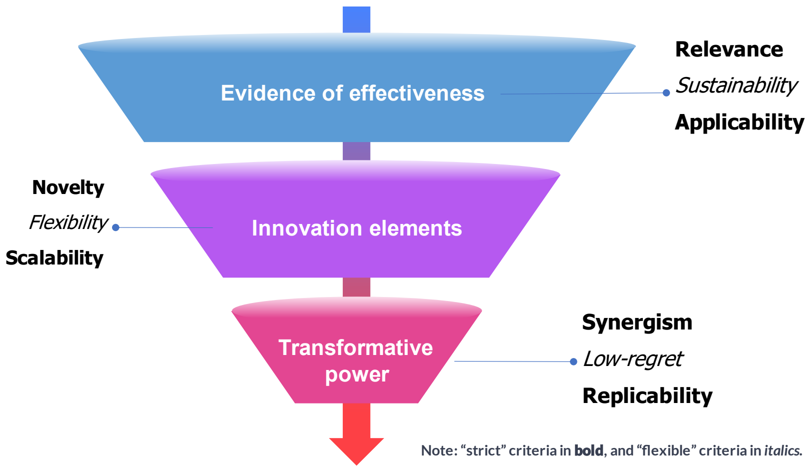

Figure 3. Three-tier approach used for selecting adaptation options

- **Exploratory Review**

An initial rapid review of the collected material was conducted by all partners involved in the task, analysing and categorizing the information against the defined criteria. From the collected material, experts pre-selected adaptation options that appeared effective, innovative, and transformative in the P2R context. We sourced 213 adaptation options from the 64 resources collaboratively compiled (Figure 4). Each pre-selected option was briefly described and characterized based on various aspects, including type of intervention (e.g., nature-based solution, structural, institutional), intervention scale (e.g., household, sectoral, cross-sectoral,

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administrative), size of intervention (e.g., small, medium, large), and KCS involved (e.g., Food Systems, Water Management Systems, Ecosystems). Based on the expert judgment of the partners involved and the evidence reported in the collected material, the compliance with each sub-criteria was qualitatively evaluated using YES, NO, NOT SURE and NO INFO. This was recorded in an Excel matrix. Adaptation options lacking sufficient evidence of effectiveness, innovation, or transformative aspects (i.e., more than six sub-criterions filled with NO INFO or NO) were discarded, as well as those that were purely conceptual options or have never been implemented.

- **Filtering Process**

The first filtering step was based on the characterization of the pre-selected adaptation options. Given the limited information on each sub-criterion, only a few adaptation options were fully characterized, with most having gaps represented by "NOT SURE" or "NO INFO." To address this, we implemented an “elastic” filtering approach, which included two “strict” and one “flexible” criterion per selection tier (i.e., effectiveness, innovation, and transformation) (Figure 3). This means that an adaptation option had to meet the strict criteria (YES) and could have varied responses for the flexible criteria (YES, NO INFO, or NOT SURE). Equally, adaptation options with NO in any of the criterion were filtered out. This approach, along with the tiered criteria one, ensured that only options meeting the effectiveness criteria progressed to subsequent levels (innovation and transformation, respectively). The number of adaptation options was then reduced to 104. This was immediately followed by an additional screening consisting of excluding those that were not completely related to adaptation (n=26), as well as merging those ones with very similar description (n=15). For example, urban green plans applied in different cities, or land use regulations that allows for more stormwater-sensitive surfaces in urban developments. We identified 3 categories of options with similarities (one category containing 7 similar options, other category containing 6 similar options, and another category merging 2 options), and produced a new, combined description out of them. That means that 213 options were reduced to 66 options (Figure 4).

- **Consensus and Validation**

To reach consensus and further filter the list of pre-selected adaptation options, the seven experts that participated in the exploratory review inspected, compared, and voted for the adaptation options with more innovative and transformative features. This was done through an online survey, where the seven reviewers voted for the two most innovative and transformative options in each intervention type category, based on their expert judgment and considering the context and scope of the P2R project. Hence, the 66 options were reduced to 37 (Figure 4).

These 37 short-listed adaptation options were then reviewed and validated by experts from the consortium who had not participated in the previous stages, ensuring objectivity and additional input from an external perspective. The validation involved a two-hour online workshop with five experts from various backgrounds, including one senior researcher on adaptation and disaster risk reduction, two consultants (one in adaptation finance and another in sustainability), and two practitioners (one from the humanitarian sector, and one from the innovation sector). During the workshop, experts provided input on the innovativeness and transformative potential of the short-listed options, as well as their relevance for regions participating in the P2R project. Based on their input, the list was further refined to maintain options with the highest relevance, innovativeness, and transformative potential (n=28), as well as including additional options which had not been identified so far (n=5). The list of 37 options was reduced to 33, including the five additional ones (Figure 4).

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- **In-depth Review**

The 33 adaptation options that remained eligible after the expert workshop underwent an in-depth review. This was a more dedicated examination of the adaptation options in the aspects considered during the exploratory review, and included additional elements such as the climate hazard addressed, expected outcomes, key enabling conditions, synergies with other sectors, additional benefits, limitations and constraints, potential trade-offs, management setup, required investment, and time needed to reach peak performance. In addition, each option was used as an entry point to identify similar successful cases to learn from. For this, a template was used to profile each adaptation option in all these aspects. Also, this more detailed review of the adaptation options served to fill in the information gaps and corroborate the compliance of each of the selection criteria.

During this in-depth review, two options (n=2) were removed: one due to being a discontinued technological approach and the other for having a major impact on climate mitigation rather than adaptation (Figure 4). Additionally, two options related to climate heat-stress planning and response were merged due to their similarity.

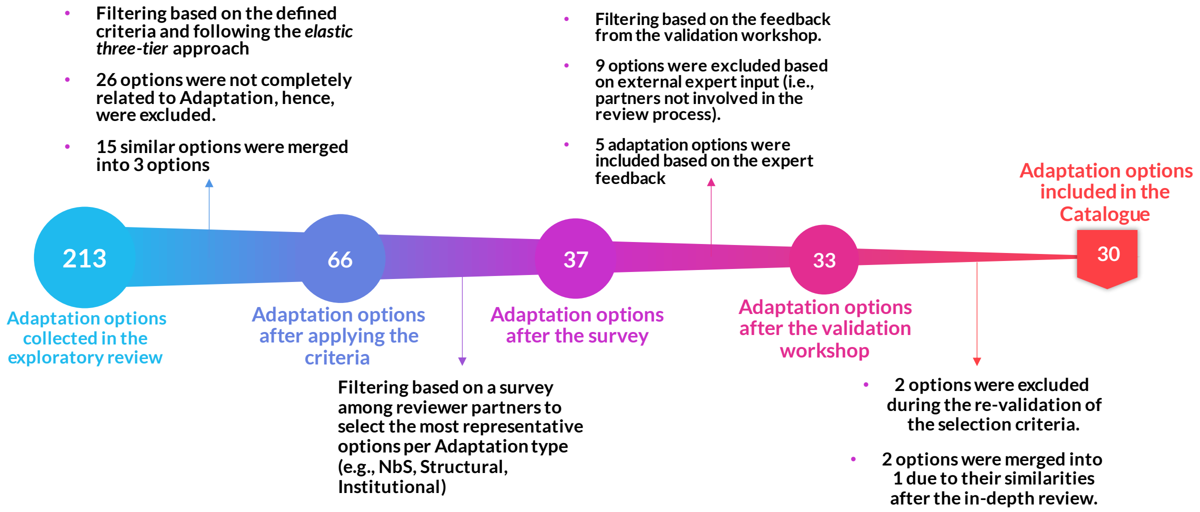

Figure 4. Selection process of the adaptation options described in the Catalogue

The final list of adaptation options (n=30) aims to be an inspirational source for the P2R regions, showcasing illustrative cases and successful examples of interventions of different natures and scales, addressing a wide range of climate hazards, and involving various KCS.

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3 A Suite of Innovative Adaptation Options for Transformation

The catalogue accompanying this deliverable (see Annex 1) presents 30 adaptation options that exemplify various forms of innovative and transformative adaptation. These options are selected to portray approaches and solutions relevant to the diverse climate-related challenges faced by European regions and cities. While this catalogue does not aim to provide an exhaustive list of adaptation strategies, it offers a compilation of relevant examples aligned with the purpose and scope of the P2R project. This group of innovative and transformative adaptation options serves as a source of inspiration for regions participating in the project, showcasing how they might tackle their unique climate challenges.

The 30 adaptation options described in this catalogue encompass different type of interventions acting at a range of scales (Table 2), covering the six KCS (Table 3) and addressing a wide spectrum of climate-related hazards (Table 4). To ensure consistency with the adaptation policy process across the EU, we have categorized the options using the framework proposed by the European Environmental Agency (Leitner et al., 2021)—Key Type Measures (KTM). This categorization, also adopted by Climate-Adapt, includes five types of adaptation options:

- Physical and Technological Measures;
- Nature-based Solutions and Ecosystem-based Approaches;
- Governance and Institutional Measures;
- Economic Instruments and Financial Solutions; and
- Knowledge and Behavioural Change.

This version of the Catalogue has an inclination for certain types of interventions. Physical and Technological Measures (n=9) are the most prevalent, followed closely by Nature-based Solutions and Ecosystem-based Approaches (n=8) and Governance and Institutional Measures (n=8), comprising 83% of the total options. These predominant types reflect the nature of the literature reviewed, which was also mostly oriented towards these KTMs given the expertise of the consortium members contributing and participating in the development of this deliverable.

Regarding the intervention scale, 17 of the 30 options are applicable on a large scale, with 10 suitable for regional application and 7 for city-level interventions, and 6 applicable for smaller scale (i.e., Building (n=2), Neighbourhood (n=3), and District (n=1)). Additionally, 7 options are designed to operate at multiple scales, demonstrating versatility and adaptability across different contexts.

As described in Deliverable 6.1, innovative and transformative adaptation measures often have spillover effects and cascading impacts across various systems. This means that adaptation measures deliver benefits (as well as adverse effects) between sectors (see Section 5.2), as do 30 of the adaptation options described in this catalogue. Overall, this catalogue engages each KCS to varying extents (in terms of breadth and depth). For instance, options such as the Smart Adaptation Suite and Transformative Public Procurement have a broader systemic impact by involving multiple KCS, while others like Smart Irrigation Systems and Climate Parametric Insurance have a more profound impact but engaging only a couple of KCS. In both cases, either their impact is broad across the system or deep in a part of it, adaptation options in this catalogue meant to have significant transformative potential.

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Furthermore, 19 of the 30 adaptation options are designed to address multiple climate hazards, while 3 are specifically targeted at a single hazard and the other 8 are targeting a couple of them. This mix highlights the importance of both innovative, multifunctional options and the effectiveness of targeted strategies in building climate resilience. Besides that, Floods (n=22), Extreme Heat (n=20), and Drought (n=17) were the hazards most targeted by the adaptation options, which may be aligned with the current trends and priorities in adaptation strategies across Europe.

We encourage the P2R regions to use this catalogue and its 30 adaptation options as a starting point for developing their own innovative and transformative adaptation initiatives. By drawing inspiration from the examples and experiences detailed in this catalogue, regions can follow a similar approach to identify, ideate, and select adaptation options that are most suitable for their unique circumstances and challenges.

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Table 2. Type and Scale of the adaptation options selected for the Catalogue

TYPE	ADAPTATION OPTION	SCALE
Physical & Technological	Resilience Hubs	Neighbourhood
	Climate-Proofing Social Housing	Neighbourhood
	Smart Adaptation Suite	Multi-scale
	Smart Irrigation Systems	Regional
	Adaptation Platforms	Building
	Advanced multi-hazard Early Warning System	Regional
	One Health Toolkit	Regional
	Climate Risk Management Dashboard	Multi-scale
	Citizen Science for mitigating vector-borne diseases	Regional
Nature-based Solutions & Ecosystem-based Approaches	Riverbed Restoration	Multi-scale
	Natural Ventilation Grids	City
	Floodable Parks	District
	Urban Green Infrastructure	Multi-scale
	Peri-Urban Agriculture	City
	Hydrological Reconnection	Regional
	Wetlands Restoration	Regional
	Sustainable Aquaculture	Regional
Governance & Institutional	Urban Green Plans	City
	Cool Neighbourhoods Strategy	Neighbourhood
	Incentives for Rainwater Harvesting	Building
	Urban Water Plans	City
	Climate Adaptation Partnerships	Regional
	Adaptive Flood Risk Management (TE2100 project)	Regional
	Planned Relocation	Multi-scale
	City Heat Plans	City
Economic & **Financial**	Climate Parametric Insurance	Multi-scale
	Corporate Climate-Resilient Strategies	Multi-scale
	Transformative Public Procurement	City
Knowledge behavioral **Change**	Self-sustaining Reforestation	City
	Climate Change Observatory	Regional

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Table 3. KCS involved in the Adaptation Options included in the Catalogue

ADAPTATION OPTION	KCS INVOLVED: Ecosystems & NbS	Water Management	Critical Infrastructure	Land Use & Food	Health & Well-being	Local Economy
Resilience Hubs			✓		✓	
Climate-Proofing Social Housing	✓		✓			
Smart Adaptation Suite	✓	✓	✓	✓	✓	✓
Smart Irrigation Systems		✓		✓		
Adaptation Platforms		✓			✓	
Advanced multi-hazard Early Warning System			✓		✓	
One Health Toolkit	✓			✓	✓	
Climate Risk Management Dashboard	✓	✓	✓	✓	✓	✓
Citizen Science for mitigating vector-borne diseases					✓	✓
Riverbed Restoration	✓	✓	✓			
Natural Ventilation Grids	✓	✓			✓	
Floodable Parks	✓			✓	✓	
Urban Green Infrastructure	✓	✓	✓	✓	✓	
Peri-Urban Agriculture	✓			✓		
Hydrological Reconnection	✓	✓				
Wetlands Restoration	✓	✓	✓			
Sustainable Aquaculture	✓			✓		
Urban Green Plans	✓	✓			✓	
Cool Neighbourhoods Strategy			✓		✓	
Incentives for Rainwater Harvesting		✓				✓
Urban Water Plans		✓			✓	
Climate Adaptation Partnerships	✓			✓	✓	✓
Adaptive Flood Risk Management (TE2100 project)	✓	✓	✓	✓		
Planned Relocation	✓	✓	✓	✓	✓	✓
City Heat Plans			✓		✓	✓
Climate Parametric Insurance			✓	✓		✓
Corporate Climate-Resilient Strategies			✓			✓
Transformative Public Procurement	✓	✓	✓	✓	✓	✓
Self-sustaining Reforestation	✓	✓	✓	✓	✓	✓
Climate Change Observatory	✓	✓	✓	✓	✓	✓

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Table 4. Climate Hazards addressed by the Adaptation Options in the Catalogue

ADAPTATION OPTION	Floods	Drought	Extreme heat	Wildfires	Extreme Cold	Storm	Sea Level Rise	Precipitation	Landslides	Biological
	CLIMATE HAZARD									
Resilience Hubs	✓	✓	✓	✓	✓	✓			✓	
Climate-Proofing Social Housing	✓	✓	✓			✓				
Smart Adaptation Suite	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Smart Irrigation Systems		✓	✓							
Adaptation Platforms	✓	✓								
Advanced multi-hazard Early Warning System	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
One Health Toolkit										✓
Climate Risk Management Dashboard	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Citizen Science for mitigating vector-borne diseases										✓
Riverbed Restoration	✓					✓		✓	✓	
Natural Ventilation Grids		✓	✓							
Floodable Parks	✓	✓	✓							
Urban Green Infrastructure	✓	✓	✓	✓	✓		✓	✓		
Peri-Urban Agriculture	✓	✓	✓					✓		
Hydrological Reconnection	✓									
Wetlands Restoration	✓					✓	✓			
Sustainable Aquaculture			✓			✓	✓	✓		
Urban Green Plans	✓		✓			✓				
Cool Neighbourhoods Strategy			✓							
Incentives for Rainwater Harvesting		✓						✓		
Urban Water Plans	✓	✓				✓	✓	✓		
Climate Adaptation Partnerships	✓	✓	✓	✓			✓			
Adaptive Flood Risk Management (TE2100 project)	✓						✓			
Planned Relocation	✓						✓		✓	
City Heat Plans			✓							
Climate Parametric Insurance	✓		✓							
Corporate Climate-Resilient Strategies	✓	✓	✓		✓	✓	✓		✓	
Transformative Public Procurement	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Self-sustaining Reforestation	✓		✓						✓	
Climate Change Observatory	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

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4 How does this Catalogue contribute to the RRJ?

This catalogue of innovative and transformative adaptation options and approaches connects to the RRJ mainly through its third step *Define Pathways* where options for *climate adaptation and transformation to climate resilience* are identified. The catalogue can be further harnessed for the formulation of Adaptation Pathways (D6.2) and the Innovation Agenda (D6.4). Moreover, the catalogue both supports and is supported by the Adaptation Investment Plan (D5.3) which sheds light on the financial implementation of the resilience journey. The first version of this catalogue will be also available in the P2R Toolbox (D6.6) as a permanent resource for the regions.

To support regions in defining individual **Adaptation Pathways** the catalogue provides inspirational and informative material. The profiles of adaptation options that the catalogue elaborates on assist in identifying and assessing options for innovative and transformative climate adaptation that regions may not have otherwise considered. When constructing adaptation pathways, regions need to rely on well-performing, proven options which include short-, medium- and long-term strategies. Options from this catalogue may be useful in any of the time horizons and may further be applied and customised to a variety of places and situations as individual interventions or compounded solutions.

For formulating **Innovation Agendas**, the catalogue provides regions with various examples of collaboration mechanisms and management settings that coordinate and connect adaptation actions more effectively and efficiently. The catalogue presents *government-led initiatives* that demonstrate a renewed understanding of the role of the public sector in addressing societal challenges. This supports knowledge creation and innovation for climate adaptation, that can be used to inspire the region's innovation portfolio. Moreover, the catalogue also provides novel approaches for coordinating and connecting adaptation actions, such as *public-private* and *multi-stakeholder partnerships*. Likewise, the catalogue describes examples of *community*-, *private*-, and *NGO-led* adaptation that highlights the relevant role of different actors in building resilience. This can then broaden the P2R regions' perspectives and understanding of the alignment of innovation processes with climate change adaptation—or Innovation Agendas Formulation in the P2R context.

The catalogue of innovative and transformative adaptation options and approaches also resonates with the RRJ **Adaptation Investment Cycle** (AIC)[2] – an iterative, 6-step process to identify bankable projects (i.e. those that meet the conditions required by the financier to finance a project) and develop Adaptation Investment Plans. This catalogue showcases multiple examples of bankable projects from where regions can learn, e.g., how other experiences have addressed strategic financial barriers or implemented innovative approaches to financing solutions, and in the other way around, the AIC delves into (green) innovation finance and externalities associated with climate action that can inspire regions to make their initiatives bankable (AIC Step 2 *Address Strategic Financial Barriers*). Further, this catalogue provides examples of technical innovations on top of the financial innovations (i.e., novel instruments, mechanisms and frameworks to finance adaptation) described in the Catalogue of sources and instruments and adaptation finance process (D5.2) supporting the AIC (Step 4 *Compile Investment Plan).* Finally, these two deliverables (D6.5 and D5.2) symbiotically assist regions to secure (long-term) financial support of their innovative options for transformative adaptation,

[2] The AIC develops the financial aspects of a Climate Resilience Strategy from the identification of adaptation needs and barriers to finance all the way to the implementation and monitoring of efficient adaptation project.

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which usually requires more elaborate financing schemes. For that, the AIC (Step 5 *Pipeline Development*) complements this catalogue with guidance on developing adaptation finance strategies and resource mobilisation plans for regions, as well as providing good practice examples of financing approaches, instruments, and business case models that meet proven.

5 Towards a Systemic Approach to Building Resilience

Given the complex nature of climate challenges, no single adaptation measure can provide a complete solution. To fully harness the potential of adaptation options, it is essential to adopt a more systematic approach to adaptation. This section introduces an approach for systemic adaptation and building long-term resilience, offering additional inspiration for the P2R regions. By conceptually explaining how to unlock the potential of adaptation actions through systems thinking, regions can strategically plan transformative interventions.

This additional information is organized into three key themes: crafting adaptation packages, synergistic and cross-sectoral action, and experimentation and learning as enablers for transformational adaptation. These themes aim to provide a comprehensive understanding of how regions can develop integrated strategies that maximize the effectiveness of adaptation measures.

The goal is to supplement the catalogue and maximize its use, as well as any other resources that regions may employ. By thinking systemically about adaptation, regions can create more robust and resilient systems capable of withstanding future climate impacts.

5.1 Crafting Adaptation Packages

Adaptation planning needs new ways of dealing with climate risks. This implies accounting for and addressing the complex nature of climate risks as well as the dynamics and interdependencies of the socio-ecological systems where adaptation measures take place (Dörendahl and Aich, 2021; Scheraga and Grambsch, 1998; UNDRR, 2022). To do so, one strategy is to craft adaptation packages. Adaptation packages combine various adaptation measures to increase the overall impact and transformational power of single adaptation options. Unlike conventional approaches that focus on a single aspect of climate risks, "**adaptation packages**" consist of differentiated measures tailored according to the various elements and facets of a particular climate risk, acting together as an overarching, systemic intervention and aiming at building long-term resilience in ecosystems and people (Seddon et al., 2020). In this regard, adaptation packages can be designed to tackle the multiple vulnerability drivers as well as cope with climate impacts, aiming to interrupt the cascading effects and chains that lead to a specific climate risk (IPCC, 2022; UNDRR, 2022).

Adaptation packages can not only maximize the impact of single adaptation options, but also increase their transformational power (Higuera Roa et al., 2023; Royer-Tardif et al., 2021; Solecki et al., 2011). By combining multiple adaptation measures, climate risks can be addressed more holistically. This consists of grouping a set of options of diverse nature (Higuera Roa et al., 2023), both incremental and transformational (Kates et al., 2012; Pelling et al., 2015), that work at different scales (Adger et al., 2005; Juhola and Westerhoff, 2011), governance levels (Leck and Simon, 2013), and timeframes (Colloff et al., 2021; Roggema et al., 2012) in a consistent and coherent manner. If they are grouped in a complementary, reinforcing, and synergistic way, adaptation packages can leverage multiple benefits (adaptation- and non-adaptation-related) while enhancing the overall effectiveness of the adaptation strategy (Berry et al., 2015; Booth et al., 2020; Browder et al., 2019; Higuera Roa et al., 2023; UNEP-WCMC and UNEP, 2019).

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Additionally, adaptation packages can be also designed to be appropriate and responsive to different plausible futures. This entails that adaptation options forming the package address a) both the underlying drivers of risks and the multi-faceted effects of climate risks; b) potential impacts in the near future and the ones that will emerge in the long run; and c) climate risks under current trends and projections, as well as other potential challenges from alternative trajectories and scenarios. Therefore, crafting adaptation packages can be seen as an approach to thinking of innovative and more effective ways to address climate risks.

The considerations outlined above are crucial for formulating both **Adaptation Pathways** and **Innovation Agendas**. By grouping complementary interventions that address climate risks differently, P2R regions can better sequence adaptation options along multiple potential implementation pathways and link them to key decision points. Although diverse sequences may lead to distinct pathways, using adaptation packages can secure a comprehensive tackling of current and future challenges. Moreover, crafting adaptation packages assists the formulation of innovation agendas by enabling the identification and design of concrete coordination mechanisms and a mix of policy innovations that support efficient and coherent implementation of the adaptation package, including its constituent adaptation options—a process that may be otherwise difficult when no considering the complementarity and synergies among adaptation options. Consequently, we encourage P2R regions to consider developing adaptation packages tailored to their specific needs, contexts, and priorities within their journeys.

However, selecting the appropriate and effective combination of adaption measures in adaptation packages is a challenging task considering the complex landscape of multiple hazards (climatic and non-climatic, expected and unexpected), the multi-faceted climate effects, the wide range of adaptation options, and their interdependency on various societal factors (i.e., social, political, cultural, economic, technological, legal and environmental) (Dogulu and Kentel Erdoğan, 2015; van Alphen et al., 2021). Accordingly, the measures selection should be carefully aligned to the identified climate-related challenge for the region and its adaptation objectives (i.e., anticipate, avert, prevent, address, minimise, protect or harness climate change effects), considering the available local resources and capacities (UNEP-WCMC and UNEP, 2019), as well as relevant context specificities. Along with these technical complications, operational constraints may arise from an integrated intervention given the multiple interactions and interrelations (see) among the adaptation measures (Berry et al., 2015). Consequently, assembling adaptation packages should focus on finding complementarity, cohesion, compatibility and synergies among the adaptation options (Birkmann and Pardoe, 2014; Dogulu and Kentel Erdoğan, 2015; Duguma et al., 2014; GIZ et al., 2018; Higuera Roa et al., 2023; Seddon et al., 2020; Solecki et al., 2011).

