IMPETUS

Turning climate commitments into action

BERLIN - BRANDEBURG

Innovation Package for adaptation and resilience

This project has reeived funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No. 101037084

September 2025

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Continental 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 (RKBs), an innovative approach that combines 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 the demo-site level. They are composed of three blocks:

1. RKBs and their digital dimension for engaging stakeholders and boosting 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 the 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.

Key concepts:
Innovation and Transformation

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

- The incorporation of a 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)

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 Repository of Solutions. Each block includes a synthesis of the 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.

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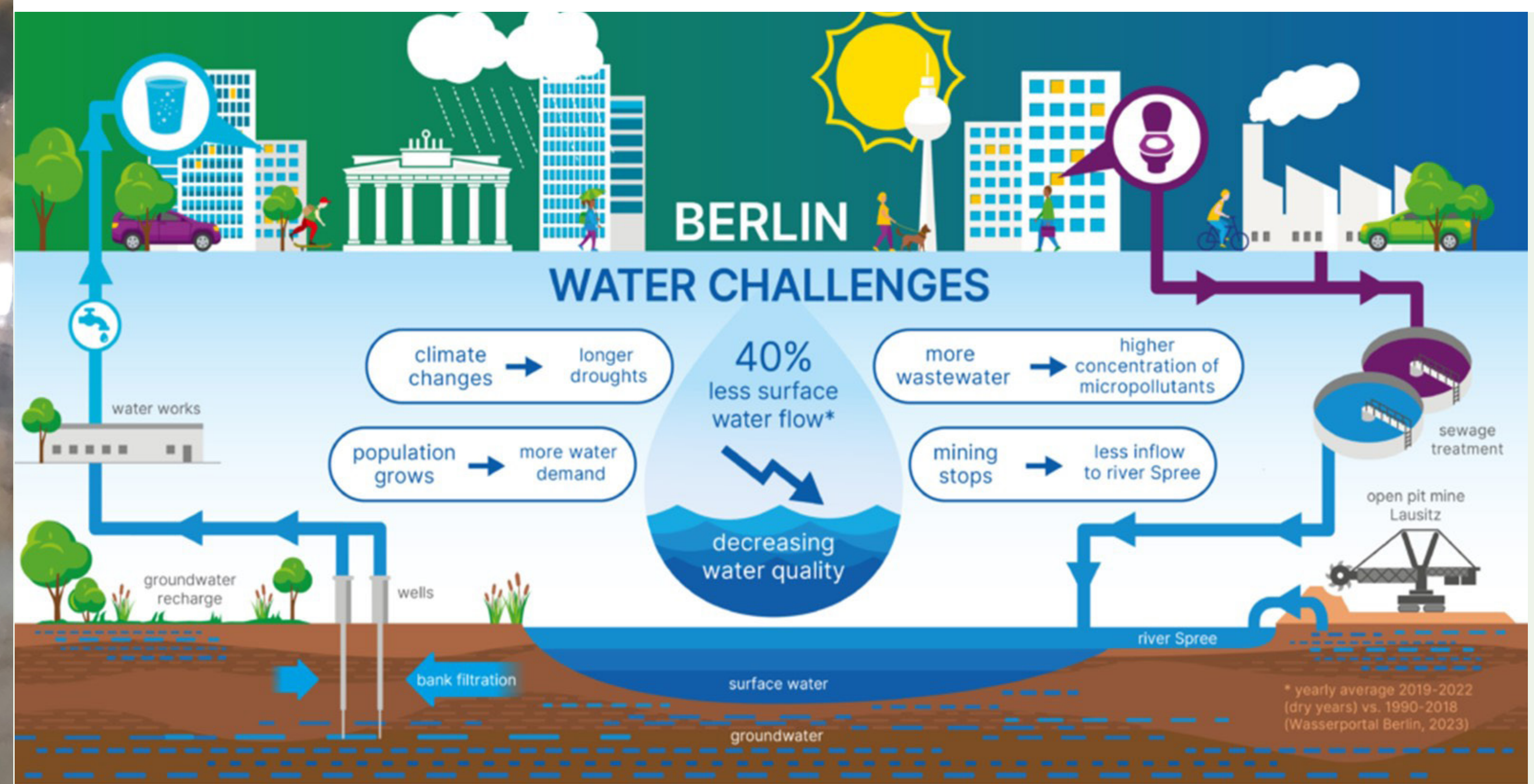
THE CLIMATE RISKS OF THE REGION

Water scarcity

The metropolitan Berlin-Brandenburg region in the north-eastern German lowlands has a relatively high surface area of rivers and lakes. The main rivers flowing through Berlin are the Spree and Havel. However, natural flow is low and increasing temperatures have led to higher evaporation rates and drought periods resulting in reduced river flows. In addition, the nearby open pit mine in Lausitz stays dry by pumping its groundwater into the river Spree. On average, one third of the river water comes from the open pit mine. Due to Germany's decision to exit coal production until 2038, the pit mine in Lausitz will also end its operation resulting in further reduced river flow in the Spree river.

For the production of drinking water, Berlin mainly relies on riverbank filtration and groundwater recharge using surface water as the main source. As some of the surface waters used for bank filtration are impacted by treated wastewater discharged upstream by wastewater treatment plants, the water cycle is partially closed. When river flows decrease, water quality in affected rivers decreases as well due to higher shares of treated wastewater resulting in increasing challenges for water management.

To address these challenges, Berlin developed the "Masterplan Wasser", Berlin's comprehensive strategic framework for future water management. The plan includes over 30 concrete measures for securing the drinking water supply, protecting water bodies, and adapting wastewater management. Significant investments are proposed to enhance water and resource protection, aiming to close knowledge gaps, minimize uncertainties, and develop adaptive measures for future challenges.

