



Innovation Packages and Financial Instruments for ARSINOE Case Studies

Deliverable 6.8

WP6: Case studies: Coordination and implementation activities

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EXECUTIVE SUMMARY

Deliverable 6.8, titled "Innovation Packages and Financial Instruments for all the Case Studies," outlines a comprehensive approach for climate adaptation and resilience in nine different European regions. This report, led by AUEB, integrates findings from two key work streams: Innovation Pathways (Work Package 2) and Financial Pathways (Work Package 7). The findings and outputs of these two streams are not analysed separately; rather, they are merged and synthesized in the Innovation Packages to ensure that proposed solutions are contextually appropriate and financially viable. Some case studies, notably those with extra governance analysis (D2.3), delve deeper into local decision-making and institutional preparation to enable effective implementation.

This report centres on Innovation Pathways that emerge from collaborative engagement with all four sectors of the innovation ecosystem—academic institutions, businesses, government entities, and community organizations—through the ARSINOE Living Labs framework. Within ARSINOE, these Innovation Pathways represent comprehensive, stakeholder-driven blueprints that map out crucial technological, social, and institutional advances across immediate, intermediate, and extended timeframes to support regional climate adaptation efforts (referenced in D2.4). These pathways deliberately encompass social innovations—including novel community participation models, inclusive governance approaches, and behaviour modification initiatives—alongside technological interventions.

Wider contribution to EU Policies: This Deliverable, in its final version (M48) aims to provide detailed information and experience-based knowledge from the nine diverse Case Studies. It is expected to contribute to regional decisions and EU policies for the implementation of actions leading to enhanced resilience to climate change at the regional level.

Related Deliverables: Deliverable 2.3 (D2.3) for the results of the government assessment, D2.4 on the identification of the innovation and Policy pathways, D5.1 for the Open Tenders on Innovations, D7.3 for the Design of Financial Instruments for Climate Change Adaptation and D7.5 for the financing pathways

List of Abbreviations

IP	Innovation Package
SIA	Systems Innovation Approach
CAP	Common Agricultural Policy
CS	Case Study
CSR	Corporate Social Responsibility
DSS	Decision Support System
EC	European Commission
EIB	European Investment Bank
EIP-AGRI	European Innovation Partnership for Agricultural Productivity and Sustainability
EU	European Union
GHG	Greenhouse Gas
IPCC	Intergovernmental Panel on Climate Change
KPI	Key Performance Indicator
LCA	Life Cycle Assessment
LULUCF	Land Use, Land Use Change and Forestry
NbS	Nature-based Solutions
NGO	Non-Governmental Organisation
NPV	Net Present Value
O&M	Operations and Maintenance
OTI	Open Technological Innovation
PPP	Public–Private Partnership
PV	Present Value
R&I	Research and Innovation
RRF	Recovery and Resilience Facility
SCBA	Social Cost–Benefit Analysis
SDGs	Sustainable Development Goals
SME	Small and Medium-sized Enterprises
SPV	Special Purpose Vehicle
SUMP	Sustainable Urban Mobility Plan
ToR	Terms of Reference

UHI – Urban Heat Island

UNFCCC – United Nations Framework Convention on Climate Change

WP – Work Package

1.0 INTRODUCTION

The ARSINOE project seeks to promote system-based climate resilience by creating Innovation Packages (IPs) that solve complex regional concerns using cross-sectoral solutions. Innovations and dedicated financial instruments are critical in climate change strategy planning because they allow regions to respond proactively to rising threats, incorporate new technology and practices, and overcome persistent barriers to adaptation and resilience. Financial tools are particularly important for expanding and maintaining these solutions over time.

Deliverable 6.8, titled "Innovation Packages and Financial Instruments for all the Case Studies," outlines a comprehensive approach for climate adaptation and resilience in nine different European regions. This report, led by AUEB, integrates findings from two key work streams: Innovation Pathways (Work Package 2) and Financial Pathways (Work Package 7). The findings and outputs of these two streams are not analysed separately; rather, they are merged and synthesized in the Innovation Packages to ensure that proposed solutions are contextually appropriate and financially viable. Some case studies, notably those with extra governance analysis (D2.3), delve deeper into local decision-making and institutional preparation to enable effective implementation.

Innovation Pathways are a detailed and sequential set of social, technological, and institutional innovations identified as required by local stakeholders participating in the ARSINOE Living Labs to achieve the long-term regional vision co-developed in each case study (as described in D2.4). Financial Pathways, developed by WP7, identify, evaluate, and design appropriate financing sources and tools to address the key challenge of adaptation finance. This provides the required monetary foundation to assure the viability and scalability of the innovations identified throughout the project.

ARSINOE is dedicated to shaping pathways to climate resilience by bringing together the Systems Innovation Approach (SIA) and the Climate Innovation Window (CIW), with the ultimate goal of building a comprehensive ecosystem for climate change adaptation solutions. The SIA serves as a methodological framework addressing the growing complexity and interconnectedness of modern societies and economies. Through this approach, stakeholders from the quadruple helix (academia, private sector, public authorities, and civil society) are actively engaged in Living Labs. In these participatory settings, they co-create and co-design innovation pathways by first agreeing upon key climate change challenges, then developing a sustainable vision for their region, and finally identifying a portfolio of actions to achieve that vision. These pathways outline a trajectory of change, underpinning chronological milestones with concrete actions and associated technological, social, and institutional innovations.

Complementing SIA is the CIW, which is the EU's reference online marketplace for climate adaptation technologies and a prime feature of the ARSINOE project. The CIW enables stakeholders to select or showcase existing or new climate technologies, thereby connecting innovators with end-users and problem owners looking for solutions. The synergy between SIA and CIW is crucial for the formation of innovation packages. The co-designed innovation pathways developed through the SIA process allow stakeholders to select relevant solutions from the CIW's diverse pool of validated technologies or from external innovation providers. Regions can integrate validated technologies already available on the CIW platform into their custom innovation packages. Furthermore, new technologies implemented in specific local innovation packages have the opportunity to be validated and subsequently become CIW members, thus expanding the market for these innovations. The CIW is strongly linked with ARSINOE's Open Tenders for Innovations (WP5), which are designed to identify promising or mature innovations to be included in regional innovation packages. These tenders aim to source solutions directly aligned with the specific adaptation needs collaboratively identified in the Living Labs. This process also facilitates collaboration between ARSINOE's case study partners and external innovators.

ARSINOE's innovation packages are designed to support stakeholder groups that play a role in the creation, validation, and adoption of climate adaptation solutions. This includes players across policy, science, innovation, investment, and community levels—essentially those who can co-create or

implement innovation agendas in the project's nine regional case-study areas. Regional and local authorities identify and adopt climate adaptation packages aligned with their specific needs and policy contexts, especially in the field of financial system efficiency and institutional framework. Researchers and academic institutions can contribute to methodology development and help validate outcomes. Start-ups, spin-offs, and innovators follow the innovation packages to present technologies via the CIW and get linked to real-world case studies. Impact investors, business angels, and industry actors can evaluate, support, and deploy scalable solutions. Civil society and citizens participate indirectly through engagement mechanisms (e.g., Living Labs, Youth Assemblies), helping shape agendas aligned with local adaptation priorities. These innovation packages, while designed for specific regions, are built with transferable and reusable components, enabling their adaptation and replication across other European regions and beyond. This integrated approach fosters a robust and sustainable innovation ecosystem for climate change adaptation and resilience.

2.0 Innovation Packages (IP): Methodological Framework & Approach

The core of D6. builds on the Innovation Pathways, which are co-created through a highly participatory process with quadruple helix stakeholders, academia, private sector, public authorities, and civil society, within the ARSINOE Living Labs in WP2. In ARSINOE, an "Innovation Pathway" is understood as a structured, stakeholder-informed roadmap of essential technological, social, and institutional innovations, sequenced in short, medium, and long-term horizons to guide each region toward climate resilience (D2.4). This explicitly includes social innovations, such as new forms of community engagement, participatory decision-making, and behavioral change campaigns, alongside technical solutions.

The operationalization of these paths is represented by Innovation Packages (Figure 1), which are bundles of technical, governance, and financial interventions that are sequentially implemented in each case study by sectors. Innovation packages, often framed as innovation portfolios or agendas, are crucial for bolstering regional adaptation strategies by providing a structured, iterative process to define, coordinate, implement, and adapt interconnected innovation actions aimed at achieving a common societal goal, such as climate resilience. The packages are designed to promote climate and socioeconomic resilience at different scales, integrating initiatives from water, agriculture, health, energy, and infrastructure. Rather than targeting discrete hazards, this systems-based approach ensures that adaptation efforts are consistent with broader policy objectives and promote a just transition. Innovation packages aim to translate high-level strategies on adaptation into tangible policies spanning across sectors and climate and socioeconomic vulnerabilities. Considering the enabling conditions, in this case predominantly finance and governance, is material for realizing the potential of the innovation pathways towards regional resilience.



Figure 1. ARSINOE Innovation Packages

Innovation packages are rooted in a shared "vision" related to a "grand challenge" or "societal goal" (e.g., climate resilience) and provide a clear "direction of travel" for multiple pathways. The process is iterative, building on ongoing actions and existing resources, and introduces a cycle of iterative learning for continuous alignment and stretching of capacities. As explicitly stated in the EU Mission Adaptation, finance is a Key Enabling Condition (KEC) for adaptation, and innovation packages explicitly integrate financial considerations throughout their development and implementation. Effective governance is also critical for the successful formulation and implementation of innovation packages and adaptation strategies. In many instances it is intertwined with the element of finance as structural bottlenecks and institutional lock-ins hinder the diversification of the regions' financial portfolio and exacerbate the adaptation finance gap.