Box 2. Analysing Compatibility between Adaptation Measures
Analysing the compatibility between adaptation measures consists of assessing two aspects: (I) interaction outcomes between two measures (*effects*), and (II) the type of relationship between two measures (*interrelation*). Regarding interaction outcomes, measures can have: positive effects (one measure beneficially influences another), negative effects (one measure adversely affects another), neutral effects (no influence), synergistic effects (both measures benefit each other), conflicting effects (both measures weaken each other) (Berry et al., 2015), antagonistic effects (one measure benefits at the expense of the other), or competing effects (the implementation of both measures at the same time is unfeasible). The measures' interrelation is determined by the adaptation goal and the targeted climate risk. Thus, adaptation measures can be complementary when addressing more risk factors than implemented individually—for example, using forest restoration and gabion walls in slope stabilization projects to prevent landslides (UNDRR, 2021). Also, measures can be substitutive when the two interventions address the same risk factors as implemented individually, such as river flood defences that can be

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replaced by rehabilitating and restoring flood plains (van Hespen et al., 2023). Moreover, measures can be supplementary when one improves the performance of the other, delivering additional benefits in the face of the risk addressed. For instance, diversifying crops using native species and soil conservation practices (no-tillage, green manure, etc.), as well as integrating market mechanisms for price stabilization, market access, and insurance. Lastly, a measure can be a safeguard when it protects the performance and ensures the implementation of an intervention, like land use planning, policies or regulations that support on-site measures (Browder et al., 2019).
Based on that understanding, and when the evidence allows it, adaptation packages should focus on grouping adaptation options with positive and synergistic effects within them, as well as prioritising those that show complementary, supplementary or safeguarding interrelations.

Real-world examples of adaptation packages illustrate how combining various adaptation measures can create more effective and transformative responses to climate challenges by leveraging synergies and addressing multiple vulnerabilities. An adaptation package in the Baltic tourism region includes constructing physical barriers, restoring natural habitats, and re-aligning coastal infrastructure to better accommodate sea-level rise and storm surges (Weisner and Schernewski, 2013). This package enhanced protection against coastal erosion and flooding while promoting biodiversity and sustainable tourism, addressing both immediate and long-term climate impacts. Another example is the cost-sharing mechanism in the Rhein River Basin (Girard et al., 2016). The package includes infrastructure improvements, ecosystem restoration, and community-based water management practices, with costs equitably shared among stakeholders. The cooperative cost-sharing mechanisms have led to a successful and smooth implementation of flood protection measures and habitat restoration projects while fairly distributing the financial burden, providing benefits to all stakeholders. Other examples include smart irrigation systems in Cartagena (Spain), consisting of the combination of artificial intelligence the Internet of things, sensors, and water-efficient devices to face water stress periods better, and the Waterplan in Antwerp (Belgium) which integrates different interventions such as green roofs, permeable pavements, fountains, tree planting and citizen science to reduce heat stress.

As described in the examples, the scale and scope of the adaptation package play an important role in shaping its transformational power. Small-scale interventions, such as community-based water management or urban green spaces, provide immediate and localized benefits. These interventions can be tailored to address specific local vulnerabilities and are often easier to implement and maintain. When aggregated, small interventions can collectively lead to significant transformation (Duguma et al., 2014). For instance, in Bremen (Germany), multiple small interventions like rainwater harvesting systems at the household level across the city cumulatively reduced water stress, improved water security, and generated new economic opportunities and livelihoods. Conversely, large-scale measures, such as coastal protection infrastructure or reforestation programs, can have a substantial impact on resilience (Fedele et al., 2020; Vermeulen et al., 2018). These measures address large geographic areas and populations and can provide widespread benefits, such as protecting entire communities or reducing urban heat island effects with cool air. These measures often encompass multiple components and sectors, promoting a holistic approach to adaptation (Royer-Tardif et al., 2021). For example, functional zoning for forest management combines land uses for conservation, forestry, agriculture, real estate, and recreation, involving various actors in need of climate resilience simultaneously. Moreover, implementing large-scale measures often requires substantial financial and technical resources, which can attract significant investments and support from national governments and international organizations, leading to transformative

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outcomes that smaller interventions might not achieve alone (Berry et al., 2015; Browder et al., 2019; Higuera Roa et al., 2023).

Thus, adaptation packages should aim to work across scales. Climate impacts and adaptation measures often have cross-scale interactions. Multi-scalar packages help address these interactions by considering how adaptation actions influence and are influenced by local and regional dynamics. These packages also involve coordination across different levels (local, regional, national) to ensure that adaptation measures are aligned and mutually reinforcing. This heightens the effectiveness of adaptation efforts by ensuring consistency and coherence across scales while preventing maladaptive outcomes (e.g., adverse effects affecting downstream regions from adaptation measures implemented upstream of a river basin).

Importantly, multi-scalar packages inherently involve multi-level adaptation strategies. Adaptation packages working across scales facilitate the integration of adaptation and other relevant policies (e.g., mitigation, conservation, economic development, social protection) across different governance levels (Adger et al., 2005; Landauer et al., 2019; Leck and Simon, 2013). These adaptation packages need to not only ensure that fit within the existing policy framework, but also that existing policies are coherent and mutually supportive of the outlined adaptation objectives (Birkmann and Pardoe, 2014; Larsen et al., 2012). The importance of multi-level adaptation strategies lies in their ability to address the complexity and interconnectedness of climate impacts across different levels of governance (Laukkonen et al., 2009; Solecki et al., 2011). Different levels of governance have varying capacities and resources, and multi-level strategies enable the sharing of those, thereby enhancing the overall adaptive capacity of communities and regions. By coordinating interventions at different levels, multi-level strategies can leverage synergies between local actions and broader policy frameworks (*see*). This ensures that small-scale interventions contribute to larger-scale objectives and vice versa.

Box 3. Enabling mechanisms for multi-level adaptation strategies

- Establish knowledge networks and platforms for sharing best practices, research findings, and innovative solutions across different levels of governance (Leck and Simon, 2013; Schmid et al., 2016; Zuccaro et al., 2020). These networks can facilitate the dissemination of successful adaptation strategies and foster collaboration.
- Create mechanisms for coordination and communication among different levels of governance (Booth et al., 2020; Juhola and Westerhoff, 2011; Leck and Simon, 2013). These can include intra-governmental committees, task forces, and regular stakeholder meetings to ensure continuous dialogue and collaboration.
- Define clear roles and responsibilities for different levels of governance (Birkmann and Pardoe, 2014; Booth et al., 2020; Serrao-Neumann et al., 2014; Van Bommel et al., 2016) through, e.g., formal agreements, ensuring that each level understands its duties and how it fits into the broader adaptation framework.
- Leverage diverse funding sources and combine funding from local, regional, national, and international sources to support adaptation efforts. This can include government budgets, private sector investments, and international climate finance.
- Implement adaptation packages in pilot case studies that provide practical insights based on real-world experiences (Castán Broto and Bulkeley, 2013; Verburg et al., 2019). Successful adaptation packages help refine multi-level strategies, serving as models that can be replicated, scaled up, or adjusted to other contexts.
- Create feedback mechanisms that allow local experiences and insights to inform regional and national policies (Bellinson and Chu, 2019; Birkmann and Pardoe, 2014; Laukkonen et al., 2009; Serrao-Neumann et al., 2014). This ensures that local adaptation packages align with broader adaptation strategies and remain relevant and responsive to emerging risks and opportunities.

Creating effective adaptation packages involves a combination of considerations that demand a comprehensive understanding of the climate-related challenge as well as the regional context

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for adaptation. While this might be a complicated task, it is a promising approach to not only better address current and future climate risks, but also increase the transformational power of the overarching adaptation strategy. By integrating diverse adaptation options and leveraging their strengths, adaptation packages can be strategically crafted to maximise systemic resilience and address the multifaceted climate risks.

5.2 Synergistic and Cross-sectoral Action for Systemic Change

Transformative adaptation options profit from a perspective that takes into account potential synergistic and cross-sectoral benefits that such may entail but might not be identifiable at first glance. Identifying and leveraging synergies in adaptation options may lead to an overall stronger performance of options, thus closing potential gaps more smoothly. For instance, climate adaptation can contribute to gender equality (Roy et al., 2022), thus showing its often sector-independent effects.

Central to this process stands climate change governance and decision making which organise and oversee options with such potential. For example, multi-criteria analyses (MCA) can help overcome cross-sectoral adaptation challenges (Lamichhane et al., 2022). Also, utilising spatial planning (Hetz, 2016), cross-sectoral planning, community planning, and strategic planning (Serrao-Neumann et al., 2015) as enablers can support in pinpointing synergies. Further, regional or multi-sectoral partnerships can catalyse cross-sectoral or cross-level policy innovations for climate change adaptation through e.g., collaboration or upscaling of activities (Bauer and Steurer, 2014; Surminski and Leck, 2016).

Combining adaptation options, taking action across sectors and levels, and exploiting their synergistic effects allows regions to make the most of positive spillovers and potential cascading effects. Analysing such benefits can be done by embracing the Multiple Resilience Dividends (MRD) thinking which has been described in P2R Deliverable 6.1. In essence, MRD go beyond delivering their single adaptation or disaster reduction goal. By facilitating holistic and sustainable adaptation options, the social, ecological or economic system of a community or region (Tanner et al., 2016) can profit from spillovers, synergistic and cascading benefits. Such benefits may entail economic development, social cohesion, increase in biodiversity, establishment of recreational spaces, etc. while reducing losses and avoiding damages. Especially transformative and innovative adaptation options that are well-planned and implemented have the potential to leverage synergistic and cross-sectoral action in climate change, and thus move away from single-use, lock-in or even maladaptive actions.

The catalogue provides 30 adaptation options, many of which embrace additional co-benefits according to MRD thinking. For example, a tree planting project in Sierra Leone combines adaptation action against landslides and heatwaves with individual, financial incentives for collective tree planting and thus improves, among other, livelihoods, biodiversity, air quality, knowledge sharing, or skill development (Fisseha et al., 2021). The action strategically adopts a cross-sectoral, synergistic approach through its “pay-to-grow” scheme, leveraging financial incentives to facilitate collective action which delivers economic, social and environmental benefits—even in the absence of any disaster event.

Another example regards natural ventilation grids as a Nature-based Solution for cooling cities. They may consist of green areas and cooling water bodies which take up heat during the day and slowly release it during the night. Their main purpose of circulating cooler, fresh air in heated cities, is complemented by e.g., improved liveability and well-being through green public space, increased biodiversity or air quality and carbon sequestration (Guo et al., 2023; Li et al., 2023;

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Wang et al., 2022). Additionally, the establishment of such multi-purpose spaces may benefit cultural events or stimulate small-scale economic activity. These examples demonstrate synergistic effects ranging from social to economic and environmental benefits.

If options are combined, their synergistic effects and cross-sectoral potential can be augmented by not only aggregating adaptation actions but also harvesting their benefits more systemically. The interconnectedness of climate risk requires inter- and transdisciplinary action through cross- or multi-sectoral partnerships to guarantee optimal outcomes (Surminski and Leck, 2016). The catalogue therefore should not only serve as an array of individual options but rather inspire to look further. Understanding action on climate adaptation as a common arena may also convince participating actors and other relevant stakeholders to join forces, which can ultimately prevent duplication of efforts and maximise resources along the climate adaptation pathway.

This logic can be extended from the public to the private sector and civil society (NGOs, associations, and grass-roots organisations) to further support transformative action across sectors and scales. This deliverable and the catalogue options (*see* Annex 1) provide explicit reference to the required management set-up (government, community, private sector, multi-stakeholder partnership, etc.). Arranging expected outcomes, synergies and benefits together with their managerial level can inspire regions to consider the whole adaptation bandwidth.

5.3 Experimentation and Learning for Transformational Adaptation

To build resilience systemically, experimentation and learning are two key enablers. On one hand, experimentation allows for testing different adaptation measures and their combinations to identify the most effective adaptation strategies in a specific context and for a particular climate-related challenge (Castán Broto and Bulkeley, 2013; Diacono et al., 2016). Also, experimentation at different scales helps identify synergies and opportunities for integration across governance levels (local, regional, national) (Adger et al., 2005; Landauer et al., 2019; Leck and Simon, 2013). Additionally, experimentation across different sectors (e.g., agriculture, urban planning, water management) fosters coordinated action and facilitates the configuration of cohesive adaptation packages capable of addressing multiple vulnerabilities and risks (Berry et al., 2015; Booth et al., 2020; Duguma et al., 2014). Thus, experimenting with multi-scalar, cross-sectoral, and integrated approaches to build climate resilience can lead to more comprehensive, innovative, and transformative adaptation strategies.

On the other hand, learning supports adaptive management necessary to better respond to the changing conditions and new information (Bellinson and Chu, 2019; Colloff et al., 2021). Continuous learning facilitates regular refinement and adjustment of adaptation strategies, which is crucial for addressing the dynamic nature of climate risks. It provides mechanisms for monitoring, evaluation, and feedback which helps build a knowledge base on what works and what doesn’t from practical experiences (Saxena et al., 2018; Vermeulen et al., 2018). This learning process and knowledge accumulation are essential for informing future adaptation planning and implementation that lead to more effective outcomes, as well as thinking of novel and more transformative ways to address climate risks.

By exploring synergies and novel ways to manage climate risks and uncertainties, experimentation and learning are mutually reinforcing enablers for transformational adaptation (Colloff et al., 2021; Folke et al., 2010; Park et al., 2012). They build a valuable knowledge base that informs better adaptation planning and helps refine future interventions, supporting the

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decision-making with sound evidence while ensuring the effectiveness of the selected adaptation measures. For instance, urban climate change experiments provide valuable insights into innovative approaches that can be scaled up or adapted to different contexts (Castán Broto and Bulkeley, 2013). Cities like New York and London have implemented green infrastructure projects as part of urban climate experiments. These projects test the effectiveness of green roofs, urban forests, and other measures in reducing heat islands, managing stormwater, and improving air quality. Also, experimentation in the Mediterranean with various agro-ecological strategies, including crop diversification, soil management, and water conservation practices, helps identify the most effective combinations for adapting horticultural systems to climate variability (Diacono et al., 2016). Moreover, the Thames Estuary 2100 project in London adopted a dynamic adaptive strategy that allows testing and implementing flood risk reduction interventions over time, as knowledge progresses and conditions change, thus, enabling long-term planning under deep uncertainty (Ranger et al., 2013). These examples demonstrate that experimentation and learning provide the flexibility, innovation, and knowledge necessary to develop and implement transformative adaptation measures.

6 Gaps, Limitations and Outlook: A Call for Innovative and Transformative Approaches for Adaptation

The catalogue presented in this deliverable serves as a starting point for a more comprehensive catalogue to be developed (D6.7) through close collaboration with P2R regions and by continuous learning from the existing practices, experiences, and needs on the ground. While we have compiled a balanced set of adaptation options across various types, scales, and climate hazards, there remain gaps in both literature and practice that require further exploration and development:

I. The first gap concerns the nature of the intervention. There is a need for a deeper exploration of innovative and transformative adaptation options, particularly within the categories of Economic Instruments and Financial Solutions, as well as Knowledge and Behavioural Change. These areas hold significant potential for driving transformative adaptation, yet they are currently underrepresented.
II. The second gap pertains to the scale of intervention. More attention should be directed towards solutions implemented at smaller scales—such as districts, buildings, and neighbourhoods—where targeted adaptation measures can have significant localized impacts as well as transformational power if widespread throughout the system. Identifying options that effectively address challenges at these scales and have high replicability is crucial for comprehensive resilience building.
III. The third gap relates to the climate hazards addressed by the adaptation options. While the catalogue covers a range of hazards, certain areas are less represented, including wildfires, extreme cold, and biological hazards (i.e., infectious diseases, pest infestations, and invasive species). Additionally, other ecological climate-induced phenomena, such as ocean warming, ocean acidification, and shifts in habitat range or phenology, have not been fully considered within the current P2R scope. Whereas these can be understood by the high pervasiveness, severity, or urgency that certain climate-related risks have over others, it is crucial not to underestimate the impacts that these less-represented climate hazards may bring to the regions.

It is important to note some of the limitations of the first version of the catalogue presented in this deliverable:

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- As mentioned, the catalogue does not offer a comprehensive list of all the available adaptation options across different KCSs, as this would not be practical and possible. It rather gives examples of options and presents a detailed methodology of how to assess whether an adaptation option is transformative and innovative, which can serve as a starting point and an inspiration for the regions while choosing their adaptation options.
- The review was based on sourcing available catalogues and examples from project partners. As such, it did not cover all the available information. However, the richness of information gathered through the review phase and a balanced division across different Key Community Systems offers a representative picture.
- A number of options which deliver adaptation and resilience benefits in practice will often be ''hidden'' in standard sectoral procedures and as such, will not be represented in the catalogues which served as a basis for the present catalogue. For instance, in the health sector actions like expanded tele-health services or upgrades in healthcare facilities (e.g., self-sufficient energy supply through solar panels) can improve adaptive capacity in remote areas, even if they are not often referred to as adaptation measures. This also occurs in other sectors, such as water (e.g., water conservation technologies and water circular solutions) and agriculture (e.g., improved grazing management, or sustainable land management). However, these examples will be context-specific, and as such, would have to be identified for a specific region and through a detailed contextual analysis (also present in the RRJ).

In the process of updating the catalogue, we aim to collaborate directly with P2R regions through multiple processes, to collect detailed feedback and further adaptation initiatives to feed into the catalogue. More specifically, we plan to gather feedback from the regions through Innovation Practice Groups (WP7) and Deep Dives (WP4), as well as through studying Adaptation Pathways and Innovation Agendas regions will develop as a part of the RRJ implementation. This will help us develop a more detailed understanding of what is considered transformational across different levels of maturity and different contextual factors.

Additionally, through regions engagement with RRJ, including developing a detailed baseline, we expect to inform the next version of the catalogue with adaptation options which: a) stem from non-adaptation-related objectives (e.g., larger national and regional developmental policies), b) identify additional practices of cross-sectoral options which create synergistic effects. Thus, advancing the understanding of innovative approaches for transformational adaptation.

Addressing these gaps and limitations together with the regions will enhance the breadth and depth of the catalogue, making it a more robust tool for guiding future adaptation strategies toward innovative and transformative interventions. Expanding the focus of the catalogue and incorporating a wider array of adaptation options not only better equip regions to face the diverse and evolving climate-related challenges but also lead to new insights into climate change adaptation processes.

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Annexes

Annex 1: Catalogue of Innovative and Transformative Options

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PATHWAYS2RESILIENCE

D6.5–Catalogue of Innovative and Transformative Adaptation Options (Annex 1)

WP6 – Task 6.2

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[4] Fundacion Tecnalia Research & Innovation
[5] Stichting Deltares
[6] Stiftung Global Infrastructure Basel (GIB)

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Introduction

Innovation in climate adaptation refers to the development and application of new ideas, practices, technologies, and approaches that address climate risks in novel or improved ways. It involves leveraging scientific advancements, technologies, and creative problem-solving to enhance the effectiveness of adaptation measures. Innovative adaptation often involves integrating diverse types of knowledge—scientific, traditional, and experiential—to generate new insights and practical solutions that are contextually relevant. Examples include the use of big data and artificial intelligence for better early warning systems or the implementation of climate-smart agricultural practices that improve adaptive capacity.

Transformation in the climate adaptation context refers to fundamental changes in the structures and functions of social-ecological systems to enhance their resilience to climate change. It supplements innovation by challenging and altering existing norms, values, power dynamics, and governance structures that contribute to systemic vulnerabilities. Hence, transformative adaptation addresses the root causes of vulnerability, such as social inequities and environmental degradation, leading to more equitable and sustainable outcomes. In practice, transformation can involve shifts in land use, economic systems, and community planning, such as transitioning from traditional agricultural practices to diversified production systems, or redefining urban planning to prioritize green infrastructure and well-being.

The importance of innovation and transformation in climate adaptation lies in their ability to address the limitations of conventional approaches, which often fail to meet the scale and urgency of the climate crisis. Traditional methods typically focus on incremental changes, which are insufficient to tackle the intricate and unpredictable impacts of climate change. Innovative and transformative approaches, thus, address the root causes of vulnerability and enhance resilience at multiple levels, leading to more equitable, sustainable, and long-lasting outcomes.

Both innovation and transformation are critical to addressing the complexity and urgency of climate-related risks. While innovation provides new tools and methods for meeting adaptation needs, transformation ensures that the underlying systemic issues are addressed, allowing for more profound and lasting resilience. For example, the implementation of green infrastructure projects in urban areas can simultaneously address flooding, heat islands, and air quality while enhancing biodiversity and human well-being. Further, these approaches also emphasize multi-stakeholder collaborations, empowering local communities, and rethinking the roles of local actors and governance to create context-specific solutions that respond better to dynamic and complex climate-related challenges. Together, innovation and transformation enable societies to better anticipate, respond to, and recover from climate impacts, currently and in the future.

We encourage the P2R regions to use this catalogue as a starting point for developing their own innovative and transformative adaptation initiatives. By drawing inspiration from the examples detailed in this catalogue, regions can follow a similar approach to identify, ideate, and select adaptation options that are most suitable for their unique circumstances. Thus, this catalogue supports regions in their Regional Resilience Journey (RRJ), particularly in the third step *Define Pathways* where options for *climate adaptation and transformation to climate resilience* are identified. This means that the catalogue can be harnessed for the formulation of Adaptation Pathways (D6.2), Innovation Agenda (D6.4), and Adaptation Investment Plan (D5.3).

We invite regions to leverage innovation and transformation to develop holistic and forward-thinking adaptation strategies that not only address current climate-related risks but also build capacity for future adaptation, ensuring long-term resilience and sustainability.

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1 Approach for Identifying Innovative and Transformative Adaptation Options

The development of the catalogue of innovative and transformative adaptation options was guided by a meticulous and iterative methodological approach[3]. This process began with the compilation of 64 resources, including existing catalogues, case studies, and ongoing European adaptation projects. The initial collection included 213 adaptation options, which were then subjected to a multi-tiered selection process. This process integrated multiple methods such as literature reviews, multi-criteria analysis, expert judgment surveys, and focus group discussions. Through these stages, the options were rigorously evaluated, characterised, and filtered, ultimately narrowing down the list to 30 adaptation options that exemplify both innovation and transformative potential.

The criteria for selecting the options in the catalogue (Table 1-A) emphasized three key aspects: effectiveness, innovation, and transformative power. Effectiveness was assessed based on the relevance, sustainability, and applicability of each adaptation measure. Innovation was evaluated in terms of novelty, adaptability, and scalability, ensuring that the options represented new or improved ways of addressing climate challenges. Transformative power was judged by the potential for synergistic effects, low-regrettable measures, and replicability across different contexts. These criteria ensured that the selected options were not only capable of addressing immediate adaptation needs but also had the potential to drive systemic changes and long-term resilience.

Table 1-A: Criteria used for selecting innovative and transformative adaptation options

EFFECTIVENESS: the ability to achieve intended objectives or outcomes successfully, addressing the identified needs or problems timely and adequately
• **Relevance**: applicability in a given context, considering the existing needs, problems, or demands of the target area/users. • **Sustainability**: capacity to operate without causing significant harm while maintaining its performance over the long term. • **Applicability**: feasibility of adopting or implementing a measure, considering factors such as resources, local capabilities, culture, and governance.
INNOVATION: capacity to address challenges in new or improved ways, leading to better outcomes, more efficient solutions, or positive changes while meeting the evolving needs and demands of the targeted entity (individuals, regions, systems).
• **Novelty**: originality, differentiation, and uniqueness of the measure in relation to existing practices. • **Adaptability**: capacity of a measure to adjust, evolve, modify or respond to changing circumstances, needs, demands, new information, or emerging challenges, while still functioning. • **Scalability**: capacity of a measure to be expanded or extended to a larger scale
TRANSFORMATIVE POWER: the extent to which a measure brings significant and lasting changes or reconfigures existing systems, processes, or practices within a given context.
• **Synergism**: the ability of a measure to trigger or amplify changes via spill-over and cascading positive effects across the system. • **Low-regrettable:** the degree to which a measure minimizes risks of counterproductive irreversible changes that lead to pathway dependencies, critical trade-offs, lock-ins, and feedback loops. • **Replicability**: refers to how easily a measure can be duplicated, transferred or applied in different contexts or settings.

[3] More information in the Deliverable 6.5.

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As both innovation and transformation are inherently context-specific, we considered the importance of the planning and implementation approach as well as the local conditions in the analysis and selection of the options included in this catalogue. As will be described for each of the 30 adaptation options further in this catalogue, the innovativeness and transformational aspects are directly defined by the local context. This means that the planning and implementation approaches of some adaptation options that have been successful in one region may not necessarily succeed in another due to differences in social, environmental, and economic conditions—or in other words, may not be innovative or transformative enough. Aware of this, this catalogue aims to provide regions with practical, well-documented examples of adaptation strategies applicable to the diverse European landscape, so they can be replicated, improved, or tailored to their unique circumstances.

Next to this catalogue is a conceptual approach to systemic adaptation (see Deliverable 6.5) that encourages regions to craft adaptation packages, foster cross-sectoral and multi-level collaborations, and promote experimentation and learning as key enablers for building long-term resilience. By integrating systems thinking and a holistic perspective in adaptation planning and implementation, this approach ensures that the adaptation strategies are not only innovative and transformative but also sustainable and effective against both current and future climate risks. Thus, regions can maximise the exploitation of this catalogue, as well as any other resources and processes that regions may employ for preparing their climate resilience journey.

2 Description of the Innovative Adaptation Options for Transformation

The adaptation options included in this catalogue (Table 2-A) are designed to be versatile and applicable across a wide range of contexts, addressing diverse climate-related challenges faced by European regions and cities. These options are categorized into five key areas: Physical and Technological Measures, Nature-based Solutions and Ecosystem-based Approaches, Governance and Institutional Measures, Economic Instruments and Financial Solutions, and Knowledge and Behavioural Change. Each option is crafted to provide practical solutions that can be adapted and scaled to suit various local conditions, needs, and capacities. For instance, options such as Smart Irrigation Systems and Climate Parametric Insurance are designed to address specific hazards like drought and flood risk, but they can be adapted to different regional climates, agricultural practices, or even different sectors (e.g., water-sensitive irrigation systems for green urban areas, or parametric insurance for residential housing).