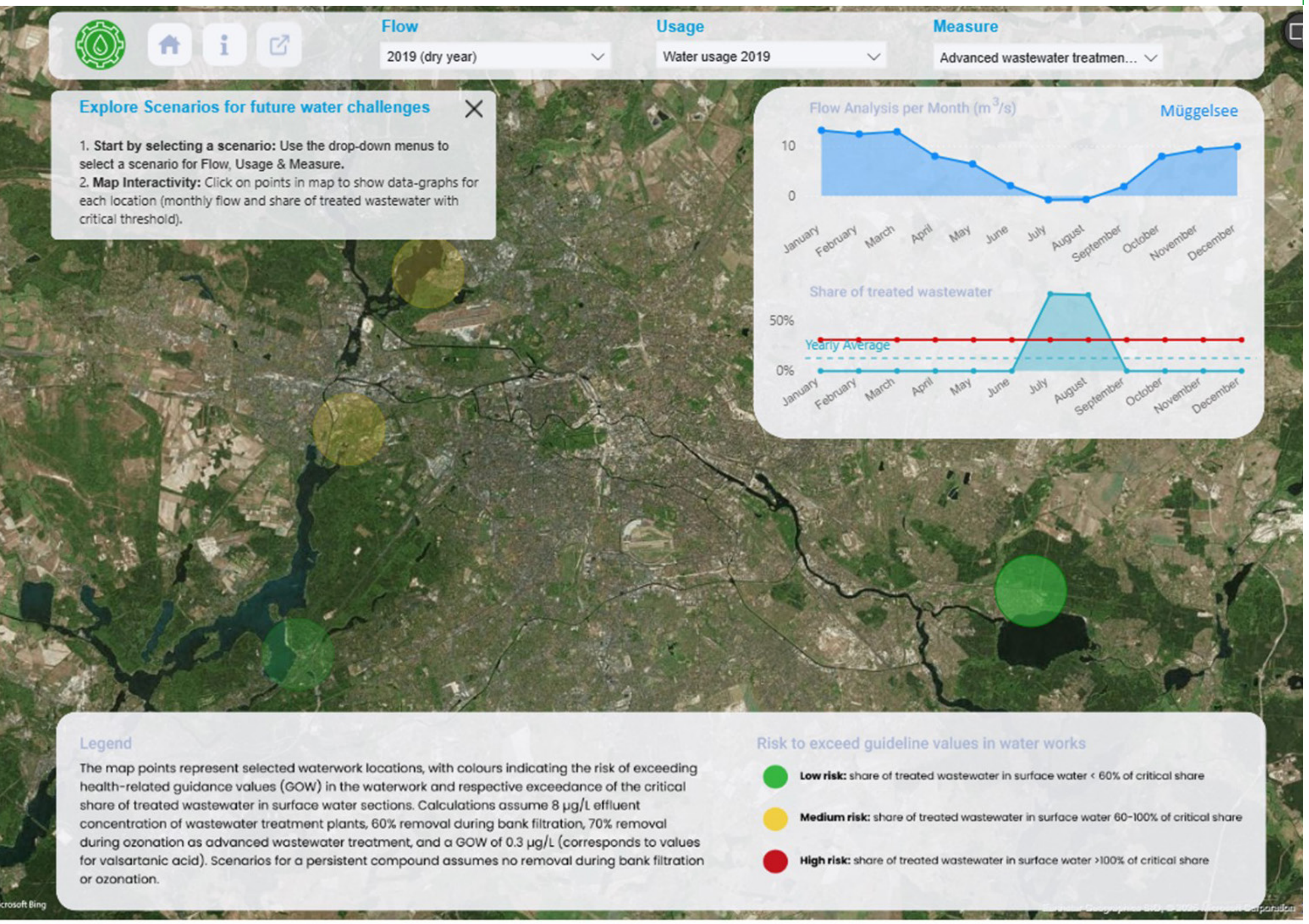


A PLATFORM TO EXCHANGE AND BOOST KNOWLEDGE

Content

The RKB (Resilience Knowledge Booster) platform presents and explains water management challenges for the region Berlin – Brandenburg and helps explore possible solutions from the perspective of climate change.
The *Solutions* section of the platform includes an interactive tool designed to allow the user to experience climate scenarios and urban water infrastructure (waterworks).
The *Adaptation* Pathways section includes a conceptual model for water scarcity (Impact chain) showcasing how hazard, exposure, and vulnerability elements interact to generate the risk of decreasing drinking water availability and safety).
Navigable maps identifying alternative Adaptation Pathways able to mitigate this risk are proposed.
In the section *Insights,* it is possible to download the Innovation Packages report including the present document.

available at:
https://impetus.mantisims.gr/knowledge-boosters/continental



BERLIN WATER TOOL

The Berlin Water Tool is an interactive online application developed within the IMPETUS project to support strategic planning for a resilient water supply in the face of climate change. It allows users to explore how future developments-such as climate-driven changes in water availability, rising water demand, and increased micropollutant loads-could impact the drinking water supply system in the Berlin region.
Users can select between different hydrological scenarios based on either the extremely dry year 2019 or a multi-year average condition from 2003-2022. These are combined with different water usage scenarios to reflect potential shifts in demand. Based on these inputs, the tool models how various water management strategies would perform at the level of individual waterworks.
The measures considered include:

- Advanced wastewater treatment combined with natural barriers.
- Micropollutant reduction strategies combined with advanced wastewater treatment and natural barriers.
- Natural barriers only.
- No additional measures (baseline scenario).

By comparing these options, users can assess how well each strategy helps mitigate water stress and improve water quality under different conditions. The results are presented in a user-friendly, spatially explicit format that supports evidence-based decision-making for utilities, regulators, and policymakers.

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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, as well as the general public. KWB (Kompetenzzentrum Wasser Berlin), BWB (Berliner Wasserbetriebe, Berlin water supply service), and the Berlin Senate played key roles in the co-development and testing of the RKB platform.

FEEDBACK FROM STAKEHOLDERS

The **Berlin water tool** was demonstrated to the Berlin Senate and to BWB in April and May 2025: generally, good interest and positive feedback from both water utility (BWB) as well as authority (senate) were registered. Some minor changes/ corrections in the description and legend texts were suggested and incorporated into the platform. The survey function included in the RKB was also valued positively. The received feedback allowed us to refine some questions of the survey to avoid misunderstanding and misuse of the results.

STRENGTHS

score 4/5

A POWERFUL TOOL TO VISUALIZE ADAPTATION OPTIONS

The potential to graphically show fundamental features of the system is considered the most important asset. Nevertheless other components are considered relevant as they are all ranked high (4 or 5).

RKB DIGITAL DIMENSION COMPONENT	SCORE
Visualisation (layout, images, graphic design)	5
Knowledge content (quality and type of information displayed)	4
Interactive functionalities (animations, customised navigation, dashboards)	4
Feedback collection tools (pools, chats)	4

OPPORTUNITIES FOR RKB USE

score 2/5

At present there are no specific new implementations for RKB envisioned in future planning and decision-making processes. Nevertheless, working with the different measures from the Berlin Masterplan Water during the development of the adaptation pathways has sparked internal interest in several specific measures. These measures warrant further investigation-ideally in the context of a future EU-funded project.

RKB - Gaps & needs

CHALLENGES FOR PLANNING AND DECISION MAKING PROCESS: FINANCE FIRST!