A fundamental aspect of the ARSINOE approach is the explicit merging of Innovation Pathways (from T2.4) and Financial Pathways (from D7.5), as well as the incorporation of governance results where applicable. The breakdown for each case study, which includes sectoral goals, implementation timetables, hurdles and enablers, funding instruments, and major innovations, is based on stakeholder co-creation, PESTLE analysis, and other WP2 and WP7 outputs. This guarantees that the Innovation Packages given in D6.8 are representative of both the priorities and operational realities outlined in each location. To support implementation, innovation packages also experiment with novel governance and finance mechanisms, including public–private partnerships, adaptive regulatory frameworks, climate insurance schemes, green and impact bonds, all aimed at lowering investment risk and unlocking new sources of adaptation finance.

In the ARSINOE project, the results of the Open Tenders for Innovations (OTIs) outlined in D5.1 and tools sourced from or linked with the CIW are integral to the formulation and implementation of region-specific innovation packages. The OTIs, detailed in D5.1, serve as a primary mechanism for identifying and integrating promising climate adaptation solutions into the regional innovation packages. The process initiates with a comprehensive stocktaking phase that identifies relevant solutions tailored to each regional context, drawing directly from problems and innovation gaps collaboratively identified within Living Labs. Following needs identification, calls for innovations are prepared and published, inviting legal entities from eligible countries to submit detailed solution applications. These submissions undergo rigorous evaluation by a Selection Committee comprising representatives from BRIGAD Connect, G.A.C. Group, UN SDSN, and case study partners. The evaluation framework encompasses multiple dimensions including technical, social, and market readiness levels, alongside qualitative criteria such as testing feasibility, innovator vision, promising value proposition, and potential contribution to social and governance transformation. Selected innovations serve as concrete building blocks within comprehensive regional innovation packages. Implementation insights from OTI-funded innovations create valuable feedback loops, contributing to the broader ARSINOE framework while informing European Union policies on climate resilience and adaptation strategies.

ARSINOE also draws existing solutions from the CIW database—covering models & tools, nature-based solutions, governance strategies, education, and more—organized by hazard type, sector, and maturity (TRL levels 1–9). ARSINOE leverages the CIW as a strategic repository of climate adaptation tools, enriched with structured metadata (e.g. hazard coverage, TRL). These tools are integrated into local innovation packages in a participatory way—backed by vulnerability assessments, matchmaking logic, and interactive visualization, fostering ownership and adaptability across regions. The integration between CIW and innovation pathways creates a comprehensive ecosystem where the local needs drive solution identification, validated innovations expand market reach, and systematic pathways guide implementation. This approach ensures that climate adaptation solutions are not only technically viable but also contextually appropriate, socially accepted, and scalable across different regional contexts, ultimately strengthening European climate resilience through collaborative innovation networks.

ARSINOE employs a comprehensive three-tier methodology to develop and implement innovation packages for climate resilience, integrating the SIA and the CIW to build a robust ecosystem for adaptation solutions. This approach aims to facilitate a fundamental transformation of economic, social, and financial systems to strengthen climate resilience. Firstly, the SIA serves as a methodological framework designed to address the complex and interconnected nature of modern societies and economies. It focuses on the cross-sectoral system "as a whole" and the diverse actors within it, rather than just individual functions or sectoral benefits. Within ARSINOE, SIA is implemented through highly participatory Living Labs, which bring together stakeholders from the quadruple helix – academia, the private sector, public authorities, and civil society – to co-create and co-design innovation pathways. The initial phase of this approach involved stakeholder identification and mapping, which is a crucial process led by case study leaders with support from WP2. The mapped stakeholders (following an influence-interest analysis), particularly the "key players" identified through the process, form the basis for selecting participants for Living Labs. These Living Labs serve as user-centred, open innovation ecosystems for systematic co-creation in real-life settings, providing a "safe" space for representatives to identify challenges, risks, opportunities, and explore innovative ideas.

Within these Living Labs, stakeholders engage in a multi-step co-creation process to develop innovation pathways. This involves (i) identifying main issues and challenges in their region, (ii) co-developing a sustainable vision for their region by describing a desirable future, (iii) co-identifying a portfolio of actions and innovations (technological, social, and institutional) needed to achieve that vision, using methods like "backcasting" from the future vision to present-day milestones and (iv) Identifying barriers and

enablers using frameworks like PESTLE (Political, Economic, Social, Technological, Legal, Environmental) to support implementation. These pathways outline a trajectory of change with chronological milestones, underpinned by concrete actions and associated technological, social, and institutional innovations. Examples include Athens focusing on extreme heat resilience and Mediterranean ports on adaptation to extreme weather, involving a mix of technological and social innovations. Finally, SIA enables regions to underscore barriers and enablers for transformative adaptation action using frameworks like PESTLE (Political, Economic, Social, Technological, Legal, and Environmental) to support implementation.

Additionally, the CIW serves as the Link to Package Formation and Open Tenders for Innovations (OTI), functioning as a dynamic marketplace and matching tool for solutions. Its operation informs regional innovation packages as it facilitates the selection of existing or new climate technologies. Regions can integrate validated technologies already on the platform or new technologies from external providers into their succinct innovation packages after considering the suitability of current financial schemes and governance structures. Furthermore, the CIW supports demand-driven selection, allowing end-users to choose technologies best suited for their specific needs, with enhanced filtering options for issues, areas of application, solutions, and types of innovation (technical or social). : New technologies implemented in specific local innovation packages have the opportunity to be validated and subsequently become CIW members, thus expanding the market for these innovations. This enhances the credibility of these innovations and facilitates broader market adoption.

The two fundamental frameworks feed into the ARSINOE matching process, which can be understood in terms of identifying regional needs (demand-side) and then sourcing appropriate technologies and solutions (supply-side). The process begins with identifying regional needs through SIA within Living Labs, which serve as user-centered innovation spaces bringing together stakeholders from academia, private sector, public authorities, and civil society. Through structured workshops, participants define climate challenges, co-create sustainable visions aligned with SDGs, and design innovation pathways using backcasting methodology. This collaborative approach identifies barriers and enablers through the PESTLE framework while highlighting innovation gaps requiring further development.

On the supply side, ARSINOE sources technologies through the Climate Innovation Window, Europe's reference marketplace for climate adaptation technologies, and Open Tenders for Innovations (OTI). The OTI process is directly shaped by needs identified in Living Labs, ensuring solutions are well-adapted to local contexts. Innovators submit comprehensive applications evaluated by a dedicated committee based on technical, social, and market readiness criteria, along with qualitative factors like testing feasibility and transformational potential. Selected innovators receive contracts for up to EUR 50,000 for co-development and demonstration activities. The selected innovations are integrated into region-specific innovation packages encompassing nature-based solutions, technologies, financial models, and governance frameworks. These packages undergo stakeholder validation before implementation. Participatory modeling tools support this process by providing analytical depth through conceptual models, risk assessments, and the Dynamic Multi-Sectoral Resilience Modeling framework. This creates a continuous loop where stakeholder engagement identifies challenges, modeling provides analytical understanding, and targeted innovation sourcing delivers validated, context-specific solutions for enhanced regional climate resilience.

Finally, the innovation packages, while initially designed for specific regions based on their unique challenges and visions, are built with transferable and reusable components. This design principle enables their adaptation and replication across other European regions and beyond. ARSINOE explicitly fosters ecosystem sustainability and growth with cross-fertilization and replication across regions and scales at a European level and beyond. The showcasing of the ARSINOE approach in nine widely varied demonstrators across Europe serves as a proof-of-concept regarding its applicability, replicability,

potential, and efficacy. These case studies encompass diverse systems and challenges, from urban heat to port operations and water scarcity, providing a wide range of contexts for testing and demonstrating solutions. This integrated methodology ensures that adaptation efforts are not isolated but contribute to a broader, interconnected framework for building climate resilience across Europe.

Participatory modelling tools, as primarily outlined in Deliverable 3.2 ("Socio-environmental systems participatory models and analysis techniques – Initial version"), play a fundamental role in the formation of innovation packages for each Case Study (CS) within ARSINOE. This approach ensures that solutions are co-created, demand-driven, and contextually relevant. More specifically, SustainGraph (Fotopoulou et al., 2022) semantically links regional data, stakeholder inputs, climate hazards, SDG targets, and policy frameworks. It helps model the socio-environmental system of each case study, highlighting leverage points, vulnerabilities, and interdependencies—crucial for designing context-specific innovation packages. The tool is interactive and explorable via dashboards like NeoDash, Bloom, or SemSpect, allowing regional stakeholders (local governments, innovators, NGOs) to see their own data, explore dependencies, and contribute to shaping strategies. This visual accessibility builds trust, understanding, and a sense of co-ownership over the innovation package. SustainGraph connects policy objectives (e.g. EU missions, local adaptation plans) with market-ready solutions from the CIW and research outputs, creating a shared language across sectors. This integration helps translate strategic visions into implementable innovation agendas that regions can champion and refine.

3.0 CS1 Metropolitan Athens - Innovation Package

3.1 Overview of the Case Study

The Metropolitan Athens case study (CS1) addresses a wide range of interconnected climate resilience challenges, including water scarcity, heat stress, energy demand, and urban liveability. The innovation pathways developed for CS1 aim to support the transition toward a more adaptive, resource-efficient, and climate-resilient urban region through a combination of nature-based solutions, low-carbon technologies, and citizen engagement. These pathways were co-developed with local stakeholders through a participatory workshop process, drawing heavily from the CIW as a source of pre-evaluated climate innovations. The innovations listed below indicate solutions that received funding through dedicated open calls. Most of the selected innovations are expected to evolve over time and may be interdependent. Though these links were considered during development, they were not formally documented in the pathway files. The distribution across milestone years (2030, 2040, 2050) reflects stakeholder prioritization rather than a fixed implementation plan, with most actions focused on urgent, near-term adaptation needs.