Many of these adaptation options are designed to be flexible and adaptable to multiple scales, from local to regional applications. For example, Urban Green Infrastructure and Transformative Public Procurement are strategies that can be implemented at city or regional levels to foster systemic changes across sectors. By leveraging local knowledge and resources, these options can be customized or improved to address local climate-related risks. The adaptability of these measures ensures that they can deliver effective outcomes in various scenarios, from urban environments to rural landscapes.

It is important to note that this catalogue does not aim to provide an exhaustive list of all possible adaptation strategies. Instead, it showcases a selection of innovative and transformative adaptation options that highlight different approaches to addressing climate challenges. The catalogue serves as an inspirational resource, encouraging regions to think creatively and adopt innovative practices tailored to their specific contexts. By highlighting successful examples and

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diverse adaptation actions, this catalogue provides a starting point for regions and communities to explore and develop unique solutions to enhance climate resilience.

Table 2-A: Adaptation options described in this Catalogue

TYPE	ADAPTATION OPTION
Physical & Technological	• Resilience Hubs
	• Climate-Proofing Social Housing
	• Smart Adaptation Suite
	• Smart Irrigation Systems
	• Adaptation Platforms
	• Advanced multi-hazard Early Warning System
	• One Health Toolkit
	• Climate Risk Management Dashboard
	• Citizen Science for mitigating vector-borne diseases
Nature-based Solutions & Ecosystem-based Approaches	• Riverbed Restoration
	• Natural Ventilation Grids
	• Floodable Parks
	• Urban Green Infrastructure
	• Peri-Urban Agriculture
	• Hydrological Reconnection
	• Wetlands Restoration
	• Sustainable Aquaculture
Governance & Institutional	• Urban Green Plans
	• Cool Neighbourhoods Strategy
	• Incentives for Rainwater Harvesting
	• Urban Water Plans
	• Climate Adaptation Partnerships
	• Adaptive Flood Risk Management (TE2100 project)
	• Planned Relocation
	• City Heat Plans
Economic & Financial	• Climate Parametric Insurance
	• Corporate Climate-Resilient Strategies
	• Transformative Public Procurement
Knowledge behavioral Change	• Self-sustaining Reforestation
	• Climate Change Observatory

We employ a set of icons for some attributes describing the adaptation options. These icons help users to quickly understand important aspects of the adaptation measures, such as their scale, management set-up, time for achieving the ideal performance (peak performance time), an estimated range of investment required, targeted climate hazards, and the Key Community Systems (KCS) involved through adaptation and resilience benefits. With this icon legend, we aim to enhance the usability of the catalogue and facilitate a quick screening of different adaptation options.

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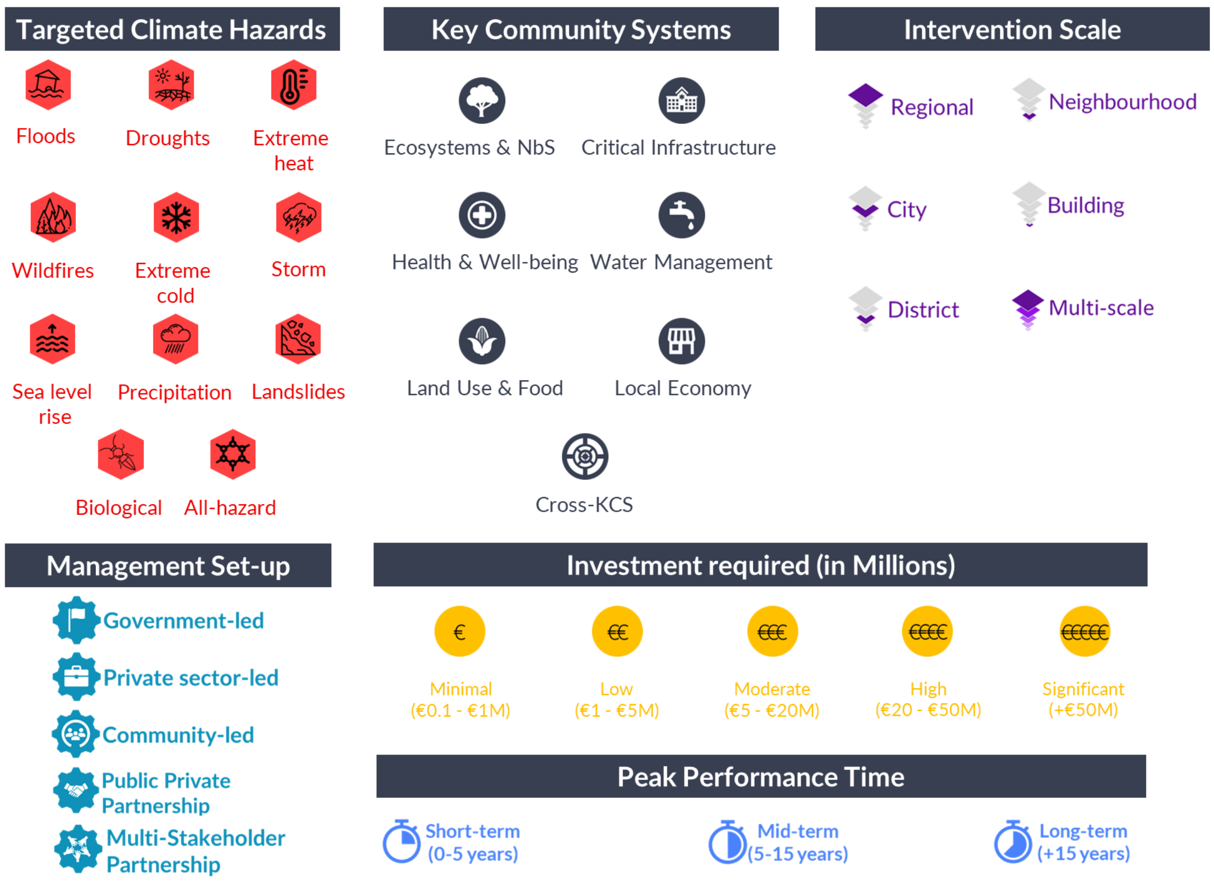

Figure 5. Legend of icons used in this catalogue

NOTE: To avoid confusion, it is important to clarify the connotation that the following icons have within this catalogue:

- *CROSS-KCS represents adaptation options that involve all KCS.*
- *ALL-HAZARDS represents adaptation options that may be applicable for all climate hazards.*
- *MULTI-STAKEHOLDER PARTNERSHIP represents adaptation options that involve actors from the private sector, public sector, and civil society.*
- *MULTI-SCALE represents adaptation options applicable to any of the other scales.*

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2.1 Physical and Technological Measures

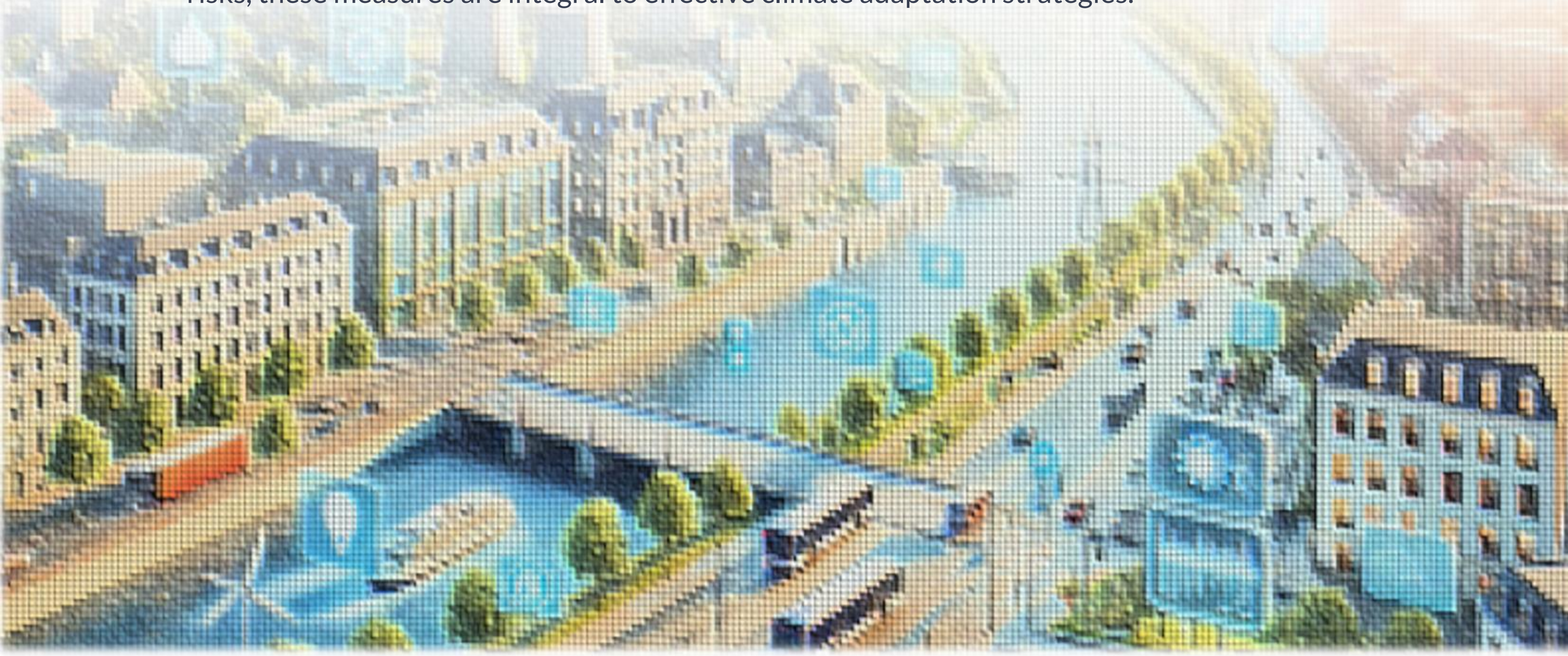
Physical and technological measures utilize engineering and technological innovations to mitigate the impacts of climate change. These measures aim to reduce vulnerability to climate risks by transforming the physical environment and leveraging advanced technologies to enhance resilience.

This type of adaptation involves several key components. Infrastructure development is a significant aspect, including the construction and enhancement of physical structures such as sea walls, flood barriers, levees, and dams. These structures are designed to protect communities from threats like sea-level rise, storm surges, and flooding. For example, the construction of levees and flood barriers provides direct protection against riverine and coastal flooding, significantly reducing the risk of property damage and loss of life.

Engineering solutions are another crucial element of physical adaptation. These approaches often involve redesigning urban and rural landscapes to improve resilience against climate impacts. This can include retrofitting buildings to withstand extreme weather or implementing stormwater management systems to reduce urban flooding. Such measures are essential for ensuring the infrastructure's resilience, allowing critical services to remain functional during climate events.

Technological innovations play also a vital role. The adoption of new technologies, such as early warning systems for extreme weather events, significantly improves preparedness and response capabilities. Advanced irrigation systems and water management technologies also fall under this category, helping to address issues like water scarcity. Here, hazard mapping and monitoring tools, facilitated by technologies such as Geographic Information Systems (GIS) and remote sensing, provide essential data for planning and decision-making. These tools enable the mapping of climate hazards and monitoring of environmental changes, allowing for proactive risk reduction measures.

Physical and technological measures often offer tangible and immediate solutions to specific climate risks. These strategies are especially important in high-risk areas where the impact of climate change is most pronounced, providing a foundation for other adaptation measures to build upon. By enhancing infrastructure resilience and facilitating protection against climate risks, these measures are integral to effective climate adaptation strategies.



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Resilience Hubs: Empowering communities with sustainable infrastructure, crisis preparedness and recovery

Scale
Neighbourhood

Management Set-up
Community-led

Time for Peak Performance
Short-term (0-5 years)

Investment required
€

Climate Hazard

KCS involved

Brief description

Resilience Hubs are enhanced community-serving facilities designed to support residents, manage communication, distribute resources, and reduce carbon emissions while improving overall quality of life. This concept is increasingly adopted by cities to redefine emergency preparedness and better serve residents during non-crisis periods[5,6]. It moves away from predominantly focusing on technical solutions, having a holistic view on resilience and meeting the needs of people year-round. By re-centering resilience around site-specific community needs, hubs provide an opportunity for governments to collaborate with communities, building their self-determination.[3] These spaces can also drive creative and innovative ideas and often focus on the vulnerable within a community, driving transformative resilience - something that traditional approached often fail to do.[4] Resilience Hubs operate under three conditions: Everyday (most of the time), Disruption, and Recovery.[2]

- Every day: Resilience Hubs act as central points for addressing vulnerabilities and promoting community well-being. They deliver preparedness information and collaborate with trusted community leaders to strengthen community ties and disseminate information effectively.
- Disruption: In times of crisis, Resilience Hubs become focal points for gathering, impact assessment, information sharing, resource access, and response coordination. Ideally, they are managed collectively by residents, businesses, and organizations, ensuring efficient internal and external communication.
- Recovery: Post-disruption, Resilience Hubs are crucial for recovery and ongoing communication. They continue to serve as central points for gathering, sharing information, and accessing resources. Additionally, they provide space for experts, aid organizations, volunteers, and support networks to gather, understand, and address community needs.[1]

Expected Outcomes

- Reduce the burden on emergency services and recover more quickly after a disaster
- Strengthen communities' disaster preparedness, and response capacities
- Community access to mental health support, childcare, or job training programs

Key Enabling Conditions

- Community and Multi-Stakeholder Engagement: Inclusive participation from residents, community leaders, local businesses, non-profits, public authorities, urban planners, and emergency response organizations.

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- Diverse Funding Mechanisms: Combination of public funding, private investments, grants, and donations to ensure financial sustainability.
- Comprehensive Consultation Process: Extensive engagement with the community to understand needs, build trust, and ensure the hubs address local vulnerabilities effectively.
- Local Knowledge and Research Capacity: In-depth understanding of community-specific risks and needs, facilitated by partnerships with academic institutions and local experts.

Synergies and Additional Benefits

- Increase community cohesion and sense of belonging
- Improved collective knowledge
- Improve communication channels
- Space for learning, recreation, and culture

Limitations and Constraints

- Challenging to bring partners together to engage
- Not sustainable without continued financing
- The location of Resilience Hubs needs to be accessible to communities while safe from climate hazards, which may be challenging to find

Potential Trade-offs and Adverse Effects

- Need to decide between a Resilience Hub better equipped for a certain risk or a more generic one designed for multiple risks.

Example of Success

The City of San Leandro pioneers a unique approach to climate resilience through its management of a network of Resilience Hubs. Serving as a facilitator and resource provider, the City organizes bimonthly online and in-person workshops covering topics such as social connectivity, emergency preparedness, and energy resilience. Collaborative governance meetings foster cross-site exchange and decision-making, enhancing partnerships with regional groups and leveraging state and regional grants. Established during the development of the City's Climate Action Plan with support from the Urban Sustainability Directors Network, the Resilience Hub network received initial funding for leadership training and has since grown with additional hub partners recruited. Grant funding has enabled small-scale climate projects and community building initiatives, leading to recognition by the Strategic Growth Council for its impactful work in 2023.[2]

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Image source: Hannah Busing, Unsplash

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Climate-Proofing Social Housing Landscapes

Scale
Neighbourhood

Management Set-up
Public Private Partnership

Time for Peak Performance
Short-term (0-5 years)

Investment required
€€

Climate Hazard

KCS involved

Brief description

Climate-Proofing Social Housing Landscapes take an integrated approach to urban climate adaptation by implementing affordable, light-engineering measures (e.g. small basins, rain gardens and green roofs) focused on retrofitting blue and green infrastructure. It also includes extensive community engagement, awareness-raising on climate adaptation opportunities, and training for local apprentices and council staff in the necessary skills to implement and maintain these measures.

Climate proofing social housing can be done through employment programs targeting the long-term unemployed, creating local jobs. In addition, it can include training modules for housing and grounds maintenance professionals, covering the entire adaptation cycle from procurement to maintenance. Another feature of this is to engage resident stakeholders with a transferable methodology, resulting in community-specific adaptation action plans and active participation in retrofitting and maintenance.[1]

Similar projects focusing on enchanting blue and green infrastructure through co-governance approaches can help alleviate lack of these spaces in low-income neigbourhoods[6] and address consequential neighbourhood microclimate differences.[7]

Expected Outcomes

- Improved local resilience to the impact of extreme weather events
- Create attractive areas for residents to relax, socialize, and connect with nature
- Reduced unemployment rates, particularly in priority groups

Key Enabling Conditions

- Extensive community engagement[2]
- Combining implementation with employment and accredited training programs for the long-term unemployed, creating local jobs[3]
- Training local apprentices and council staff in the skills required to implement and maintain the adaptation measures[4]
- Engaging maintenance contractors during the design process to address their concerns and adapt designs accordingly[5]

Synergies and Additional Benefits

- Social cohesion
- Skill development
- Employment generation
- Changes visual and functional aspects of social housing
- Climate adaptation education
- Enhanced social well-being and interaction
- Support urban biodiversity

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Limitations and Constraints

- Limited resident engagement initially due to low awareness on urgency of climate change[1]
- Concerns around anti-social behavior in green spaces[1]
- Incomplete identification of underground services despite utility company drawings and radar surveys, necessitating design changes during construction.[1]

Potential Trade-offs and Adverse Effects

- There can be concerns about construction work near homes and changes to access routes in neighborhoods.[1]
- Concerns around anti-social behavior in green spaces[1]
- These infrastructures require regular maintenance, which might increase operational costs to the residents.
- Enhancements in social housing landscapes could lead to increased property values and potential gentrification, displacing the very communities the measures aim to help.

Example of Success

The Climate-Proofing Social Housing Landscapes project aimed to implement comprehensive climate change adaptation solutions across three social housing estates in the London Borough of Hammersmith and Fulham. These adaptations were characterized by high levels of deprivation and increased climate-related risks. Concluding in September 2016, the project showcased an integrated approach to urban climate adaptation through a set of affordable, light-engineering measures centered on retrofitting blue and green infrastructure. This included food growing beds, tree and shrub planting, swales and basins, permeable pavings. It also emphasized extensive community engagement, raising awareness of climate adaptation opportunities, and training local apprentices and authority staff in the necessary skills for implementation and maintenance.[1] This project integrated both blue and green infrastructure to redefine urban social living spaces, making them not only more resilient to climate change, but also provided esthetically pleasing spaces where community members can interact while creating employment opportunities and fostering substantial involvement of non-traditional stakeholders.

Sources & more info:

Image source: created by OpenAI's DALL-E

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Smart Adaptation Suite: Digital Innovations For Climate Resilience

Scale
Multi-scale

Management Set-up
Multi-Stakeholder Partnership

Time for Peak Performance
Short-term (0-5 years)

Investment required
€€

Climate Hazard

KCS involved

Brief description

Gathering and combining innovative, data-driven digital tools for climate resilience "*can help to illustrate the effects of climate change*" which can eventually support in bridging the science-stakeholder-policy gap and raise citizen awareness.[1] Examples that can be leverage include e.g., digital twins, urban heat island modeling, simulations, augmented and virtual reality, or climate resilience models.[1, 2, 3, 4]
Insights provided by these technologies can significantly support each stage of the adaptation cycle – from strengthening risk analytics to monitoring and evaluating adaptation outcomes – by suiting decision-makers with solutions to better address the complex climate challenges. These technologies can deal with the interconnectedness of natural, socioeconomic and economic systems, cope with many variables and degrees of uncertainty, and align climate action across multiple time horizons and levels.[7]

Expected Outcomes

- Increase of effectiveness and accuracy of adaptation options
- Visualizing potential climate impacts
- Strengthen adaptation planning and decision-making
- Improved implementation through more accurate data and information

Key Enabling Conditions

- Expertise in using and making use of the tools
- Open collaboration among technology developers, local authorities, and private sector
- Improved policy and financing for digital transition, digitalization and development
- Technological infrastructure
- Public and stakeholder buy-in

Synergies and Additional Benefits

- Increase of social participation and multi-stakeholder engagement
- Increase of data usage and data efficiency
- Fostered entrepreneurship & innovation
- Building/strengthening institutions

Limitations and Constraints

- Heavy dependance on digital tools
- Limited access to some technologies due to high costs
- Dependency on data availability and quality
- High expertise required
- Short-term actions may falsify long-term effort (e.g., resources for (re-evaluation, continuous learning and improvement)

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Potential Trade-offs and Adverse Effects

- Opportunity costs due to high upfront investment in the adoption/ development of the technology
- Potential lock-in to one technology, software, or system
- Need for upskilling and additional training for end users

Example of Success

As part of the EU Horizon Regions4Climate project[5] the four regions Pärnumaa in Estonia[1], Burgas in Bulgaria[2], Køge Bay in Denmark[3], and Uusimaa in Finland[4] are currently participating in the Smarter Adaptation Challenge Suite which aims to prepare the regions for e.g., extreme storm events, flooding, high temperatures or droughts by "*enhancing climate adaptation through data*" and data-driven, innovative tools.[5] Køge Bay as frontrunner region uses "*augmented and virtual reality applications to improve the general understanding of climate risks and solutions*"[3] to focus on and enhance societal resilience and wellbeing along the coast, to prepare vulnerable groups against flooding or to select suiting nature based solutions for biodiversity enhancement.

While the implementation of the tools in the regions is still in its infancy, the innovative and transformative aspects relate to the option's overarching character of integrating digital, data-driven tools with participatory and decision-making processes to build climate resilience.

Sources & more info:

Image source: Digital twin presentation in Helsinki by Toomas Toodu

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Combatting Drought Through Smart Irrigation Systems: Applying the Right Amount of Water at the Right Time

Scale
Regional

Management Set-up
Private sector-led

Time for Peak Performance
Short-term (0-5 years)

Investment required
€

Climate Hazard

KCS involved

Brief description

Smart irrigation systems are a powerful tool for addressing increased drought frequency and unpredictable water shortages in agriculture. These technologies precisely manage crop irrigation using sensors, Internet of Things (IoT), Artificial Intelligence (AI), and automated controls to optimize the quantity and timing of water delivery based on real-time data. They can detect early signs of drought stress, adapt to changing conditions, and minimize water loss, reducing crop losses and maintaining productivity during dry periods. They also improve resilience against shifting rainfall patterns and manage salinity in coastal areas. [1,2,3]

Beyond agriculture, smart irrigation can maintain urban green spaces during droughts. By integrating weather forecasts, these systems help farmers and cities prepare for heatwaves, water shortages, and unexpected rainfall.[1,2]

Expected Outcomes

- To improve the water-use efficiency.
- To adapt proactively and dynamically to dry periods and shifting rainfall patterns.
- To prevent crop losses.

Key Enabling Conditions

- Land ownership
- Associated infrastructure require (e.g., irrigation districts, telecommunications).
- Training of farmers on the use of smart irrigation technologies and data interpretation
- Establishment of agreements with farmers
- Financial investment and budget for ongoing maintenance

Synergies and Additional Benefits[1]

- Maintain and increase agricultural productivity.
- Improve soil health and prevent land degradation.
- Improve food and water security.
- Reducing pollution and other environmental hazards.

Limitations and Constraints

- High upfront costs for system installation.
- Additional budget required for technology maintenance and training.
- Low technical capacity and knowledge on how to manage the technology.

Potential Trade-offs and Adverse Effects

- High upfront costs, and affectation to the project's budget.
- Higher reliance on external systems, such as energy and internet connectivity, which can malfunction and harms crops.
- Farmers can lock in with some systems and software, limiting their choices in the long run.

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- High dependency on automation, which can lead to the loss of traditional and local knowledge and practices.
- High costs increase the gap of access and affordability to water-saving technologies and crop productivity of small-scale farmers.

Example of Success

The City of Cartagena has implemented a smart irrigation management system as part of its commitment to the European Green Deal and the Sustainable Development Goals. This system, designed for the city's parks and gardens, leverages technologies such as AI, IoT, and Data-Quality to autonomously and efficiently manage water resources in real-time. By incorporating sensors for weather, soil moisture, and irrigation scheduling, the system adapts irrigation schedules to the specific needs of each green area, reducing water consumption by up to 30% and CO2 emissions by 40%. This not only ensures the optimal maintenance of urban green spaces but also prevents the excessive use of water and chemicals, thereby safeguarding both terrestrial and marine ecosystems. Additionally, the integration of this technology ensures comprehensive data management and compatibility, enhancing the city's overall smart infrastructure.[4]

Sources & more info:

Image source: Image by jcomp on Freepik

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Adaptation Platforms: Enabling Households to Combat Climate Risks

Scale
Building

Management Set-up
Private sector-led

Time for Peak Performance
Short-term (0-5 years)

Investment required
€

Climate Hazard

KCS involved

Brief description

Information and Communication Technologies (ICTs) tools are proving to be valuable allies for empowering the public to adapt to climate change[1]. Often disseminated as online platforms or web portals, these ICT tools address knowledge and action gaps in urban and rural populations. They provide urban residents and farmers, decision-makers, and actors along different value chains with clear and accessible information about climate risks specific to their regions or activities, as well as potential solutions and climate-proof behaviours[1]. These platforms use interactive maps and comprehensive data to visualize local impacts, thereby aiding communities in prioritizing adaptation efforts[2,3,4]. Beyond just raising awareness, ICT tools offer personalized recommendations to different users[3]. By analyzing local data on factors like soil composition and water levels, this new generation of platforms can suggest tailored actions for users to take on their own activities and communities. This could involve water storage solutions, flood prevention measures, or adjustments to landscaping to face floods and droughts proactively.
Furthermore, these platforms empower residents to become active participants in climate adaptation, fostering collaboration with local authorities for a more effective collective response[2]. These platforms enable residents to identify high-risk areas and valuable community assets and allow community members to share their insights and concerns, integrating local knowledge into adaptation planning[1].
Besides that, ICT tools can support other activities such as capacity building, early warning, and real-time monitoring[1]. Initiatives like Digital Green use participatory video to share knowledge on sustainable and climate-smart practices[2], and mobile-enabled climate information services deliver timely weather updates and agricultural advice in case of climate variability[1,2]. With residents armed with knowledge and personalized tools, communities can build resilience and adapt to a changing climate.