- Capacity: a version fully in the local language (German) will help overcome possible usage restrictions.
- Capacity: the tool focuses on problem understanding and communicating the effects of measures – decision making will be based on more detailed and complicated analysis results not possible to include in such a tool
- Finance: Sustaining, updating, and expanding the RKB platform requires stable long-term funding, which is currently not secured. This financial uncertainty limits the potential for institutional uptake or integration into official planning processes.
- Governance: There is no formal mandate or institutional mechanism in place to embed the RKB into strategic planning or policy-making. This limits its practical use beyond consultation and communication purposes.
- Knowledge: While the tool presents relevant and scientifically grounded information, the usefulness of this knowledge depends on regular updates, contextual interpretation, and integration with more detailed sector-specific data. Stakeholders noted the need for clearer guidance on how to interpret and apply the presented knowledge in operational decision-making contexts.

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

WHAT TO IMPROVE

RKB should be able to capture future updates of data and to rework maps and graphics accordingly. This would entail a more dynamic design of the RKB and dedicated management in the future.

RKB - Transformational potential

A NOVEL MULTI-SECTOR APPROACH CO-DEVELOPED WITH STAKEHOLDERS

The main innovative and transformational feature of RKB is the capacity to gather together **several actors** that, with the diversity of their competences and interests can really make the difference in the approach toward climate adaptation. RKB provides a novel framework to give concreteness to the **participatory process**.

The platform could be **scaled** to other regions, but would require adjustments to local data, governance, and user needs.
The RKB platform is **flexible** and may be easily adapted to changing climate and socio economic conditions but future adaptability depends on who maintains the platform beyond the IMPETUS lifetime.

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

ADAPTATION PATHWAYS TO ADDRESS WATER SCARCITY

Content

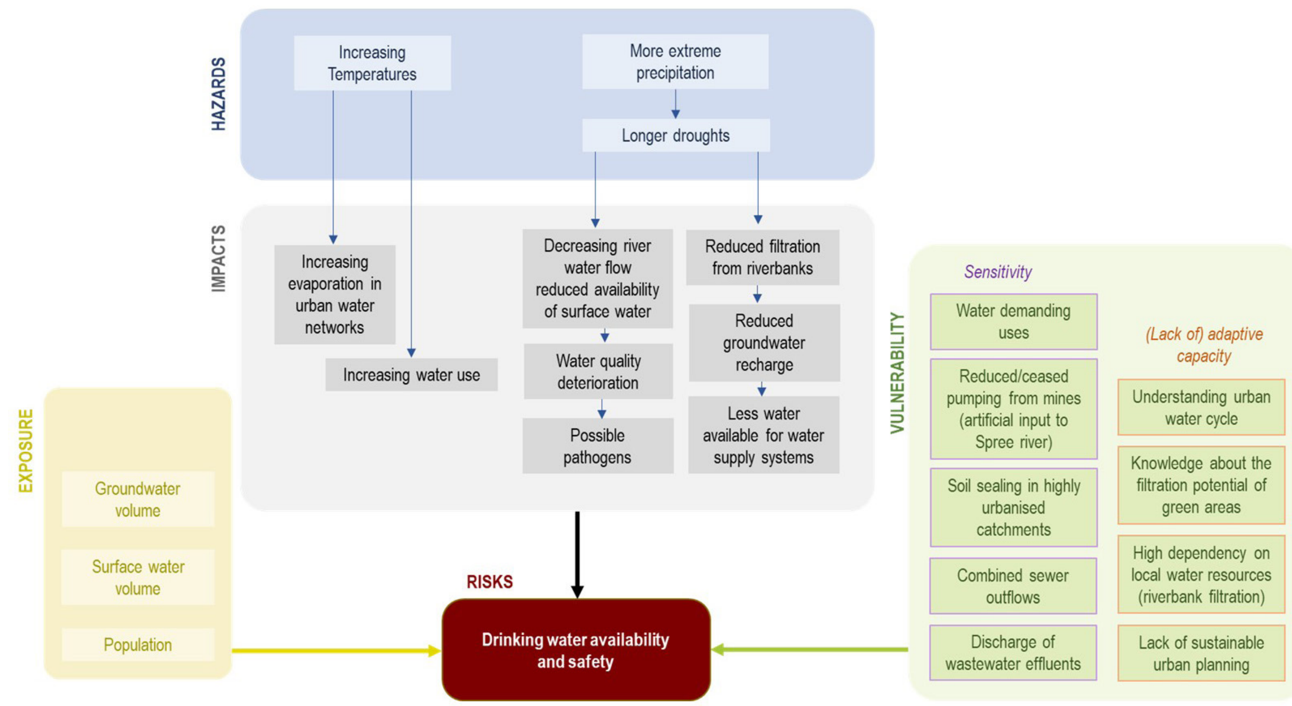
INTRODUCTION

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 the entire 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 outcomes.
In the years 2018 and 2019, the region experienced exceptionally warm and dry conditions, resulting in a significant decrease in surface water flows and groundwater levels. While the drinking water supply remained secure, these conditions raised concerns about the sustainability of urban water resource management in the face of climate change. The objective of the Metropolitan Region Berlin-Brandenburg Adaptation Pathway is to secure a resilient drinking water supply by preserving and/or enhancing the quality and quantity of surface and groundwater resources through the adoption of transformational adaptive solutions targeted at improving regional and city water management. The adopted approach includes the application of detailed as well as simplified water models to better understand all components of water cycling in the region

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.
Berlin's primary water sources are the Spree and Havel rivers. The Spree, encompassing a catchment area of approximately 10,000 km², including the Dahme catchment, serves purposes ranging from irrigation and industry to bank filtration. Historically, the river has also received pumped groundwater from the Lusatia (Lausitz) region to support lignite mining operations upstream, although these inputs will cease with the planned phase-out of coal mining in Germany by 2038. The Havel, converging with the Spree, drains a catchment area of about 3,500 km². Both rivers experience low discharge rates in summer, exacerbated by significant evaporation from alternating lake-stream sequences. The Spree's tributaries vary in urbanization, featuring urban areas, green spaces, forests, wetlands, and agricultural land (Kuhlemann et al., 2022).

Increasing pressure on Berlin's urban water resources stems from population growth, urbanization, industrial expansion, and the impending end of coal mining in Lusatia. For more than a century, open-pit mining in Lusatia has artificially bolstered the Spree River's flow by injecting groundwater, a practice integral to Berlin's drinking water supply. However, the cessation of lignite mining will profoundly alter the region's water balance.
Berlin operates a semi-closed water supply system comprising nine waterworks that predominantly draw from local groundwater resources. Approximately 60% of this water is sourced through riverbank filtration from nearby surface waters. Well galleries located along the riverbanks further extract water via bank filtration. However, diminishing surface water availability poses a risk to this filtration process, jeopardizing the city's water supply.
As river flows are projected to decline, the proportion of effluents from wastewater treatment plants is expected to rise, leading to a deterioration in overall water quality. Challenges are compounded by the presence of combined sewage systems in the city center and occurrences of overflow events. Annually, around 7 million m³ of water flow into the Spree River, constituting up to 10% of its total volume during summer low-flow periods (Kuhlemann et al., 2020).