SIA serves as ARSINOE's core methodological framework for addressing climate change challenges through comprehensive, cross-sectoral understanding rather than isolated interventions. This approach emphasizes engaging diverse actors to understand interconnected systems holistically, particularly demonstrated through the Athens Case Study focused on extreme heat adaptation by 2050. SIA implementation follows structured stages within Living Labs, collaborative spaces bringing together stakeholders from academia, private sector, public authorities, and civil society. The process begins with defining scope and system boundaries, followed by mapping stakeholders, issues, and challenges using influence matrices. Problem definition occurs through participatory workshops, with Athens identifying the central challenge as increasing heat impacts on health, society, and economy, encapsulated in their vision of becoming "a green and cool city" with integrated green-blue infrastructure, sustainable mobility, and active citizenship.

The approach employs backcasting methodology, working backward from desired future visions to identify innovation pathways. Athens developed pathways addressing extreme heat preparedness,

planning, and emergency responsiveness. Throughout this process, the PESTLE framework identifies barriers and enablers across political, economic, social, technological, legal, and environmental dimensions. For Athens' water sector, political prioritization and European funding served as enablers, while resource requirements for changing urban development practices presented barriers. Citizen engagement represents a crucial component, incorporating citizen science through the MINKA application for biodiversity monitoring, youth climate assemblies, and teacher training seminars. The process integrates with ARSINOE's resilience wheel framework, developing conceptual models that address urban heat islands, air pollution, and infrastructure considerations.

SIA outputs directly inform innovation packages through Open Tenders for Innovations, where identified problems and gaps guide solution sourcing. Athens selected three innovations through this process: the Kausal Platform for climate action management, Singular Ribbon for hydroponic urban cooling, and Urban Green Oasis initiatives for community-based urban greening. This participatory, iterative process ensures that technical solutions align with locally identified needs while building comprehensive climate resilience strategies supported by appropriate financial instruments and governance frameworks.

To provide a clearer picture of how climate innovations can address specific vulnerabilities, the following sections break down the innovation package by sector. Each includes sectoral goals, key milestones, challenges and enablers, financial instruments, and the specific innovations proposed for the Metropolitan Athens context.

3.2 Sectors

Water

The water sector in Metropolitan Athens faces increasing challenges due to the compounded impacts of rising temperatures, increasing frequency of droughts, aging infrastructure, and limited progress on water reuse. Water scarcity and heat stress are exacerbated by the city's dense urban fabric and high seasonal demand, placing additional strain on public services and infrastructure. As a result, ensuring a reliable and sustainable water supply, improving water quality, and integrating climate adaptation into water management have become urgent priorities for both the municipality and local stakeholders. To address these vulnerabilities, the sector is moving toward innovative solutions that combine blue-green infrastructure, decentralized water reuse technologies, and urban cooling interventions, aiming to deliver climate-resilient public services while simultaneously enhancing urban biodiversity and quality of life.

Sectoral Goals

The main goals for the water sector in Metropolitan Athens are to enhance water reuse and decentralized treatment in urban contexts, improve access to potable water in public and high-footfall spaces, and incorporate blue-green solutions to both mitigate urban heat and support local biodiversity. These objectives reflect the priorities set by local stakeholders and are aligned with the climate adaptation vision for the city, as developed through the ARSINOE participatory process (D2.4).

Implementation Timeline & Milestones

The implementation timeline for water sector innovations in Metropolitan Athens is structured across both short- and long-term horizons, reflecting stakeholder priorities identified through the ARSINOE participatory process. Within the next five years, by 2030, the focus will be on initiating decentralized greywater systems, deploying adaptive rooftops and rain gardens in schools and community spaces, and implementing the first wave of water art and cooling stations throughout the city. Looking further ahead, for the period 2040 to 2050, the ambition is to expand water reuse capacity, integrate smart monitoring technologies into infrastructure management, and promote wide-scale adoption of these innovations within residential areas.

Innovations in Focus

A diverse set of innovative solutions has been identified to help the Metropolitan Athens water sector achieve its goals and milestones. These innovations were selected through a collaborative process with local stakeholders, drawing on both the best international practices and context-specific needs highlighted during the ARSINOE Living Labs. The following innovations represent a portfolio that combines nature-based solutions, advanced water treatment methods, and urban cooling interventions, each tailored to address the city's unique vulnerabilities and opportunities for resilience.

- **Rain Gardens:** Vegetated, engineered depressions that collect and treat rainwater runoff from surfaces like roads and rooftops, helping to reduce flooding, filter pollutants, and enhance biodiversity in urban areas.
- **RESILIO Adaptive Rooftops:** A network of smart “blue-green” roofs in Amsterdam fitted with sensors and automated valves (‘Smart Flow Control’) that dynamically retain or release rainwater based on weather forecasts, helping reduce flood risk, support cooling, and enhance biodiversity across urban areas.
- **RichWater:** A modular technology that recovers and treats domestic/urban wastewater for use in irrigation and fertilization, enabling safe reuse of greywater to support sustainable agriculture and landscaping.
- **LooPi® / vertECO®:** Innovative vertical sanitation systems that treat greywater through vertical plant-based filters, transforming wastewater into reclaimed water while integrating green aesthetics in compact modular units.
- **SolarDew:** A standalone water purification unit that uses solar thermal energy to produce safe drinking water via membrane distillation, offering a decentralized solution for clean water in off-grid environments.
- **Cooling Water Bodies:** A design-based approach that develops urban waterbody prototypes capable of delivering measurable cooling (1–5 °C) around ponds or channels, helping to reduce local heat stress and inform resilient urban design practices.
- **Water Art / Fountain (Cooling Measure):** An artistic water feature installed in a paved square (Christiana Torv) that recirculates shallow water to provide passive cooling and enhance the aesthetic and social quality of the space during heat waves.
- **The Refreshing Waters (Cooling Station 2.0):** A low-tech, community-focused outdoor cooling station that combines misting lines, fans, and seating in a public plaza to deliver thermal relief and social interaction during extreme heat events.

Barriers & Enablers

The barriers and enablers identified for the water sector are specifically linked to achieving the sectoral goals and milestones outlined above. They were selected through a participatory process involving local stakeholders, who assessed each innovation using the PESTLE (Political, Economic, Social, Technological, Legal, and Environmental) framework as part of the ARSINOE Living Labs. Among the key enablers are a growing demand for visible cooling measures in public spaces, strong institutional interest in decentralized water reuse solutions, and significant co-benefits for energy efficiency and public health. However, several barriers persist, including constraints on installing new public infrastructure, the need for substantial upfront investment in modular systems, and regulatory complexities surrounding wastewater reuse in urban environments.

Financial Instruments

A diversified financing strategy is being pursued in Athens to overcome the water sector's financial barriers. European grant programs like the LIFE Programme and the Recovery and Resilience Facility (RRF) are pivotal for providing upfront capital to pilot innovative water solutions. These funds help bridge the gap for high-cost, unproven technologies by financing modular reuse systems (e.g. the RichWater

greywater treatment modules) and blue-green infrastructure (such as rain gardens) on a demonstration basis. The RRF (part of the EU's post-COVID recovery plan) includes dedicated support for green and digital transitions, which Athens can tap to build water reuse facilities and install nature-based cooling features. Likewise, the LIFE programme, as an EU environmental funding instrument, can directly support decentralized water recycling and urban biodiversity projects, addressing the lack of long-term financing for these novel measures. By relying on such grants for initial implementation, Athens mitigates the risk for local budgets and proves the concepts, encouraging broader investment once results are shown.

Moving beyond EU grants, domestic and market-based instruments will scale up successful pilots. The city's municipal water utility is expected to co-finance and maintain new systems, for example, incorporating the cost of operating fountains or recycled water networks into its capital plans and rates. Athens is also considering issuing green bonds to raise capital for water resilience projects. A green bond earmarked for climate adaptation allows the city (or the utility) to borrow funds from investors with repayment over many years, spreading out the upfront investment needed for large-scale initiatives like city-wide cooling fountains or the rollout of green roofs and cisterns. Such bonds would be designed with clear environmental targets (e.g. volume of water reused or number of cooling installations) to attract investors focused on sustainable impact. The viability of a municipal bond will depend on maintaining a strong credit rating and preparing a pipeline of bankable projects with measurable outcomes, giving investors' confidence in both the city's creditworthiness and the projects' climate benefits. In addition, public-private partnerships (PPPs) are on the table for infrastructure like decentralized wastewater treatment units or extensive green roofing on public buildings. Under a PPP model, a private firm could finance and build these installations and then recuperate its investment via a long-term service contract or a performance-based payment (for instance, the city paying a fee indexed to water saved or temperature reductions achieved). This approach leverages private capital and expertise, alleviating the immediate burden on public finances, but requires clear contractual frameworks and risk-sharing arrangements to ensure public value for money.

Critically, mechanisms are being put in place to address financial barriers related to public acceptance and revenue generation. One challenge identified is that reusing wastewater is unfamiliar to residents, making it hard to introduce tariffs or charges to fund such systems. To tackle this, any plan to pass on costs to end-users (for example, a small surcharge on water bills to fund climate-resilient infrastructure) must be accompanied by public engagement. Targeted communication campaigns will precede these measures to explain the benefits of water reuse and cooling projects *ex ante* (before implementation), and tangible results will be transparently reported *ex post* (after implementation). For instance, if a new greywater recycling system in a public building reduces water consumption by 30%, or if neighborhood rain gardens demonstrably lower local flood incidents, these outcomes will be publicized to build trust. Such transparency and outreach are conditions for success: they help build public willingness to pay for or otherwise support innovative water measures. Moreover, integrating modest user fees or "water innovation charges" into utility bills can create a sustainable revenue stream for maintenance and future upgrades, but only if citizens perceive value and fairness in these charges. Thus, the city is planning social marketing efforts and potentially pilot programs in public facilities (e.g. installing reuse systems in government buildings first) to showcase efficacy before scaling up to wider residential areas.

