IMPETUS

Turning climate commitments into action

ATTICA REGION

Innovation Package for adaptation and resilience

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Mediteranean demo-site

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ABOUT THIS DOCUMENT

The Impetus project

The EU-funded IMPETUS project (2021-2025) helps accelerate Europe's climate adaptation strategy and meet the European Union's ambitions to become the world's first climate-neutral continent by 2050. The objective is to turn climate commitments into tangible, urgent actions to protect communities and the planet.
Central to the IMPETUS project are the Resilience Knowledge Boosters (RKB), an innovative approach to combine the voice and experience of local and regional communities with the power of digital tools. In this way, policy-makers, businesses, citizens and other stakeholders can explore climate change evidence together, share information, learn, test ideas and co-create knowledge, discover which actions could constitute the best paths towards climate adaptation, and so contribute to decision making and policies.
IMPETUS has demonstration sites in 7 European biogeographical regions. Here, multidisciplinary teams and local stakeholders work together to shape adaptation by testing diverse solutions for the local impacts of climate change and exploring alternative pathways for risk reduction and transformative change.

The innovation packages

Innovation packages are built on major IMPETUS results achieved at demo-site level. They are composed of three blocks:

1. RKBs and their digital dimension for engaging stakeholders and boost knowledge for developing a long-lasting territorial resilience.
2. Adaptation pathways, to explore alternative sequences of measures to address specific climate risks at the regional level.
3. Portfolio of climate adaptation solutions, to learn from alternative adaptation options, tested or discussed across the project, and evaluated through a common set of criteria.

The objectives are:

- To present an organised synthesis of results achieved at demo-site level within the IMPETUS project.
- To facilitate mutual learning among demo-sites by comparing different solutions to face various climate risks.
- To facilitate replication and upscaling.
- To highlight major limiting or success factors that hinder or enable the progress toward adaptation and resilience.

Reader's guide

This document provides an overview of the climate risks in the region and a synthesis of the knowledge, tools and solutions produced, tested or analysed in the framework of the IMPETUS project. After the section presenting the climate risks, the document is organized following the three building blocks of the Innovation package: RKBs, Adaptation Pathways, and Portfolio of Solutions. Each block includes a synthesis of main results achieved during the project, followed by a 3-angle evaluation proposed by demo-site leaders after extensive consultation with stakeholders:

- Exploitation potential for further boosting knowledge and adaptation in the region.
- Major gaps and needs to translate ideas into concrete commitments.
- Potential for fostering transformational adaptation.

Expert judgment was used to score the evaluation elements using a 1 to 5 scale.

Key concepts: Innovation and Transformation

The "innovation component" of innovation packages is related to:

- The incorporation of transformational approach: adaptation that changes the fundamental attributes of a social-ecological system in anticipation of climate change and its impacts (IPCC, 2022; Cools et al., 2025).
- The inclusion of new technologies and tools.
- The inclusion of non-structural solutions (governance, finance and knowledge) as enabling factors to implement adaptation interventions.

INNOVATION

1. Adopting a transformational approach to adaptation.
2. Working with data-driven and digital technologies.
3. Proper consideration to enabling conditions for adaptation.

TRANSFORMATION

1. Scope of change (e.g. holistic, cross-sector, systemic)
2. Impact of change (e.g. governance, behaviour, socio-ecologic systems)
3. Depth of change (e.g. path shifting, path restructuring, innovative)
4. Temporality of change (e.g. future looking, long lasting)
5. Inclusivity (e.g. participatory, equity)


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THE CLIMATE RISKS OF THE REGION

Water scarcity and drought

The Attica region, located in the southern part of Greece, includes the capital city of Athens and its surrounding areas. The region faces significant concerns related to water scarcity and droughts driven by its climate, which is characterized by long, hot, dry summers and mild, wet winters. Rainfall is concentrated in the winter months, with minimal precipitation during the summer. As a result, water supplies in reservoirs significantly decrease during prolonged dry periods, leading to water scarcity. While dry conditions are typical in the summer, the frequency and intensity of extended droughts have increased due to climate change. Reduced winter rainfall, coupled with higher evaporation rates from water bodies, makes it challenging to replenish water reserves. Increased evaporation further reduce the availability of surface water, while extreme whether events, such as heatwaves and storms, are expected to become more frequent. These changes intensify the vulnerability of the region's water resources. The growing population of Athens, along with urbanization, tourism, and agricultural needs, has significantly increased the demand for water, placing immense pressure on available resources. This demand, coupled with insufficient infrastructure in some areas, exacerbates water scarcity. Overuse of both surface water and groundwater has led to depletion of local sources and potential seawater contamination in coastal aquifers. Additionally, pollution from agricultural runoff (fertilizers and pesticides), untreated sewage, industrial discharge, and urban runoff further degrade the quality of both surface water and groundwater. To tackle these critical issues, scalable and transferable solutions can be implemented, focusing on water recycling and reuse, resource efficiency and conservation, decision-making tools, stakeholder engagement, public awareness and policy improvements.

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A PLATFORM TO EXCHANGE AND BOOST KNOWLEDGE

Content

The Resilience Knowledge Booster (RKB) platform presents and explains climate-related risks in the region. It provides to users the opportunity to interact with the Attica Digital Twin and access a range of several solutions developed both at local level or spatial services and tools at a regional level. The Adaptation Pathways section includes a conceptual model for water scarcity (Impact chain), showcasing how hazard, exposure, and vulnerability factors interact to generate the risk of drought. Navigable maps identifying alternative Adaptation Pathways able to mitigate this risk are proposed. In the section Insights, users can download the Innovation Packages report including the present document.

Available at:
https://impetus.mantisims.gr/knowledge-boosters/mediterranean/.

Attica Digital Twin
The Digital Twin of Greece's Attica Region is a dynamic, virtual representation of real-world applications and water related distributed solutions and geospatial services. The cutting-edge platform leverages real-time data, advanced analytics, and simulation models to mirror the physical system's behaviour and performance enabling climate adaptation initiatives and solutions and serving as a central hub for knowledge-sharing and action. The platform facilitates a co-creation process that actively engages stakeholders and policymakers to drive green business development and enhance climate resilience.

Attica's Digital Twin aspires to become a one-stop shop for identifying innovative solutions already implemented across the region. Designed with scalability in mind, the Digital Twin can be easily expanded and adapted to incorporate new data sources, technologies, and evolving system requirements, including integration with third parties' developments. Its flexibility makes it an indispensable asset for promoting sustainable, data-driven decision-making across the region.

DISTRIBUTED INTERVENTIONS

Sewer mining
Sewer mining is an innovative wastewater recycling technology that transforms wastewater into a valuable resource, promoting urban circularity, resilience, and sustainability in the face of climate change.
The concept involves installing compact treatment plants directly where demand exists and wastewater is available. Wastewater is extracted from local sewers, treated on-site, and either reused immediately or stored. This approach is gaining traction due to its efficiency and minimal space requirements. Ongoing research in Markopoulo (eastern Attica) demonstrates its viability, particularly in dense urban areas facing drought and space constraints. By integrating sewer mining with freshwater conservation, cities can expand green

spaces, mitigate urban heat effects, and reduce pressure on central treatment facilities, unlocking the hidden potential of wastewater as a resource beneath city streets,

Controlled Environmental Agriculture
This CEA solution is an innovative decision support system piloted in a Mediterranean greenhouse. Using sensors, actuators, and intelligent networks, it monitors conditions and provides machine learning–based recommendations to optimize crop microclimates, improve energy and water efficiency, and support sustainable farming. As part of the IMPETUS project, the demo site is Attica Green in Spata, a peri-urban hydroponic facility facing environmental constraints (e.g., high-salinity water, proximity to the airport). Serving as a proof of concept, it demonstrates how advanced decision support can enhance precision, resilience, and sustainability in greenhouse agriculture.