Expected Outcomes

- Improve water management and sustainability at the household level to address shortages and excesses during droughts and floods

Key Enabling Conditions

- Accessible high-quality data and information
- Having technical and technological capacity
- Budget to build the platform and eventually expand it to the national level

Synergies and Additional Benefits

- Ownership and accountability of adaptation strategies at the household level
- Possible to scale up and provide advice to other stakeholders (e.g. private company buildings) beyond households
- Improved collective knowledge

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- Enhanced urban services
- Community empowerment
- Increased public awareness and preparedness
- Fostered entrepreneurship & innovation

Limitations and Constraints

- Limited retrofitting options possible for urban buildings in some cases
- Funding constraints for continuous updates and maintenance
- Implementation of the option is subject to personal expenditure and may not be possible for low-income households

Potential Trade-offs and Adverse Effects

- Limited accessibility and usability for some user groups (e.g., due to digital illiteracy or no access to Internet)
- Discouragement of adaptative behaviours if the solution does not provide relevant options or accurate information.
- It may steer adaptation efforts towards certain types of measures at the expense of other important adaptation strategies.

Example of Success

IkBenWaterproof (IAmWaterproof) is an example of a platform in the Netherlands that focuses on empowering residents to address flooding and drought exacerbated by climate change. In urban areas, where up to 70% of the land is privately owned and often paved, effective climate adaptation requires collective action from both local governments and private landowners. Many residents lack knowledge about effective measures and how to implement them. IkBenWaterproof uses a platform that provides personalized advice using public data on local soil, pavement, and groundwater levels. By entering the zip code and house number, residents can receive tailored recommendations on what measures they can take to make their houses and gardens waterproof. The platform offers easy-to-understand labels and attractive examples to encourage adaptive measures. Background information and practical tips on water storage and mitigation measures, in addition to insights into costs for measures have helped many families make climate smart choices. The platform also provides information on government subsidies and schemes available to support the citizens in making these changes to their buildings and gardens. The platform also provides the opportunity of supporting citizens and communities with customized communication plan around climate adaptation, community forums for people actively involved in water storage and integrating with other themes like greening, biodiversity, energy transition. The initiative has underscored the joint responsibility of government and citizens in climate adaptation, helping residents contribute to overall climate resilience.[5,6]

Other examples of web platforms focusing on climate change adaptation include *The Knowledge Bank* that provides adaptation data targeted at municipal decision-makers in Norway[3], a geo-visualisation platform (Adapt NS) showing flood risk in Nova Scotia, Canada used for education and to foster adaptation discussions[4], and platforms communicating climate and agricultural related information to help small farmer decision-making for improved livelihoods and climate adaptation.[1,2]

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Advanced Multi-Hazard Early Warning Systems: The Use of AI and Other Emerging Technologies

Scale

Regional

Management Set-up

Multi-Stakeholder Partnership

Time for Peak Performance

Short-term (0-5 years)

Investment required

€€€€

Climate Hazard

KCS involved

Brief description

Multi-hazard early warning systems (EWS) are vital for saving lives, leveraging advanced technology to enhance their impact. Artificial Intelligence (AI), Big Data, and cloud computing improve the predictive accuracy of EWS, while Internet of Things (IoT) networks and satellite-based technology enhance hydro-meteorological services and optimize alert dissemination. EWS respond dynamically to crises by:

- using AI for humanitarian data collection through social media and satellite imagery for post-crisis assessments[9];
- strengthening decision-making with AI tools that predict crisis developments and resource deployment[8];
- optimizing real-time processes with drones for search-and-rescue and AI for evacuation route planning; and
- facilitating adaptive behaviors with AI-driven post-crisis mental health support via accredited chatbots.

These systems also provide real-time situational awareness, enabling faster and more effective responses[5]. Moreover, integrating these technologies ensures that alerts reach at-risk individuals promptly, improving overall disaster preparedness and resilience. For example, a machine learning model that predicts corn production under different climate scenarios has been developed[7], or a mobile application that assesses farmers vulnerability based on responses to a questionnaire[8]. These advancements collectively enable more effective, efficient, and adaptive responses to emergencies, significantly reducing the impact of disasters on communities.[1]

Expected Outcomes

- Improved preparedness to multiple hazards and reduced negative impacts from disasters

Key Enabling Conditions

- Technological Infrastructure: high-speed internet and reliable Communication Networks are essential for the real-time transmission of data and alerts, advanced Computing Power and trained personnel will be required for processing large datasets and running complex algorithms; and satellite and sensor networks for data collection and Earth observation.
- Comprehensive Datasets: Including historical data on weather patterns, geological activity, and other relevant factors and data sharing protocols between agencies and countries to share critical data

Synergies and Additional Benefits

- Public Health and Safety
- Reduced economic losses

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- Improved business continuity
- Cross-sectoral collaboration
- Reduction in insurance costs
- Data driven decision making
- Fostered entrepreneurship & innovation

Limitations and Constraints

- High initial costs
- Data integration and interoperability issues
- Limited skilled personnel
- Privacy and data security concerns
- Maintenance and operational sustainability

Potential Trade-offs and Adverse Effects

- Privacy concerns regarding potential for data misuse or breaches affecting individual privacy.
- Unequal access to technology could lead to disparities between different regions or communities.
- Considerable energy needed by operating systems for cooling and operation of AI can undermine efforts towards carbon neutrality.
- The production, service and disposal of e-waste can have negative consequences, including initial mining[6]

Example of Success

The UN's "Early Warnings for All" initiative aims to ensure that everyone worldwide is protected by early warning systems (EWS) by 2027. The economic case for EWS is compelling: investing $800 million in EWS in developing countries can avert losses of $3-$16 billion each year.[2]

Artificial Intelligence for Disaster Response (AIDR) is an AI tool within the open-source MicroMappers project, developed in collaboration with the UN Office for the Coordination of Humanitarian Affairs (OCHA).[3] This platform automatically gathers and categorizes tweets during emergencies, using keywords and hashtags like "floods" for filtering. Through continuous refinement, AI processes and applies this intelligence to all collected tweets in real-time, which are then automatically labeled and visualized on a live dashboard and crisis map, facilitating real-time monitoring and response coordination.[4]

Sources & more info:

Image Source: NASA

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One Health Toolkit: Preparing for Emerging Climate-Driven Disease Outbreaks

Scale
Regional

Management Set-up
Multi-Stakeholder Partnership

Time for Peak Performance
Short-term (0-5 years)

Investment required
€€€

Climate Hazard

KCS involved

Brief description

IDAlert, part of the Climate-Health Cluster funded by the European Commission Horizon Europe programme and the European Health and Digital Executive Agency (HaDEA), addresses the growing threat of infectious diseases exacerbated by climate change. Rising temperatures, variable rainfall, and biodiversity loss are increasing the spread of zoonotic diseases in Europe. By developing decision-support tools and employing a co-creation approach involving stakeholders, IDAlert aims to improve anticipation, forecasting, and response to disease outbreaks. This initiative integrates an Eco-Health and One-Health perspective, recognizing the interconnectedness of human, animal, and environmental health, to enhance preparedness and adaptation strategies against climate-induced health risks.[1]

Expected Outcomes

- Increased preparedness and response capacity to climate-induced infectious disease

Key Enabling Conditions

- Past and present data on impacts of climate change[2]
- Access to technology to use innovative tools and early warning systems[2]

Synergies and Additional Benefits

- Improved health
- Improved human capital
- Community ownership of societal health outcomes
- End user's engagement with design and production of the platform
- Production of policy relevant information[4]

Limitations and Constraints

- Data security and privacy concerns
- High initial costs

Potential Trade-offs and Adverse Effects

- Potentially inaccurate or biased data due to citizen input, which may be unrepresentative or inaccurate
- Limited generalizability, meaning that findings from some areas might not be directly applicable to other regions with different climates and ecosystems.
- Citizen science might require using specific apps or technologies, potentially excluding those without access or digital literacy.

Example of Success

The tools and methods developed in the ID Alert project will be validated at key hotspot sites in Spain, The Netherlands, Greece, Sweden, and Bangladesh, where rapid urban transformation and climate-induced disease threats are prevalent. These sites will test innovative data collection approaches such as engaging citizens for mosquito and tick

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surveillance, examine fine-scale drivers and mechanisms of disease transmission and emergence, and assess the direct and upstream effects of policy. Local stakeholders will co-design and co-produce activities at each site, ensuring the provision of essential, high-quality data.[1]

Sources & more info:
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Dashboard for Improved Decision-Making in Climate Risk Management

Scale
Multi-scale

Management Set-up
Government-led

Time for Peak Performance
Short-term (0-5 years)

Investment required
€

Climate Hazard

KCS involved

Brief description

A decision dashboard is an innovative technology for strengthening knowledge acquisition and information collation for improved decision-making. It typically consolidates various sources of data and presents them in a visually, intuitive format, such as graphs, charts, tables, and maps.

The purpose of a decision dashboard is to enable users to quickly assess key performance indicators (KPIs), trends, and patterns, facilitating informed and timely decision-making. Climate-related decision dashboards are often used to monitor and manage the vulnerability, impacts and risks as well as the status, performance, and outcomes of climate actions. Key features of a decision dashboard may include:

1. Customization[1]: Users can often customize the dashboard to display the specific metrics and data that are most relevant to their decision-making needs.
2. Real-time or near-real-time data updates[2]: Many decision dashboards are designed to pull data from various sources in real-time or with minimal latency, ensuring that decision-makers have access to the most up-to-date information.
3. Alerts and notifications: Some decision dashboards include alerting mechanisms to notify users of significant changes or anomalies in the data, prompting further investigation or action.
4. Accessibility: Decision dashboards are typically designed to be accessible to a wide range of users, including executives, managers, and frontline staff, with varying levels of technical expertise.

Expected Outcomes

- Enhanced Decision-Making
- Improved Risk Monitoring and Management
- Increased operational processes and resource allocation.

Key Enabling Conditions

- Active engagement with government and stakeholders in co-design ensures policy alignment and stakeholder buy-in.
- High-quality data and expertise ensure trust, accuracy, reliability, and relevancy of dashboard information.
- Building stakeholder capacity in data interpretation maximizes dashboard impact.
- Adequate financial resources are essential for developing, implementing, and maintaining decision dashboards.

Synergies and Additional Benefits

- Facilitate cross-project dialogues and learning exchanges, promoting knowledge sharing and collaboration among stakeholders.

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- Foster cross-sectoral action
- Enhance cross-sectoral action
- Strengthening institutions and governance[3]
- Increase public awareness and preparedness

Limitations and Constraints

- Stakeholder input dependency[3]: a dashboard requires regular input and updated information from relevant stakeholders, which demands high engagement levels.
- Data availability, quality and integration[3]: Climate data comes from various sources, and ensuring its accuracy and completeness can be difficult.
- User interpretation and expertise: the effectiveness of a dashboard relies on the users' ability to interpret the information correctly, requiring proper training or domain expertise.
- Limited scope: dashboards typically focus on a specific set of metrics or indicators, which might neglect other crucial information not included in the dashboard.

Potential Trade-offs and Adverse Effects

- Partial or biases in data collection, sampling methods, or algorithms can lead to skewed insights and erroneous conclusions, potentially perpetuating existing inequalities or misconceptions.
- Inconsistent formats, gaps in data collection, and data quality issues can all affect the reliability of the information presented on the dashboard, resulting in misleading visualizations and a narrow understanding of the overall risk landscape.
- The introduction of digital softwares could worsen the existing digital divide, especially when involving vulnerable stakeholders in the use and deployment of the dashboard.

Example of Success

The Strengthening Landscape-Level Baseline Assessment and Impact-Monitoring project, implemented by World Agroforestry (ICRAF) aimed to bolster food security and resilience in smallholder farming and agro-pastoral systems across Eswatini, Kenya, Lesotho, Malawi, and Uganda. Through the development of decision dashboards, based on Earth Observation technology, the project sought to enhance access to high-quality data and diagnostic evidence for ecosystem health and household resilience.

Using a user-centered approach, stakeholders including government bodies, NGOs, and farmers collaborated in designing the dashboard, which integrated biophysical and socio-economic data. The dashboard facilitated data visualization and interpretation, aiding decision-making processes. Noteworthy achievements included identifying key needs for rangeland management, linking socio-economic data with biophysical indicators, and developing co-design frameworks for Earth Observation-assisted platforms. Additionally, in Lesotho, a new framework for national rangeland health assessment initiated.

Lessons learned emphasized the importance of stakeholder engagement and alignment among projects. To ensure scalability and sustainability, clear stakeholder priorities and needs must be established early, with ongoing communication and adaptability to contextual changes. Overall, the project showcased the effectiveness of decision dashboards in enhancing data-driven decision-making and fostering collaboration for resilient agricultural systems.[1]

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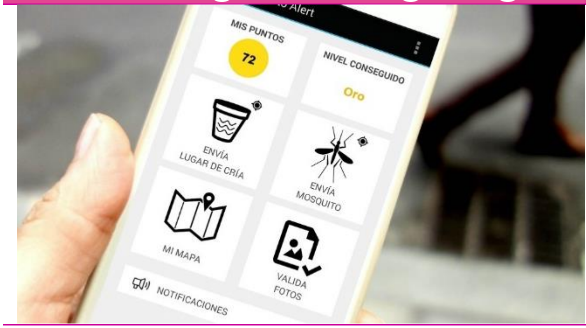
Combating Vector-Borne in Real-Time: Citizen Science for Monitoring and Mitigating Vector-Borne Diseases



Scale	Management Set-up
Regional	Community-led
Time for Peak Performance	**Investment required**
Short-term (0-5 years)	€

Climate Hazard	KCS involved

Brief description

Climate change is increasingly impacting the incidence and distribution of vector-borne diseases in Europe. Warmer temperatures, changes in precipitation patterns, and milder winters create favorable conditions for vectors such as mosquitoes or ticks to thrive and expand their range. This shift has led to a rise in outbreaks of diseases like dengue, and malaria in regions previously unaffected[1].

Monitoring and mitigating these diseases in real-time is critical for preventing outbreaks and controlling their spread. Traditional surveillance methods, while effective, often lack the granularity and immediacy needed for timely interventions. This is where citizen science becomes valuable. Citizen science involves public participation in scientific research, allowing volunteers to assist with data collection, analysis, and reporting. This collaborative approach helps gather large-scale data across various fields such as risk, ecology, and health sciences. Participants contribute through mobile apps, online platforms, or fieldwork, providing data related to vector presence, breeding sites, disease incidence, symptoms of diseases, and share environmental data that influence vector habitats. This method enhances scientific research, promotes public engagement, and increases awareness and education on scientific issues. Citizen science thus harnesses collective public power to enhance preparedness and response capacities by, for example, more accurate mapping of vector distribution and disease hotspots, early detection of outbreaks, swift public health responses, and the development of targeted interventions to areas most at risk[2].

Expected Outcomes

- Improved strategies for disease outbreak control.
- Provide a robust evidence base for policymakers.

Key Enabling Conditions

- Availability of user-friendly technology
- Active engagement and collaboration with local communities
- Policy frameworks that recognize and support citizen science initiatives

Synergies and Additional Benefits

- Awareness raising and educational outcomes around climate change impacts improving climate resilience by empowering individuals to take proactive steps to reduce the risk of e.g. mosquitos-borne diseases.

Limitations and Constraints

- Subject to citizen engagement: to be relevant and significant, requires a sustained long-term engagement and participation from volunteers.

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Potential Trade-offs and Adverse Effects

- Maintaining participant privacy while promoting transparency about data collection and usage.
- Without proper validation mechanisms and quality control measures, there's a risk of inaccuracies or biases in the reported observations, which can undermine the scientific integrity of the project.

Example of Success

Mosquito Alert[3] is a nonprofit citizen science project coordinated by various public research centers. It combines citizen-sourced data with authoritative data from public entities and universities to develop predictive models and methods. These models are crucial for managing public health by tracking mosquito species that carry arboviruses such as Zika, dengue, and chikungunya. The platform enables effective, low-cost early warning systems and integrates into public health frameworks through voluntary citizen participation.

The project originated in 2013 in Catalonia with the goal of mapping the distribution of the tiger mosquito (*Aedes albopictus*) in the region. The initiative began with a pilot in Girona, which later expanded to cover the entire country by 2014. By engaging citizens to report sightings of tiger mosquitoes and yellow fever mosquitoes (*Aedes aegypti*) via a mobile app, the project created a comprehensive database for research and control.

Mosquito Alert leverages citizen observations to build a common database for research and control of these mosquitoes. These observations help improve predictions about the presence and spread of these mosquitoes, with reports indicating increased risks and frequency of outbreaks in Europe.

In 2016, the project's citizen observation data and maps became accessible through the United Nations Environment Programme (UNEP) portal, positioning Mosquito Alert as a reference project. In 2017, it launched the "Global Mosquito Alert" platform with UN support to address mosquito-borne diseases globally, uniting scientific and public efforts against health threats exacerbated by climate change and globalization.

The project has expanded globally, with a translated app and collaborations across continents. The open-source software facilitates public participation, ensuring anonymity. Mosquito Alert aims to provide real-time risk predictions for disease transmission and develop strategies for mosquito control. It also educates the public on mosquito prevention.

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Image source: Alex Ritcher- Boix/Fototeca CENEAM

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2.2 Nature-Based Solutions and Ecosystem-based Approaches

Nature-based solutions (NbS) and ecosystem-based approaches (EbA) are adaptation strategies that leverage the power of natural processes and ecosystems to address the impacts of climate change. These approaches focus on using the inherent resilience and adaptability of ecosystems to mitigate climate risks while providing co-benefits such as biodiversity conservation and improved human well-being.

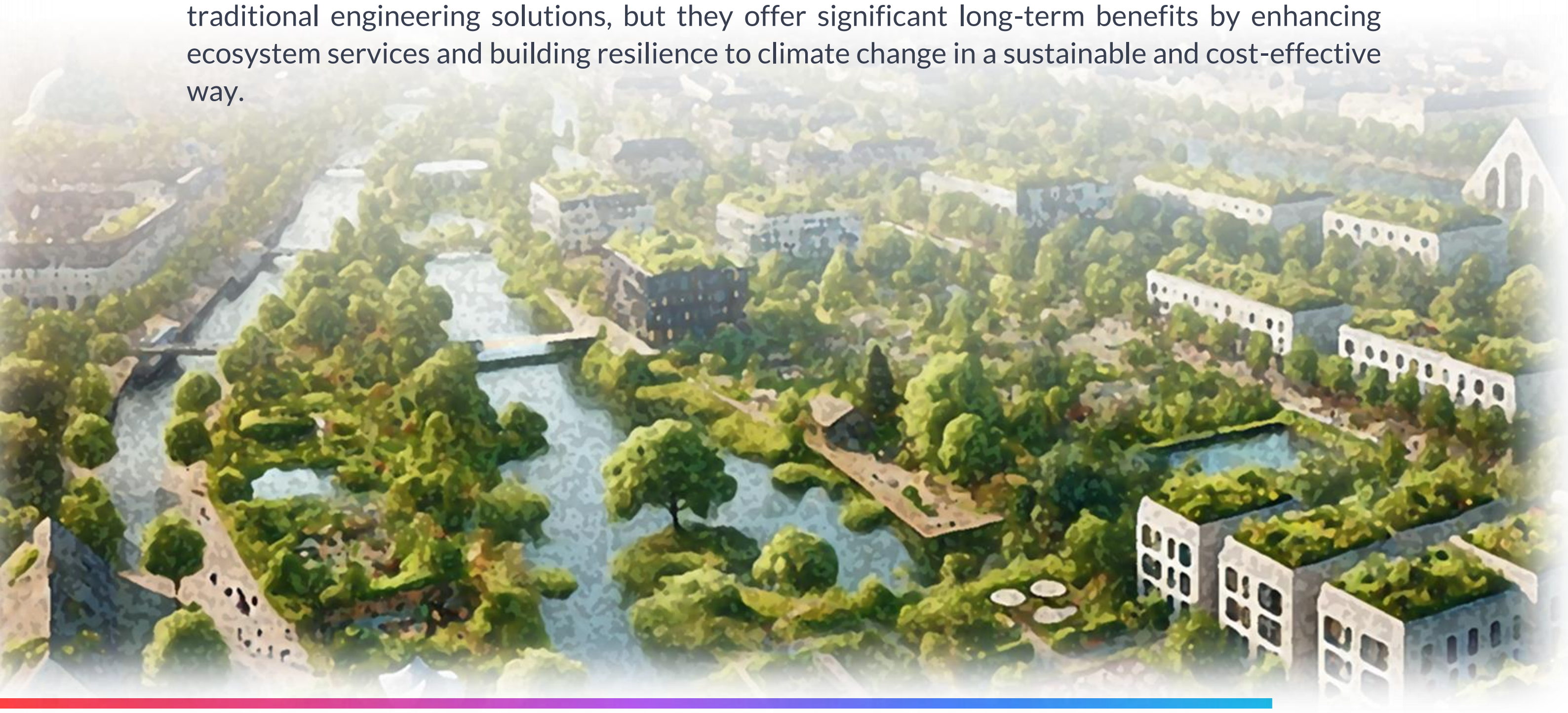
This type of adaptation option encompasses a wide range of interventions that utilize natural features and processes to enhance resilience. These solutions include, for instance, the restoration of mangroves and salt marshes, which act as natural buffers against storm surges and coastal erosion. By stabilizing shorelines and reducing wave energy, these ecosystems protect coastal communities from the impacts of sea-level rise and extreme weather events. Additionally, the restoration of wetlands and floodplains can help manage floodwaters, reducing the risk of flooding in downstream areas.

Green infrastructure (GI) is another group within this category. Urban parks, green roofs, and street trees are examples of GI that can help manage stormwater, reduce urban heat islands, and improve air quality. These features not only enhance the resilience of urban environments but also provide recreational spaces and improve the quality of life for residents.

EbA emphasize the sustainable management and conservation of ecosystems and natural resources to support adaptation. For example, sustainable agriculture practices, such as agroforestry and soil conservation, help maintain soil fertility, increase crop yields, and enhance resilience to drought and other climate impacts. These practices integrate ecological principles into farming, promoting biodiversity and reducing the reliance on chemical inputs.

By preserving and restoring ecosystems, NbS and EbA also work for other societal challenges such as biodiversity loss and carbon mitigation. Forest restoration and reforestation efforts are prime examples of how these approaches can simultaneously address multiple societal goals.

As their implementation involves managing land and resources at a landscape scale, these adaptation options often require collaboration across sectors and community engagement to succeed. This collaborative aspect makes these approaches more complex to implement than traditional engineering solutions, but they offer significant long-term benefits by enhancing ecosystem services and building resilience to climate change in a sustainable and cost-effective way.



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Managing Floods by Restoring and Making Space for Riverbeds

Scale	Management Set-up
Multi-scale	Government-led
Time for Peak Performance	**Investment required**
Mid-term (5-15 years)	€€€€

Climate Hazard

KCS involved

Brief description

Riverbeds restoration, also referred to as room for the river projects, aim at restoring riverbeds to their (close to) original land area. Historical alluvial floodplains in developed countries have often been converted through flood protection dykes and/or embarkments, to facilitate agriculture, aquaculture and intensive forestry[1,2]. As a result, relatively narrow floodplains remain available for rivers[2,3], which has resulted in higher flood peaks and large economic flood risks[2,4].

Riverbed restoration measures aim at (partly) reversing existing structural measures, thereby providing additional room for the river to flow and restoring the natural hydrologic benefits of floodplains[5]. The additional riverbed area is not flooded year-round but becomes flooded during high peaks, thereby providing additional space for the water to flow. For instance, in the Netherlands, it has been estimated that lowering the flood levels by 0.5m can translate into a factor 10 reduction in the probability of system failure[2].In practice, room for the river interventions also consists of technical measures like the strengthening of dikes (which are placed further away from the riverbed), measures within the riverbanks like lowering floodplains, and measures beyond the banks like dike relocation or 'repoldering'[6]

Expected Outcomes

- Restoring and re-expanding riverbeds to reduce flooding damages, number of affected populations and fatalities[2].

Key Enabling Conditions

- Alignment with current land-use planning and clear land tenure
- While investments highly depend on the scale of the project, interventions can range from moderate to very high.
- Often, compensations for land use change needs to be done to private land owners.
- Understanding how floods play an important role in ecosystem health going beyond just associated risks[5]
- Co-production and/or intensive collaboration with NGOs and civil society[5]
- Establishing political commitment and ensuring strong leadership in the project, as this will ensure that decisions made through the collaborative process are also translated into formal decision-making[5,6]
- Mobilizing considerable time and resources not only for implementation, but also monitoring and assessment[4]
- To ensure that the projects go beyond just flood risk reduction, projects should formulate dual objectives, thus explicitly combining flood risk reduction with e.g. spatial quality[6] (as in the Netherlands case).

Synergies and Additional Benefits

- Increasing infiltration of flood water and nutrient cycling[5]
- Carbon sequestration[5]

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- Supporting biodiversity conservation, particularly birds[8]; invertebrates and fish[5]
- Livelihood diversification opportunities like fishing, tourism, reed harvesting and seasonal livestock grazing[5,9]
- Improving water quality[5,10]
- Provision of additional recreational space[5]
- Economic benefits associated with ecosystem services provision[11]
- Groundwater recharge[15]

Limitations and Constraints

- Suitable topography and sufficient land available [5]
- Additional investments for land use change and required compensatory measures [4].
- Political barriers related to the restoration process[4].