In terms of innovative instruments, Athens is also exploring the use of Resilience Bonds to finance water-related climate adaptations. Resilience bonds are a subset of green bonds specifically designed to fund

projects that reduce climate risks. They are structured to monetize the future risk reduction achieved by an intervention. For example, if installing permeable pavements and rain gardens in flood-prone districts is projected to significantly cut stormwater runoff and thereby diminish flood damage, a resilience bond could be issued to fund these installations upfront. The payoff to investors is then partially derived from the avoided costs or losses due to improved resilience – often through insurance mechanisms or cost savings. In practice, this could mean partnering with insurance companies: as adaptation measures lower the expected payouts for water damage or drought-related losses, insurers or the city could channel those savings to repay bondholders. Similarly, resilience bonds for building-scale water recycling or cooling could be justified by future benefits like reduced strain on water supply in droughts or lower healthcare costs from heat stress. While the resilience bond concept is still emerging, it holds promise in Athens' context as it directly links financing to performance in risk reduction. The condition for tapping such instruments will be robust data and metrics: Athens will need to quantify how much each euro invested in, say, "adaptive green roofs" yields in terms of risk mitigation (cooler temperatures, flood avoidance, etc.). Pilot projects supported by grants will help generate this evidence. If successful, resilience bonds and similar outcome-based finance could significantly expand resources for the water sector by attracting climate-conscious investors.

Overall, the water sector's financial pathway in Metropolitan Athens is about blending traditional and innovative funding sources to match the staged innovation pathway. Upfront grants and public funds kick-start pilot implementations, while long-term capital from bonds, utilities, and private partners allows scaling and maintenance. This blended approach broadens the funding base, enables demonstration projects to materialize, and signals a wider institutional readiness to invest in water resilience. It addresses the core financial barriers: lack of long-term funding and revenue models, by creating new channels for money to flow into water innovation, from EU offers to citizen pockets to capital markets. Crucially, it ensures that as technical solutions like wastewater reuse and urban cooling advance, the financial mechanisms to support them advance in parallel, securing both the initial adoption and the sustainable operation of these climate resilience innovations.

Policy & Governance Recommendations

Building resilience across sectors in the Athens Metropolitan Region requires a cohesive policy framework and coordinated governance structures. The ARSINOE governance analysis and stakeholder engagement processes underscore several cross-cutting priorities. Chief among these is the need for enhanced coordination among municipal departments—spanning urban planning, environment, health, water, education, and social services—to facilitate integrated solutions to complex challenges. Streamlining regulatory and permitting procedures, fostering cross-sectoral collaboration, and institutionalizing participatory mechanisms (e.g., living labs and consultation platforms) can break down administrative silos and ensure that local knowledge informs strategic decisions. Aligning municipal strategies with regional, national, and EU frameworks increases access to funding, technical assistance, and compliance with sustainability directives. Strengthening institutional capacity, particularly in technical expertise, project management, and monitoring and evaluation—will be key to maintaining momentum and achieving long-term goals.

A critical barrier across all sectors is the lack of sufficient and specialized personnel to implement and manage climate adaptation projects. The municipality should invest in upskilling and reskilling programmes for existing staff and create new, dedicated positions for climate resilience, particularly in technical areas like green infrastructure maintenance, digital tool management, and participatory planning. This can be supported by EU funds like the European Social Fund Plus (ESF+).

The ARSINOE project's success is built on the Systems Innovation Approach (SIA) and Living Labs, which engage stakeholders from academia, the private sector, public authorities, and civil society. Policy should be enacted to make these participatory processes a standard component of all major urban development and climate adaptation planning, not just a feature of externally funded projects. This includes formalising the use of citizen science tools like the MINKA platform for biodiversity monitoring and continuing educational initiatives like the Youth Assemblies and Training for Trainers (T4T) seminars to ensure sustained public input and ownership.

For Water, it is material for the transformation of the Athens Metropolitan Area to streamline the regulatory framework for decentralized water reuse. This can be implemented by developing clear and simplified permitting processes for installing greywater recycling and rainwater harvesting systems in both new constructions and existing buildings. This policy should be accompanied by public awareness campaigns to address social barriers like reluctance to reuse wastewater. This action directly tackles legal and regulatory barriers such as "strict health regulations" and a "lack of legislative framework for adoption" of such innovations. It would enable the wider implementation of technologies like RichWater (wastewater treatment for irrigation) and LooPi® / vertECO® (vertical green sanitation systems).

To incentivize Blue-Green Infrastructure, the Municipality of Athens should update its building codes and urban planning regulations to either mandate or strongly incentivise the installation of RESILIO Adaptive Rooftops and Rain Gardens. This can be financed through a combination of municipal funds and European instruments like the Recovery and Resilience Facility (RRF) and the LIFE Programme, which are identified as key financial enablers. This reform directly addresses the bottlenecks in the building legislative framework highlighted in the participatory process of the ARSINOE project and leverages the strong political will and public demand for visible cooling measures like Cooling Water Bodies and Water Art / Fountains. It requires strong coordination between the Urban Planning, Green Areas, and Water departments.

Energy

Energy-related interventions in CS1 focus on reducing building-level energy demand through passive cooling and smart building design, while simultaneously improving the institutional capacity of municipalities to identify and support energy-vulnerable populations. Given the high prevalence of energy poverty and increased heat risk in Metropolitan Athens, energy efficiency and cooling are critical for both public health and urban resilience. By blending nature-based retrofitting with targeted policy interventions and digital tools, the energy innovation pathway addresses the dual objectives of climate change mitigation and adaptation, ensuring that solutions are equitable and accessible across the city's diverse neighborhoods.

Sectoral Goals

The key goals for the energy sector in Metropolitan Athens are to promote energy efficiency and improved cooling in the urban built environment, support vulnerable populations through dedicated institutional mechanisms and tailored energy support tools, and leverage both low-tech and digital innovations to enhance climate resilience in the energy domain. These objectives were defined in collaboration with local stakeholders and reflect the urgent need to address energy poverty, improve building performance, and mainstream adaptive solutions throughout the city.

Implementation Timeline & Milestones

The implementation of energy sector innovations in Metropolitan Athens is planned across both immediate and longer-term horizons, in line with stakeholder priorities identified during the ARSINOE project. Within the next five years, by 2030, the focus will be on piloting visual cooling solutions and energy support systems, as well as establishing the Energy Poverty Office in target municipalities to better assist vulnerable groups. Looking ahead to the period from 2040 to 2050, the strategy includes integrating advanced energy monitoring and planning tools within local governance frameworks and replicating

successful low-emission retrofits across a broader range of public and private buildings. This phased approach aims to achieve incremental improvements in both energy efficiency and resilience citywide.

Innovations in Focus

A suite of innovative solutions has been identified to advance energy efficiency, improve cooling, and support vulnerable populations in Metropolitan Athens. These innovations were selected through a collaborative, stakeholder-driven process as part of the ARSINOE Living Labs and are designed to address both the physical challenges of the city's building stock and the social dimensions of energy vulnerability. The following approaches represent a mix of nature-based systems, novel building materials, institutional innovations, and digital tools, each contributing to the city's overarching climate resilience and mitigation strategy.

- **LeafSkin® Vertical Gardens:** A lightweight hydroponic vertical garden system, pre-grown off-site and designed for fast, modular installation, delivering insulation, air purification, and aesthetic greening benefits in urban environments.
- **Colorful Low-Emissivity Paints:** Innovative bilayer coatings combining an infrared-reflective base and a visible-color layer, offering up to ~80–90% reflectance in the IR spectrum while retaining aesthetic appeal, they can cut building heating and cooling energy use by around 7–27%, depending on climate.
- **Establishment of Energy Poverty Office at Municipal Level:** A municipal 'one-stop shop' designed to identify energy-vulnerable households, provide personalized energy-saving guidance, facilitate access to public support schemes, and ensure social protection through targeted tax exemptions.
- **Thermal Assessment Tool (REACH OUT, H2020):** A user-friendly digital platform that visualizes the frequency, intensity, and future projections of extreme heat events across European cities, helping urban planners assess heat risk levels and design adaptation strategies.

Barriers & Enablers

The barriers and enablers identified for the energy sector are directly linked to achieving the sector's main goals and implementation milestones. Among the key enablers are the strong visibility and demonstrable impact of innovations such as LeafSkin®, significant municipal interest in tackling energy poverty, and the alignment of proposed actions with both mitigation and adaptation targets. On the other hand, substantial barriers persist, including the high cost of retrofitting existing structures, administrative fragmentation that can impede the delivery of social energy services, and limited public awareness or access to digital tools. Effectively overcoming these challenges and capitalizing on enabling factors will be essential for widespread adoption of energy innovations in Athens. Establishing a municipal 'one-stop shop' dedicated to Energy Poverty implies an institutional reform and transfer of key responsibilities related to energy to the municipality. This can prove to be a lengthy process hindered by bureaucracy unless there is a comprehensive dialogue between different levels of governance.