Content

GEOSPATIAL SERVICES

Reforestation service

The Reforestation and Biodiversity Monitoring Tool provides information to monitor forest loss, biodiversity loss, forest tree species and offers localized restoration insights. By leveraging advanced data analytics, digital tools, satellite images, knowledge and information from relevant stakeholders and end-users, this initiative seeks to enhance forest restoration planning and decision-making at various governance levels. This tool provides accessible information, strengthens collaborative management, and supports evidence-based policies.

Meteorological heatmaps

The Meteorological heatmaps are created using real-time data from multiple sources-including meteorological stations, APIs, satellites, and radars-and standardized using FIWARE's Smart Data Models. To maximize usability, this data is visualized through interpolated heatmaps, which provide an intuitive and easily interpretable representation of evolving climate conditions. By translating complex datasets into clear visual patterns, heatmaps support faster situational awareness, informed decision-making, and the design of timely interventions, thereby strengthening urban resilience to climate change impacts.

Floodrisk analysis

Advanced flood modeling, risk analysis tools, and post-processing techniques can provide comprehensive flood risk assessments. Stakeholders can simulate and explore the impact of various rainfall scenarios-both historical and forecasted-and visualize the outcomes through an immersive 3D representation of the region. By translating complex flood data into intuitive visualizations, this approach supports proactive planning, faster decision-making, and the design of timely mitigation measures, thereby enhancing urban resilience to climate change–related flooding events

RKB - Exploitation potential

STAKEHOLDERS INTEREST

score 4/5

MAIN STAKEHOLDERS INVOLVED
The main stakeholders engaged in the RKB belong to academia, industry and economy, State, government and policy.

FEEDBACK FROM STAKEHOLDERS
Stakeholders found the proposed adaptation pathways particularly interesting, considering them realistic and well-suited for local adaptation. The sewer mining pilot was also highlighted as an effective, efficient and easily replicable technology for addressing water scarcity. The Attica Digital Twin received very positive feedback regarding its usage as a integrative tool, combining data from multiple sites, pilots and assets to support decision-making process.

STRENGTHS

score 3.5/5

A POWERFUL TOOL FOR THE VISUALIZATION AND EXPLORATION OF ADAPTATION OPTIONS.

RKB DIGITAL DIMENSION COMPONENT	SCORE
Visualisation (layout, images, graphic design)	4
Knowledge content (quality and type of information displayed)	4
Interactive functionalities (animations, customised navigation, dashboards)	3
Feedback collection tools (pools, chats)	3

OPPORTUNITIES FOR RKB USE

score 3/5

Some opportunities for the use of the RKB have been identified, although they are not yet fully concrete. Once fully operational, the RKB could serve as a centralized knowledge repository, facilitating the sharing of best practices, technical data, and adaptation strategies among stakeholders. The RKB in Attica could support more informed decision-making within regional planning, such as prioritizing water management interventions, assessing climate adaptation measures, and coordinating actions across municipalities and sectors. It is anticipated that in the near future the RKB may enable the development of concrete partnerships with local authorities, research institutions, and other stakeholders, fostering collaborative planning, enhancing knowledge exchange, and promoting the adoption of evidence-based solutions.

RKB - Gaps & needs

CHALLENGES FOR PLANNING AND DECISION MAKING PROCESS: Involve institutions and take care of the human dimension!

The major challenge for using the RKB in the Region of Attica's planning and decision-making process is securing the commitment of key authorities, particularly the Regional Authority of Attica and the Ministry of Environment, to formally incorporate the RKB into their strategic planning frameworks. Without their active engagement and endorsement, the RKB risks being underutilized or treated as a supplementary resource rather than as an integral tool for guiding adaptation and water management decisions. Beyond the digital aspect, the human dimension is crucial, the value of the RKB depends not only on the quality and structure of the digital platform but also on the willingness and capacity of people to use it effectively. Even a highly sophisticated digital system cannot influence decision-making unless stakeholders trust the data, understand how to navigate and interpret it, and see clear relevance to their responsibilities. Building this human-dimension capacity, through engagement, workshops, and co-creation activities, is therefore essential to ensure the RKB translates into actionable knowledge and drives informed, coordinated planning at the regional level.

PRIORITY	CHALLENGE
1	Governance challenges
2	Capacity challenges (ability and motivation to use knowledge for action)
2	Finance challenges
3	Knowledge (availability of information)

WHAT TO IMPROVE

The main weakness of the RKB lies in its reliance on continuous maintenance and updates by a limited group of authorized users. This dependency can restrict the longevity of the system, as well as its accessibility and effective utilization by stakeholders over time. If key users are unavailable or if resources for maintenance become scarce, the RKB risks becoming outdated, potentially undermining stakeholder trust and reducing its practical value. To improve the RKB, a more open and collaborative architecture could be considered. For example, implementing a wiki-like system would allow a broader range of users, including stakeholders from different sectors, to contribute updates, corrections, and new content. Such a model would distribute the maintenance responsibility, increase the frequency and relevance of updates, and enhance user engagement. Additionally, features such as version control, user tracking, and moderation could ensure data quality and reliability while maintaining an open-access structure. In the long term, this approach could improve the sustainability, scalability, and adaptability of the RKB, making it a living knowledge base that evolves with emerging challenges, technologies, and stakeholder needs. By leveraging collective knowledge in a structured yet flexible way, the RKB could become a more robust tool for supporting decision-making, fostering collaboration, and accelerating the adoption of best practices across sectors.

RKB - Transformational potential

A NOVEL FLEXIBLE AND EASY-SCALABLE APPROACH WITH LONG TERM VISION AND OUTCOMES

This approach emphasizes adaptability to emerging challenges, broad stakeholder engagement, and the sustainable evolution of the system over time. Its scalability ensures that it can be applied across different contexts and regions, while the long-term focus supports strategic planning and the continuous adoption of best practices.

TRANSFORMATION ELEMENT	SCORE
SCOPE: Responsive (flexible) to changing conditions	4
SCOPE: Developed at scale or easily scalable	4
DEPTH OF CHANGE: Novel approach for the region	4
TEMPORALITY: Long-term vision/expected to produce long-term and durable outcomes	4
SCOPE: The RKB platform includes a multi-sector approach	3
INCLUSIVITY: Co-developed/discussed with stakeholders	3
DEPTH OF CHANGE: Expected to generate radical shift or large restructuring in your region	2
INCLUSIVITY: Consideration for the equity of measures, attention for vulnerable groups	1