THE PATHWAYS MAPS

The first sequence of adaptation options corresponds to a pathway that adopts a proactive strategy in which all measures begin implementation simultaneously (**Immediate implementation pathway**).
Each measure's full impact was considered effective once its defined implementation period was completed. During the implementation phase, a linear increase in effectiveness was assumed (e.g., 50% impact after half the time). No assumptions were made about the lifetime or phasing out of measures; their impact was treated as ongoing once implementation was complete.
To evaluate the effectiveness of this strategy, the Water Supply Stress Indicator (WSSI) was calculated for four key time steps: 2020, 2040, 2060, and 2080. The WSSI reflects the ratio between water demand and available supply, with values ≤ 1.0 indicating a balanced system, and values > 1.0 indicating stress-i.e., a tipping point where action is required.
As a second approach, a **Staggered Adaptation Pathway** was developed, aiming to implement measures only when needed, to keep the Water Supply Stress Indicator (WSSI) at or below 1.0 throughout the planning horizon from 2020 to 2080. This pathway focuses on timely, efficient use of resources, rather than the immediate implementation of all measures at once.
The sequencing of measures was based on:

- their effectiveness (impact on water demand or capacity),
- their implementation time, and
- the timing of expected stress events, i.e., projected points at which the WSSI would exceed 1.0 without intervention.

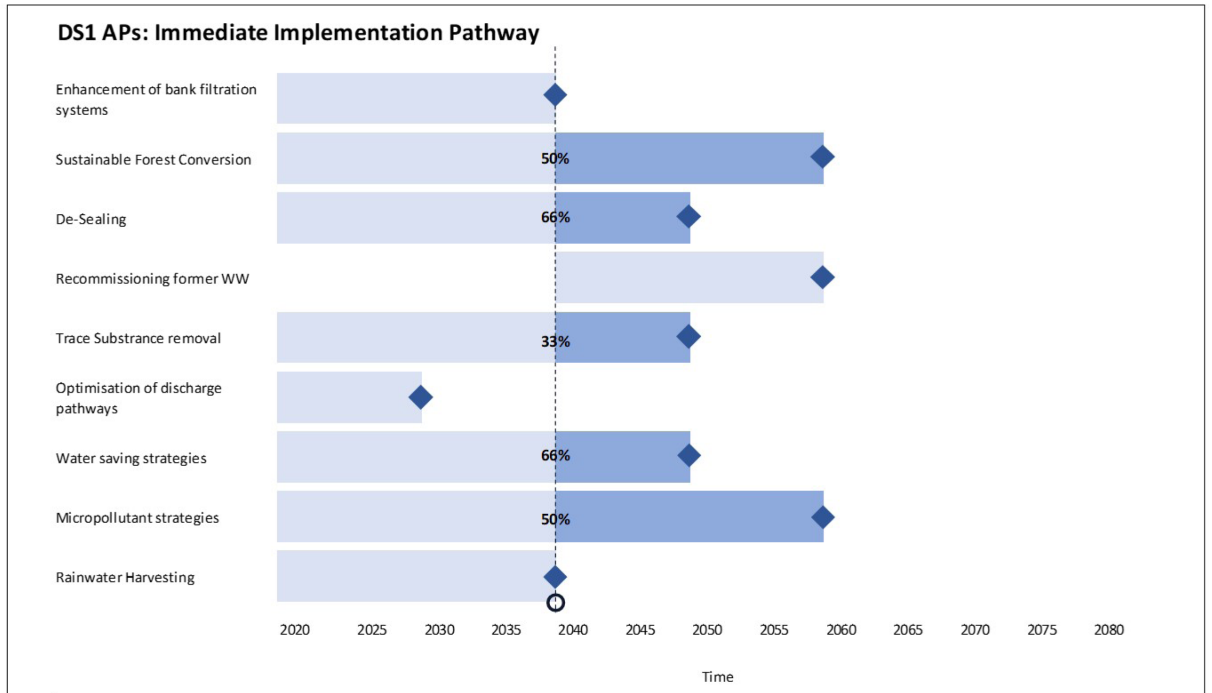
Each measure was introduced at the earliest point at which its effect was needed to avoid crossing a critical threshold. A linear build-up of effectiveness was again assumed during the implementation phase. Unlike the immediate implementation pathway, this approach seeks to optimise timing, delaying certain interventions until their contribution becomes essential.
These pathway were applied to two water availability scenarios:

Scenario 1 - Constant dry-year conditions: Assumes a waterworks capacity of 230 million m³/year, based on 2019, a particularly dry year used as a benchmark.

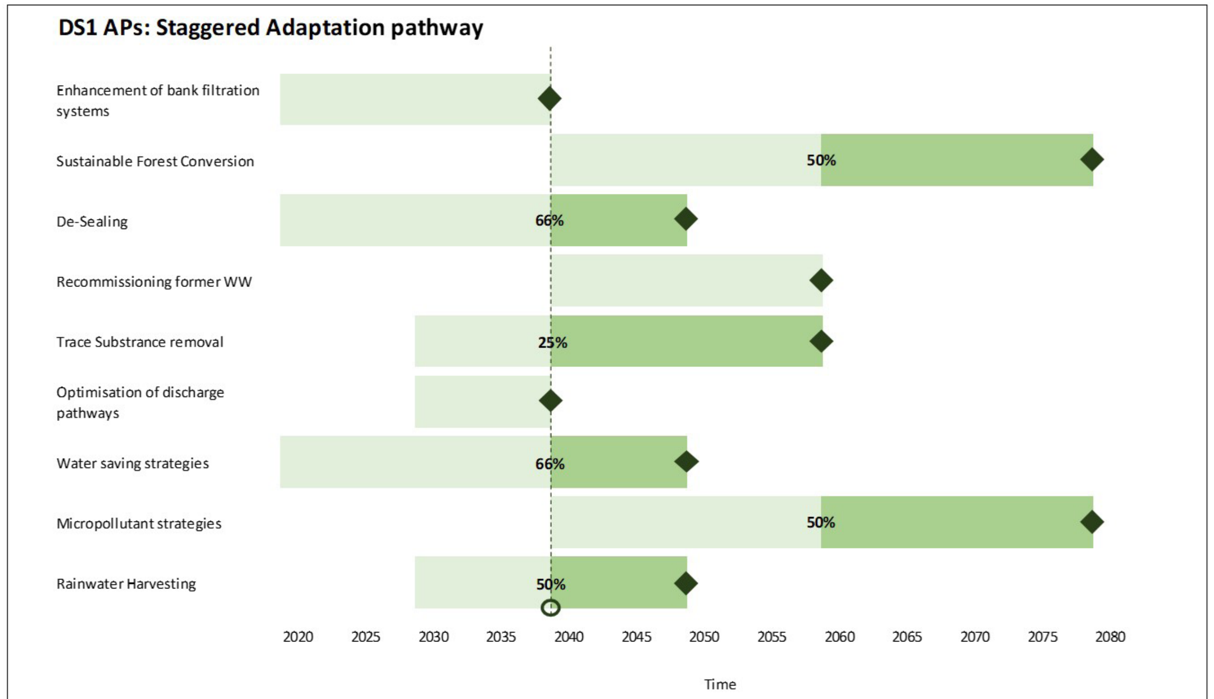
Scenario 2 - Reduced inflow scenario: Reflects climate change impacts through a 75% reduction in Spree inflow and a 25% reduction in Havel inflow compared to 2019, reducing capacity to 177 million m³/year.