Financial Instruments

Financing the energy sector's innovation package in Athens requires targeting both upfront investment needs and ongoing support for vulnerable populations. A mix of European, national, and local funding instruments has been identified to overcome the key barrier of limited initial capital for retrofits and the high costs of energy poverty alleviation. On the European side, ERDF is set to play a central role. ERDF resources (through Greece's regional programs) can co-fund extensive building retrofit projects, for example, insulating homes, installing passive cooling features like shading or reflective materials, and upgrading public buildings for energy efficiency. By subsidizing a significant share of these project costs, ERDF funding directly addresses the upfront cost barrier that often prevents energy-saving renovations in older buildings. Alongside ERDF, the European Social Fund Plus (ESF+) is being leveraged to support the

Energy Poverty Offices and related social innovations. ESF+ focuses on social inclusion and can finance the establishment of these municipal one-stop-shops for energy-vulnerable households. This might include covering staff training, outreach programs, and the development of digital tools to identify and assist at-risk families. Tapping ESF+ and similar social funding streams ensures that the ongoing operational costs of supporting vulnerable groups, such as personalized energy advisory services or subsidy schemes, are not left solely to the municipal budget. In addition, national social protection programs are expected to contribute, for instance through government-funded discounts or vouchers for low-income households to purchase cooling equipment or pay electricity bills. By combining infrastructure funding (ERDF) with social funding (ESF+ and national welfare funds), Athens aims to deliver energy efficiency improvements equitably, ensuring that low-income and marginalized communities can benefit from and afford the new innovations.

To scale up pilots and sustain long-term momentum, more innovative financial instruments are being pursued. One such tool is the creation of revolving funds dedicated to energy efficiency. In a revolving fund model, initial capital (potentially from state or EU grants) is used to provide loans or grants for retrofit projects, and as energy savings are realized (or loans are repaid), the money flows back into the fund to finance new projects. Athens could, for example, set up a revolving fund to help apartment building owners install low-emissivity (low-e) paints or cool materials on rooftops. The fund might pay a portion of the installation cost upfront, and building owners would reimburse the fund over time out of the savings achieved on cooling bills due to lower indoor temperatures. Such a mechanism directly addresses financial barriers by reducing upfront costs for property owners while creating a sustainable financing loop for continuous improvements. Public-private partnerships (PPPs) are also under consideration to deploy innovations like LeafSkin® vertical gardens or solar shading systems at scale. In a PPP approach, private energy service companies or investors (sometimes known as Energy Service Companies, ESCOs) could finance and install energy-saving interventions (e.g. high-reflectance paint coatings on many buildings across the city) in exchange for a share of the energy cost savings achieved or a fixed service payment from the municipality. This model has been used successfully in other cities for street lighting upgrades and solar panel installations; in Athens it could be applied to climate adaptation measures that also yield energy savings (for instance, green facades that cool buildings and cut air-conditioning use). By inviting private capital and expertise, PPPs help stretch public funds further and accelerate implementation, but they require robust contracts and monitoring to ensure the promised performance (energy reduction) is delivered. The ARSINOE project's financial mapping also suggests exploring municipal climate bonds specifically targeted at energy resilience. For example, Athens could issue a "cool cities bond" a type of green bond where proceeds are devoted to retrofitting buildings with passive cooling and renewable energy systems. Investors in such bonds would be repaid from the city's budget over, say, 10-15 years. This spreads out the cost of today's investments and aligns with the long-term nature of benefits (lower energy demand and improved public health). Notably, because Athens' energy innovations contribute to both mitigation (reducing emissions) and adaptation (cooling and resilience), the city can market these bonds as supporting multiple EU and global climate goals, potentially attracting a broad base of impact-focused investors. The feasibility of a bond issuance will depend on Athens' fiscal capacity and credit status, but if conditions are favorable, it could significantly boost the funding available for large-scale retrofitting beyond what grants alone provide.

Several conditions and support mechanisms are being put in place to ensure these instruments effectively address barriers. Administrative coordination is key: accessing EU funds like ERDF/ESF+ requires co-financing and project management capacity at the municipal level, so Athens is strengthening its project pipeline and proposal writing teams. The city is working closely with national authorities to align projects with national energy retrofit programs (for instance, Greece’s “Exoikonomo” schemes for building energy upgrades) so that local efforts qualify for maximum funding and technical support. For revolving funds and PPPs, establishing a clear regulatory framework is important, this includes standardizing contracts for energy performance guarantees and ensuring procurement rules allow innovative financing arrangements. To avoid bureaucratic hurdles, Athens is streamlining approval processes for energy projects (e.g. simplifying permits for installing insulation or green roofs), which in turn increases investor confidence that projects can be implemented on schedule. Another condition for success is ensuring social buy-in and protecting vulnerable groups during the transition. The city recognizes that even heavily subsidized retrofit programs can face uptake challenges if homeowners are unaware or skeptical. Therefore, part of the Energy Poverty Office’s role will be to run outreach campaigns and technical assistance for households, helping residents navigate grant applications or advising landlords and tenants on the benefits of efficiency improvements. Some of these activities could be funded by ESF+ or the forthcoming Social Climate Fund (SCF). The SCF is a new EU mechanism (2026-2032) that will mobilize over €86 billion to help vulnerable households across Europe adopt clean energy and efficiency measures. Athens, through Greece’s national Social Climate Plan, can tap the SCF for additional support like subsidizing efficient cooling appliances or rooftop solar panels for low-income neighborhoods. Notably, the SCF encourages the creation of one-stop shops for energy renovations as a best practice validating Athens’ approach of establishing municipal energy help desks. By planning to utilize SCF grants alongside ERDF and national funds, the city will further alleviate the cost burden on its most vulnerable citizens, ensuring that no one is “left behind” in the energy transition.

Finally, the blended financial approach in the energy sector is closely aligned with the innovation timeline outlined for Athens. In the immediate term (by 2030), pilot projects like installing colorful low-e paints on a set of public buildings or launching the first Energy Poverty Office rely on grant funding and municipal budget allocations to get started. As these pilots demonstrate success (e.g. measurable drops in indoor temperatures or effective relief for households in energy distress), the city can unlock larger-scale financing, through bonds, revolving funds, and PPP investments, to replicate and upscale these solutions by 2040 and beyond. By the 2040-2050 phase, Athens envisions that many energy efficiency measures will be integrated into standard practice and building codes (e.g. requiring cool roofs or updated insulation in renovations), at which point financing will shift more toward private investment by homeowners and developers, supported by incentives from the state. The groundwork laid now with innovative public financing is creating the conditions for that future self-sustaining market. In summary, the current plan blends EU structural funds, social funds, innovative financing (PPPs, revolving funds, green bonds), and local budget efforts to ensure that the energy innovations, from green building facades to digital thermal assessment tools, are not only piloted but persist and proliferate city-wide. This comprehensive financial package directly addresses the barriers of high upfront costs and fragmented funding by introducing new streams of capital and fostering partnerships, thereby securing the long-term viability and equity of energy resilience measures in Metropolitan Athens.

Policy & Governance Recommendations

The energy sector requires robust governance to support innovations, particularly in addressing energy poverty. Interdepartmental coordination (e.g., energy, welfare, urban planning) is essential for delivering integrated interventions. Simplified permitting and clear retrofitting guidelines can catalyze project implementation. Active engagement with communities, NGOs, and private actors fosters inclusive policy design, while alignment with national and EU climate directives ensures funding eligibility and strategic coherence. Strengthening monitoring systems and evaluation frameworks will help track progress and optimize outcomes.

The metropolitan area would benefit greatly from the operation of an Energy Poverty Office, which will act as a 'one-stop shop' to identify and support energy-vulnerable households. In addition, it would provide guidance, facilitate access to subsidies, and coordinate with social services, funded through a blend of municipal budget and social funds like ESF+. This institutionalises a key social innovation identified in the project and addresses the barrier of "administrative fragmentation" by creating a single, accountable entity for a critical social and climate issue.

Having said that, the administration should consider revising the municipal building code to require the use of high-reflectivity materials and passive cooling solutions in all new constructions and major renovations. This should be supported by a public subsidy programme, leveraging ERDF and revolving funds, to incentivise retrofitting in existing buildings. An initiative like this is most likely to accelerate the adoption of innovations like LeafSkin® Vertical Gardens and Colorful Low-Emissivity Paints, which contribute to both energy efficiency and urban cooling.

Urban Greening & Infrastructure

Urban greening in CS1 focuses on re-integrating biodiversity into the dense city fabric, expanding citizen access to ecosystem services, and turning underused land into climate buffers. Given the limited availability of open space and increasing urban heat in Metropolitan Athens, these interventions are especially important for mitigating climate risks and improving the quality of urban life. These solutions are highly visible and participatory, contributing both to long-term environmental resilience and community engagement. By prioritizing nature-based solutions and fostering local stewardship, urban greening initiatives aim to create a more livable, equitable, and climate-adaptive city.

Sectoral Goals

The primary goals for urban greening in Metropolitan Athens are to enhance urban biodiversity and ecological connectivity, improve citizen access to quality green space within walking distance, and promote nature-based solutions that deliver both climate mitigation and urban wellbeing. These objectives reflect the city's broader vision for sustainable development and have been shaped through stakeholder input during the ARSINOE participatory process.

Implementation Timeline & Milestones

The implementation of urban greening initiatives in Metropolitan Athens will proceed in a phased manner. Within the next five years, by 2030, the city plans to launch pilot programs for urban microforests and pocket parks, as well as to deploy biodiversity assessment tools in selected districts to inform strategic planting and connectivity decisions. Looking further ahead, from 2040 to 2050, the vision is to scale up the creation of green corridors throughout the metropolitan region and to align greening efforts with broader climate mitigation targets and sustainable mobility planning. This staged approach enables the city to build on early successes and incrementally expand the benefits of urban greening to more neighborhoods over time.

Innovations in Focus

Urban greening in Metropolitan Athens relies on a mix of practical, highly visible, and community-centered innovations that respond directly to the city's density, limited open space, and biodiversity challenges. The selection of these solutions was informed by extensive input from local residents, planners, and ecological experts through the ARSINOE process, ensuring that each approach is grounded in both scientific evidence and everyday urban experience. Together, these innovations aim not only to increase green coverage but also to strengthen social ties, support pollinators and native species, and demonstrate how even small-scale interventions can transform neighborhoods and enhance urban life.