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ADAPTATION PATHWAYS TO ADDRESS FLOODING RISK

Content

INTRODUCTION

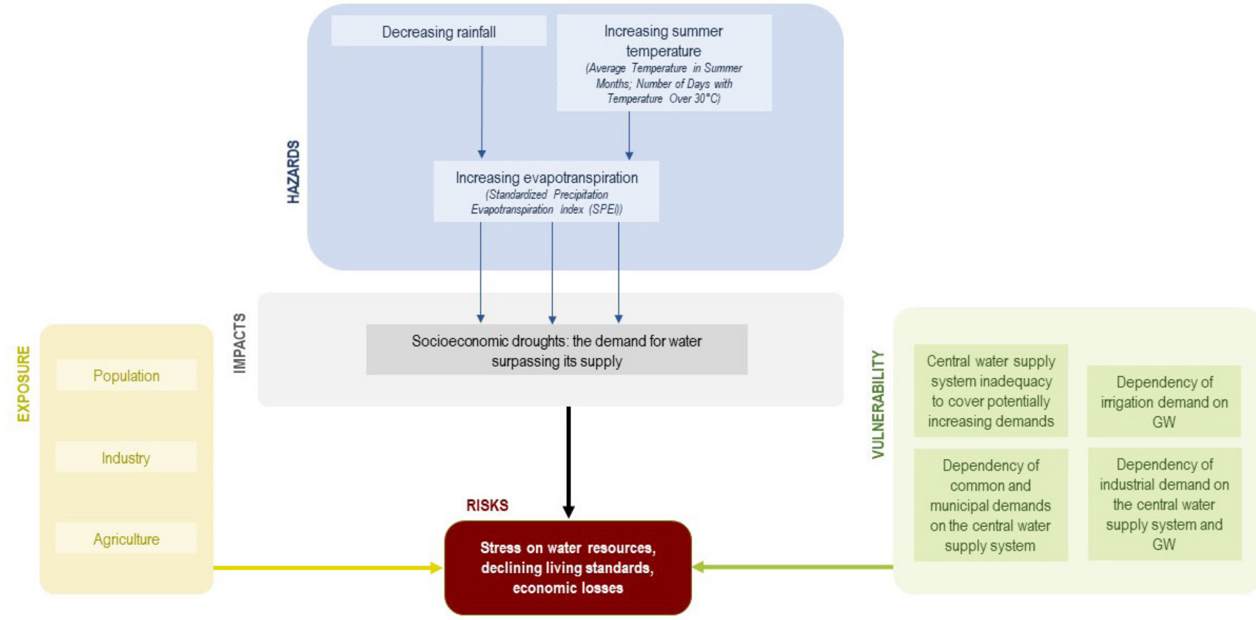
Adaptation pathways are sequences of adaptation measures that are planned to be progressively implemented to cope with the increasing or evolving risks posed by climate change. The implementation of additional, different or larger measures is triggered when current adaptation measures and policies are no longer effective to withstand climate change (tipping points), marking the need to shift to different and more effective solutions. The IMPETUS methodology for developing adaptation pathways (AP methodology) was applied in the seven project demo-sites. Stakeholder interactions were performed in each region with formal events and informal interactions. Interactions were continuously ensured from the beginning and across all the process of pathway development, also considering that key stakeholders include public administrations and utilities. Stakeholders were specifically consulted for discussing adaptation options and adaptation pathways, and their feedback was used to refine or even change the final outcomes.

East Attica in present times is facing urbanization, altering landscapes and straining water resources. Despite challenges, agriculture persists alongside emerging industries. Inadequate water infrastructure and urban expansion threaten the region's biodiversity, emphasizing the need for balanced development and conservation efforts.

The developed Adaptation Pathways focus on **water scarcity**, which is intimately related to temperature and precipitation, and (depending on its magnitude) can have significant impacts such as the degradation of several ecosystems (e.g. wetlands), the increased salinization of coastal aquifers, the -desertification and the reduction of available water resources used to meet the various needs of human activities. Urban sprawl (driven by population growth), as well as the expansion of economic sectors such as agriculture and industry can further intensify water stress. So, the main objective of the Adaptation Pathway developed for East Attica is related to building adaptive capacity (resilience) through actions for reducing the socioeconomic drought risk under certain climatic and socioeconomic scenarios. In the definition adopted for this work socioeconomic drought includes various types of water demand to satisfy civil, industrial and agricultural use.

THE IMPACT CHAIN

Impact chains (GIZ and EURAC, 2017; Zebisch et al., 2022, 2023) are useful tools to delineate conceptual models for climate change risk assessment. They are cause-effect chains that include all major factors and processes leading to specific climate risks in a specific context. Drinking water for the wider Attica region is largely supplied by Athens Water Supply and Sewerage Company (EYDAP). The water supply system essentially relies on four reservoirs: Mornos, Evinos, Yliki and Marathonas. Out of those, only Marathonas is in the Region of Attica, however it is rarely used and serves primarily as an emergency source. Furthermore, groundwater is also used by the system, mainly as a backup supply. Agricultural water demand in Attica is largely covered by groundwater extractions. To an extent, groundwater is also used for industrial uses. The impact chain is focused on the impacts of climate change (decreasing rainfall and increasing temperature) in terms of socioeconomic drought. This model has been used to calculate the consequential risk of stress on the water resources, deterioration of living standards and economic losses. In this context, factors that can contribute to the quantification of this risk were identified. These factors include climatic variables (hazards), exposure and vulnerability elements. Meteorological droughts induced by climate change will propagate to the surface water and groundwater bodies, reducing the available water resources. This reduction (especially when accompanied by an increase in water demands by multiple society's sectors) can trigger socioeconomic drought. This can affect the population of East Attica, as well as different economic activities such as agriculture, tourism and industry, which take place in the region. Those are used in the impact chain as exposure elements. The related risks would further increase with an increase in population (e.g. due to urbanization), as well as the intensification of agricultural activities and the expansion of industry. The vulnerability elements express the potential inadequacy of the water supply system by EYDAP to meet the demands, while also the dependency of the different considered water uses on the water supply system by EYDAP and the groundwater bodies. Vulnerability can decrease by a) reducing the water demands, e.g. via raising public awareness and implementing relevant policies) and b) partially "decoupling" the water demands from the central water supply network and the groundwater, e.g. via decentralized systems (rainwater harvesting, sewer mining), reuse of treated water from the WWTPs (for irrigation), improved agricultural practices and desalination.



THE PATHWAYS MAPS

To identify and evaluate alternative pathways for climate adaptation, the Dynamic Contingency Response Tool (DCRT) - developed by the National Technical University of Athens (NTUA) in the framework of IMPETUS project - was employed. The modelling work was performed for two climate scenarios: SSP2-RCP 4.5 and SSP5-RCP 8.5, utilizing risk projections derived from another tool (REPIE) developed by NTUA. Risk's dynamics were analysed also for SSP1-RCP 2.6, but since related results were not very different from SSP2, modelling activity with DCRT was limited to SSP2 and SSP5. The following visuals show the adaptation pathways maps for SSP5 scenario. DCRT identified and evaluated 181 potential pathways on a Pareto Front, focusing on optimizing two main primary objectives: Efficiency in the reduction of risk and Total cost associated with the implementation of selected interventions. Four pathways were then identified:

- **Pathway 1 (AP1):** the most effective pathway.
- **Pathway 2 (AP2):** the least cost pathway.
- **Pathway 3 (AP3):** the "optimal" pathway based on the elbow point from the Pareto Solution. The elbow point is identified as the pathway where the marginal gain in effectiveness starts diminishing relative to the increase in cost.
- **Pathway 4 (AP4):** A pathway considering with equal importance all possible criteria (efficiency, costs, adherence to annual budget constraints, technical and social feasibility, hidden risks, co-benefits)., establishing a resilient, future-proof urban landscape that not only mitigates heat stress but also enhances overall liveability.