WSSI values were calculated for both climate scenarios and compared with a no-action baseline.

figures: DS1 Adaptation Pathways Maps



Scenario 1	WSSI with no measures	1.00	1.13	1.23	1.34
	WSSI after the implementation of the pathway	1.00	0.85	0.78	0.84
Scenario 2	WSSI with no measures	1,31	1,47	1,60	1,75
	WSSI after the implementation of the pathway	1.30	1.00	0.80	0.94



Scenario 1	WSSI with no measures	1.00	1.13	1.23	1.34
	WSSI after the implementation of the pathway	1.00	1.00	0.74	0.86
Scenario 2	WSSI with no measures	1,31	1,47	1,60	1,75
	WSSI after the implementation of the pathway	1,3	1,19	0,72	0,87

Adaptation pathways - Exploitation potential

STAKEHOLDERS INTEREST

score 3/5

MAIN STAKEHOLDERS INVOLVED

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

FEEDBACK FROM STAKEHOLDERS

All stakeholders appreciated the Berlin-specific tailoring of the adaptation pathways (APs). They highlighted the value of using APs to illustrate potential climate impacts and intervention options over time. Rather than seeing APs as a tool for ranking or prioritising measures, they viewed them primarily as a visual communication and planning instrument, supporting shared understanding and strategic dialogue. The feedback underlined that while the AP approach is not directly suited for decision-making on concrete prioritisation, it is useful to show dependencies, timing, and potential interactions of measures under different climate or development scenarios. This function was considered particularly helpful for internal discussions and communicating long-term perspectives within administrations and public utilities.

OPPORTUNITIES TO USE ADAPTATION PATHWAYS

score 2.5/5

Several concrete opportunities for the use of Adaptation Pathways (AP) in current and future planning processes in the Berlin region were identified through stakeholder engagement and co-creation activities. A clear potential for strategic use in the following areas was recognised:

- **Long-term water resource planning and inter-state coordination:** The discussion around the Sustainable management of the Spree River highlighted the complexity and urgency of coordinated water governance across federal states (Berlin, Brandenburg, Saxony, Saxony-Anhalt). Stakeholders saw potential for the AP approach to support scenario-based dialogue on how climate change, coal phase-out, and shifting water demands could affect the region over time. This is particularly relevant in light of the ongoing Länder cross-border river basin management processes and emerging needs for joint planning frameworks
- **Strategic dialogue within public utilities and administration:** Institutions like BWB and Berline Senate see added value in the APs to structure internal discussions, especially where decisions span multiple departments or rely on uncertain long-term developments. The APs help visualise timeframes, interdependencies, and adaptive options, which can inform administrative planning horizons.
- **Knowledge platforms and communication:** Stakeholders acknowledged the potential of the Adaptation Pathways to support knowledge-sharing and cross-sectoral dialogue, especially due to their narrative and visual qualities, which help convey complex, long-term developments to a wider audience, including decision-makers. However, they also expressed concerns about possible over- or misinterpretation, particularly if the APs are presented without sufficient context. To avoid misunderstandings—such as perceiving the pathways as fixed implementation plans—stakeholders strongly recommended clear communication of the development status, assumptions, and purpose when using the APs in public-facing formats (e.g. websites or outreach materials).

Adaptation pathways - Gaps & needs

CHALLENGES - HOW TO TRANSLATE INTO PRACTICE

The key challenges to putting Adaptation Pathways into practice in Berlin include:

1. **Lack of formal integration into planning and decision-making processes**
   While stakeholders found the APs useful for strategic thinking and communication, they are not embedded in existing governance or planning frameworks. There is no institutional mechanism yet to link AP outputs to official adaptation strategies, investment plans, or regulatory procedures.
2. **Perception of APs as illustrative, not operational tools**
   Stakeholders see the APs primarily as visual aids to explore future developments, not as instruments to prioritise or select concrete measures. This limits their uptake in contexts where decisions require clear cost-benefit justification or implementation roadmaps.
3. **High number of assumptions in indicator use and calculations**
   Particularly in the use of indicators and modelling steps, many assumptions had to be made, which reduces the transparency and robustness of the outcomes. Stakeholders noted that this makes the APs more vulnerable to criticism, especially when used to support decisions or communicate with a broader audience. There is a need for more robust data, clearer assumptions, and transparency in how calculations are performed and interpreted.
4. **Resource constraints (time, capacity, data)**
   Developing and maintaining APs requires significant effort, particularly in facilitating stakeholder processes, updating data, and monitoring tipping points. Without dedicated resources or institutional mandates, there is a risk that the AP approach remains a one-time exercise.
5. **Fragmented responsibilities and limited coordination**
   Adaptation involves multiple actors across levels and sectors, and Berlin faces challenges in achieving cross-institutional coordination, especially in areas like water management, which require cooperation between state and regional actors (e.g., for Spree management). Without stronger alignment, the implementation of long-term, adaptive strategies remains difficult.

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

WHAT TO IMPROVE

1. Sustainable management of the Spree River was highlighted as highly relevant and should be considered for integration into the list of selected measures. This measure focuses on the inter-state coordination between Berlin, Brandenburg, Saxony and Saxony-Anhalt to ensure long-term, sustainable water management in the Spree catchment. It includes key challenges such as reduced water availability due to coal phase-out, increasing water demands, and the need for sulphate control.
2. A clearer mapping of all measures to relevant fields of action (e.g., governance, water infrastructure, water quality) was recommended to improve accessibility and alignment with policy domains.
3. While the APs are not seen as a ranking tool, stakeholders suggested that an optional ranking based on effectiveness or impact might provide useful insights, especially for internal strategy discussions.
4. Transparency regarding the development status and assumptions underlying the pathways is essential to prevent misinterpretation by the public or political actors.