Potential Trade-offs and Adverse Effects

- Low public buy-in, especially when stakeholders affected by the intervention have not been effectively involved in the project and or the associated compensations.
- Increase of social conflicts and protests against the widening of river beds[6].

Example of Success

Room for the river ('Ruimte voor de rivier') project in the Netherlands: a national-scale level governmental project started in 2005 following extreme high waters in 1993-1995[12]. The project was centrally coordinated, but its implementation was decentralized and involved municipalities, provinces, water boards and Rijkswaterstaat[6]. The first phase of the interventions was completed in 2017 and lowered flood levels by 0.3m per year on average. This has partly been executed by adding 4400ha of extra floodplain area along the Rhine branches within the Netherlands territory. The next phase of the project involved implementing the project along the Meuse river[2]. The project signifies a paradigm shift in Dutch water management from fighting against water to working together with water[3]

Yolo Bypass in California (USA): this is a system of multiple flood bypasses constructed to facilitate the transport of waters around cities within the Sacramento Valley[5]. The bypasses are not flooded year-round, but are designed to only flood during large floods and can quickly drain excess water away from the system. The bypasses are intensively farmed during the dry season[13], and provide habitats to waterbirds and native fish[13,14] during the wet season.

Isar River restoration project ('Isarplan') in Munich, Germany: this is an 8km long river restoration project within the city of Munich[5]. In this project, flood risk has been reduced by setting back levees from the active channel and by raising them in height, thereby increasing the river's conveyance capacity throughout the city (river width expanded from 50 to 90m).

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Natural Ventilation Grids: Combatting the Urban Heat Island Effect with Green and Blue Infrastructure

Scale	Management Set-up
City	Government-led
Time for Peak Performance	**Investment required**
Mid-term (5-15 years)	€€€€

Climate Hazard

KCS involved

Brief description

Natural ventilation grids are continuous corridors that facilitate the inward and outward flow of air through the city center[1,2]. These corridors are composed of interconnected linear landscape elements such as water bodies and green areas, serving as cooling sources[1]. While vegetation contributes to this cooling effect through transpiration and shading, water bodies contribute to reducing temperature by absorbing heat from the air and releasing it slowly in the nighttime[1,3]. These grids play a significant role in mitigating urban heat by introducing cooler, fresher air from the countryside to urban heat hotspots[4,5], resulting into a land surface temperature reduction between 2°C to 4°C in summer[1]. To maximize wind circulation and the cooling effect, it is crucial to consider the optimal spatial distribution of green spaces, rivers, lakes, and ponds[1,2,3]. Rather than dense vegetation, these green grids consist of half-open spaces with scattered trees and blue infrastructure, allowing wind to circulate freely[3,4].

Expected Outcomes

- Reduce urban heat and regulate microclimate[1,2,3].

Key Enabling Conditions

- Civil and multi-stakeholder, including representatives from the districts, companies, charities, public authorities, urban planners, architects, academia, NGOs, and grass-roots organisations[5]
- A variety of funding mechanisms and Private-Public Partnerships[5]
- High investment capacity[5]
- Budget for an extensive consultation process [5]
- Research capacity, information, and knowledge of local conditions, especially on heat[6]
- Building codes and zoning regulations fostering climate-positive transformation[6]
- Cross-collaboration between local departments[6]
- Having a robust and science-based model[8]

Synergies and Additional Benefits

- Enhance water retention
- Carbon sequestration
- Improve liveability and well-being
- Increase public space
- Space for recreation
- Support biodiversity
- Improve air quality
- Multifunctional spaces
- Noise reduction

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Limitations and Constraints

- Densely compact urban forms, impervious surfaces, and high-rise buildings may hinder not only the deployment of this option but also its performance[1]
- Limited data availability to model and identify ventilation potential[1]
- Limited space available for constructing water bodies or green areas, especially in heavily dense built-up areas[5]

Potential Trade-offs and Adverse Effects

- Increasing maintenance costs of public spaces.
- Add stress on the water demand during the dry seasons (irrigation).
- Limitations on real estate, traffic, and other developments.
- Loss of potential tax revenue from construction.
- Exacerbate housing costs and needs.

Example of Success

The transformation of the Lee Valley Regional Park (London) was an ambitious initiative that linked East London to its surrounding environments (including the Green Belt and the Thames) through an integrated network of green and blue infrastructure. Stretching over 40 km and encompassing 61 hectares, this park not only contributes to address heat waves and increasing urban air temperature but also improved air quality, water retention, human health and biodiversity. A once-neglected industrial area, it is today a revitalized vibrant and resilient hub for residential, economic, cultural, and ecological activities.[4,5]
Similarly, the city of Stuttgart developed a series of planning and zoning regulations aimed at preserving and expanding open spaces and green areas in densely built-up districts. The strategy focused on enlarging and connecting green spaces, as well as preserving valleys and hillsides from development. As a result, the city now boasts a network of green ventilation corridors designed to mitigate hotter summers and more frequent heatwaves.[6,7,9]

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Image source: created by OpenAI's DALL-E

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Floodable Parks to Increase Coastal Resilience

Scale: District

Management Set-up: Government-led

Time for Peak Performance: Mid-term (5-15 years)

Investment required: €€€€

Climate Hazard

KCS involved

Brief description

Flood-resilient coastal parks are designed as communal recreational spaces as well as a part of the urban water drainage system.

These parks can be effective in mitigating risks from sea-level rise and heavy rainstorms, minimizing flood damages. This type of green infrastructure, as well as other similar urban Nature-based Solutions (e.g. rain gardens, retention ponds, constructed wetlands, or swales), can retain or slowly release water to prevent runoff or storm surges from causing catastrophic flooding[1].

Typically, these parks are previously developed spaces - whether for industrial, commercial or residential purposes - that have suffered repeated flood damage over time and whose original use no longer serves their intended function.

Although they are often created by public entities, it is not uncommon for a private project to include them as part of a larger design. They are most common along riverbanks.[2]

Expected Outcomes

- To rehabilitate a no longer used area.
- To create a public space that has multiple functions (cultural, recreational, etc) for the community.
- To improve the flood resilience of the coastal area where it is located.
- To recover and restore the surrounding deteriorated ecosystem.

Key Enabling Conditions

- Knowledge of coastal ecosystems, and economic activities in the surroundings
- Establishment of agreements with surrounding population
- Strategic plan for sustainable area development
- Knowledge of coast’s history and cultural heritage
- Budget for maintenance

Synergies and Additional Benefits

- Tourism and recreation
- Air pollution mitigation
- Biodiversity conservation
- Soil formation
- Educational value

Limitations and Constraints

- Land acquisition
- Misalignment with city’s urban plan
- Low use of facilities by community due to perception concerns
- Limited effectiveness in very large floods or storm surges.

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Potential Trade-offs and Adverse Effects

- Conflicts with stakeholders and other land-use needs (e.g., commercial, industrial)
- High maintenance to preserve functionality

Example of Success

The Shenzhen Bay Coastal Park Phase 1 in Guangdong Province, China concluded nearly three decades of continuous coastal development, where the bay was incrementally filled with materials mined from nearby mountains to support the city's evolution from fishing villages to a massive manufacturing center. Ironically, the park's construction involved filling 87.6 acres of the bay to create a narrow strip of parkland between the newly-built coastal parkway and the water's edge. The Coastal Park serves as a vibrant, tropical green belt that blends natural and artificial ecologies, featuring carefully designed landscapes alongside two restored mangroves and intertidal mudflats. This project plays a crucial role in redefining Shenzhen as a green, livable city of 18 million, recognized for its cosmopolitan nature as well as its manufacturing prowess. The park transforms the bay into a central hub of urban life rather than a mere boundary, offering stunning views of Shenzhen and Hong Kong across Shenzhen Bay.

Also, the Hunter’s Point South Park in Long Island City, New York showcases innovative flood resilience and urban renewal. Developed on a 30-acre former industrial site, the park aims to protect against rising floodwaters and revitalize the area. Its innovative design features an elevated riverwalk that safeguards 1.5 acres of new wetlands, which absorb and gently release floodwater. Additionally, a tree-filled peninsula becomes an island during high tide, complemented by a 36-foot-wide viewing platform offering 360-degree views of Brooklyn, Manhattan, and Queens. The park also includes a multipurpose synthetic turf oval lawn, encircled by a concrete retaining wall, serving as an overflow catchment area for flood control. Demonstrating its resilience, the park successfully withstood Hurricane Sandy in 2014.[3,4]

Beyond enhancing flood resilience, New York City aimed to provide affordable housing and better connect the city to the waterfront through this development. Phase 1 of the project cost about $66 million, while phase 2 cost approximately $100 million.[5]

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Image source: created by OpenAI's DALL-E

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Green Infrastructure to Mitigate Climate Risks and Enhance Urban Resilience

Scale	Management Set-up
Multi-scale	Government-led
Time for Peak Performance	**Investment required**
Mid-term (5-15 years)	€€

Climate Hazard

KCS involved

Brief description

Green Infrastructure (GI) comprises engineered systems that imitate natural processes. These nature-based solutions address issues typically managed by traditional grey infrastructure. GI increases urban resilience to climate change by reducing the urban heat island effect, managing stormwater, and improving air quality. For instance, green roofs and urban trees can lower surface and air temperatures, reducing energy demand for cooling and mitigating heat stress[1].

Innovative GI solutions such as permeable pavements, rain gardens, and constructed wetlands help manage stormwater runoff, reducing the risk of flooding[2]. These systems mimic natural water cycles, enhancing water infiltration and purification.

Also, GI supports biodiversity and ecosystem services, contributing to healthier urban environments. By providing habitats for various species, green spaces enhance ecological connectivity and resilience against climate impacts.

In urban planning, GI represents a shift from traditional gray infrastructure to more sustainable and multifunctional solutions. Examples of GI include green roofs and facades in densely populated urban areas, permeable roads and pavements, high-quality vegetative margins and buffer strips, bioswales, and other sustainable urban drainage systems such as water channels, retention ponds, wetlands, and ditches for stormwater management[3] which fosters sustainable development and long-term climate resilience.

Expected Outcomes

- To improve the management of stormwater and reduce the burden on general drainage systems.
- To reduce the urban heat island effect.
- To mitigate the urban flooding risks.
- To improve the resilience of the city against climate change.

Key Enabling Conditions

- Ownership of land, building, or infrastructure.
- Permits and authorization for the modifications.
- Community buy-in.
- Availability of financial investment and budget for future maintenance.
- Alignment with land-use and urban planning and development strategies.
- Buy-in and collaboration of the private sector.

Synergies and Additional Benefits

- Increased energy efficiency
- Provision of wildlife habitat
- Improved air and water quality
- Improved mental and physical health due to green spaces

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- Increased liveable spaces in the city

Limitations and Constraints

- High maintenance costs associated.
- Insufficient extension of urban areas to be modified.
- Weak community buy-in.
- Structural and engineering impediments (e.g., load capacity of certain structures to support vegetation and humidity).
- Limited performance against extreme events (e.g., slow infiltration rates).

Potential Trade-offs and Adverse Effects

- Conflicts with existing land use and associated users.
- Competition of space for other uses and developments (e.g., housing, industry).
- Add financial burden for municipalities related to maintenance, and may restrict public budget for other development needs.
- They can take longer to implement and achieve their full benefit than conventional grey infrastructure.
- Improperly designed or poor maintained GI can become a source of vectors and pests, which may increase risks to human health.

Example of Success

The "Adapting to heat stress in Antwerp, Belgium" project focuses on mitigating urban heat through various green infrastructure initiatives. Detailed thermal mapping identified urban heat islands, leading to targeted interventions like green roofs on new or renovated buildings, permeable pavements, fountains, ponds, tree planting initiatives in renovated public spaces, and the use of citizen science to map and measure heat stress. The project not only aims to reduce heat stress but also to improve overall urban livability, enhance biodiversity, and engage the community in climate adaptation efforts. These measures help manage stormwater, reduce energy consumption, and provide habitats for wildlife, contributing to a more resilient urban environment.[4,5]

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Peri-Urban Agriculture: Green Shields to Protect Cities from Climate Change

Scale: City

Management Set-up: Community-led

Time for Peak Performance: Short-term (0-5 years)

Investment required: €€€€

Climate Hazard

KCS involved

Brief description

Peri-urban agriculture (PUA) consists of developing and stimulating sustainable and resilient small- and medium-scale agricultural practices in the proximity of cities. PUA leverages agricultural activities to create buffers that protect urban environments from the adverse impacts of climate change. These practices can allow agricultural land to act as a, for example, floodwater receptacle and thus prevent flooding, stimulating local water storage and infiltration[1,2,3.] It can also reduce the urban heat island effect by providing green spaces that cool the surrounding areas[4]. By promoting local food production, PUA reduces dependency on long supply chains, which can be vulnerable to climate-related disruptions[5]. Further, it can provide employment opportunities and promote community engagement, involving local residents in farming activities. For a successful implementation, this option must consider alignment with existing and future urban development plans.

Expected Outcomes[1,2,3]

- Build urban resilience and climate-proof cities
- Tackle the heat island effect through additional greening
- Increase adaptive capacity of both local farmers and city dwellers
- Improve food access and urban food production
- Increased income for local farmers

Key Enabling Conditions[6]

- Availability of (traditional) farming knowledge, practices and experiences of local farmers and/or project staff.
- Seed inputs, solid waste management and agri-technologies.
- Available financial schemes for farmers, particularly at the beginning.
- Local farmers and citizens involvement and dissemination activities.

Synergies and Additional Benefits[7]

- Climate change mitigation through sustainable farming practices and increased peri-urban green spaces
- Increased urban biodiversity due to creation of green corridors and habitats beneficial for insects
- Human wellbeing benefits due to increased green space, such as mental and psychological health and stress recovery
- Increase social inclusion and community building by creating a sense of belonging
- Urban renewal and regeneration through the requalification of vacant/abandoned spaces for farming activities
- Conservation of common property resource areas in the peri-urban zone, including open land, water bodies, forests and pastures

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Limitations and Constraints

- Limited space availability and land competition with other sectors.
- Misalignment with current land use planning and zoning regulations and associated laws (eg., food safety regulations, water quality, etc.)
- Blocking or delays due to unclear land ownership or tenure.
- Technical complications related to soil and water quality, water access, and low labour/manpower available
- Challenges related to competition with large producers and market access
- Useful up to certain levels of flooding: beyond its limit the performance in risk reduction decreases or disappears altogether

Potential Trade-offs and Adverse Effects[8,9]

- Process gentrification of the (peri-)urban land
- Reduction of space for other urban expansion developments (industrial, commercial, infrastructure, and residential areas)

Example of Success

South Milan Agricultural Park (Milan, Italy), made up of agricultural areas, forested areas, rivers and historic estates (total of 47,000he) where silviculture, crop production, and livestock breeding are practiced. The transformational nature of the case consists in its objective to bring together protection of ecosystems, connection of city dwellers with nature, sustainable local food production and tourism. Products from the park can be purchased both within the park limits and at a local organic market in the city center twice a month[10].
The case of the horta-(agricultural belt) of Valencia is also a known example of successful PUA, which allows local food production in semi-arid climatic conditions. In particular, it showcases how resilient PUA has been practised traditionally and does not need to require new technologies. The irrigation system consists of a gravity-fed irrigation method which has historically allowed the cultivation of fruits and vegetables in a dry area[2].

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Hydrological Reconnection and Habitat Improvement: Restoring Natural River Values

Scale
Regional

Management Set-up
Government-led

Time for Peak Performance
Mid-term (5-15 years)

Investment required
€€€

Climate Hazard

KCS involved

Brief description

Hydrological reconnection and habitat improvement initiatives focus on restoring natural water flows and enhancing ecosystems, thus reversing a degradation practice that was common in the late 20th century. While these projects aim to undo past human interventions like channelization and re-establish the connectivity between rivers and their floodplains or wetlands, an innovative and transformative approach makes use of an interdisciplinary focus that goes beyond combining ecology and hydrology. Doing so reduces the flood risk but can unlock additional benefits such as an increase in biodiversity, improvement of water quality, or space for additional recreational areas.

Efforts involve various actions such as reopening natural river courses, creating or restoring wetlands, removing barriers, and enhancing riparian habitats, where nature based solutions are given higher relevancy. Additionally, innovative methods such as the use of hydraulic complexity metrics (explaining habitat heterogeneity and evaluating ecological patterns in rivers) or the analysis on how different catchments respond to climate variability (e.g. Base Flow Index Analysis).[2, 3, 4]

Successful implementation, including the realization of additional benefits, requires collaboration between government agencies, local communities, and environmental organizations. Further, to integrate advanced risk assessment, climatic projections, innovative water management strategies or fitting, synergistic nature based solutions requires inter- and cross-sectoral engagement.

Expected Outcomes

- Flood mitigation and restore the hydric regulation of the water stream[5]
- Enhanced biodiversity and ecosystem services provision[6]
- Improved water quality[7]

Key Enabling Conditions

- Comprehensive knowledge of the local hydrology, geomorphology, and ecology.
- Involvement of local communities, landowners, environmental groups and governmental agencies.
- Political support and buy-in of decision-makers
- Coordination with larger watershed management plans to ensure comprehensive and sustainable outcomes.
- Supportive legal and regulatory framework that facilitate restoration activities.

Synergies and Additional Benefits

- Enhance visual appeal of natural and restored landscapes
- Improve liveability of a region
- Improved habitat connectivity

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Limitations and Constraints

- Insufficient financial resources for a large-scale and long-term restoration process, not only for the high upfront costs but also for periodic maintenance expenses.
- Limited availability of technical expertise and a comprehensive understanding of hydrological and ecological systems.
- Lack of expertise and sensitization of stakeholders and decision-makers
- Conflicts and legal hurdles related to land ownership.
- Opposition and low acceptance from local communities and stakeholders due to perceived negative impacts on their livelihoods, property values, or way of life.

Potential Trade-offs and Adverse Effects

- Ecological restoration is complex[8]; unforeseen (environmental) variables or implementation challenges pose the risk to alter the desired outcome.
- Restoring natural floodplains can increase the risk of flooding in nearby areas in the near and mid-term, necessitating careful planning.
- Relocation and conflicts associated with current land uses.

Example of Success[1]

The Arga River in Spain had a meandering course that was straightened and channelized in the 1970s to contain floods. However, this intervention proved insufficient and, coupled with climate change, have caused ecological imbalances and damage to the area.
The river restoration project of the lower Arga River aims to recover the river's natural values, including the functionality of the meanders to reduce flood risk and improve habitats, especially for species like the European mink and otter. Two phases of the project have been executed, including actions such as channel opening, water quality improvement, wetland creation, and naturalization of affected areas. The involvement of various stakeholders, including local and regional governments, has been crucial in project execution. Outreach actions have been conducted to engage the local community. The project is considered successful so far, with evident improvements in drainage capacity and reduced flood damage. The total budget exceeds 9 million euros, and it is part of the National River Restoration Strategy and the Flood Risk Management Plan, aiming to provide a novel approach to flood risk management and river ecosystem restoration. The ultimate intention of this strategy is replicating restoration measures in other areas of the basin.

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Wetlands Restoration: Protecting Shorelines from Coastal Floods

Scale	Management Set-up
Regional	Government-led
Time for Peak Performance	**Investment required**
Mid-term (5-15 years)	€€

Climate Hazard	KCS involved

Brief description

Coastal wetlands and marshes have historically often been destroyed for agricultural reasons, which has resulted in elevation loss through decrease of sediment deposition.[2,3] Restoring and protecting them can help surrounding areas to become more resilient against sea level rise and coastal floodings.[1] To restore marshes, strategic breaching of levees can be implemented, sometimes supported by sediment enhancement[4,7], thereby reopening space for sedimentation and revegetation.[3] In addition to risk-reduction benefits, the measure can provide transformational potential through increased biodiversity and habitat provision, carbon sink potential, recreational areas or alternative farming methods.[5,7,17]

Another type of wetland is peatlands, which have similarly increasingly been lost due to a combination of land use change, peat extraction, agriculture and forestry.[6] The loss of peatlands can result in altered water flow regimes, land subsidence, increased flood and fire risk and reduced resilience of ecosystems.[9,10] Conversely to coastal wetlands, rewetting and restoring peatlands usually entails blocking drainage ditches with dams, thereby stopping water from running off and uprising the groundwater table.[11,12]

Expected Outcomes

- Creation of a natural barrier for floods[13,14]
- Prevention of coastal erosion[15] (salt marshes)
- Increased water retention (in comparable level as artificial water retention systems)
- Regulation of water cycle and resilience against water stress[1,10,16]
- Prevention of peatland fires

Key Enabling Conditions

- Availability of water (fresh for peatlands, salt- or brackish for salt marshes)[5]
- Involvement of sensitized stakeholders and government
- Availability of land, or acceptance of land loss, as more land will be taken up by wetlands

Synergies and Additional Benefits

- Serving as carbon sequestration and storage areas and contributing to climate mitigation by reducing GHGs emissions[5,7,17]
- Increasing biodiversity and resilience of wetlands ecosystems, by serving as a nursery ground for birds, and fish and, in marshes, fish and shellfish[7,18,19]
- Provision of food sources through increased biodiversity or saltmarsh tolerating livestock (e.g. longhorn cows)[7]
- Increased recreational spaces[7]
- Increase in water quality

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Limitations and Constraints

- Restoration of wetlands can become more difficult, more expensive, and less successful when particularly damaged areas are to be restored. The restoration area should thus be carefully chosen to maximize benefits.
- Requires a minimum permanent water level to function, particularly in the case of peatlands

Potential Trade-offs and Adverse Effects

- Potential eutrophication of the ecosystem[8]
- Loss of farming land with associated costs of land purchases and loss in cropping area[16]

Example of Success[7]

The coastal part of the Somerset levels and moors on the Steart Peninsula in the United Kingdom has started its transformation in 2014. With breached embankments, the tide was able to cover about 300 hectares of former agricultural, low-lying land, depositing silt as well as plants typical for salt marshes. With this nature-based solution it was possible to protect, living, business and industrial areas. However, since 2014 additional benefits have manifested. The saltmarsh creeks that were formed through the tide have become habitat for fish stocks such as the sea bass. The area has also provided socio-economic benefits e.g. by introducing the saltmarsh tolerating longhorn cows or by providing additional recreational spaces.

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Sustainable Aquaculture for a Climate-Resilient Future

Scale
Regional

Management Set-up
Public Private Partnership

Time for Peak Performance
Mid-term (5-15 years)

Investment required
€

Climate Hazard

KCS involved

Brief description

Aquaculture, the farming of aquatic plants and animals, is economically and socially significant for many regions and is the world's fastest-growing food sector[1]. However, it faces challenges from climate change, such as rising water temperatures, altered oxygen levels, ocean acidification, and extreme weather events[2,3]. To ensure a climate-resilient future, aquaculture must integrate sustainable practices that align with conservation goals, reducing pressure on wild fish stocks, providing healthy food, creating jobs, and supporting rural economies[1,4,5]. This involves the development of multi-purpose and well-designed management strategies, consisting of:

- Nature-Based Climate Solutions: actions to protect, conserve, restore, and sustainably manage aquatic ecosystems while supporting the cultivation of species for food security and livelihoods. These should also be responsive to and empowering for the most vulnerable[6].
- Conservation Aquaculture: using human cultivation of aquatic organisms for the planned management and protection of natural resources. It can provide wild harvest alleviation, particularly for over-exploited species, and ecosystem services such as improved water quality and reduced coastal erosion[4].
- Hybrid production systems: a combination of different production systems. For instance, employing mariculture techniques in fisheries for restocking endangered marine species populations and flooding the market with farmed products to reduce poaching of endangered species[7]. Also, integrating seaweed farming with other aquaculture practices can act as an important source of carbon sequestration, benefiting coastlines affected by eutrophic, acidic conditions or high nutrient loads[8].
- Integrated Spatial Planning[7]: identifying suitable locations for aquaculture that minimize environmental impacts, avoid conflicts with other marine and coastal activities, and support the long-term viability and resilience of aquaculture operations. This includes mapping sensitive habitats and assessing sites' carrying capacities.

Aligning aquaculture farming practices with sustainability objectives is particularly pressing to ensure the effective, resilient, equitable, and inclusive growth of the sector.

Expected Outcomes

- To improve adaptive capacity of the marine aquaculture sector against climate change
- To contribute to sustainable, healthy, and climate-resilient food systems

Key Enabling Conditions

- Promoting investment in research, development, and innovation (R+D+I)[9].
- Active engagement and collaboration among all stakeholders (government, R+D+I agents, business, and society) in adaptation planning [9].
- High-quality data and expertise ensure trust and relevancy of impact analysis.
- Adequate financial resources are necessary for plan development and deployment.

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- Policies, regulations, and incentives to facilitate access and adoption, particularly for small and medium-scale aquafarmers[5,10].

Synergies and Additional Benefits

- Increased fish stock productivity
- Advancement of scientific research
- Fostered institutional collaboration and co-agency
- Secure livelihoods and support food security as well as supply chain stability
- Improved business continuity
- Restoration of natural areas
- Support biodiversity and ecosystem services provision

Limitations and Constraints

- Lack of specific studies on relevant species and systems.
- Difficulty analyzing impacts due to the complexity of climate change effects.[2]
- Complex collaboration among stakeholders hindering identification and integration of all relevant groups.