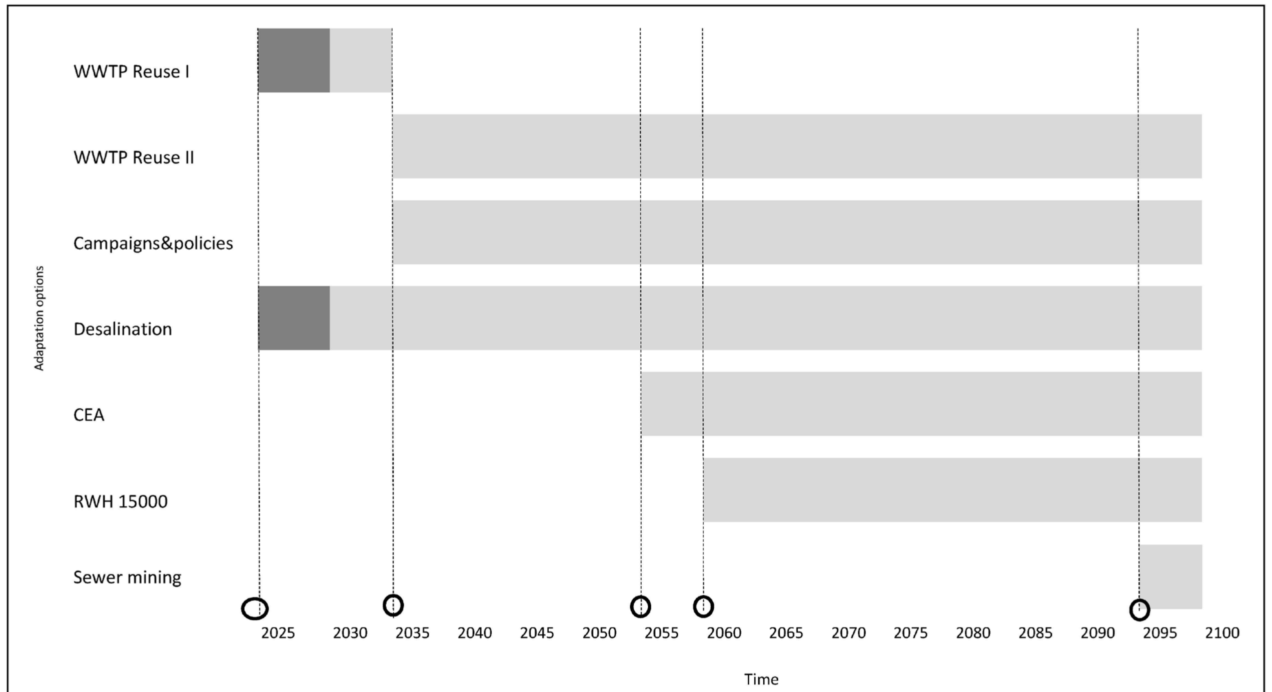
The option of reusing water from wastewater treatment plants for irrigation was divided in two phases of progressive implementation: the first phase of the project (WWTP REUSE I) is expected to be able to cover the irrigation demands of about 1,600 ha of agricultural land. The second phase (WWTP REUSE II) is expected to cover the irrigation demands of about 2,500 ha overall. The rainwater harvesting adaptation option is split in two phases as well: implementation in 5,000 buildings and in 15,000 buildings.

Under SSP5 scenario the risk reduction achieved by AP2 (Least cost) and -AP4 (Equal weight to all objective) is too low, definitely not sufficient even if AP2 could be more feasible and AP4 could bring higher co-benefits and lower hidden risks. According to this, a substantial investment between €2.2 billion (AP3 Elbow Point) and €2.5 billion (AP1 Most Effective) appears necessary to achieve meaningful risk reduction. Among these, AP3 offers the best cost-effectiveness balance, making it a compelling choice for decision-makers aiming to optimize both risk reduction and financial feasibility. The choice between pathways ultimately depends on decision-makers' priorities regarding cost, effectiveness, and the balance between competing objectives.

A description and detailed analysis of the measures included in the adaptation pathways is reported in the next section "Portfolio of Solutions".

In the following graphs, the dark colour of the bars represents the implementation time of measures, while the light colour represents how long they stay in place.

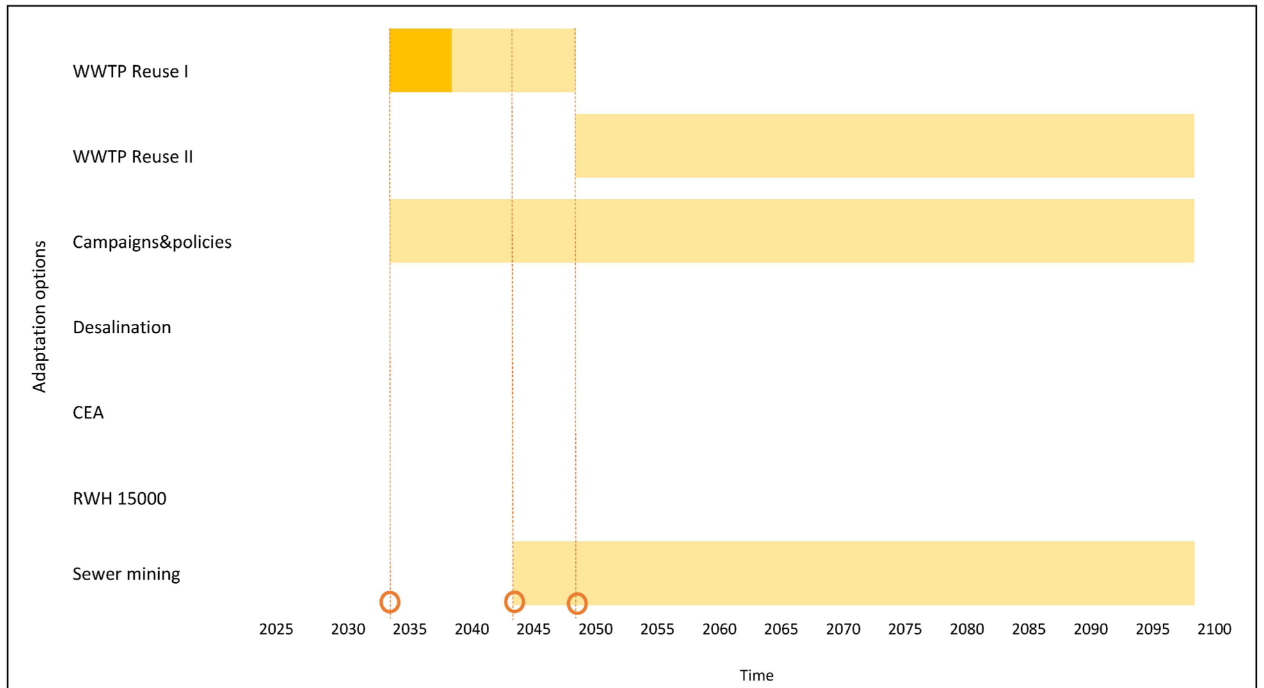
SSP5 SCENARIO Adaptation Pathway 1 (SSP5-AP1): The Most Effective