- **Pocket Parks:** Small, publicly accessible green spaces created in underused neighborhood areas to enhance local wellbeing, deliver pocket-sized cooling, and revitalize communities; Athens opened its first in 2020 and has since developed eight dense districts.
- **Urban Biodiversity Assessment Framework:** A structured methodology for evaluating urban biodiversity values by combining habitat quality, connectivity, and species data, designed to inform planning and design decisions in city contexts.
- **A Square Meter for Butterflies:** A small-scale urban greening project that creates pollinator-friendly planting beds using native wildflowers, contributing to biodiversity, ecological connectivity, and public awareness in city settings.
- **SingularRibbon / GreenShades (Vegetal Awnings):** A flexible green shading system made of suspended hydroponic "ribbons" of vegetation; designed for easy installation above pedestrian zones or façades to provide ambient cooling, enhance biodiversity, and improve urban aesthetics.
- **Tiny Forest in Athens:** A community-driven urban reforestation project planting small, native-species woodland patches with local volunteers and schools, aimed at enhancing biodiversity, improving air quality, and strengthening social cohesion.
- **Urban Green Oasis:** A climate-adaptive refuge within the Serafio complex, combining dense vegetation and an innovative hydro misting system to create a refreshing microclimate. Designed as a sanctuary for visitors and employees, it enhances biodiversity, mitigates heat stress, and offers a model of sustainable, human-centric urban cooling.
- **Green Corridors:** Linear green infrastructure projects that connect fragmented pocket parks and urban forests, designed to enhance biodiversity, improve pedestrian access to nature, and mitigate local heat stress along active travel routes.
- **Citizens' Accessibility to Green Urban Areas (15-minute City Concept):** A planning approach ensuring residents can reach essential services and green spaces within a 15-minute walk or bike ride, supporting urban health, equity, and resilience.
- **Life Tree Check (Smart Tree App):** A mobile application using AI to identify tree species from a photo and provide data on shade coverage, water evaporation, and cooling potential, encouraging citizen engagement in urban tree care through features like photo logging and gamified rewards.

Barriers & Enablers

The barriers and enablers for urban greening in Metropolitan Athens are closely linked to achieving the sector's goals and milestones and were identified through stakeholder engagement and PESTLE analysis during the ARSINOE project. Key enablers include the availability of underutilized urban land, strong local enthusiasm for creating community green spaces, and ongoing support from NGOs and academic partners. However, several barriers remain significant: limited capacity for the maintenance of green spaces, fragmented land ownership patterns that complicate project implementation, and frequent conflicts with other urban land use priorities. Addressing these challenges and building on existing enablers will be crucial for the successful and sustainable expansion of urban greening initiatives throughout the city.

Financial Instruments

Financing the urban greening initiatives in Athens requires flexibility, community involvement, and multi-tier support to overcome challenges like limited public space and maintenance costs. The strategy therefore combines traditional public funding with innovative, inclusive instruments. At the core, Athens is leveraging government and EU funding to provide a stable backbone for large-scale green infrastructure. The Green Fund of Greece, a national environmental fund, serves as a key source of grants for urban nature projects. The Green Fund reinvests revenues from environmental fees and fines into sustainability projects, and recently it has boosted its support to municipalities for green urban development, for example, launching a €79 million program (2025-2026) to finance new parks, tree planting, bike lanes, and schoolyard upgrades across all Greek cities. Athens can capitalize on this infusion by preparing shovel-ready projects like pocket parks and urban green oasis to submit for Green Fund financing. In parallel, European Structural Funds such as the European Regional Development Fund are being tapped to co-finance major undertakings like the creation of green corridors that connect parks and the restoration of larger urban green spaces. ERDF support is crucial for these higher-cost interventions, as it can cover a significant portion of construction and landscaping expenses, especially when the projects align with EU priorities like climate adaptation, biodiversity, and urban regeneration. The blended use of national and EU grants thus addresses the financial barrier of limited municipal budgets by injecting external capital for upfront investment in greenery.

To ensure that smaller-scale and experimental greening projects also flourish, Athens is embracing community-based financing mechanisms. One approach is participatory budgeting, where a portion of the city's budget is set aside for citizens to directly propose and vote on local projects. Through this process, neighborhood groups can secure funding for initiatives such as "A Square Meter for Butterflies" (installing pollinator-friendly micro-gardens) or converting an abandoned lot into a pocket park. Participatory budgeting not only provides funds (typically grants in the order of tens of thousands of euros per project), but also boosts local ownership and ensures the chosen projects have public support, addressing the barrier of community buy-in. Another grassroots tool is crowdfunding platforms. Athens plans to partner with or create dedicated online crowdfunding campaigns to raise donations for urban greening from the general public. For instance, a campaign might invite residents and local businesses to contribute small amounts towards planting street trees on their block or installing a "SingularRibbon" vegetated awning over a popular pedestrian alley. Early examples in other cities have shown that crowdfunded greening is viable for projects that capture the public's imagination (such as community gardens or schoolyard green renovations), especially when the municipality provides matching funds or publicity. In Athens, the authorities could kick-start crowdfunding by pledging to match every euro raised with an equivalent amount from the city's climate fund, thereby doubling the incentive for residents to chip in. Corporate sponsorships and public-private community agreements are another innovative avenue: local companies might "adopt" a small park or row of trees, funding their planting and upkeep in return for social responsibility recognition. This was not explicitly mentioned in the draft but aligns well with broadening the funding base and has precedents (for example, private firms funding the maintenance of specific parks or plazas in exchange for discreet acknowledgement signage). Such sponsorships address the ongoing maintenance cost barrier, supplementing what can be a strain on city maintenance crews and budgets.

For scaling up and long-term investments, Athens is exploring financial instruments that mobilize larger capital markets with a climate focus. One idea is to issue municipal green bonds dedicated to urban greening. These bonds would allow the city to raise a significant sum upfront (potentially in the millions of euros) from investors, with repayment over a period (e.g. 10-15 years) using municipal revenues. The proceeds could fund transformative projects like the expansion of the “Green Corridors” network or the creation of large urban forests on the city’s periphery. To appeal to investors and meet best practices, the bond would be structured with clear climate adaptation and social targets, for example: *(i)* increasing the percentage of Athens residents who live within a 15-minute walk of a green space (supporting the 15-minute city goal), *(ii)* measurable reductions in the urban heat island intensity in neighborhoods where interventions occur, and *(iii)* a quantified increase in urban green cover or tree canopy city-wide. These targets resonate with environmental, social, and governance (ESG) criteria that many institutional investors now prioritize. If Athens can demonstrate a favorable credit rating and a robust Climate Action Plan behind the bond, the interest rates can be quite favorable due to high demand for green investments. A successful issuance of a greening bond would significantly scale up funding availability, but it requires careful financial management: the city must ensure it can service the debt (via general budget or cost savings gained from ecosystem services) and that projects are executed effectively to achieve the promised outcomes.

Another pathway to finance greening is through integrating it into urban development and leveraging regulatory tools. For instance, the city can employ land value capture mechanisms: when new green amenities (like a park or greenway) raise nearby property values, a portion of that value uplift can be captured via special assessments or development fees to help fund the project. Athens could update its urban planning policies so that large private developments must either include green space or pay into a “Green Infrastructure Fund”. Such a fund, filled by developer contributions, could then bankroll greening projects elsewhere in the city, effectively making urban growth pay for urban greenery. Additionally, the Natural Capital Financing Facility (NCFF), an initiative of the European Investment Bank, was referenced in Athens’ climate projects. This facility blends EIB loans with EU grants to support nature-based solutions. Athens has already participated in NCFF projects for blue-green infrastructure design, and further NCFF-supported financing (or its successor programs under InvestEU) could provide low-interest loans or guarantees for large-scale green investments with repayment partially covered by the monetized benefits of ecosystem services (such as flood mitigation or recreational value).

To ensure sustainability and equity, certain conditions must accompany these financial instruments. Maintenance of new green spaces is a known financial hurdle: a park is only as good as its long-term upkeep. Thus, Athens is considering innovative maintenance funding models like social enterprises or job training programs that can be financed via the European Social Fund Plus (ESF+) or national employment programs. For example, an ESF+-funded initiative could train and employ local youth or unemployed residents as urban gardeners and park stewards, thereby covering maintenance needs while providing social benefits (jobs and skills): a win-win that makes the greening efforts more politically and socially sustainable. Community engagement is another condition: instruments like participatory budgeting and crowdfunding inherently require strong citizen interest, so the city will continue robust awareness campaigns about the value of urban nature. By publicizing the co-benefits of greening (cooler temperatures, improved air quality, better health outcomes, aesthetic and property value boosts), Athens aims to bolster public willingness to participate financially or in-kind (through volunteering) in

greening projects. Transparency and accountability in use of funds is also essential. The city will need to clearly report how bond proceeds are spent or how crowdfunding contributions are used and demonstrate the impacts (e.g. publishing metrics on new green area created per euro spent). This builds trust and justifies continued or increased investment from all sources.

In conclusion, the financial architecture for urban greening in Athens is a multi-layered mix of EU and national grants, municipal budget commitments, civic funding, and potential market financing, each chosen to tackle a specific scale or aspect of the greening challenge. Large projects rely on stable public funding and possibly bond financing; neighborhood projects lean on community and participatory funding; and maintenance and scale-up benefit from private sector and innovative finance involvement. This blended approach not only broadens the funding base but also deepens stakeholder engagement – by having residents, businesses, and investors literally invest in the city’s green future, it cultivates a sense of shared ownership. Ultimately, aligning these financial instruments with Athens’ innovation pathway means that as the city rolls out micro-forests, pocket parks, green roofs, and tree-lined streets, it does so with a financial plan as verdant as the vision itself: one that is resilient, inclusive, and capable of growing over time along with the urban forest.