Potential Trade-offs and Adverse Effects

- Some adaptation strategies, such as expanding aquaculture operations into new areas or intensifying production in these new areas to meet production targets and the sector's economic profitability, may conflict with conservation goals.[11]

Example of Success

The AQUADAPT project[9] addresses the effects of climate change on Spain's marine aquaculture sector and its socio-economic impacts. Focusing on sea bream, sea bass, and turbot cultivation, AQUADAPT delves into climate change's repercussions, designing adaptation strategies to bolster sectoral resilience and improve sustainability. AQUADAPT identifies key climate change-related variables impacting species and systems—temperature, oxygen levels, wave action, and extreme events— and collaboratively engages academia, industry, and government to craft adaptation measures for the 2050 time horizon, filling the void of a national adaptation plan. AQUADAPT's methodology can be replicated to other species, systems, geographical areas, and sectors such as agriculture.

The Innovating for Equity (I4E) Initiative[12] aims to promote inclusive and resilient aquaculture nature-based climate solutions in the Asia-Pacific region. It focuses on action-based research to develop sustainable aquaculture systems for climate-vulnerable communities, including marginalized groups. The Initiative addresses climate change, biodiversity loss, and food insecurity through applied research. It champions multisector partnerships by working with 35 institutions, including universities, civil society organizations, governments, and the private sector, and engaging community, scientists, farmers, experts, and other stakeholders.

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2.3 Governance and Institutional Measures

Governance and institutional measures are critical adaptation strategies that focus on the policies, regulations, and frameworks necessary to facilitate effective climate adaptation. These measures aim to enhance adaptive capacity by establishing clear guidelines, promoting coordination among stakeholders, and integrating climate considerations into decision-making processes.

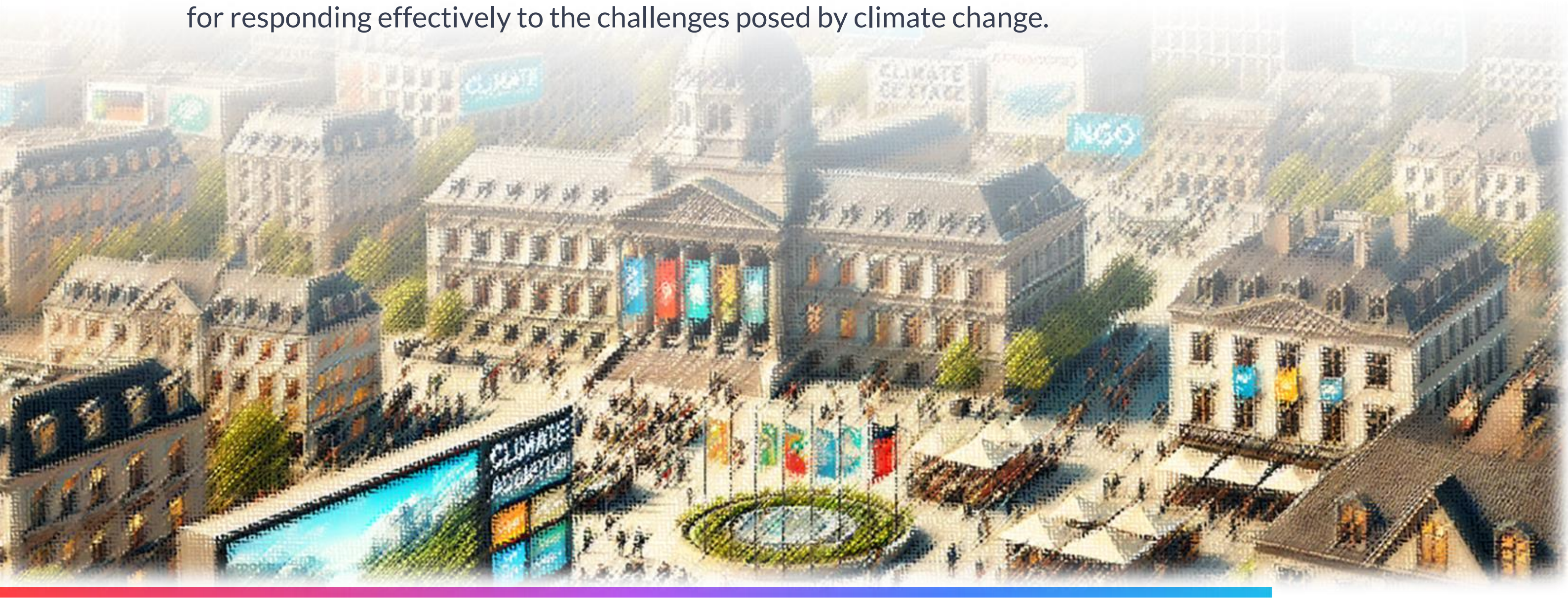
A fundamental aspect of governance and institutional adaptation is the creation and revision of policies and regulations that address climate risks. This includes the development of comprehensive adaptation strategies and plans that outline priorities, set targets, and allocate resources for adaptation efforts. By embedding climate adaptation into sectoral planning and policy-making, governments can ensure that climate risks are systematically addressed across all areas of governance.

Effective governance also involves establishing coordination mechanisms among various stakeholders, including government agencies, private sector actors, non-governmental organizations, and local communities. Creating platforms for stakeholder engagement and dialogue helps facilitate the exchange of knowledge and best practices, fostering collaboration and joint action on adaptation initiatives. These mechanisms are key for aligning efforts and ensuring that adaptation measures are implemented in a cohesive and integrated manner.

Institutional measures often involve the development of instruments to support adaptation projects and initiatives. By, for example, reducing barriers to investment and clarifying land tenure and legal rights over resources, these instruments enable investment in resilience-building activities and long-term adaptation strategies.

By fostering an enabling environment for adaptation, governance and institutional measures play a pivotal role in building resilience to climate change. They also promote accountability and transparency, enhancing the effectiveness of adaptation actions and ensuring that resources are used efficiently.

Overall, governance and institutional measures provide the enabling environment for adaptation through frameworks and processes needed to support adaptive actions across all sectors and scales. These measures ensure that adaptation efforts are coordinated, comprehensive, and aligned with broader development goals at various levels. Thus, integrating climate considerations into governance structures and institutional processes is foundational for responding effectively to the challenges posed by climate change.



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Urban Green Plans to Enhance Urban Resilience

Scale

City

Management Set-up

Government-led

Time for Peak Performance

Long-term (+15 years)

Investment required

€€€€

Climate Hazard

KCS involved

Brief description

Urban Greening Plans (UGP) represent a comprehensive and systematic strategy for integrating nature into city and infrastructure design to enhance environmental resilience and community well-being. It can help to understand what is already there, what needs to be improved and what needs to be tackled.

UGPs focus on creating a network of green spaces that provide a range of ecosystem services and benefits to cities, including climate change adaptation. This involves transformation and improvement of urban spaces and infrastructure for enhancing climate resilience while addressing other respective urban challenges. Multifunctional Nature-based Solutions (NbS), can e.g., help manage stormwater runoff, reduce heat island effect, and even improve water and air quality, while supporting an increase in biodiversity.[1, 4]

To make UGPs impactful, governance, regulatory and financing schemes as well as guidance needs to be ensured. This entails for example an *Urban Greening Strategy* or *Plan*, a stakeholder participation strategy, the prioritization of nature and biodiversity or the recognition of co-benefits in finance and business. Successful implementation includes a co-development with stakeholders and the public and may as well include collaboration across departments.[4,5]

Expected Outcomes

- Enhance urban resilience and reduced vulnerability to climate change impacts (e.g., extreme heat, heavy rainfall, floods).
- Improve biodiversity and ecosystem services within urban areas.
- Reduction in urban heat island effects and improved microclimate.

Key Enabling Conditions

- Strong government support and policy frameworks for urban greening.
- Community and stakeholder participation; cross-sectoral collaboration, including NGOs, local businesses or academic institutions.[5]
- Adequate funding and resources for implementation and maintenance.
- Expertise in landscape architecture, urban planning, and ecology.
- Sensitization of the finance and business sector for urban greening measures and NbS[4]

Synergies and Additional Benefits

- Improved air and water quality
- Enhanced community cohesion, recreational opportunities, mental health improvements.
- Increased property values
- Contribution to climate change adaptation.
- Enhance quality of life and well-being for urban residents.

Limitations and Constraints

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- Initial planning and implementation can be expensive.
- Ongoing maintenance and management needed.
- Effectiveness may vary depending on local conditions.
- Limited urban space.

Potential Trade-offs and Adverse Effects

- Conflicts with previous land use
- Additional burden on the public budget due to high maintenance costs
- Additional pressure on the water demand due to the need for irrigation during summer season.
- Increased property prices

Example of Success

Vitoria-Gasteiz in Spain applied a UGP concept to its strategic planning and urban management. It was launched in 2012, aiming to regenerate degraded areas through eco-design techniques, improve connectivity of urban green areas and promote public use of green space. This system includes the green belt, parks, gardens, tree-lined avenues, green sports areas, urban horticultural gardens, streams, and green facades and roofs, among other components.

The UGP aims to address heatwaves (urban heat island effect) but also other climate risks such as flooding, and air pollution, enhancing the city's resilience by improving biodiversity, managing stormwater, and reducing temperatures. It also provides social benefits through recreational spaces and community engagement.[2,3]

To implement such, Vitoria-Gasteiz developed a Green Urban Infrastructure Strategy which was co-developed through public and stakeholder participation. Measures taken include the transformation of green spaces, an increase in biomass and trees, the restoration of a river corridor or the promotion of peri-urban agriculture and green facades, to name a few.[1]

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Cool Neighbourhoods Strategy: Combating Extreme Heat

Scale	Management Set-up
Neighbourhood	Government-led
Time for Peak Performance	**Investment required**
Mid-term (5-15 years)	€€

Climate Hazard	KCS involved

Brief description

Cool Neighborhoods is a comprehensive citywide strategy aimed at addressing extreme heat and its impact on residents, aligning with the city's broader climate action plans like the 2015 Paris Agreement[1]. Adaptation strategies include launching climate risk training for home health aides, encouraging residents to check on at-risk neighbours through 'Be-a-Buddy', partnering with health and weather reporters for preventative messaging, advocating for Low-income Home Energy Assistance Program reforms, improving residential ventilation and window operability, and enhancing signage and programming at cooling centers.[2,3]

The combination of these diverse strategies that reinforce each other is an innovative way to reduce heat risks. The focus on community resilience building and engaging communities in green infrastructure fosters co-benefits such as encouraging and harnessing relationships, bringing in local knowledge and novel ideas and building community self-determination[4]. Moreover, concentrating on the most vulnerable communities helps to equalise the variations in microclimate seen across neighbourhoods of varying economic statuses, thereby advancing climate justice. Monitoring strategies involve collecting data to shape inclusive, health-focused climate policies.

Expected Outcomes

- Reduce urban heat and improve preparedness to address impacts from heatwaves[1]

Key Enabling Conditions

- Comprehensive data collection and analysis: Gather local climate data to inform targeted interventions and measure their effectiveness.
- Stakeholder collaboration: Engage a wide range of stakeholders, including local government agencies, community organizations, health experts, and climate scientists.
- Funding and resources: Allocate resources for targeted projects such as street planting, training of support aide, green infrastructure, and CoolRoofs.
- Community engagement and education: Implement community programs, such as *Be a Buddy*, NYC to encourage residents to check on at-risk neighbours.

Synergies and Additional Benefits

- Create local economy
- Improve public health
- Increase climate knowledge
- Contribute to improved coping capacities
- Improve social cohesion
- Improve collective knowledge and public awareness
- Biodiversity benefits from green infrastructure

Limitations and Constraints

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- Limited effectiveness during extreme heat: while cool neighbourhoods can help mitigate heat, during extreme heat events, they may not be enough to keep people safe. Additional measures may still be necessary

Potential Trade-offs and Adverse Effects

- Upfront Costs: Implementing Cool Neighborhoods measures (e.g., planting trees, installing reflective surfaces) can be expensive which can be a hurdle for low-income communities or areas with tight budgets.
- High maintenance needs: infrastructure and cooling systems can be resource-intensive and require ongoing maintenance, otherwise they may lose their effectiveness.

Example of Success

In 2017, the Ney York City introduced Cool Neighborhoods NYC, its first heat resiliency plan, featuring strategies and programs backed by nearly $100 million in investments. These efforts have enhanced the City's tree canopy, established climate-risk training programs for community partners, and expanded cool roofs and other building-scale investments in the most heat-vulnerable communities. Guided by the Heat Vulnerability Index—a tool rooted in climate and racial justice that identifies the communities most at risk from extreme heat—these investments have been strategically targeted. Since 2017, the City has continued to build on Cool Neighborhoods NYC to ensure New Yorkers are well-prepared for the summer.[2] The NYC °CoolRoofs initiative, part of these efforts, trains local jobseekers to install reflective rooftops, reducing energy use and heat, with over 10 million square feet of rooftops coated since 2009 in the city's most heat-vulnerable districts.[3]

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Incentives for Rainwater Harvesting Systems in Cities: Reducing Domestic Water Demand to Combat Water Scarcity

Scale
Building

Management Set-up
Government-led

Time for Peak Performance
Mid-term (5-15 years)

Investment required
€€

Climate Hazard

KCS involved

Brief description

The management of rainwater represents an additional cost for cities' water management systems. In this context, many cities have introduced rainwater fees to cover these costs. In addition, cities have introduced rebates and other incentives to increase the adoption by private owners of Rainwater Harvesting Systems (RWHS)[1], as a measure to supplement rainwater management solutions in densely populated areas.

RWHS consist in capturing and storing rainwater and preventing its runoff, which comprises collection, storage, treatment and distribution of rainwater from roofs, rooftop terraces and impermeable surfaces to be used on site.[2]

A typical RWHS system consists of a rainwater catchment (mostly roof tops) a storage tank and treatment options (filters, disinfection).[3] RWHS applied at domestic level is an established technology that allows households and public buildings (such as school) to store rainwater for human consumption. When widely applied in a region, RWHS has the ability to buffer the effects of drought while maximizing water use efficiency.

RWHS are also suitable measures for rainwater management at the city level. They reduce surface runoff, reducing the burden on sewer systems and drinking water infrastructure. These systems first retain and then use rainwater, hence their effectiveness needs to be assessed both in ecological, economic and social dimensions.

Expected Outcomes[2]

- Reduction of vulnerability to water scarcity (drought).
- Flood mitigation in urban basins and reduced runoff during storms.
- Decreases in runoff peak flow, support to centralized water infrastructures and increased robustness and flexibility, reduced electricity use for water systems, among others.

Key Enabling Conditions

- High initial investment at the household level.
- Subsidies or grants to improve affordability.
- Clear water price regulations, specifically rainwater fee and rainwater rebates based on the amount of rainwater used.

Synergies and Additional Benefits

- Reduce the pressure on centralized water supply system, extending their lifetime.
- Reduce energy use
- Reduce soil erosion
- Reduction of pressures on the sewer systems (lower runoff discharges)
- Fostered entrepreneurship & innovation

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Limitations and Constraints

- High upfront costs for individual property owners [1]
- Unpredictable rainfall patterns can affect performance and return period.
- Limited space for installing the rainwater harvesting system. [2]
- Local laws regarding use of rainwater might restrict how much rainwater can be harvested and used[3]
- Limited local expertise and technical skills to install and maintain the systems.[3]

Potential Trade-offs and Adverse Effects

- Potential health risk due to the increase concentration of Escherichia coli and other bacteria in stored rainwater.[2]
- Increased vector breeding due to water storage, if not managed correctly.
- Overreliance on RWHS, especially in context with poor water infrastructure, can delay investment in public water services and further enhance water inequalities in a community.

Example of Success

In Australia, many states have introduced regulations and incentives for the installation of RWHS, in order to save on municipal water. Many Australian states are now required to have RWHS installed into new properties. Furthermore, under the Water for Future Initiative, the Australian Federal Government introduced a rebate scheme in 2009 to help owners purchase and install RWHS for non-potable purposes, a programme that ended in 2011. This resulted in 32% of the houses that met the standard requirements installing RWHS.[5]

The RWHS implemented in Semarang, Indonesia has been implemented as a means to reduce vulnerability to drought and flooding. The activity has resulted in a 30% reduction of water used during the rainy season, benefiting around 20,500 people in the city. It consists of a water tank used to collect water during the rainy season, which uses gravity for flow (no electricity needed). The water is available to be consumed during the dry seasons when there is a shortage of clean water.[6]

Regulatory changes in the German municipality of Bremen have created incentives to the collection of rainwater in private property. This translates in lower rainwater fees per m^2. To incentivise the use of these technologies for climate adaptation goals, the municipality is applying split fees, giving a refund if rainwater can infiltrate into the soil or if rainwater is used within the household. The city is also subsidising investment to the use of rainwater in toilets, garden irrigation and collection tanks.[7]

RWHS have been traditionally used in many areas of the world. However, when these systems are deployed at larger scale (e.g., city level), with innovative pricing structures and financial incentives (as in the city of Bremen), and associated to urban planning, they can have transformative effects in water management systems, as well as water use practices of citizen. Further, they can support novel ways of community-based water resource management, including responsibilities over water management and supply, as well as empowering communities to become more self-sufficient in the provision of water for domestic use.

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Image source: Rainwater catchment system| Appropedia.org

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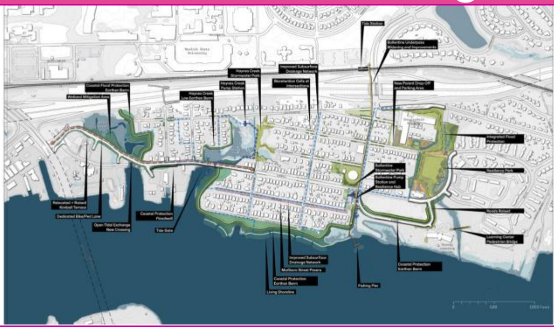
Urban Water Plans: Integrating Water into The Cityscape



Scale
City

Management Set-up
Government-led

Time for Peak Performance
Mid-term (5-15 years)

Investment required
€€€

Climate Hazard

KCS involved

Brief description

Urban Water Plans can allow adaptive and long-term water management within city limits and their surroundings. One way to develop a resilient water plan consists of identifying so-called 'rainwater cascades' within the system of interest. This approach involves identifying the main patterns of water transport, storage and loss within the city, and focussing on maximizing the amount of water collected at each 'layer' of the cascade. The water that is left then moves to the next step in the cascade, in such a way that only a minimum amount of water needs to be pumped out of the rivers at the end of the cycle. In an Urban Water Plan, identifying rainwater cascades helps spot key locations in the city that can optimize water collection and retention within the city limits[1]. In doing so, urban water plans allow cities and towns to develop a strategy to manage water within the urban area and its surroundings. To do so, the creation of public multi-purpose spaces where water is essential and visible is key.

Expected Outcomes

- Maximize the spatial qualities of water by activating existing (hidden) water systems, (re-) connecting open waters, facilitating water recreational activities and prioritizing water in landscaping for new city development project.[1]
- Limiting damage from flooding (e.g. new developments with the high climate scenario 2050 projection in mind).[1]
- Guaranteeing water availability; and increasing water quality.[1]
- Increasing water awareness by developing a water story for the city, sharing it with the citizens and building awareness on positive actions that can be taken.[1]

Key Enabling Conditions

- Financial and technical resources for the planning process.[1]
- Even with external collaborations, participation and effort will be required from the city government, in the form of provision of information on current water challenges and management approaches and sharing and formulation of challenges and objectives.[1]
- Awareness raising and social acceptance of the plan.[1]
- Citizens and stakeholder engagement activities for preparing the plan.[1]
- Budget available for implementing actions.[1]
- Private capital to invest in additional management actions (e.g., infrastructure).[1]
- For the plan to ensure long-term resilience, it is important to build synergies with other themes (e.g. energy transition, social protection) and other sectoral plans (e.g., industry, agriculture, environment).

Synergies and Additional Benefits[2]

- Health benefits associated with decreasing temperatures[5]
- Groundwater recharge due to increasing local water retention[3]

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- Increased wellbeing associated with additional blue-green infrastructures and larger space for water recreation within and surrounding the cities[4]
- Improved aesthetic and amenity of the city

Limitations and Constraints

- Infrastructure Complexity: Designing and building the necessary infrastructure for rainwater cascades can be complex. It requires precise engineering to ensure efficient water flow and storage without causing flooding or waterlogging.
- Space Requirements: Urban areas often have limited space, which can restrict the installation of large-scale rainwater harvesting and storage systems.
- Integration with Existing Systems: Integrating new rainwater cascade systems with existing urban water infrastructure can be challenging. It requires careful planning to ensure compatibility and avoid disruptions

Potential Trade-offs and Adverse Effects

- Potential health-related issues due to the increase of mosquito's populations, particularly in warmer climates[6,7]
- Costs associated with stricter water quality monitoring and safety measures for swimmers, due to increase in water recreation activities[6,7]
- Given that regular maintenance is essential to ensure the systems function properly, this can become an operational and financial burden for the local institutions.

Example of Success

Waterplan Antwerp (Belgium)[1]: the project was designed starting in 2018 for the city of Antwerp to collectively organize information provision. The innovative and transformative characteristics of the Water Plan are its dynamic and robust planning. On one hand, it provides flexibility to the increasing (and sometimes unpredictable) climate change impacts[8], by for example distinguishing between 'fixed' elements of the plan that will be implemented no matter what, and those which can be taken when necessary[1]. On the other hand, its robustness ensures that the plan reaches its objectives under a broad set of climate (and socioeconomic) scenarios[9] by, for example, ensuring that the plan can still be implemented under changes in policy, smaller funding, temporary power outages, etc.[1]. The plan also implements the rainwater cascades approach described above. Moreover, it fosters experimentation and learning by leaving space for and stimulating a community of practice around the idea of living with water within the city[1].

Another example is the urban water plan of the Greater New Orleans (USA)[10]. It introduces a paradigm shift from fighting against water to living with it. It does so by setting up a multi-layered, ground-up, science- and place-based, and adaptable plan. An approach similar to the water cascades is also applied in the form of maximizing slowing down, storage and use of water and thus limiting drainage.

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Image source: Norfolk Ohio Creek Watershed Resilience | Waggoner & Ball

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Climate Adaptation Partnership

Scale	Management Set-up
Regional	Multi-Stakeholder Partnership
Time for Peak Performance	**Investment required**
Short-term (0-5 years)	€€

Climate Hazard

KCS involved

Brief description

Climate Adaptation Partnerships (CAP) are collaborative arrangements in which government, business, research and civil society to facilitate climate adaptation. These are non-hierarchical associations based on collaboration, learning and experimentation. CAP can be a catalyzing activity for other adaptation options, such as heat plans, coastal management, flood mitigation, wildfire prevention, etc. Since these partnerships focus on strengthening collaborative, transdisciplinary science-policy interphase, they can boost policy innovation and the scaling up of climate adaptation actions.[1]

These partnerships facilitate adaptation actions by building adaptive capacities among decision-makers in the public and private domain, and informing policy formulation.[2]

Depending on the scope of the CAP, this can be implemented through private-public partnerships, partnerships with local universities, embedding scientists in city teams, city panels on climate change, among others. These partnerships require continuous attention and dialogue, because of shifting contexts, and tensions that might unveil power dynamics. Nevertheless, this dialogue allows cities to make more robust decisions and promote flexible solutions to climate resilience.[3]

CAPs are enablers of the key conditions required to achieve transformational results: creation of transdisciplinary knowledge, work across silos, support learning and experimentation, trust building, and raising adaptation awareness.

Expected Outcomes

- Coordination, collaboration and de-siloing, facilitating the application of climate adaptation research in policy decision making
- Research, assessment, and program integration
- Climate education and adaptation technical assistance

Key Enabling Conditions

- A starting set of stakeholders that include policy entrepreneurs as well as researchers, private sector and/or civil society.
- Political commitment and funding
- Clear sense of direction and topic and what the partnership wants to achieve.

Synergies and Additional Benefits

- Building/strengthening institutions
- Improved collective knowledge

Limitations and Constraints

- Limited technical expertise and capacity within some partner organizations can hinder the development and implementation of effective adaptation measures.
- Securing adequate and sustained funding for climate adaptation initiatives can be challenging given different priorities among the partners.

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- Uncertainty around future policies and regulations related to climate change can impede long-term planning and investment.
- Political changes can result in shifts in priorities and funding, leading to a lack of continuity in long-term adaptation efforts.
- Aligning goals and strategies requires significant effort and diplomacy.
- Navigating bureaucratic processes across different organizations and governmental levels can slow down decision-making and implementation.
- Partners may have different capacities, perspectives, and values that can influence priorities and approaches to climate adaptation.
- Monitoring effectiveness of these partnerships, required to keep engagement, can be challenging due to the multiplicity of goals, actors and actions.[4]

Potential Trade-offs and Adverse Effects

- Overreliance on the partnership as the driver of solution at the expense of others, more established adaptation mechanisms.
- Disagreements over how to allocate resources fairly and effectively can arise, potentially leading to conflicts or delays in project implementation
- Balancing short-term economic benefits with long-term climate resilience goals can be difficult, especially for businesses focused on immediate profitability.

Example of Success

The New York Panel on Climate Change (NPCC) is a partnership between research and the city government to serve the city with regular climate information. This is an example of transdisciplinary collaboration, where city authorities balance the NPCC recommendations with other pollical priorities, and create an actionable climate adaptation plan.[5]

The London Climate Ready Partnership (LCRP), launched in 2001, focuses on knowledge sharing and awareness raising between public and private actors at city level, as well as supporting activities on single issues such as water flooding, involving city and local actors. The coordination and facilitation of this partnership is government-led, with funding from the environmental programme and the Greater London Authority. It includes 19 partners, and it works in coordination with the 33 London boroughs and other knowledge networks, as well as in development of specific climate resilience projects. [6]

The Rotterdam Climate Initiative (RCI) focused on flood risk management in the outer dyke areas of the Port Area of Rotterdam. It is a partnership between the city of Rotterdam, the port of Rotterdam, DCMR Environmental Agency Rijnmond and Deltalinqs. Their actions have included the development of Nature Based solutions, as well as green rooftops.