	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
Risk in a business as usual scenario	2,5	3,5	5	5,8	6,2	7	8	8,2	8,5	9	9,2	9,6	9,7	9,8	9,9	10
Residual Risk after the implementation of alternative adaptation pathways																
SSP5 AP1 (the most effective)	2,5		3,5				4	5								7,8
SSP5 AP2 (the least cost)			5		5	5,5										9
SSP5 AP3 (balanced strategy)	2,5	3,4	4	4,5												7,8
SSP5 AP4 (equal weight to all criteria)		3,5	5	4,2		5	6									9

figure: DS3 Adaptation Pathways Maps

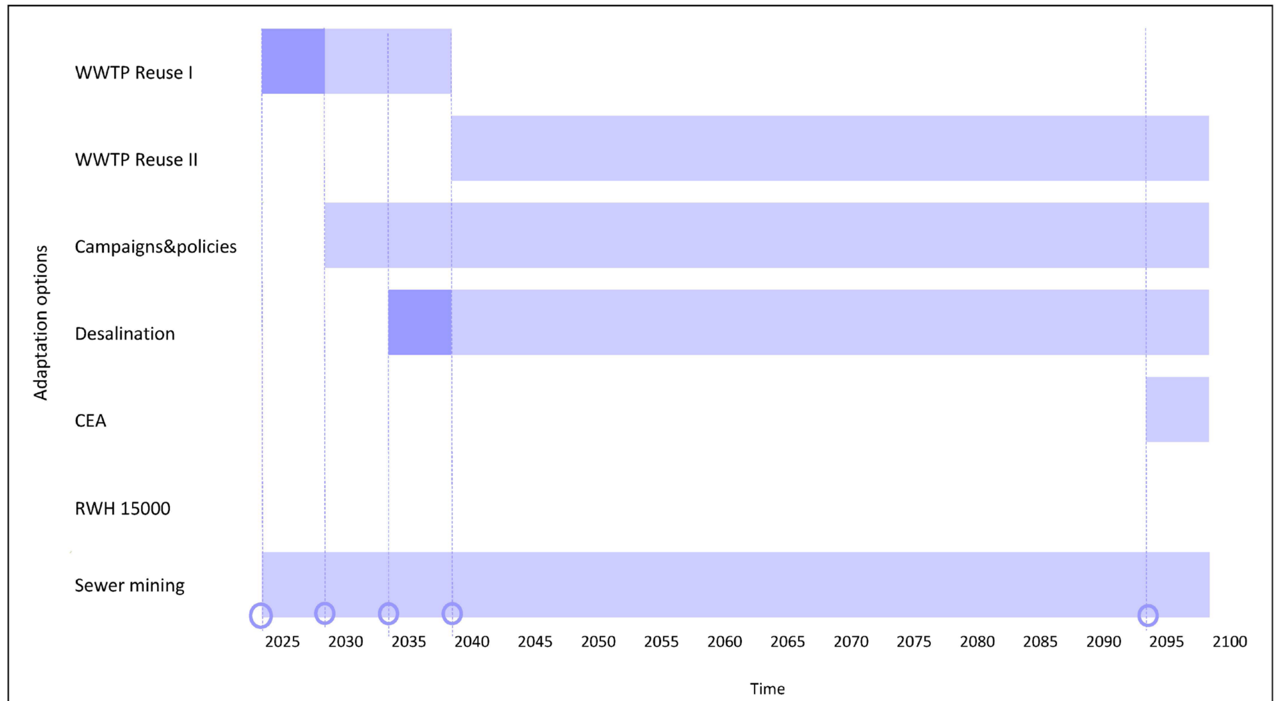
SSP5 SCENARIO Adaptation Pathway 2 (SSP5-AP2): The Least Cost



	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
Risk in a business as usual scenario	2,5	3,5	5	5,8	6,2	7	8	8,2	8,5	9	9,2	9,6	9,7	9,8	9,9	10
Residual Risk after the implementation of alternative adaptation pathways																
SSP5 AP1 (the most effective)	2,5		3,5				4	5								7,8
SSP5 AP2 (the least cost)			5		5	5,5										9
SSP5 AP3 (balanced strategy)	2,5	3,4	4	4,5												7,8
SSP5 AP4 (equal weight to all criteria)		3,5	5	4,2		5	6									9

figure: DS3 Adaptation Pathways Maps

SSP5 SCENARIO Adaptation Pathway 3 (SSP5-AP3): Balanced Strategy



	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
Risk in a business as usual scenario	2,5	3,5	5	5,8	6,2	7	8	8,2	8,5	9	9,2	9,6	9,7	9,8	9,9	10
Residual Risk after the implementation of alternative adaptation pathways																
SSP5 AP1 (the most effective)	2,5		3,5				4	5								7,8
SSP5 AP2 (the least cost)			5		5	5,5										9
SSP5 AP3 (balanced strategy)	2,5	3,4	4	4,5												7,8
SSP5 AP4 (equal weight to all criteria)		3,5	5	4,2		5	6									9

figure: DS3 Adaptation Pathways Maps

SSP5 SCENARIO Adaptation pathway 4 (SSP5-AP4): Weight to all Criteria

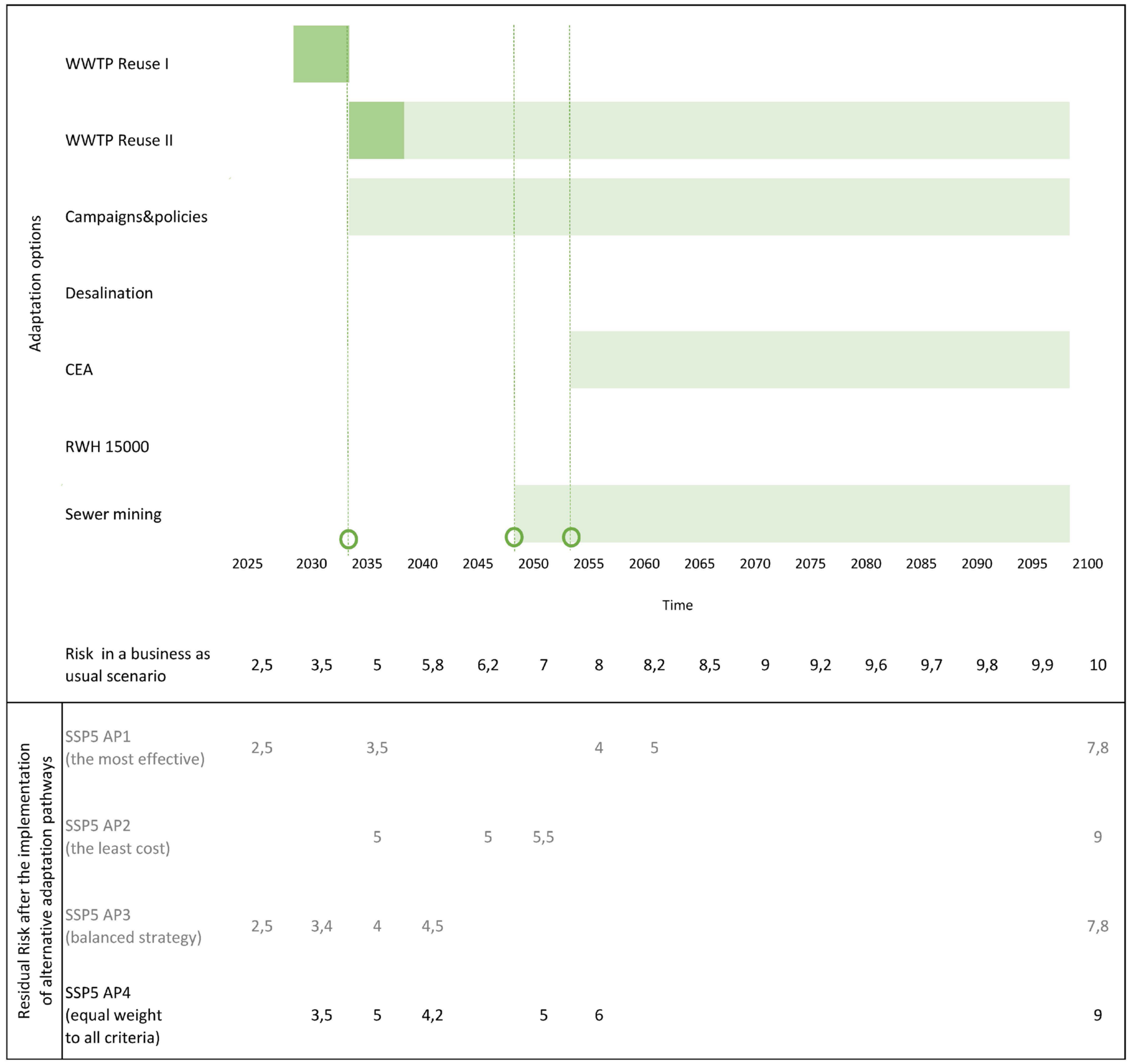


figure: DS3 Adaptation Pathways Maps

Adaptation pathways - Exploitation potential

STAKEHOLDERS INTEREST

score 4/5

MAIN STAKEHOLDERS INVOLVED

The main stakeholders belong to academia, industry and economy, state government and policy sectors.