Adaptation pathways - Transformational potential

ELEMENTS OF TRANSFORMATION

A multi-sector approach co-developed with stakeholders and responsive to changing conditions

The process included actors from **multiple sectors** like research, utilities, and public administration, and addressed interlinked challenges such as water governance, land use, and infrastructure planning.

The APs were developed through co-creation with key institutional **stakeholders** (e.g., Berlin Senate, BWB, KWB), who actively shaped the process.

The AP approach enables **flexible planning** across different future scenarios and integrates climate uncertainties through tipping points and multiple options.

While scenario-based planning exists, the structured AP methodology and its application across institutions are relatively **new** in the Berlin context.

While the AP process promotes **long-term thinking**, its practical impact depends on further integration into planning and governance structures. Without formal uptake, long-term effects remain uncertain

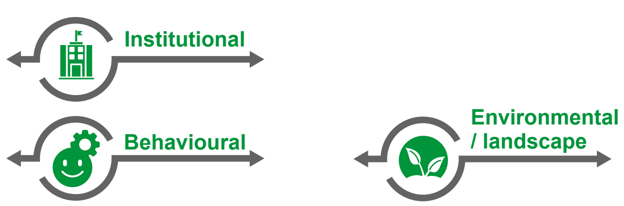
The pathway process is **partly scalable**, especially in areas like interstate water governance (e.g. Spree management). However, full-scale implementation would require stronger institutional uptake and integration into formal planning processes.

The APs triggered strategic reflection but are not expected (at this stage) to result in **major restructuring**, as they are not formally embedded in policy processes. **Equity aspects** were not a main focus of the AP process in this DS. Vulnerable groups were not directly involved, and gender considerations were not explicitly addressed.

TRANSFORMATION ELEMENT	SCORE
SCOPE: The AP elaboration process includes a multi-sector approach	4
INCLUSIVITY: Co-developed/discussed with stakeholders	4
SCOPE: Responsive (flexible) to changing conditions	4
DEPTH OF CHANGE: Novel approach for the region	3
TEMPORALITY: long-term vision/expected to produce long-term and durable outcomes	3
SCOPE: Developed at scale or easily scalable	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	2

IMPACT OF TRANSFORMATION

If implemented, the Adaptation Pathway could support institutional transformation by fostering more integrated and forward-looking governance structures-particularly in inter-state water management. It may also contribute to behavioural changes within public institutions by encouraging longer-term planning under uncertainty. Environmental impacts could arise through improved water quantity and quality management in the Spree catchment. Broader economic, technological, or social transformation is not the direct focus of the pathway process in this DS.

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A PORTFOLIO OF CLIMATE ADAPTATION SOLUTIONS

Content

Eleven adaptation solutions to address water scarcity were assessed. Three of them were specifically tested in IMPETUS: “Water Balance Models”, “Cooperation framework for the Water Master Plan” and “Enhancement of bank filtration system”. In particular, the last one was tested only with the groundwater model (no new wells will be built): pumping rates were increased in some scenarios to test changes in bank filtrate share.

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). So, the three solutions tested in IMPETUS belong to the groups “Technological options”, “Information and awareness raising”, “Grey options” respectively for “Water Balance Models”, “Cooperation framework”, and “Enhancement of bank filtration system”. The other solutions deemed relevant to increase the resilience of the region are consistent with those envisaged in the Berlin Water Master Plan (Masterplan Wasser). Among them, four solutions are “Grey options”, two are “Green options” one is a “Blue option” and one “Capacity building, empowering, and llifestyle” action.

OPTION	DESCRIPTION	MAIN OBJECTIVE(S)	IMPETUS CLIMATE RISK	KEY TYPE OF MEASURE	TESTED IN IMPETUS
Water Balance Models	Different models to assess water balances, surface waters and groundwater.	To represent surface water and groundwater hydraulic conditions, identify the critical share of treated wastewater to surface water, define minimum water flow to meet the increasing demand for drinking purposes.	Water scarcity	C2 - Technological options	Y
Cooperation Framework for the Water Master Plan	IT-supported discussion (with interactive visualization environments) enabling result-driven discussions with relevant stakeholders.	To discuss with stakeholders the possible futures of regions threatened by water scarcity and parallel demographic and economic growth.	Water scarcity	E1 - Information and awareness raising	Y
Rainwater management	Various measures, including: green roofs (which reduce pressure on urban drainage systems), infiltration swales (which contribute to groundwater recharge), and cisterns (which collect - rainwater for various purposes, reducing demand from the public water supply.	To encourage local retention and use of rainwater instead of directly discharging it into the sewer system.	Water scarcity	D2 - Blue Options	
Micropollutant strategies	Improved monitoring, advanced treatment technologies, and source control (e.g. pharmaceutical take-back programs). This measure (source control strategy) complements Trace substance removal (end-of-pipe treatment).	To reduce the environmental and drinking water burden caused by persistent trace substances.	Water scarcity	C1 - Grey options	
Water saving strategies	Efficiency improvements, behaviour change, incentive systems, and technological innovation—targeting households, public institutions, and industry alike.	To address rising water demand due to population growth and climate change.	Water scarcity	E2 - Capacity building, empowering, and lifestyle actions	
Optimization of discharge pathways	New and Modified Discharge routes from Wastewater Treatment Plants.	To optimize the water cycle—wastewater to surface water to drinking water- while minimizing impacts on key resources like drinking water, ecosystems, shipping, and recreation.	Water scarcity	C1 - Grey options	
Trace substance removal from wastewaters	Ozonation as a tertiary treatment for wastewater can be implemented.	To reduce the concentration of trace organic substances such as pharmaceutical residues.	Water scarcity	C1 - Grey options	
Recommissioning of the former waterworks site	Reactivation of 3 fomer waterworks for groundwater supply.	To increase groundwater supply through enhanced annual extraction capacity, to relieve pressure on existing plants, and to improve redundancy.	Water scarcity	C1 - Grey options	
De-sealing	Unsealing areas to restore soil functions and create valuable habitats for animals, plants, and soil organisms.	To increase groundwater recharge and promote decentralized rainwater management.	Water scarcity	D1 - Green Options	
Sustainable forest conversion	Transformation of the unnatural pine stands into deciduous mixed forests while consistently advancing near-natural forest management.	To increase groundwater recharge. Under deciduous trees, more precipitation can reach the forest floor and percolate as groundwater compared to under coniferous trees.	Water scarcity	D1 - Green Options	
Enhancement of bank filtration systems *	Induced bank filtration by water abstraction close to the surface water. It includes the construction of new wells near the shore or raising the pumping rates of exisiting wells.	To increase the available supply for drinking water provision through increased bank filtration.	Water scarcity	C1 - Grey options	Y

* Tested with the groundwater model: pumping rates are increased in some scenarios to test changes in bank filtrate share; no new wells will be built.