Policy & Governance Recommendations

Sustaining and expanding green infrastructure in Athens demands dedicated policies and coordinated governance between urban planning, environmental, and public works departments. Streamlined land access procedures, protections for existing green areas, and integrated planning approaches are essential. Engaging local communities, academia, and NGOs can enhance the design and stewardship of green spaces. Embedding greening goals into broader urban and mobility strategies strengthens funding access and policy coherence, while adaptive management capacities will support long-term viability.

The main challenge around this focal area is to formally integrate the "15-minute City" Concept into Athens' Urban Master Plan. To this end the authorities and regional stakeholders need to push forward a rich set of measures. These include the amendment of zoning laws, transport plans, and spatial planning documents to explicitly prioritise the creation of interconnected green spaces accessible to all residents within a 15-minute walk or bike ride. Empower local communities to lead the creation of Pocket Parks and Urban Green Oasis initiatives through participatory budgeting. This way, innovations aimed at improving well-being for citizens are institutionalized and citizens and political support is mustered for one of the key objectives for regional resilience.

A Public-Private-Community Partnership framework for greening initiatives can further support the effort in this area. It can allow companies and community groups to "adopt" or sponsor the creation and maintenance of green spaces like **SingularRibbon** vegetal awnings or pollinator gardens (**A Square Meter for Butterflies**). This initiative could be incentivised through tax breaks, public recognition, or streamlined permits.

Heat Risk Management

Heat risk management is a critical pillar in CS1’s strategy due to Athens’ significant exposure to extreme summer temperatures and the growing impacts of heat on public health, energy systems, and urban infrastructure. Prolonged and increasingly frequent heatwaves pose severe risks, particularly for vulnerable populations and those living in densely built environments. The innovations identified for this sector are designed to link planning, prediction, and action, with solutions ranging from advanced spatial modeling platforms and digital early-warning systems to heat-adapted urban design strategies. By integrating data-driven tools with practical adaptation measures, the heat risk management pathway aims to build a more resilient and prepared city.

Sectoral Goals

The main goals for heat risk management in Metropolitan Athens are to minimize the exposure of vulnerable populations to extreme heat, support municipal decision-making by localized climate data and scenario planning tools, and mainstream both early warning systems and heat-adapted urban design strategies across the city. These objectives were developed in close consultation with local stakeholders and reflect the urgent need to strengthen the city's capacity to anticipate, respond to, and recover from heat-related hazards.

Implementation Timeline & Milestones

The implementation of heat risk management innovations in Metropolitan Athens is structured to address both immediate and future challenges. Within the next five years, by 2030, the city will focus on deploying pilot monitoring systems and heat resilience tools, as well as integrating green accessibility principles into local planning frameworks to reduce urban heat exposure. Looking further ahead, from 2040 to 2050, the aim is to embed advanced digital tools, such as CityClimateX and QoAir, directly into the city's urban heatwave response protocols. In this period, efforts will also be made to link population vulnerability mapping with healthcare and infrastructure planning, ensuring that the most at-risk groups are protected and that adaptive responses are both targeted and effective. This phased approach provides a roadmap for building sustained heat resilience across Metropolitan Athens.

Innovations in Focus

Innovations in heat risk management for Metropolitan Athens center on leveraging data-driven tools, spatial analysis, and collaborative platforms to anticipate and reduce the impacts of extreme heat events. The selection of these solutions was informed by both local needs and global best practices identified during the ARSINOE project, ensuring that each approach is responsive to the city's climate realities and adaptable to rapid urban changes. Together, these technologies and initiatives empower municipal authorities, planners, and communities to monitor heat risks, design more resilient urban environments, and implement targeted interventions that protect the health and wellbeing of all residents.

- **Citizens' Accessibility to Green Urban Areas (15-minute City Concept):** A planning approach ensuring that residents can access essential services, green spaces, and amenities within a 15-minute walk or bike ride, supporting urban health, equity, and climate resilience.
- **UHI and Heat-related Parameters along the Hadrian Aqueduct:** A high-resolution spatial study of air and surface temperatures along the Hadrianic aqueduct corridor in Athens, using Landsat satellite data and urban climate modeling to identify heat vulnerability hotspots and guide targeted cooling interventions.
- **QoAir (Blockchain-based System for Heatwave Management in Urban Areas):** A decentralized digital platform leveraging blockchain and IoT sensors to track urban heatwave events, enable transparent data sharing, and support community-level early warning and adaptation planning.
- **Modeling Future Population's Vulnerability to Heatwaves:** This tool uses demographic projections and climatic scenarios to spatially assess how exposure and sensitivity to heatwaves may shift over time, identifying future vulnerability hotspots to support proactive adaptation planning.
- **AST2.0 (Climate Resilient Cities Toolbox): Climate Adapt Platform**
- **Extreme Heat Resilience Alliance:** A global coalition of public health, climate, finance, and governance experts led by the Adrienne Arsht-Rockefeller Foundation's Climate Resilience Center, working to protect frontline communities from extreme heat through research, policy advisory, capacity building, and financing tools.
- **WEO: Environmental Analytics from Space:** An environmental analytics startup that harnesses satellite imagery and AI to deliver scalable, regularly updated climate insights such as urban heat, vegetation, and water management analytics to cities and municipalities around the world.

- **BitGreen:** A climate-adaptation platform spun off from Brussels University that provides urban stakeholders with high-resolution geospatial modeling, AI-driven scenario analysis, and cost-benefit insights to support nature-based resilience strategies at city and asset scales.
- **Kausal Platform:** A collaborative digital platform that empowers city planners and resilience teams to co-design data-driven adaptation strategies, enabling analysis, visualization, and decision-making around thermal comfort, urban form, and climate resilience at the neighbourhood scale.
- **CityClimateX:** A 3D urban resilience platform that models thermal comfort, urban heat islands, and air quality, allowing users to simulate and visualize the impacts of urban design decisions on local microclimates.
- **Heat Stress Tool for Athens:** A rapid-response digital tool that maps urban heat-stress hotspots and allows users to model the effectiveness of different mitigation strategies, with a focus on public health by visualizing heat risks and potential cooling interventions.

Barriers & Enablers

Among the main enablers are increased public awareness of the health risks posed by extreme heat, improved access to digital climate and spatial data, and growing alignment between urban planning and public health strategies. Conversely, several barriers persist: institutional fragmentation that complicates coordinated responses, limited availability of high-resolution urban climate data, and persistent coordination gaps between departments responsible for public health, the environment, and urban planning. Overcoming these challenges and maximizing enabling factors will be essential for building an effective and equitable heat resilience strategy for Athens.

Financial Instruments

Innovations in heat risk management, such as advanced climate modeling tools and heat early-warning systems, require a combination of funding for high-tech solutions and investments in on-the-ground adaptation measures. Athens recognizes that meeting the sector's goals will involve European, national, and local resources working together. On the European front, the city can leverage research and innovation funds to support its digital tools for heat resilience. Notably, Horizon Europe programs focusing on digital transition and smart cities are potential sources of grants for deploying technologies like CityClimateX, Kausal Platform, or QoAir in real-world municipal operations. These tools, identified as key innovations, could qualify under calls for proposals that fund climate adaptation through big data, IoT (Internet of Things), and AI, aligning with EU priorities to foster climate-resilient digital transformation. By securing Horizon Europe funding or similar EU innovation grants, Athens can offset the usually substantial upfront costs of software platforms, data infrastructure, and pilot implementations of city-wide heat monitoring networks. In addition, the Digital Europe Programme (an EU funding program specifically for accelerating digital capacity) might be tapped for investments like high-resolution climate data systems or urban digital twins that help model heat scenarios. Utilizing these EU- programs addresses the financial barrier of limited local funds for cutting-edge technology by bringing in external grant money designated for innovation.

Meanwhile, European structural and recovery funds provide avenues for financing more tangible heat adaptation measures and integration into public services. The RRF, through Greece's national recovery plan, includes funding for climate adaptation and civil protection upgrades. Athens can use RRF grants or low-interest loans to invest in things like expanding the network of automated weather stations, creating cooling centers or retrofitting public buildings (like schools and hospitals) with heat-resilient designs, and modernizing emergency response systems. These investments often have dual benefits (e.g. energy efficiency plus heat relief), making them eligible under RRF components for green infrastructure. Municipal climate funds are also cited as important: this refers to dedicated budget set-asides by the city or region for climate action. Athens has begun to mainstream climate considerations into its budgeting,

and a portion of local funds each year can be allocated to heat mitigation projects (like planting shade trees along heat-prone streets, installing reflective pavements, or funding community heat liaison personnel). The European Social Fund Plus (ESF+) is another option. Although ESF+ primarily targets social and employment projects, it can support capacity-building and public health measures related to extreme heat. For instance, ESF+ could finance training programs for healthcare workers and social workers in heatwave response or support community outreach initiatives that ensure vulnerable groups (elderly, homeless, etc.) are identified and assisted during heat events. By combining RRF (infrastructure focus), municipal funds (local ownership), and ESF+ (social capacity), Athens can tackle heat risks in a holistic manner, strengthening physical systems and human systems together.