FEEDBACK FROM STAKEHOLDERS

Participants from various stakeholder groups were actively involved in discussion on the Adaptation Pathways approach. These included the Athens Water Supply and Sewerage Company (EYDAP), the Region of Attica, the Water Directorate of the Decentralized Administration of Attica, the Green Fund, small and medium-sized enterprises (SMEs), the City of Athens, as well as universities and municipalities across Attica. Water scarcity is a pressing environmental issue in Attica. For this reason, the Adaptation Pathways methodology-used to identify a sequence of interventions and determine their priority based on multiple criteria-was considered highly valuable. During the workshops, participants engaged with a series of interactive online exercises addressing water scarcity challenges in Attica. They respond simultaneously while discussing and reflecting with other participants. Most stated that they intended to apply the proposed Adaptation Pathways methodology and its outcomes in their work to support climate change adaptation planning. Such engagement solicited participants to express their concerns regarding water scarcity under climate change, in particular as regard to agricultural risks and rising water costs. According to participants, the suggested methodology can:

- Promote dialogue and collaboration among governmental bodies and key stakeholders.
- Facilitate decision-making on climate change adaptation strategies and actions.
- Support the allocation and justification of funding for necessary interventions.

OPPORTUNITIES TO USE ADAPTATION PATHWAYS

score 4/5

Based on the discussions and the overall process of engagement and co-creation for the development of Adaptation Pathways, several concrete opportunities were identified for the application of the methodology in the Region of Attica's current planning and decision-making.

A key opportunity that emerged is the integration of the **sewer mining decentralised solution in combination with the central water reuse systems** into regional water management strategies. Stakeholders recognized this as a highly promising intervention to address water scarcity, with clear applicability in urban, semi-urban and agricultural contexts. Specifically, EYDAP, as the main operator and owner of water and wastewater infrastructure, is already developing a master plan to implement these solutions. This includes the installation of over 20 sewer mining units in urban parks to ensure a sustainable supply of water for green spaces, as well as the reuse of treated effluent from central wastewater treatment plants to support the agricultural sector. These initiatives directly respond to pressing challenges in current planning, including the need to secure water for food production, maintain urban ecosystems, and build resilience to prolonged drought periods. Another important opportunity relates to r**egulatory and institutional learning**. Through the Adaptation Pathways process and pilot applications, both local and central governance authorities have gained valuable experience in wastewater reuse, which has contributed to a gradual maturation of the regulatory environment. This is expected to support decision-making by enabling faster permitting processes, clarifying institutional responsibilities, and creating a more supportive policy framework for the expansion of water reuse projects. In addition, stakeholders highlighted the potential of the methodology to generate co-benefits that extend beyond water scarcity management. For example, the promotion of sewer mining and reuse can reduce environmental pressures on ecosystems, improve urban liveability through the preservation of green spaces, and create new opportunities for SMEs active in water treatment technologies. These broader benefits align with the Region of Attica's long-term priorities for sustainable development and climate change adaptation, thereby reinforcing the relevance of Adaptation Pathways in current planning processes. Overall, the engagement and co-creation activities revealed that the Adaptation Pathways methodology offers not only a framework for prioritizing interventions but also a practical tool to guide investment decisions, regulatory reforms, and cross-sectoral collaboration in Attica. Its integration into ongoing planning is already visible through EYDAP's strategic initiatives, and it holds significant potential to shape future adaptation strategies at the regional level.

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Adaptation pathways - Gaps & needs

CHALLENGES - HOW TO TRANSLATE INTO PRACTICE

Several major challenges were identified in translating the Adaptation Pathways (AP) methodology into practice in the Region of Attica. The first challenge concerns the **regulatory and institutional framework**. While there is growing acceptance of innovative solutions such as sewer mining and central water reuse, the current legal and administrative procedures remain complex, fragmented, and often slow. Lengthy permitting processes, overlapping responsibilities among authorities, and a lack of clear guidelines for decentralized reuse applications hinder the ability to move quickly from pilot projects to large-scale implementation.

A second challenge is f**inancial sustainability and resource mobilization**. Large-scale investments in new technologies, infrastructure, and decentralized solutions require substantial funding, which is often not readily available in municipal or regional budgets. Although stakeholders acknowledged that Adaptation Pathways can guide cost-effective prioritization, uncertainties about long-term financing mechanisms and the allocation of responsibilities between public and private actors remain barriers to implementation. For this matter, EYDAP is considering the possibility of undertaking the funding of the investment, provided that the end users (e.g. municipalities) will further support the operation and maintenance of the infrastructure.

A third challenge relates to **coordination and governance capacity**. Effective application of the AP methodology requires close collaboration among multiple stakeholders, including EYDAP, municipalities, regional authorities, ministries, SMEs, and civil society. While the co-creation process successfully initiated dialogue, stakeholders noted that sustained collaboration and integrated planning across sectors is still difficult to achieve in practice, especially given differing institutional agendas and resource constraints.

Another important challenge is **public perception and acceptance**. Although stakeholders showed strong support for reuse and adaptation solutions, broader societal acceptance is not guaranteed. Concerns about water quality, safety, and the “acceptability” of treated wastewater for uses within the urban environment for the irrigation or parks may affect the uptake of proposed interventions unless robust and dedicated communication and engagement strategies are implemented.

Finally, there is the overarching challenge of **uncertainty under climate change**. The AP methodology provides flexibility, but stakeholders emphasized that unpredictable climate dynamics, combined with socio-economic shifts, may complicate the timing and sequencing of interventions. This requires continuous monitoring, adaptive governance structures, and the willingness to revise plans as conditions evolve. In summary, the main challenges to translating Adaptation Pathways into practice in Attica revolve around institutional and regulatory hurdles, financial constraints, cross-sectoral coordination, public acceptance, and the management of long-term uncertainty. Addressing these challenges is crucial to ensure that the promising solutions identified through the AP process can be effectively embedded into the region’s adaptation planning and decision-making.

PRIORITY	CHALLENGES
1	Governance challenges
	Financial challenges
	Knowledge (availability of information)
2	Capacity challenges (ability and motivation to use knowledge for action)

WHAT TO IMPROVE

Building Adaptation Pathways is a complex and dynamic process, for which both **data availability and modelling capacity** play a major role. In particular, higher-resolution climatic and socioeconomic data (both temporal and spatial) would be beneficial. Also tailor-made models for the simulation of the regions behaviour under the changing conditions would be beneficial for sequencing adaptation options as well as identifying and assessing alternative pathways.