Portfolio of solutions - Evaluation

All solutions are quite mature, since they are characterized by a high technological readiness level
(TRL). The “Recommissioning of former waterworks sites” is considered as the most efficient to address the water scarcity issue. Such a solution also has a high social readiness level (SRL) together with the “Enhancement of bank filtration systems” and the “Trace substance removal from wastewaters”, even if the last one requires significant investments. On the other hand, “Recommissioning” requires a long implementation time, also because a rigorous environmental impact assessment process is needed. From the point of view of added environmental and social benefits, “Rainwater management” and “Micropollutant strategies” are the solutions that bring the highest positive impacts. The first one can recharge groundwater and at the same time to favour an increase in biodiversity, to reduce the heat island effect, to release pressure on the urban drainage system and to increase public awareness about the use of water resources. Moreover some type of rainwater management implementation has the potential to create new habitats and to remove urban water pollutants. The micropollutant strategies directly guarantee a safer drinking water and increase the environmental and chemical status of surface and groundwater.

		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	Water Balance Models T4.7.1	+	+	+++	+	-		+	+		-	-	--	No	Possible low willingness to participate from the federal state of Brandenburg Uncertainty about future scenarios (i.e. coal mining) and climate data.
2	Cooperation Framework for the Water Master Plan T4.18	+	+	+++	+++	-		+	++		-	-	-	No	
3	Rainwater management	+	+++	+++	++	- -	Groundwater recharge and associated environmental benefits. Increased biodiversity. Positive effect on local climate (reduction of heat islands). Less pressure on urban drainage systems. Increased public awareness about the use of valuable water resource. New habitat creation (e.g. for green roofs and swales). Removal of urban water pollutant.	+++	+++	Extra maintenance can be needed.	-	-	-	No	Needs urban planning integration, legal and regulatory clarity (e.g. on reuse standards), and often financial incentives to support adoption. Successful uptake also depends on maintenance guidance and technical expertise.
4	Micropollutant strategies	+	+++	++	++	- -	Safer drinking water. Increased environmental state of surface and ground water.	+++	+++		-	-	- -	No	Requires policy support (e.g. for take-back systems), intersectoral coordination (health, environment, utilities), and often legal clarity on responsibilities. Public awareness and producer involvement are essential.
5	Water saving strategies	++	+++	+++	+	-	Enhanced awareness about use of valuable water resources. Higher water availability in the system and associated environmental benefits.	+++	+		-	- -	- -	No	Needs sustained public engagement, supportive policy instruments (e.g. incentives or regulations), and monitoring of actual savings. Behavioural change takes time and requires ongoing communication efforts.
6	Optimization of discharge pathways	++	+++	+++	++	- -	Improved protection of water resources. Improved protection of bathing areas.	+	+	Possible risks for drinking water security, due to possible increase in the share of treated wastewater in some drinking catchment areas.	-	-	- -	No	
7	Trace substance removal from wastewaters	++	+++	+++	+++	- - -	Better quality of surface waters for drinking purposes. Reduced environmental impact on river ecosystems.	++	++	High energy demand. Increase of water price due to high costs. Incomplete removal of certain substances. Potential formation of ozonation by-products.	-	-	- - -	No	It requires high investment costs.
8	Recommissioning of former waterworks site	+++	+++	+++	+++	- -	Increased availability of water for drinking purposes.	+	++	Overpumping groundwater resources. Negative impact on ecosystems.	-	-	- - -	No	Rigorous Environmental Impact Assessments needed.
9	De-sealing	+	++	+++	++	-	Restoration of soil functions and development of valuable natural habitats. Reduced surface runoff. Improved air and water quality and reducing noise pollution. Increasing biodiversity. Reduction of urban heat.	+	++	Competition for space in the growing city. Unsealing measures must always be combined with measures to restoration of soil functions and renaturation. Contaminated Soil Exposure: De-sealing may expose soil contaminated with pollutants, requiring costly remediation. Increased Groundwater Pollution: If runoff infiltrates areas with harmful chemicals, it can pollute groundwater. Reduced Parking and Infrastructure: Removing paved areas, like parking lots, could lead to logistical problems, especially in densely populated areas. Unintended Waterlogging: Poorly designed de-sealing projects may cause waterlogging, particularly in areas with high rainfall or inadequate drainage.	-	-	- - -	No	Community engagement, long-term maintenance and plans, environmental and technical assistance. Space requirements. Environmental and Technical Assessments: detailed environmental impact studies and technical assessments are crucial to ensure that de-sealing does not expose contaminated soils or lead to unintended consequences like waterlogging. Urban spatial planning needed to ensure space is properly allocated without compromising other uses.
10	Sustainable forest conversion	+	+++	++	++	-	Preservation of groundwater resources. Recreation. Biodiversity. Increased resilience of forest to climate change due to mixed stands.	++	+	No further expected unintended effects, compared to the current situation with forests dominated by conifers. Climate change effects on forests are generally related to: Spreading tree diseases. Pests. Forest fire.	-	-	- - -	No	Availability of young trees, care, especially during the first years. Long time before the effects of the measure get measurable.
11	Enhancement of bank filtration systems	++	+++	+++	+++	- -	Biodiversity. Recreation.	+	+	Reduced surface water level Water quality issues.	- -	-	- -	No	Space needed along shore line.

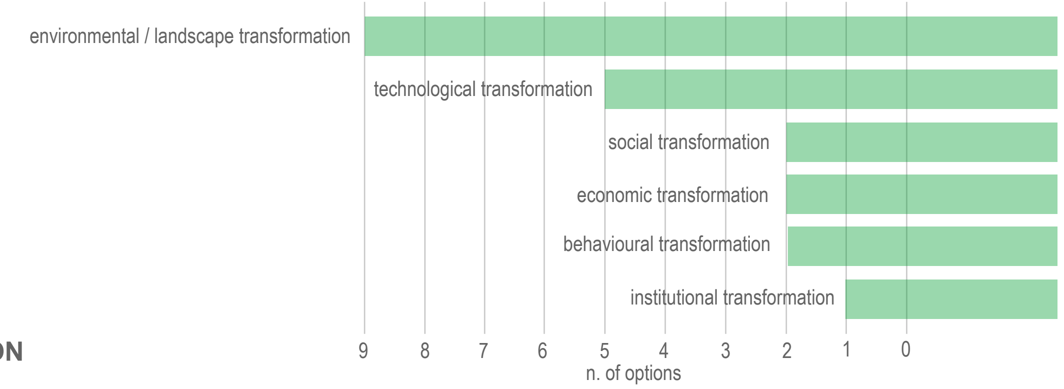
Portfolio of solutions - Transformational potential

ELEMENTS OF TRANSFORMATION

The set of measures outlines a good potential for transformation as the average score of all solutions is 3.3 (on a scale of 5). The strongest potential resides in Scope of Change, in particular in the capacity to be responsive to changing climatic conditions and to include a multisector approach. As regards the specific solutions, Rainwater management has the highest potential, both because of its broad scope of change and because of the long-term impact expected by its implementation. Trace substance removal is considered important for the Depth of change it can introduce, since it is quite novel and can produce important restructuring in the region with a long reach impact.