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Image source: Image by freepik

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Adaptive Flood Risk Management: The Thames Estuary 2100 Project

Scale
Regional

Management Set-up
Government-led

Time for Peak Performance
Long-term (+15 years)

Investment required
€€€€

Climate Hazard

KCS involved

Brief description

The Thames Estuary (TE) 2100 project was developed with the objective of determining whether and when the existing Thames Estuary flood management system would need to be modified, and to provide a plan on how flood protection should continue for the next 100 years, while accounting for deep uncertainties related to climate change and ageing infrastructure[1].

The transformative nature of the project is clear when considering how this was one of the first major infrastructure projects to explicitly account for climate change-related deep uncertainty throughout the whole planning process[1].

Additionally, the project adopted an adaptation pathways approach to develop a dynamic adaptive strategy. This approach could then support decision-makers in designing a plan where measures are implemented iteratively over time, so to maintain flood risk below acceptable levels in a way that is cost-effective while keeping options open to manage future risks.

Expected Outcomes

- Manage tidal flood risks adaptively in London and the rest of the Thames Estuary (from Teddington to the west up to Shoeburyness in the east) over 100 years[1].

Key Enabling Conditions

- Technical capacity is required for carrying out all studies, in particular for detailed hazard and risk modelling, engineering analyses, Cost-Benefit Analysis and Multi-Criteria Decision Analysis [1,4].
- Stakeholder consultation should also be considered.
- It requires continuous monitoring and evaluation, so to determine when thresholds of current measures are reached and thus the implementation of next measures should be triggered [3].

Synergies and Additional Benefits

- Enhanced recreation and tourism
- Increased property values
- Improved public treasuries and fiscal stability
- Improved credit rating
- Improved business continuity

Limitations and Constraints

- Developing an adaptive, elaborate and cost-effective plan requires time (around 10 years in the TE2100 case).

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Potential Trade-offs and Adverse Effects

- Raising flood defenses through time will have environmental impacts, because higher defenses take up more space, resulting in coastal squeezing[2].

Example of Success

The main component of the TE2100 plan consists of a strategy for updating and/or replacing the existing movable Thames Barrier, built in 1984 following a 1953 major surge and initially designed to last until 2030[2]. By 2021, the TE2100 project had protected a tidal area of 1.42 million residents, 586,000 residential properties and 55,640 commercial ones[3].

Besides its adaptive management approach, the project brought forward the following innovations for long-term planning under deep uncertainty[1]:

- A decision-centered planning process: at the core of every analysis were the characteristics of the decision problem (i.e. objectives, stakeholder preferences, decision constraints, etc.), the vulnerability of the system, and the adaptation options.
- Long-term climate scenarios: these were designed specifically for decision-makers to test the robustness of different options and strategies against uncertainties and vulnerabilities.
- Narrative scenarios for extreme water levels: the project built plausible (although unlikely) scenarios for the 21st century that were used for sensitivity analysis, testing the robustness of the considered strategies instead of showcasing 'best guesses' of future climate.
- Key decision points: the plan included when decisions should be made and when is necessary to trigger implementation, based on the conditional observation of sea-level rise and other relevant indicators.

Plan implementation started in 2012 and will span for a period of 40 years[1,5]. Nevertheless, the project remains at full performance the whole time, additional measures are implemented when needed to maintain such performance depending on how future climate impacts unfold.

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Image source: Environment Agency UK

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Planned Relocation: Preventing Climate Damages Proactively

Scale	Management Set-up
Multi-scale	Government-led
Time for Peak Performance	**Investment required**
Mid-term (5-15 years)	€€€€€

Climate Hazard	KCS involved

Brief description

Planned or managed relocation, also referred to as managed, planned or strategic retreat, managed realignment or anticipatory or strategic relocation, is a management response that involves transporting existing development from existing and/or future danger to a safer area[1,2]. In most cases, this involves retreat from coastal or other low-lying areas, in some cases following significant (weather) events[3]. Lately, this has been also the case for areas affected by landslides, heatwaves, wildfires or multiple simultaneous risks. Retreat policies can range from planning restrictions for areas at risk up to policies for the removal of existing development infrastructures, depending on the specific local situation and needs[4].

Planned retreat can be broken down into three main stages:

1) Preparation, where community engagement is built to gain an understanding of the need for relocation, associated risks and opportunities, and the upcoming retreat actions are planned in detail, including monitoring and establishing required funding;
2) Active retreat/relocation: including the acquisition of property and/or buyout and actual removal and relocation of houses, people and economic activities;
3) Cleanup: rehabilitation and repurposing of the abandoned land for activities which can carried out safely, e.g. nature conservation, recreational use, etc.[5].

Planned relocation does not happen all at once and is a multi-decadal sequence of actions. Methodologies like adaptation pathways can thus be helpful in staging retreat and breaking it up into manageable smaller steps across time[5].

Expected Outcomes

- Reduce sensitivity of socio-ecological systems to hazards, thus resulting in prevention of risk to life and infrastructure[2,4]
- Encouragement of just development and resilient long-term use of land [2]

Key Enabling Conditions

- Community acceptance [6].
- Long-term and deep community engagement
- Before actual implementation, the community should be informed of the need for planned relocation with sufficient time ahead (e.g., up to 10 years) [7].
- Clear rules that ensure the self-determination of the community.
- Understanding of future risks and how this may affect communities in the long term[5]
- Policies and regulations for anticipatory planning[5]
- Long-term funding schemes[5]
- Adaptive and flexible management that supports decision-making as the knowledge progresses and conditions change [5]
- Building and maintaining strong political leadership[5]
- Protection of land rights and maintenance of social ties in the new location[8]

Synergies and Additional Benefits

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- Land conversion towards nature conservation, sustainable tourism and/or nature recreational purposes[2,9].

Limitations and Constraints

- Identify an area where the community can retreat to and which is preferably close to the original location and protected from current and future climate hazards[10].
- Legal conflicts associated with private property laws and rights[11].
- Limited timeframe since it must be done before any extreme weather event[20].
- Political barriers and lack of coordination between government levels [13,14,15].
- Limited financial capacity to cover the losses, demolition, compensation, and relocation of the existing infrastructure[4].
- Mistrust in regional authorities[7] (especially when the option and need to relocate are perceived as a surprise).

Potential Trade-offs and Adverse Effects

- Social conflicts related to the retreat[4].
- Risk of loss of culture, livelihoods, identity, attachment to the land and social ties[16].

Example of Success

Geltinger Birk, Baltic Sea Coast, Germany: local relocation scheme funded by the German federal government which took a total of 25 years from proposal to implementation[6]. The project was embedded within the flood defense and adaptation strategy along the Baltic Sea shore. Considerations of resettlement started after a series of floods between 1979-1986[9,17] and triggered by the 1988 decision of the state government to abandon the old existing dike, which was becoming too expensive to repair and maintain. A set of activities was organized to foster public acceptance of the measure, including fora to address public resistance and control misinformation, the creation of an information center and hiring a permanent communication manager[6]. Coastal realignment following relocation started in 2013, and the abandoned area was revalidated with nature restoration and by fostering nature tourism by including walk trails, seasonal rentals and wild horses. The transformation of the area into a local touristic and natural spot strongly improved the local support of the project, which the local population has defined as successful[9].

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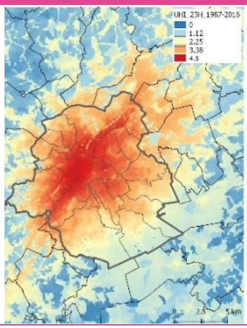
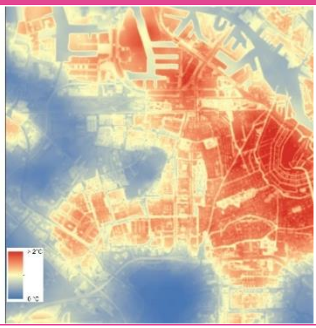
City Heat Plans: Boosting Preparedness and Partnerships for Extreme Heat Events





Scale

City

Management Set-up

Multi-Stakeholder Partnership

Time for Peak Performance

Short-term (0-5 years)

Investment required

€

Climate Hazard

KCS involved

Brief description

Heat plans developed at the city level allow city planners to partner with local organisations to identify vulnerable populations to heat (like elderly individuals living alone, people with chronic illnesses, and the homeless) and develop action plans accordingly. Thus, fostering strong partnerships and coordinated actions with various organizations during heatwaves should be at the core. Heatwave response plans should include short-term response actions (emergency response, individual preparedness) as well as longer-term heat mitigation solutions such as "cooling" public infrastructures (cooling roofs, trees and vegetation, cool pavement and surfaces, etc.).

These plans can be implemented with simple, cost-effective technologies and strategies, such as promoting self-reliance, social solidarity and community support, and identifying cool public spaces like libraries, places of worship, tunnels, malls, and government buildings that could be used as temporary cooling centres. Moreover, they can be complemented by adapting buildings and critical infrastructure to extreme heat events, as well as by preparing citizens and emergency services better. For example, by simulating a city-wide crisis in response to a scorching heatwave exceeding 50°C.

Expected Outcomes

- Have a coordinated response to heat waves, as well as newly or repurposed public infrastructures that increase the resilience of cities to heat waves.
- Citizens will be better informed and prepared to deal with heat waves.

Key Enabling Conditions

- Knowledge and data regarding heat vulnerability across the city and to different populations.
- Capacity building of government officials, community organisations and emergency response professionals.
- Clear leadership (appointment of a health officer)
- Collaboration among public and private stakeholders for the implementation of the plan
- Continuous monitoring, evaluation and updating of the plan.

Synergies and Additional Benefits

- Reduce heat-related illness
- Alleviate congestion of health centres during extreme heat
- Social cohesion and community empowerment
- Reduce energy consumption

Limitations and Constraints

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- Limited access to and availability of high-detailed data on health and vulnerabilities
- Limited funding for building and infrastructure upgrades, as well as for large-scale drills and training.

Potential Trade-offs and Adverse Effects

- A common example of maladaptation is the widespread use of air-conditioning units in buildings without proper energy-efficient design, increasing energy demand and associated emissions.
- Public cooling spaces can encourage gentrification.
- A compromise between short-term emergency strategies and long-term infrastructural solutions.[1]

Example of Success

As part of the Paris Resilience Strategy, the city of Paris conducted a Heat Dome Exercise (or large drill regarding heatwaves) in October 2023. The exercise spanned two days and involved an array of stakeholders, including the police department, school children, social housing residents and the press. This exercise aimed to simulate real-life conditions under a severe heatwave, mobilising citizens and simulating various emergencies that require the coordination of multiple entities[2]. The lessons learned from this exercise have been incorporated into a report to the city government[3].

The Hague Heat Plan[4] was developed by the city of The Hague, Netherlands, together with 24 organisations with access to people experiencing health risks, beyond the reach of healthcare institutions. They outlaid a plan on how to limit and deal with health-related issues, promoting self-sufficiency and group cooperation, and exchange of knowledge and experience.

Miami's Extreme Heat Action Plan[5]. The plan was launched in 2022 and includes three core objectives: cool neighborhoods through green solutions, increase home's and emergency facilities' access to cooling, and increase outreach and education on the risks of extreme heath. The plan also gives a blueprint for the investment in cooling solutions for the city.

A plan that is strongly focused on rapid response to heat waves might focus on the use of more incremental solution. If accompanied and resourced to introduce changes in the city infrastructure, this can lead to more transformative and long-term changes, for instance, in the use and identify of certain public spaces that changes behaviors (mobility, or work patterns, etc.).

Sources & more info:

Image source: DestinE for human heat stress | ECMWF

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[3] CDN.Paris.fr | "Paris a 50 C Le Rapport"

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[5] Onebillionresilient.org | "Miami's Extreme Heat Action Plan"

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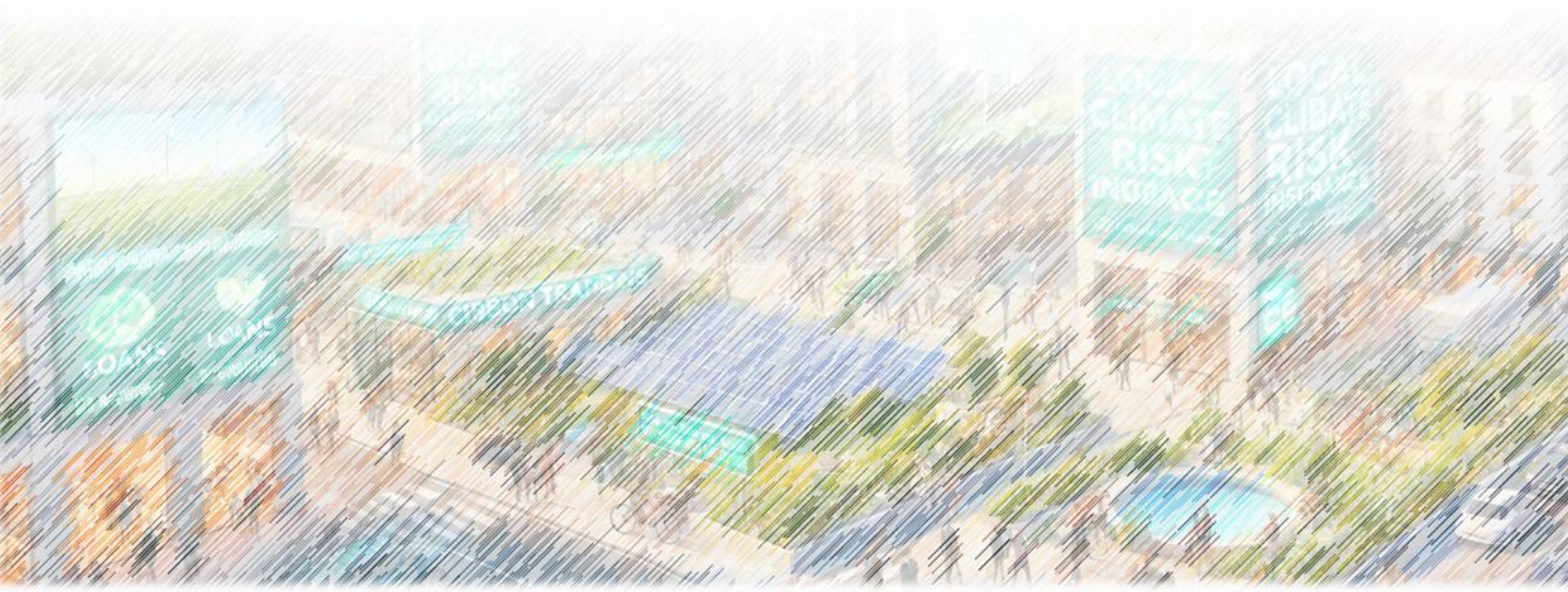
2.4 Economic Instruments and Financial Solutions

Economic instruments and financial solutions provide the necessary resources and incentives to support adaptation efforts. These measures aim to facilitate investment in adaptation projects, reduce financial barriers, and encourage proactive risk management in response to climate change impacts. These include a variety of financing mechanisms designed to support adaptation activities, such as grants, subsidies, and concessional loans that provide financial assistance to individuals, communities, and businesses undertaking adaptation projects. In addition to direct financial assistance, these options also encompass incentive mechanisms that promote adaptive behaviours and practices. For instance, tax credits or rebates can be offered to businesses that invest in resilience-building initiatives in vulnerable areas or to individuals that implement water-saving measures. By lowering the cost of implementing adaptation measures and incentivizing the adoption of adaptive practices, these adaptation options tackle the adaptation finance gap at different levels.

Insurance schemes for climate adaptation fall under this category as well. On the one hand, insurance schemes incentivize risk reduction behaviours by encouraging policyholders to implement adaptation measures that minimize potential damages, and thus, their risk rating and premium. On the other hand, risk-sharing instruments such as index-based weather insurance and catastrophe bonds provide financial protection against climate-related losses. These instruments help stabilize incomes and support recovery efforts after extreme weather events, offering automatic payouts triggered by predefined climate conditions or events.

Economic instruments and financial solutions also promote private sector engagement in adaptation efforts. By creating favourable investment conditions and reducing financial risks, these measures encourage private sector participation in developing and implementing adaptive solutions. Public-private partnerships can leverage private sector expertise and resources to scale up adaptation actions and achieve broader resilience objectives. Furthermore, establishing dedicated funds for climate adaptation can facilitate the mobility of private resources to resilience-building activities locally. These funds aim to channel financial support available from different sources to sectors and areas with limited financial capacities, enabling them to implement adaptation strategies while bridging the resource gap.

In summary, economic instruments and financial solutions ensure that adaptation efforts are adequately funded, contributing to more sustainable and resilient regions.



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Climate Insurance and Parametric Options for Urban Resilience and Rapid Recovery

Scale
Multi-scale

Management Set-up
Public Private Partnership

Time for Peak Performance
Short-term (0-5 years)

Investment required
€€

Climate Hazard

KCS involved

Brief description

To address the climate protection gap and underinvestment in climate adaptation, the insurance sector has increasingly introduced insurance products and services that incentivize asset managers and investors to finance climate-resilient infrastructure, protection of natural assets, and incorporate climate risk management and adaption in project designing and planning.

Parametric insurance allow affected areas and groups to recover more quickly by triggering payouts based on pre-defined parameters of a climate event, such as rainfall exceeding a certain amount in a 24-hour period or strong winds surpassing a specific speed. Compared to traditional insurances that requires damages assessment, parametric process claims and payouts faster which is crucial for jumpstarting recovery efforts in communities and cities.

By ensuring quicker access to funds for repairing damaged infrastructure, providing emergency shelter or financial assistance to affected residents, cities can become more resilient to climate disasters. In addition, insurance companies can also help to assess, communicate and signal risks through premiums, deductibles and payments, facilitating the understanding of the threats posed.

Beyond this, insurance also contributes to raising awareness of climate risks, incentivizing risk mitigation actions, and fostering economic expansion by stabilizing finances and facilitating capital flows.[1]

Expected Outcomes

- Transfer and reduce risks from climate-related hazards
- Enhance fiscal resilience to help withstand unexpected financial shocks
- Provide incentives for proactive climate risk management.
- Raise awareness of climate risks.
- Incentivize risk reduction and adaptation behavior.
- Enhance finance readiness in recovery phases.

Key Enabling Conditions

- Collaboration among the insurance industry, government, and various stakeholders
- Development of innovative insurance solutions by insurance companies
- Regulatory framework or incentives from public authorities
- Risk data availability, data management system

Synergies and Additional Benefits

- Improved disaster preparedness capacity
- Enhanced financial stability and investment attractiveness
- Reduced fiscal pressure on city budgets for disaster response and recovery

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Limitations and Constraints

- Affordability of the insurance solution, particularly for the ones with lower economic capacity.
- Insurability of the hazard type and limited coverage to specific climate events (e.g., droughts, floods, wildfires, extreme heat, and storms).
- Data availability and accessibility
- Lack of regulatory framework
- Limited insurance penetration

Potential Trade-offs and Adverse Effects

- Budget allocated for insurance premium cannot be used for other purposes
- Disincentivize investment in preventative adaptation measures
- Losses and damages under the payout threshold are uncovered by the insurance.

Example of Success

NFU Mutual, the leading rural insurer in the UK, has introduced a pioneering parametric heat-stress insurance for dairy farmers, developed in partnership with Skyline Partners, Markel, and Gallagher. This insurance model provides predetermined payouts based on monitored temperature thresholds, offering financial protection against the adverse effects of heat stress on cattle. The policy's payouts are triggered by independent satellite and weather-station data, enabling farmers to mitigate production losses and improve farm infrastructure. The insurance product offers four coverage levels, tailored to farmers' risk appetites, budgets, and herd sizes.[2]

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Image source: Kindel Media on Pexels

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Corporate Climate-Resilient Strategies: Harnessing the Power of the Private Sector to Improve Economic Resilience.

Scale	Management Set-up
Multi-scale	Private sector-led
Time for Peak Performance	**Investment required**
Short-term (0-5 years)	€€

Climate Hazard

KCS involved

Brief description

Developing climate-resilient strategies (CRS) is crucial for the private sector to proactively address the growing risks associated with climate change[1], from core operations and supply chains to frontline communities that service the supply chain [1,2]. This approach ensures long-term sustainability, the company's resilience, and seizing business opportunities[1,3].
Developing CRS involves integrating resilience into core business operations, products, and services[3]. This entails cross-organisational work involving sustainability, finance, strategic planning, innovation, and business development departments[3,4]. It consists of reviewing and adapting business models to ensure compatibility with changing climatic conditions and build resilience across supply chains[2,3]. Many businesses have already incorporated climate considerations into their planning, avoiding or mitigating potential impacts such as property damage, business interruptions, and service disruptions[1,4]. A CRS integrates adaptation, mitigation, and transformation as three key intertwined components for building systemic resilience[5,6]. This includes developing mitigation (net-zero) policies, adapting to frequent disruptions, and transforming operations, products, and services, thus, establishing a robust governance approach[5]. This offers several benefits, such as return on investment, mitigating systemic vulnerabilities, meeting disclosure and regulatory requirements, managing risks and corporate reputation, and gaining a competitive edge[1]. Companies excelling in this are expected to have a better position to maintain resilience against extreme weather events and other climate impacts[4,5]. By preparing for future challenges, businesses can significantly contribute to building systemic resilience. Developing CRS is not just beneficial but essential for sustainable business success in the face of climate uncertainty[5,6].

Expected Outcomes

- Increased long-term sustainability and resilience of business operations.
- Improved ability to mitigate and adapt to the impacts of extreme weather events and other climate-related disruptions.
- Enhanced capacity to identify and seize emerging business opportunities related to climate change.
- Strengthened resilience of supply chains and frontline communities.

Key Enabling Conditions

- Broad understanding of climate risks and vulnerabilities across all business areas.
- Strong leadership and commitment from top management.
- Collaboration with stakeholders (suppliers, customers, and local communities).
- Investment in research and development to innovate and adapt business models.

Synergies and Additional Benefits

- Strengthening and supporting local institutions.
- Safeguard business continuation and economic productivity.

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- Opportunities for innovation and development of new products and services.
- Increased competitiveness and market positioning.

Limitations and Constraints

- High initial investment costs and resource requirements.
- Limited access to accurate and localized climate data for effective risk assessment.
- Resistance to change within the organization.
- Aligning short-term business goals with long-term resilience objectives.
- Dependence on external factors, such as government policies and global market.

Potential Trade-offs and Adverse Effects

- Disparities in access to technology, information, and resources could increase inequalities in competitiveness, favoring larger corporations over small and medium-sized enterprises (SMEs).
- Potential financial risks associated with implementing new strategies, as well as possible disruptions in existing supply chains and business operations during the transition phase.
- Trade-offs between immediate business profitability and long-term resilience investments, including short-term financial impacts due to reallocation of resources towards climate-resilient initiatives.
- Risk of overlooking justice considerations in vulnerable communities.

Example of Success

Mountain Equipment Co-operative (MEC)[7] has embedded climate resilience into its core operations, leveraging analytics to adapt to climate change and better serve its customers. MEC addresses climate impacts on both sales and supply chain effectively. For example, unpredictable weather patterns influence customer buying habits, prompting MEC to adjust inventory accordingly. Additionally, extreme weather events impact stock transit and availability, necessitating robust infrastructure and diversified sourcing strategies. By integrating climate adaptation into operational decisions, MEC not only mitigates potential disruptions but also capitalizes on emerging business opportunities.

Iberdrola's MeteoFlow[8,9] system exemplifies how advanced weather forecasting can optimize renewable energy production and operations. It incorporates modern techniques like machine learning, artificial intelligence, and big data to provide precise production forecasts for wind, photovoltaic, and hydroelectric plants, enhancing decision-making in energy markets and scheduling maintenance to minimize disruptions. Serving over 16GW across 12 countries, MeteoFlow anticipates weather events, positioning Iberdrola to better manage climate risks while boosting profitability and operational efficiency.

Travelers Companies, Inc[1]. is a property and casualty insurer that has implemented a cohesive approach to climate risk. The company reassesses coastal underwriting practices, updates catastrophe modelling, and offers Risk Control services to mitigate losses and enhance resilience. Additionally, it engages in community outreach to promote disaster preparedness and supports the adoption of robust building codes. By redesigning pricing strategies to incentivize loss mitigation and environmentally responsible behavior, Travelers not only protects its financial interests but also encourages broader societal climate resilience.

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Image source: Drupa.de

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Utilising Procurement Powers to Promote Climate-Positive Transformation

Scale
City

Management Set-up
Government-led

Time for Peak Performance
Short-term (0-5 years)

Investment required
€

Climate Hazard

KCS involved

Brief description

Public Procurement (PP) is the area of public administration concerned with the acquisition by the government of goods, services and works from the marketplace.[1] PP can be a driver of transformative change due to the large purchasing power of the public sector, and its ability to shape markets. The public sector can be a lead in introducing innovative solutions and changing and/or creating markets to make climate adaptation consideration a core component, for example, on roads or infrastructure development. The purpose of incorporating climate change adaptation into regional procurement processes is to maximize value in long-term public investments and reduce future losses due to climate change. Sea level rise, increased precipitation, higher temperature and increased frequency of intense storms are likely to have the highest impact on PP decisions. PP can include negative effects, opportunities and co-benefits.