Adaptation pathways - Transformational potential

A MULTI-SECTOR APPROACH IMPACTING THE SCOPE OF CHANGE WITH LONG-TERM OUTCOMES

ELEMENTS OF TRANSFORMATION

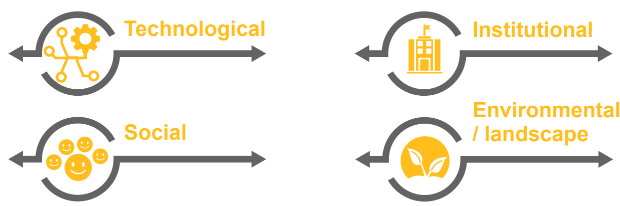
The Adaptation Pathways approach:

- Embraces a **multi-sector perspective**, as it brings together diverse stakeholders, such as water utilities, regional and local authorities, agriculture, SMEs, and civil society, to co-design interventions that address climate risks across environmental, social, and economic sectors.
- Is **designed to be responsive and flexible**, as it allows for adjusting the timing and sequence of interventions based on the different climate scenarios and related uncertainties evolve over time.
- Is designed to be **scalable**. While initial applications are often implemented as pilots at the local level, the methodology supports expansion to larger scales by providing a **structured framework** for prioritizing, sequencing, and adapting actions over time.
- Is a very good start and might be considered **novel** for the region, as it introduces a structured, flexible, and participatory framework for climate change adaptation planning. By integrating multi-stakeholder engagement, sequencing interventions over time, and allowing adjustments based on evolving climatic conditions, it goes beyond traditional sectoral planning.
- Is not expected to generate a sudden radical shift, but it can lead to **significant long-term restructuring** in the region's planning and decision-making processes.
- Was **not fully co-developed with stakeholders**. Instead, it was presented to them and validated through their feedback, allowing stakeholders to provide input and confirm the relevance and feasibility of the proposed interventions.
- Presently includes **no consideration of equity aspects.** While it engages multiple stakeholders in planning, specific attention to vulnerable groups, marginalized communities, or gender balance has not been systematically incorporated into the process so far.
- Is expected to produce **long-term and durable outcomes**. By prioritizing flexible, sequenced interventions that can be adjusted over time in response to evolving climatic and socio-economic conditions, the AP approach, supports sustainable planning, strengthens resilience, and fosters lasting improvements in water management and climate adaptation strategies.

TRANSFORMATION ELEMENT	SCORE
SCOPE: The AP elaboration process includes a multi-sector approach	5
SCOPE: Responsive (flexible) to changing conditions	4
SCOPE: Developed at scale or easily scalable	4
DEPTH OF CHANGE: Novel approach for the region	4
TEMPORALITY: long-term vision/expected to produce long-term and durable outcomes	4
INCLUSIVITY: Co-developed/discussed with stakeholders	3
DEPTH OF CHANGE: Expected to generate radical shift or large restructuring in your region	2
INCLUSIVITY: Consideration for the equity of measures, attention for vulnerable groups	1

IMPACT OF TRANSFORMATION

Implementation of the pathway would drive technological advancements (e.g., sewer mining and water reuse, enhancing efficiency and sustainability in water management), foster social and institutional coordination among stakeholders to strengthen collaboration and engagement among diverse stakeholders and improve coordination and decision-making across agencies and sectors, and generate significant environmental and landscape benefits through sustainable water management practices, protecting ecosystems, enhancing urban green spaces, and improving overall environmental quality.



A PORTFOLIO OF CLIMATE ADAPTATION SOLUTIONS

Content

Eleven adaptation solutions to address water scarcity were assessed. Most of them (six) were specifically tested in IMPETUS.

In order to facilitate comparison among the high variety of adaptation options considered across all DSs, adaptation options were categorised according to the Key-Type-of-Measure (KTM) system, defined at the European level (Leitner et al., 2021) as voluntary mechanism to report climate adaptation actions in the EEA member countries, as part of the EU Regulation on Governance of the Energy Union and Climate Action Energy Union Governance Regulation (2018/1999). The overall set of solutions is quite diversified, even if the majority refers to “grey options” (five solutions). The two green solutions are represented by “Biodiversity monitoring – forest fires and restoration” and “Controlled environmental agriculture”.

OPTION	DESCRIPTION	MAIN OBJECTIVE(S)	IMPETUS CLIMATE RISK	KEY TYPE OF MEASURE	TESTED IN IMPETUS
Sewer mining	Retrieving wastewater from local sewers, treating it and using it for local non-potable uses.	To provide new sources of water supply for non-drinking use.	Water scarcity	C1 - Grey options	Y
Biodiversity monitoring - Forest fires and restoration	Online service developed to monitor continuously the biodiversity of different landscapes in the Attica region to offer restoration strategies based on existing biodiversity and ecosystem services.	To increase biodiversity knowledge and enhance restoration potential.	Water scarcity	D1 - Green Options	Y
Water-Energy Model	Water-Energy simulation and optimization model for wastewater systems acting as regional circular economy and climate resilience hubs.	Address the climate change vulnerability matters and provide solutions to increase the Region's resilience.	Water scarcity	C2 - Technological options	Y
Digital Twin	A Regional Digital Twin for climate adaptation and green business development.	To facilitate stakeholders' engagement and co-creation in the climate adaptation and green business development.	Water scarcity	E1 - Information and awareness raising	Y
Water-Energy Masterplan	Water-Energy Masterplan and Business Plan for autonomous climate proof regions.	To provide the central government with a plan in the water-energy sector that will increase the climate resilience of the region, also ensuring the plan's viability under climate change.	Water scarcity	A2 - Management and planning	Y
Controlled Environment Agriculture	Growing crops indoors, in controlled environments (greenhouses).	To facilitate the adoption of smart CEA solutions and to shift towards a sustainable and more environmental friendly CEA.	Water scarcity	D1 - Green Options	Y
Rainwater harvesting	Collection of rainwater falling on surfaces such as roofs and using it (after treatment when needed) to cover certain non-potable water demands.	To cover some non-drinking water demand.	Water scarcity	C1 - Grey options	
Wastewater reuse from Water Treatment Plants (WWTP) for irrigation of agricultural areas	Additional treatment in the WWTP to subsequently use the treated water for irrigation of agricultural fields.	To provide new sources of water supply for non-drinking use.	Water scarcity	C1 - Grey options	
Desalination	Desalination plant - Removal of mineral components from sewater to make it usable for further use.	To enhance water availability by converting seawater to potable water.	Water scarcity	C1 - Grey options	
Information campaigns and policy	Information campaigns to raise public awareness and the establishment of regulations and policies aiming at reducing water demands.	To reduce water demand.	Water scarcity	E1 - Information and awareness raising	
Reducing water leaking from the water distribution system	Renovation of water supply distribution networks.	To reduce water supply losses.	Water scarcity	C1 - Grey options	

Portfolio of solutions - Evaluation

Decision support tools such as the Digital twin and the Water-energy model as well as Controlled Environmental Agriculture (CEA) solutions co-designed through a Decision Support system were considered as the most effective to address the climate hazards of the region. From the interventions point of view, reducing water leakages from the distribution system is considered equally important even if, on the other hand, it is quite costly. Almost all solutions are considered highly feasible and able to bring a consistent amount of co-benefits (a total of 23 were identified) compared to a relatively low amount of possible negative effects (11). Several solutions such as the decision support tools aforementioned, the water-energy masterplan and the online service to monitor forest biodiversity can activate fruitful synergies with the climate mitigation sector.