	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
Water Balance Models	4	4	NA	4	1	5	NA	3
Cooperation Framework for the Water Master Plan	5	3	NA	3	1	5	2	3
Rainwater management	5	5	4	3	2	NA	NA	4
Micropollutant strategies	4	4	3	3	1	NA	NA	4
Water saving strategies	5	5	4	3	2	NA	2	3
Optimization of discharge pathways	3	3	1	3	2	NA	NA	3
Trace substance removal from wastewaters	3	4	4	4	3	NA	NA	4
Recommissioning of former waterworks site	3	4	3	3	1	NA	NA	4
De-sealing	5	4	4	4	2	NA	NA	3
Sustainable forest conversion	4	4	3	3	2	NA	NA	4
Enhancement of bank filtration systems	3	5	2	2	1	NA	NA	4

Figure: Impacted sectors



IMPACT OF TRANSFORMATION

The implementation of the solutions is destined to have very important impacts on the environment and the landscape of the region. Only a non-structural solution such as the "Water saving strategies" is not contributing to transforming the landscape, the "Recommissioning of former waterworks" is reasonably considered not to bring significant changes to the landscape, even if changes on the surface and groundwater environment may be expected. The second most impacted sector is the technological, since the set of solutions involves technologies ranging from the engineering, modelling and chemical fields to the architectural and urbanistic ones.

	IMPACT OF TRANSFORMATION					
Synthetic name of the option	Economic transformation	Technological transformation	Social transformation	Institutional transformation	Behavioural transformation	Environmental/ landscape transformation
Water Balance Models		X				X
Cooperation Framework for the Water Master Plan			X			
Rainwater management		X				X
Micropollutant strategies	X			X		X
Water saving strategies	X				X	
Optimization of discharge pathways		X				X
Trace substance removal from wastewaters		X				X
Recommissioning of former waterworks site		X				
De-sealing			X			X
Sustainable forest conversion						X
Enhancement of bank filtration systems						X

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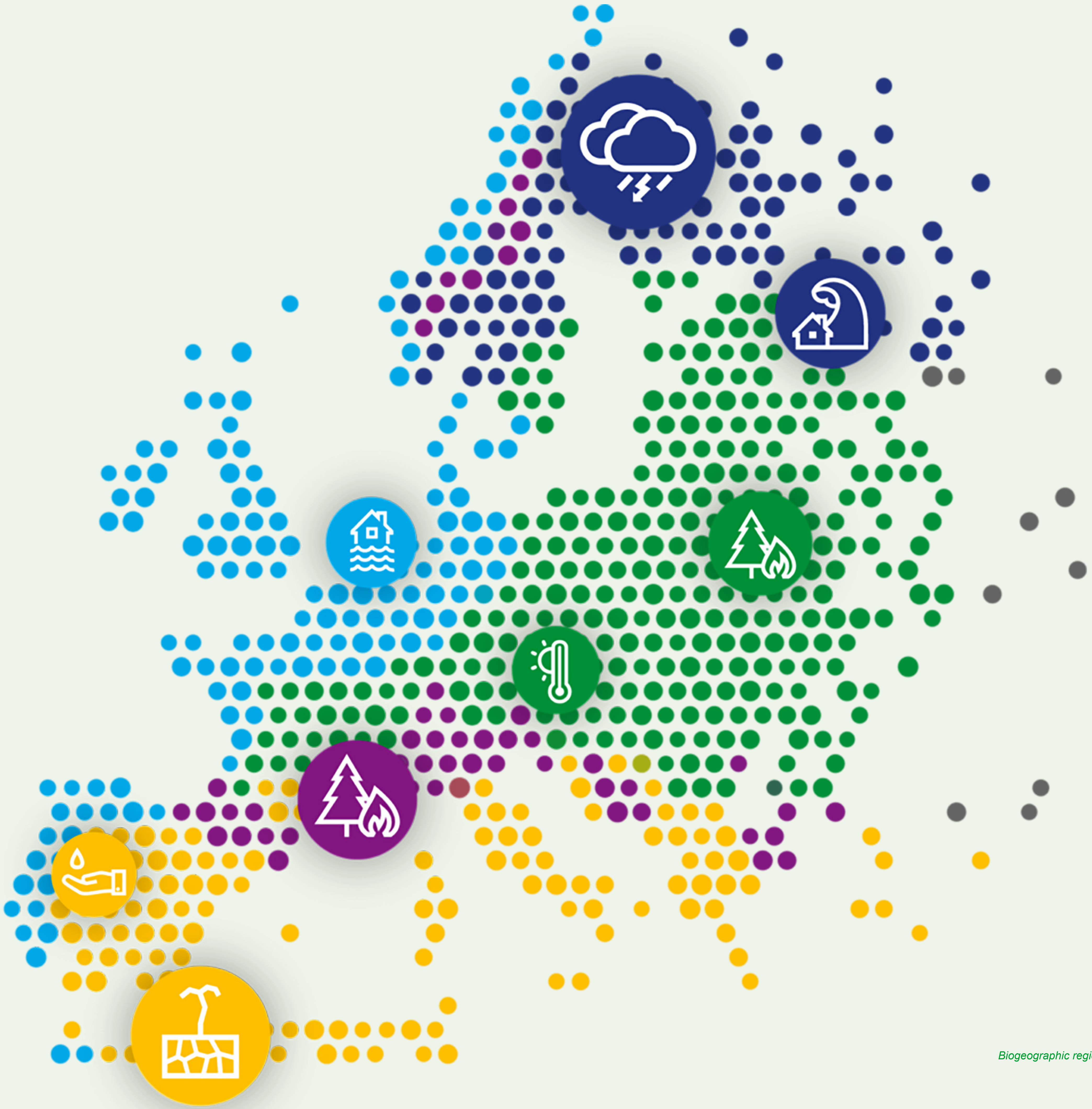

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