Relevant procurement frameworks in the EU context include Green Public Procurement (to reduce environmental impacts), Innovation procurement (to develop innovative solutions not yet available in the market[2,3]) and Pre-commercial procurement (to procure Research & Development services[4]).

Public agencies can integrate climate adaptation into PP by setting criteria in tender documents (e.g., consideration of heat-resistant materials or floodproofing measures in buildings), having a life-cycle perspective (e.g., considering the future climate conditions and their impacts on maintenance or upgrading costs), and encouraging climate-resilient solutions (e.g., use of permeable materials to reduce floods). Integrating climate adaptation into public procurement is a way for governments to spend smarter, reduce risks, and be better prepared for the impacts of climate change.

Expected Outcomes

- Support the development of resilient infrastructure and services.
- Support new technologies and strategies that build resilience better, beyond solutions for the public sector.

Key Enabling Conditions

- Requires upskilling of both contracting authorities and contractors.
- Needs to be embedded in an overall decision-making context where climate adaptation is a key priority.
- Needs to be part of an integrated approach including building regulations, design standards and procurement specifications that are aligned with climate adaptation.
- Requires moving away from traditional procurement criteria (cost, experience) to consideration of costs, benefits and risks associated with each option.[5]
- There are multiple procurement procedures, the right procedure needs to be identified.[6]

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Synergies and Additional Benefits

- Possible combination with Nature based Solutions, infrastructure based solutions, or mitigation strategies
- Facilitation the creation of new markets for innovative solutions
- Promotion of green jobs and green investments
- Increase of knowledge and awareness of climate issues among public administration and suppliers
- Supports the development and adoption of technical frameworks and procedures to assess the climate suitability of solutions (i.e. life cycle assessment, etc.)

Limitations and Constraints

- Limited knowledge of public procurement procedures and/or technical knowledge can hinder the implementation of this option
- Greenwashing or selection of solutions with unknown, potentially adverse effects
- Public accountability procedures need to be balanced with the need for adaptability.
- Selection based on "best value" limiting the understanding of complex goals and trade-offs.[7]

Potential Trade-offs and Adverse Effects

- Maladaptation or unsustainable decisions due to lacking expertise of knowledge, lack of consideration of complex trade offs, or vested interests.

Example of Success

Austria's implementation of Green Public Procurement at the federal level is an example of good practice. In 2010 the National Action Plan (NAP) for sustainable procurement was adopted (naBe-Aktionsplan) covering goals and measures for sustainable procurement, and environmental criteria for products from 16 product groups. This approach takes into account the country's federal structure and fosters collaboration between all levels of government.[8]

Sydney – Barangaroo South, which was a process of re-development of a former container terminal into a new financial services hub. A suitable partner able to deliver a vision of a climate positive business district was selected through competitive procurement that had Climate Positive as a requirement of the biding process. This includes commercial and residential spaces, energy efficient design, as well as cooling, water and waste management that provides efficiencies and economies of scale. [9]

Fiji has implemented the first Climate Relocation of Communities trust Fund, that is implemented through a participatory process where affected communities identify their adaptation needs and opportunities, and if needed, relocate. The relocation process is managed through a public procurement process based on the needs identified by the community.[10]

Sources & more info:

Image source: Image by rawpixel.com on Freepik

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2.5 Knowledge and Behavioural Change

Knowledge and behavioural change are highly effective and transformative climate adaptation strategies. They focus on increasing awareness, understanding, and engagement to foster adaptive actions at individual, community, and institutional levels. These measures aim to equip people with the information and skills needed to respond effectively to climate risks and encourage behavioural shifts that support resilience-building.

A key aspect of these interventions is the dissemination of knowledge and information related to climate risks and adaptation strategies. This enables communities and individuals to prepare and respond effectively, minimizing potential damages. For example, educational programs and awareness-raising campaigns aim to inform the public about climate science, the importance of adaptation, and practical steps that can be taken to reduce vulnerability, which is critical for building adaptive capacity locally.

Also, training and empowering individuals and organizations through capacity-building activities enhance the ability of communities and sectors to adapt to climate change. For instance, this can include technical training for farmers on sustainable agricultural practices, workshops for local governments on integrating climate considerations into planning processes, or courses for businesses on sustainable resource management. Thus, stakeholders are provided with the necessary skills and knowledge to undertake adaptation action.

Behavioural change is a powerful approach to transformative adaptation strategies, as it encourages individuals and communities to adopt practices that reduce vulnerability and enhance resilience in their daily lives. Adaptation measures capable of shifting attitudes, beliefs, and values, thus motivating people to make changes towards more resilient and adaptive practices, can directly address the root causes of climate risks. For this, integrating traditional and local knowledge with scientific research is an effective way to promote behavioural change. Local communities often have deep-rooted knowledge of local ecosystems and practices that can be harnessed to develop culturally relevant and effective adaptation strategies.

Moreover, participatory approaches, such as community-based adaptation planning, engage stakeholders in identifying vulnerabilities, assessing risks, and developing adaptation strategies. By involving local communities, adaptation plans are not only grounded in local knowledge but also address the specific needs and priorities of communities. This involvement fosters a sense of ownership and responsibility, increasing the likelihood of successful implementation and long-term sustainability.

Equipping individuals, communities, organizations, and businesses with the information and skills needed to respond to climate risks can encourage shifts towards more sustainable behaviours. This lays the groundwork for effective adaptation. Besides ensuring that adaptation efforts are inclusive and aligned with the needs and priorities of those most affected by climate change, knowledge and behavioural change measures are crucial for fostering a culture of adaptation and resilience.

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Self-Sustaining Reforestation: Leveraging Finance and Digital Innovation for Just Resilience

Scale	Management Set-up
City	Multi-Stakeholder Partnership
Time for Peak Performance	**Investment required**
Long-term (+15 years)	€€

Climate Hazard

KCS involved

Brief description

Large-scale tree planting has been applied in several cities to tackle various climate hazards[5]. However, planting trees through an innovative "pay-to-grow" scheme[4] which is mapped and coordinated by an app can become a self-sustainable and scalable activity. Community members, who plant trees at relevant locations and take care of them ensure their growth and to e.g., reduce landslides, heat stress or flooding. Successful validation of such actions through an app leads to remuneration through micropayments which may stem from an initial (project) budget and can, in the long term, be covered by carbon credits and offsets[1,2,,4].
Further, this community approach aims at going beyond just planting trees by delivering additional benefits to a variety of KCS, such as fostering social (e.g., increased participation, green jobs) and environmental benefits (e.g., increased biodiversity) or improve water management. Further, it fosters just resilience and community empowerment where most needed.

Expected Outcomes

- Reduction of landslides, heat stress and flooding combined with social and economic benefits for a community.

Key Enabling Conditions

- Initial capital investment (e.g., app development, trees, certification).
- Entity taking care of set up, app development and control of tree planting and growth
- Social buy-in and community organization
- Supporting regulations and political will
- Local ecological knowledge

Synergies and Additional Benefits

- Protect water reservoirs
- Improved air quality
- Support biodiversity
- Direct financial profit for the community
- Increase of social cohesion and skill development
- Knowledge sharing and improved collective knowledge
- Opportunities for people looking for employment[3]

Limitations and Constraints

- High upfront investment and financing in the long-term
- Misalignment with the current land-use planning
- Limited space for reforestation
- Tree suitability for future conditions
- Labor available for planting and maintenance

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Potential Trade-offs and Adverse Effects

- Land-use competition and conflict with other potential users
- Increased burden on the urban water demand
- Negative effects on biodiversity due to monoculture or reduced species variety causing maladaptation

Example of Success

"Freetown the Treetown" in Sierra Leone aims at planting one million trees by 2024 to reduce disaster risks, with a focus on landslides that were caused due to an anthropogenically caused, rapid tree loss. Besides that main focus, trees have also been planted by roadsides, schools, residential areas and the greenbelt to decrease heat stress and improve water security as well as air quality.[1] From 2020 until 2022 560.000 trees have been planted with an approximate survival rate of 80%.[4] The innovative community approach, with financial incentives for tree planting coordinated through an app (which allows for collaborative mapping), delivered benefits that went beyond its risk reduction potential. The project shows how an integrated approach to resilience building can work by facilitating environmental, social and financial (co-)benefits. It has created "more than 1,000 green jobs along the value chain, from workers in tree nurseries to community growers – of whom 80% are youths and 48% are women."[1]

Sources & more info:

Image source: created by OpenAI's DALL-E

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Climate Change Observatory: understanding climate change evolution to improve climate action

Scale
Regional

Management Set-up
Government-led

Time for Peak Performance
Long-term (+15 years)

Investment required
€€

Climate Hazard

KCS involved

Brief description

A climate change observatory is an effective platform to produce, present and exchange scientific information, both on mitigation and adaptation. Observatories can support in defining climate change indicators in sectors of interest, ensure their long-term monitoring, and may also be leveraged "to raise awareness on climate change impacts on human societies, cultural diversity, biodiversity, ecosystem services, and the world's natural and cultural heritage".[3] More importantly, by providing this information, climate change observatories hold the potential to assist regions in adapting to their respective risk and thus transform its purpose from passive observation to active adaptation.[1, 4]

For this, an observatory can develop tools and methodologies for climate change adaptation decision-making and disseminate research results to socioeconomic actors in the region. Further, by coordinating and visualizing sectoral climate action in the field, information on climate change impacts or sustainable growth requirements of the territory can be presented. To generate optimal outcomes, all stakeholders contributing to climate action in their area of competence should participate, be informed and connected.

Expected Outcomes

- Improved knowledge leading to informed decision-making and policy development

Key Enabling Conditions

- Establishing a robust technical infrastructure to support data collection, storage, processing, and dissemination.
- Recruiting and retaining qualified scientists and researchers with expertise in climatology and sectoral fields.
- Securing adequate funding and financial resources to support the establishment, operation, and maintenance of the observatory.

Synergies and Additional Benefits

- Building/strengthening institutions
- Increased cooperation within and among groups
- Created/ strengthened social networks

Limitations and Constraints

- Data accessibility: Ensuring universal access to or production of high-quality data and expertise can be challenging, potentially limiting the inclusivity of the project.
- Technological infrastructure: Developing and maintaining the necessary technological infrastructure for data collection, analysis, and dissemination requires ongoing investment and expertise.
- Stakeholders: Gathering stakeholders and relevant groups for participation; translating scientific findings to non-experts.

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Potential Trade-offs and Adverse Effects

- Generalization: When broad, generalized data is applied to specific sectors, nuances and critical details pertinent to that sector may be overlooked. This can lead to decisions that do not fully address the unique challenges or characteristics of the sector.
- Bias introduction: Extrapolating information can introduce biases, as the assumptions made during extrapolation may not hold true across different contexts. This can skew the decision-making process and lead to suboptimal outcomes.

Example of Success

The Pyrenees, a mountain range spanning Spain, Andorra, and France, face diverse climate challenges. The Pyrenean Observatory of Climate Change (OPCC) serves as a vital platform for monitoring and adapting to these changes.[5] Through collaboration with stakeholders, it defines climate change indicators, monitors them over time, and assists in adaptation efforts. Key objectives include scientific analysis, tool development for decision-making, and enhancing the mountainous region's visibility. Implemented solutions include consolidating climate knowledge, assessing vulnerability, and offering operational recommendations to improve resilience. The project's success lies in its governance structure, fostering cooperation among 80 organizations. Through funding sourcing from different levels, the OPCC ensures transnational coordination while adhering to regional and national adaptation strategies. It is a pioneer in fostering cross-border collaboration and raising awareness, essential for confronting climate challenges in mountainous regions. Since 2010 the OPCC has achieved significant milestones by initiating operational actions such as leveraging partnerships to propose specific action programs. Further innovational and transformational aspects are added through a coordination committee overseeing and harmonising these action programs to ensure effective implementation through cooperative efforts, and by thematic working groups, focusing on climate, biodiversity, forests, natural risks, and adaptation. The project has successfully established a coherent and enduring transboundary network of stakeholders engaged in climate change issues across the Pyrenees region.

Sources & more info:

Image source: created by OpenAI's DALL-E

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With innovation as the catalyst and transformation as a guide to create new opportunities, regions can build systemic resilience that not only adapts to change but redefines their future in harmony with the uncertainty of climate challenges.

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Annex 2: Catalogues and Other Resources to Consult

Type	Title	Description
Catalogue	Catalogue Of Adaptation Measures To The Effects Of Climate Change In The Coastline	The LIFE ADAPTA BLUES project aims to demonstrate that the conservation and restoration of estuarine ecosystems is an efficient strategy to enhance adaptation to climate change in coastal areas of the European Atlantic coast.
Catalogue	Resin Aol	It is an adaptation option library in which 100 measures are included and their environmental effectiveness or economic performance (when available) is included
Knowledge Hub/ Platform	Resilience Measures Inventory	The ARCH Resilience Measure Inventory is a database to build local resilience with special focus on heritage
Catalogue	Climateapp	App of climate adaptation solutions for urban designers, engineers, and others.
Catalogue	Urban Green Blue Grids For Resilient Cities	Searcher of green-blue solutions
Catalogue	Forest Adaptation Measures	Forest-based Adaptation measures in the UK.
Knowledge Hub/ Platform	WeAdapt Transformational Adaptation Solutions	The WeAdapt platform has a range of different resources on Transformational Adaptation - what it is and how to implement it.
Catalogue	Catalogue Of Innovations: Enhancing Smallholder Agriculture And Food System Resilience	Catalogue prepared by IFAD for East and Southern Africa
Catalogue	Glasgow City Region Climate Adaptation Strategy And Action Plan	Annex of Glasgow Blue Print
Catalogue	31 Climate Actions For Councils	Ashden Climate Solutions (Mainly mitigation action!)
Catalogue	Nature-Based Solutions To Build Climate Resilience In Informal Areas	UN-HABITAT NbS IN INFORMAL AREAS
Catalogue	Nature-Based Solutions For Cities	Elgar NbS catalogue
Projects/ Case studies	Climate-ADAPT Case Study Explorer From EEA	Showcase of implemented adaptation options and initiatives, searching through map, impacts or key actions.

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Knowledge Hub/ Platform	Adaptecca	Experiences, initiatives and projects aimed at developing and implementing specific actions to adapt to climate change, connected to Climate-ADAPT
Projects/ Case studies	Valencian Experiences For Adaptation To Climate Change	By sectors. In Spanish and Valencian (Catalan)
Projects/ Case studies	Network Nature	NetworkNature is a resource for the nature-based solutions community H2020 project
Projects/ Case studies	Transformar	Accelerating and upscaling transformational adaptation in Europe: DEMONSTRATION OF WATER-RELATED INNOVATION PACKAGES
Projects/ Case studies	Rescueme	RescueME is a Research Action funded by the Horizon Europe programme, focusing on enhancing the resilience of coastal cultural landscapes in Europe.
Projects/ Case studies	Regions4Climate	Regions4Climate project aims to reduce the vulnerability of European regions to the impacts of climate change through cross-sectoral roadmaps developed with regional stakeholders and implementing sociocultural, technological, digital, business, governance, and environmental solutions.
Projects/ Case studies	Regilience	REGILIENCE is a European project that aims at sharing the most promising cross-sectoral adaptation solutions, supporting cities and regions across Europe to become more resilient to climate change.
Projects/ Case studies	Resilient Regions: Clyde Rebuilt - What Does Transformational Adaptation Look Like?	Literature review synthesis paper / DEL10: Possible transformative adaptation solutions for portfolio
Projects/ Case studies	Brigaid Connect	BRIGAID Connect is the experts platform that strives to help innovators to market and launch their resilience ideas.
Projects/ Case studies	Arsinoe	The ARSINOE project combines SIA (Systems Innovation Approach) and CIW (Climate Innovation Window) to create an ecosystem for climate change adaptation solutions. Stakeholders co-create and co-design pathways to solutions and select technologies from existing or new providers to form an innovation package.
Projects/ Case studies	Clever Cities	Project related to NbS in european cities.
Projects/ Case studies	Innovation For Sustainable Development At Local Level: Instruments And Examples To Get Started	This is an introductory guide to innovation at the local level. It provides basic information in simple language and references other tools and guides for further reading. This Guide emphasizes the local dimension of innovation for sustainable development, and local action to sustainability challenges such as climate change and biodiversity loss.

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Organization/ Expert	IISD	We work with governments and local organizations to accelerate efforts to adjust to the current and anticipated impacts of climate change.
Projects/ Case studies	Adaptation Gap Reports	The UNEP Adaptation Gap Report (AGR) series provides an annual science-based assessment of the global progress on adaptation planning, financing, and implementation. It also explores options for enhancing and advancing national and global adaptation efforts and provides in-depth analysis of selected issues of interest.
Projects/ Case studies	Upskill 4 Future	The aim of the project is to investigate how HR transformation can support the employability of vulnerable workers, who are at risk of losing their jobs due to technological progress and companies' restructurings.
Projects/ Case studies	Maia	The MAIA project connects communities, platforms, knowledge and research on climate change.We maximise the impact and synergy of climate change research and innovation, by working to make currently dispersed knowledge more interoperable, accessible, usable and economically viable.
Catalogue	Infrastructure for a Climate-Resilient Future	This OECCD report leverages the expertise of several OECD committees to demonstrate how to integrate climate resilience in infrastructure development – from planning to financing to construction.
Organization/ Expert	Dark Matter Labs	This organization has been pushing the creation of NBS platforms for investment. Working to create institutions, instruments and infrastructures for more equitable, caring and regenerative futures.
Organization/ Expert	The Climate Adaptation Partnership (CAP)	CAP fosters collaborations among CSU researchers and center leaders working on climate adaptation, with two core emphases: interdisciplinary research efforts to address complex climate challenges, and building connections between researchers and policymakers to apply climate adaptation research in policy venues.
Organization/ Expert	CEREMA	Cerema (which stands for Centre for Studies and Expertise on Risks, the Environment, Mobility and Urban Planning) is the major French public agency for developing public expertise in the fields of urban planning, regional cohesion and ecological and energy transition for resilient and climate-neutral cities and regions.
Organization/ Expert	CERDD	Resource Center for Sustainable Development (Cerdd) equips and supports stakeholders in the Hauts-de-France region towards new models of society and encourages them to contribute to economic, social and ecological transitions in the territories.
Organization/ Expert	Plan Bleu Mediterranean Region	Regional Activity Centre of Mediterranean Action Plan

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Organization/ Expert	Sustainable City By France (SCBF)	Local authorities, State, companies and experts together to accelerate the transition of cities and territories
Organization/ Expert	Research Institute For Sustainability (RIFS)	The global challenges of climate action, energy security and resource efficiency require novel approaches that transcend scientific and geographical boundaries. RIFS Potsdam offers space for this, encourages out-of-the-box thinking and at the same time enables top scientific performance.
Organization/ Expert	Transition Network- Rob Hopkins	Transition Expert
Knowledge Hub/ Platform	Climate Adapt	Adaptation options
Knowledge Hub/ Platform	Placard	The PLAtform for Climate Adaptation and Risk reDuction (PLACARD) project seeks to establish a comprehensive coordination and knowledge exchange platform for climate change adaptation (CCA) and disaster risk reduction (DRR) for multi-stakeholder dialogue and consultation.
Knowledge Hub/ Platform	Global Adaptation Network	The Global Adaptation Network shares adaptation knowledge and expertise with an aim to accelerate action on climate adaptation.
Knowledge Hub/ Platform	Climate Adaptation Platform	Climate Adaptation Platform aims to publish research papers, lectures, books, reports, news, scholarly articles on climate adaptation.
Knowledge Hub/ Platform	Nature-Based Solutions Community	We disseminate knowledge and develop Nature-Based Solutions that provide multiple benefits in various landscapes. These solutions include protecting coastal systems from erosion and flooding, enhancing ecological productivity, improving water quality levels, and safeguarding urban and community health.
Knowledge Hub/ Platform	UNFCC Adaptation Knowledge Portal	Database of case studies from UNFCCC
Knowledge Hub/ Platform	GCA- Adaptation Knowledge Portal	The GCA Knowledge Portal makes information and knowledge on adaptation accessible and actionable – as a comprehensive online source connecting adaptation science, policy and practice.
Knowledge Hub/ Platform	UK 100- Knowledge Hub	UK100 is a network of local leaders who have pledged to lead a rapid transition to Net Zero with Clean Air in their communities ahead of the government's legal target. We provide our network with the knowledge, tools and connections to make this happen.
Knowledge Hub/ Platform	Oppla	Oppla is the EU Repository of Nature-Based Solutions. It provides a knowledge marketplace, where the latest thinking on natural capital, ecosystem services and nature-based solutions is brought together.

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Knowledge Hub/ Platform	C40 Knowledge Hub	Knowledge library about Climate Action, including adaptation to climate change.
Knowledge Hub/ Platform	Words Into Action- UNDRR	Series of guidelines, based on global expertise, communities of practice, and networks of Disaster Risk Reduction (DRR) practitioners. The guidelines provide practical, specific advice on implementing a people-centered approach to DRR in line with the Sendai Framework for Disaster Risk Reduction 2015-2030.
Knowledge Hub/ Platform	Preventionweb-UNDRR	PreventionWeb is the global knowledge sharing platform for disaster risk reduction (DRR) and resilience
Knowledge Hub/ Platform	Disaster Risk Management Knowledge Center- JRC	The DRMKC has been working in close collaboration with the Community of Users on Secure, Safe and Resilient Societies (CoU) of DG HOME to develop the Projects Explorer: a common repository of relevant research and operational projects along with their results that is accessible through both, the DRMKC and the CoU web-platforms.
Knowledge Hub/ Platform	Adaptation Community GIZ	adaptationcommunity.net was developed for the interested public and adaptation experts to provide information on applying approaches, methods and tools that facilitate the planning and implementation of adaptation action.
Knowledge Hub/ Platform	WeAdapt PROVIA Tool	weADAPT is an online 'open space' on climate adaptation issues (including the synergies between adaptation and mitigation) which allows practitioners, researchers and policy makers to access credible, high quality information and to share experiences and lessons learnt with the weADAPT community.
Knowledge Hub/ Platform	Regions4Knowledge Hub	
Catalogue	Good Practice Guides	C40 Good Practice Guides provide mayors and urban policymakers with practical solutions to tackle climate breakdown, reduce climate risk, and encourage sustainable urban development.
Catalogue	Ideas That Are Changing The World 2023	Ashoka report
Catalogue	Synergy Solutions For A World In Crisis: Tackling Climate And SDG Action Together	UN report
Catalogue	COP28 Agriculture, Food And Climate National Action Toolkit	Taking stock of good practices, initiatives, and tools for food system transformation through Nationally Determined Contributions and National Adaptation Plans

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Catalogue	Sharing Innovative Experiences: Succesful Social Protection Floor Experiences	UNDP Publication; focus on South-to-south exchange.
Catalogue	UNCCD - The Contribution Of Integrated Land-Use Planning And Integrated Landscape Management To Implementing Land Degradation Neutrality: Entry Points And Support Tools	
Catalogue	Companies and Climate Resilience: Mobilizing the power of the private sector to address climate risks	This Report argues to reimagine the engagement of the private sector in addressing the humanitarian consequences of climate change.
Tool	UKCIP Adaptation Wizard	The Wizard is a 5-step process to help you assess your organisation's vulnerability to current climate and future climate change, identify options to address your organisation's key climate risks, and help you develop and implement a climate change adaptation strategy.
Catalogue	Innovation And Adaptation In The Climate Crisis: Technology For The New Normal	A report on advanced applications and knowledge related to technology for climate adaptation developed by WEF
Catalogue	Building climate resilience: Toward a practical corporate framework	This report presents a practical framework to help companies enhance resilience in their operations and the broader systems in which they operate, and illustrates the practical application of this framework through case studies for an industry at the forefront of climate resilience: electric utilities.
Catalogue	Adapting To Climate Change: A Business Approach	Presents case studies of three companies that have begun to look at climate risks. These case studies highlight the very different circumstances that motivated each company, and how the companies may be moving towards different conclusions about the appropriate response to the changing climate.
Catalogue	Business Climate Resilience: Thriving Through the Transformation	The work brings together important global developments on adaptation and resilience - such as new, fit-for-purpose frameworks for enterprise risk management, as well as the Task Force for Climate-related Financial Disclosure's (TCFD) key recommendations - in order to help business understand the importance of building climate resilience while outlining initial steps for doing so.

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Catalogue	Using Insurance In Adaptation To Climate Change	This brochure presents the main findings of a study into insurance mechanisms dealing with climate-related extreme weather events.
Catalogue	Adapting To Climate Change: The Role Of Public Procurement	This report shows that much can be done to design for future climate without additional cost today. Even where adaptation measures do cost more up front, they can reduce running costs, improve tenant satisfaction and improve resale value.
Catalogue	Working paper: Increasing the application of ecosystem-based approaches to DRR	This paper by the G20 Disaster Risk Reduction (DRR) Working Group outlines ways of increasing the application of ecosystem-based approaches to DRR.
Catalogue	Good Practices For Increasing The Application Of Nature-Based Solutions And Ecosystem-Based Approaches For Disaster Risk Reduction	This paper presents cases that provides compelling documentation that NbS offer multifaceted benefits, including conservation of biodiversity, climate change mitigation and adaptation, enhanced disaster resilience, and socioeconomic development. The cases presented here provide valuable insights into the effectiveness and versatility of NbS.
Knowledge Hub/ Platform	Risk Centre	The Centre offers a wide range of centralised resources to help members assess and find opportunities in climate and nature risk through technical skill-building workshops, working groups that develop cutting-edge risk management tools and guidance, and sessions with leading external experts, regulators, modellers and data providers. It provides access to an extensive library of publications, tools, and resources for Sustainable Insurance.

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