		ASSESSMENT													GAPS & NEEDS for implementation
#	Synthetic name of the option	Effectiveness for the expected objective	Lifetime	Feasibility - TRL	Feasibility - SRL	Economic costs	Benefits	Evaluate Environmental benefits	Evaluate Social benefits	Negative unintended effects/hidden risks	Evaluate Environmental negative unintended effects/ hidden risks	Evaluate Social unintended effects/hidden risks	Implementation time	Synergy with mitigation	
1	Sewer mining T4.5.2			+++	++		Less pressure on WWTPs. Less pressure on potable water system and groundwater resources. Source of fertilizer from sludge. More green urban areas, if used for watering parks. Shift in people's mindsets regarding the need for a transition to a circular economy.			Relatively low acceptability, in need of maintenance, occasional disturbances (e.g., odors) in case of mulfunctioning, occasional blockages due to incoming effluents.				No	Public acceptance. Regulatory framework (lack of legislation which frames the sewer mining solution). Financial feasibility. Technical challenges (e.g. how to extract sewage, how to adapt to the variability of demand, what to do with by products).
2	Biodiversity monitoring - Forest fires and restoration T4.4	++	++	+++	+++	-								Yes	Multiple number of datasets that need to be combined but most likely will have temporal or spatial incompatibility. Immaturity of holistic remote sensing approaches for biodiversity detection and species determination, great complexity of ecological systems and drivers impacting them. The amount of data that have to be processed can easily categorize it into the field of Big Data. Difficulty to collect in situ measurements and find local ecological georeferenced datasets.
3	Water-Energy Model T4.5.3	+++		- - -	- - -	No								Yes	
4	Digital Twin T4.10.4	+++	+	+++	+++		More data and knowledge available for policy makers of the Attica Region. Enhanced green businesses. Increased public awareness on climate change challenges.							Yes	Fragmented information and knowledge on implemented solutions. Technical challenges of the platform. Issues in reaching out to the engaged parties to use the DT platform.
5	Water-Energy Masterplan T4.15	++	+++	+++	++	- -	Local farmer communities supported. Enhanced protection for sensitive groundwater bodies. Improved conditions of coastal aquifers and mitigated saline intrusion. Provision of ecosystem services from restored sensitive ecosystems. Improved firefighting and reforestation activities after forest fires.							Yes	Immaturity/applicability of solutions. Public acceptance of innovative initiatives. Coordination of various involved parties to determine suitable vulnerable areas of the Region for the interventions. Uncertainty in the financial assessment of the proposed interventions.
6	Controlled Environment Agriculture T4.20	+++	++	+++	++	- -	Reduced water consumption. Reduced energy consumption. Improved resource efficiency. Enhanced agricultural productivity. Strengthened local economies.	+++	+++	Inaccurate model predictions due to insufficient data collection from IoT network.				Yes	Lack of infrastructure of existing CEA farms.
7	Rainwater harvesting		+++	+++	+++		Lower pressure on sewer system. Reduced use of groundwater.			Maintenance. Not effective when there is no precipitation. Can attract mosquitos if not properly managed.				No	Building code, some difficulty in installing large systems in existing homes.
8	Wastewater reuse from Water Treatment Plants (WWTP) for irrigation of agricultural areas			+++	++					Health issues from reused water transported, e.g., to aquifers.			- - -	No	Need to persuade farmers to use reclaimed water.
9	Desalination			+++	+++					Residual salt and other substances are discharged in the sea and can harm ecosystem.				No	Costs.
10	Information campaigns and policy				++		Increase in community awareness and engagement.			Disruption of current living/consumption habits.	- - -			No	
11	Reducing water leaking from the water distribution system	+++	+++	+++	+++	- - -	Reduction of water extracted from water bodies. Reduction of energy and costs for water treatment and transport.						- - -	No	

Portfolio of solutions - Transformational potential

ELEMENTS OF TRANSFORMATION

The set of measures outlines an excellent potential for transformation as the average scoring of all solutions is 4.1 (on a scale of 5). The portfolio of solutions ranks high in all aspects of Scope, Depth of Change and Inclusivity. In particular, most of the solutions has a strong potential to be replicated at scale, e.g. from local to regional, and are expected to produce long term and durable changes. They are also inclusive, since a significant process of co-creation was developed together with relevant stakeholders in the region.

As regards the specific solutions, the of "Water-energy model" and the "Reuse of treated wastewater in agriculture" are considered as the ones able to bring the most valuable contribution to adopt a transformational approach to adaptation. In this respect, some efforts to imagine and elaborate new approaches, styles, methods and messages to communicate in order to raise social awareness and have a stronger impact on society at large as well as the discussion of new regulations aimed at reducing water demand could be produced.

In this way the transformational potential of such type of solutions would reach levels comparable to other more structural solutions.

	SCOPE			DEPTH OF CHANGE		INCLUSIVITY		TEMPORALITY
Synthetic name of the option	Include a multi-sector approach	Responsive to changing climatic conditions	Developed at scale or easily scalable	Novel for the region	Expected to generate radical shift or large restructuring in your region?	Co-developed/ discussed with stakeholders	Consideration for the equity of the measure with specific attention to vulnerable groups, marginalised communities and gender balance	Expected to produce long-term and durable outcomes
Sewer mining	2	5	5	5	4	5	4	5
Biodiversity monitoring - Forest fires and restoration	3	5	5	3	4	5	not applicable	4
Water-Energy Model	4	5	5	5	5	4	not applicable	5
Digital Twin	4	4	5	5	3	4	not applicable	3
Water-Energy Masterplan	5	4	5	4	4	5	4	5
Controlled Environment Agriculture	4	4	5	4	4	4	3	5
Rainwater harvesting	2	4	5	4	5	3	3	5
Wastewater reuse from Water Treatment Plants (WWTP) for irrigation of agricultural areas	4	4	5	5	5	5	4	5
Desalination	2	5	5	5	5	4	5	5
Information campaigns and policy	3	2	3	3	3	4	not applicable	2
Reducing water leaking from the water distribution system	2	1	5	2	3	4	not applicable	5

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Portfolio of solutions - Transformational potential

IMPACT OF TRANSFORMATION

The implementation of the solutions is destined to have very important impacts on the technology sector (seven options) and on the institutional organization of the region (six options). Several options (five) involves an important behavioural transformation in the society.

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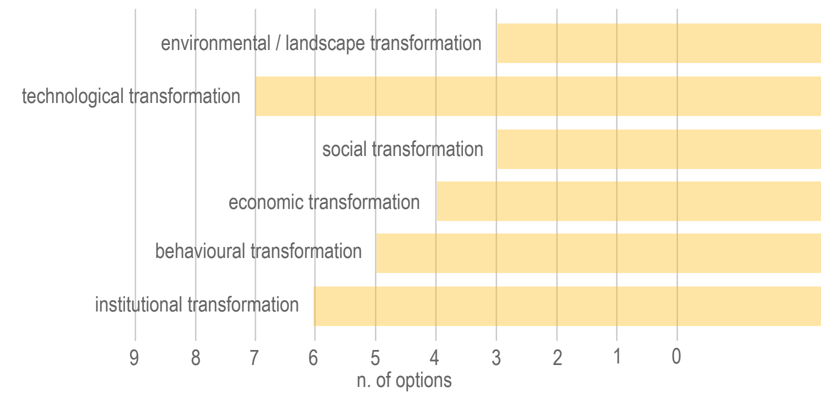
Figure: Impacted sectors



IMPACT OF TRANSFORMATION						
Synthetic name of the option	**Economic transformation**	**Technological Transformation**	**Social transformation**	**Institutional transformation**	**Behavioural transformation**	**Environmental / Landscape transformation**
Sewer mining		X				X
Biodiversity monitoring - Forest fires and restoration				X		X
Water-Energy Model	X	X		X		
Digital Twin				X		
Water-Energy Masterplan	X	X		X		
Controlled Environment Agriculture	X	X			X	X
Rainwater harvesting			X		X	
Wastewater reuse from Water Treatment Plants (WWTP) for irrigation of agricultural areas		X	X	X	X	
Desalination		X	X		X	
Information campaigns and policy				X	X	
Reducing water leaking from the water distribution system	X	X				

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IMPETUS

Turning climate commitments into action