Public-private partnerships and private sector engagement are emerging as supplementary avenues, particularly for technology deployment. Some heat resilience technologies, like sensor networks or data platforms, can involve partnerships with tech companies or utility providers. For example, telecom companies might partner with the city to send heat alert SMS messages to residents as a public service, or an energy utility might co-fund neighborhood cooling projects (such as cool roofs or water misting installations in public squares) as part of its corporate social responsibility and reduce peak electricity demand during heatwaves. These arrangements often don't require full cost recovery from the private partner, since they gain goodwill or indirect benefits, making them quasi-philanthropic in nature. Additionally, philanthropic grants and international initiatives play a role. The city of Athens has been a pioneer in joining global networks for heat resilience (it was among the first to appoint a Chief Heat Officer, supported by a collaboration with the Adrienne Arsht-Rockefeller Resilience Center). Through these and similar partnerships, Athens has access to technical assistance and modest grants to kick-start projects (for example, Arsht-Rock's Extreme Heat Resilience Alliance has provided expertise and some funding for heat health alert systems and public awareness). While these contributions might be smaller than EU or national funds, they are significant for innovative pilots and policy experiments, such as testing a new heatwave ranking system or designing a cooling-refuge map for the city. Moreover, Athens' involvement in the EU Mission on Adaptation to Climate Change (a Europe-wide initiative to support regions in becoming climate resilient by 2030) could unlock further funding and guidance. By being a Mission participant, the city can apply for special Mission grant calls to implement demonstrator projects for heat adaptation and receive consulting support to develop its comprehensive heat resilience plan.

Implementing these financial instruments effectively will require meeting certain conditions and aligning incentives. A key barrier identified was institutional fragmentation and data gaps. To counter this, some funding (potentially from ESF+ or national sources) will be directed to improve coordination, for example, establishing an inter-departmental "Heat Resilience Task Force" within the municipality, with a small operational budget to convene agencies (health, emergency, urban planning) regularly and maintain data sharing platforms. Ensuring this coordination is a precondition for efficient use of funds: if departments work in silos, investments like new climate data platforms might go under-utilized. Capacity building is another condition: when adopting advanced tools like CityClimateX or the Kausal Platform, the city must invest in training staff to use and interpret these systems. That training can be financed as part of the project budget (often EU grants allow a portion for training and change management) or through technical support instruments. Similarly, maintenance costs for digital systems (software updates, data storage, sensor calibration) need to be budgeted for; hence Athens might create a dedicated budget line or reserve within its IT or emergency management departments to sustain these systems beyond the

initial grant. The city's climate finance strategy also emphasizes aligning heat adaptation projects with broader funding opportunities. For example, some heat mitigation measures overlap with energy efficiency (cool roofs, insulation) and can thus tap into energy funding streams (as discussed in the energy sector), a form of co-financing. Athens will package projects to meet multiple objectives, increasing their eligibility for various funds. An illustration of this is the plan to integrate green accessibility (15-minute city) principles into heat adaptation; by doing so, a project like creating a shaded, tree-lined walking route to a public cooling center might qualify for both a climate adaptation grant and a sustainable mobility grant. Packaging and co-financing in this way is a strategic condition to stretch resources and avoid each department chasing separate funds for similar goals.

From a long-term perspective, Athens is conscious that adapting to rising heat is not a one-off effort but an ongoing need. Thus, part of the financial strategy is to embed heat resilience into regular budgets and planning cycles. The city aims to incorporate heat risk criteria into its urban development and infrastructure investment plans, for instance, any new public building or renovation will include a budget for heat adaptation features (like cool materials or better ventilation), funded by the project's base budget rather than special grants. Over time, this mainstreaming means fewer standalone funding efforts are needed because heat resilience becomes a standard component (and cost) of doing business. However, until that point, external funding is catalytic. By using the current mix of Horizon Europe grants for pilots, RRF for immediate infrastructure, and local funds for quick-win measures, Athens is effectively front-loading investment to reduce future costs. A cooler, more prepared city will face fewer economic losses from heatwaves (like healthcare expenses, productivity drops, or infrastructure damage), which in turn protects the city's financial health. In fact, this argument is used to justify many of the expenditures: for example, installing early-warning systems and cool shelters now with EU-support can prevent high emergency response costs later, a classic invest-to-save rationale.

In summary, Athens' financial pathway for heat risk management is characterized by a multi-source, multi-phase approach. Early-stage and high-tech innovations lean on EU innovation grants and philanthropy; infrastructure and capacity improvements draw on EU recovery funds and local budget allocations; and everything is knit together by building institutional capacity supported by social funding. By strategically blending these instruments, the city can accelerate the deployment of monitoring technologies and heat-health platforms while also implementing on-ground adaptations like cool pavements and shade infrastructure. This comprehensive funding approach ensures that investments not only meet immediate needs (like the next summer's heatwave preparation) but also fit into long-term objectives for 2050.

Policy & Governance Recommendations

Addressing rising heat risks requires integrated planning between health, environment, and urban development departments. Developing clear protocols for climate data sharing and emergency coordination enables timely and informed responses. Mainstreaming heat resilience into urban development codes and public health policies institutionalizes adaptive practices. Community engagement and inclusive design of early-warning systems are critical for reaching vulnerable populations. Building capacity for monitoring and iterative learning will ensure Athens remains agile in the face of intensifying heatwaves.

Public authorities, especially planning and emergency response departments, should be required to use integrated digital tools for climate resilience planning. This entails collaborative digital platforms for data analysis, scenario modelling, and decision-making. Investment in staff training is essential for effective adoption. This can be funded through programmes like Horizon Europe and the Digital Europe

Programme. This directly addresses the issues flagged during the participatory process for the Athens Metropolitan Area, namely institutional fragmentation and limited availability of high-resolution urban climate data. It ensures that powerful innovations like the **Kausal Platform** (for collaboration), **CityClimateX** (for 3D microclimate simulation), and **WEO** (for satellite analytics) are embedded into routine governance, leading to more informed and effective heat adaptation strategies.

Building on the work of the **Extreme Heat Resilience Alliance**, the Municipality, in coordination with the Ministry of Health and the Ministry of Climate Crisis and Civil Protection, should co-develop and legislate a tiered heatwave warning and response system. This protocol should define clear roles, responsibilities, and pre-defined actions for each alert level, ensuring a coordinated response from all relevant agencies. This creates a clear, predictable, and accountable system for crisis management. It moves beyond ad-hoc responses and institutionalises preparedness, ensuring that actions to protect vulnerable populations are swift and systematic.

Health and Social Awareness

Awareness and social innovation in CS1 centres around inclusive risk communication, education, and local knowledge systems that help residents prepare for and adapt to climate-induced health risks. Given the diversity and density of Metropolitan Athens, effective outreach must address varying needs across neighborhoods, age groups, and socioeconomic backgrounds. These interventions focus on access, trust, and intergenerational outreach, leveraging both digital and community-based platforms to ensure that climate information is understandable, actionable, and equitably distributed throughout the city.

Sectoral Goals

The primary goals for awareness and social innovation in Metropolitan Athens are to raise public awareness of climate-induced health risks, particularly those related to extreme heat, foster behavioral change and public preparedness through accessible and clear communication, and promote inclusive participation in climate resilience efforts across all demographic groups. These objectives are designed to ensure that climate adaptation is socially embedded, that no community is left behind, and that individuals have both the knowledge and motivation to take protective action.

Implementation Timeline & Milestones

In the next five years (by 2030), Metropolitan Athens will focus on building practical systems for early warnings and public outreach, while also bringing climate literacy into schools and everyday municipal communications. As these efforts develop, the city plans, over the following two decades (2040–2050), to connect awareness systems with predictive analytics and healthcare services, and to broaden the reach of participatory planning platforms. This timeline matches the city's commitment to making risk communication, education, and engagement a lasting part of its climate response.

Innovations in Focus

Innovations in awareness and social engagement for Metropolitan Athens are built around tools and platforms that help residents get the information and support they need when they need it most. Chosen with input from local stakeholders and tested in real-world conditions, these solutions are designed for clarity, reliability, and broad accessibility, whether that's through apps, websites, helplines, or educational spaces. Together, they make risk communication, education, and preparedness a practical part of everyday city life.

- **Helpline & Early Warning Messaging System:** A centralized public service tool enabling two-way communication between authorities and residents during heatwaves and other climate-related events
- **Municipality Website Dedicated to Extreme Heat**
- **I-REACT (Improving Resilience through Cyber Technologies):** A smartphone app and sensor-based system empowering citizens to report real-time environmental hazards, receive tailored

emergency alerts (e.g., floods, heatwaves), and access situational maps for improved community resilience.

- **EXTREMA Global (Urban Heat App):** A city-customized mobile and dashboard tool providing real-time heat risk assessments, routes to cooling spaces, air quality data, and municipal planning features, all designed to help cities and residents manage extreme heat events.
- **RESpring EDUPark:** An interactive educational platform and urban outdoor space where learners can explore seasonal climate adaptation features, like shade structures, drought-resistant plantings, and rainwater harvesting systems, to foster hands-on understanding of sustainable urban design.

Barriers & Enablers

The barriers and enablers for social innovation and awareness in Metropolitan Athens are directly tied to achieving the sector's goals for risk communication and community engagement. Key enablers include strong academic and NGO involvement in outreach efforts, momentum gained from recent EU communication campaigns, and the readiness of local schools and digital platforms to support new initiatives. At the same time, barriers remain: not all residents have equal access to digital tools; institutional capacity for managing participatory programs is limited; and trust gaps persist in certain communities. Overcoming these obstacles and capitalizing on the strengths already present will be vital for effective and inclusive climate communication in Athens.

Financial Instruments

Financing social innovation and climate awareness initiatives in Athens relies on a blend of partnerships, public funding, and creative financing that mirrors the cross-cutting nature of this sector. Unlike infrastructure-heavy sectors, many interventions here are “softer” (communications, education, community engagement), but they still face financial hurdles, notably, securing continuous funding for programs that don't generate revenue and ensuring reach across diverse communities. To address this, Athens is assembling a mix of funding sources to support both the development and long-term operation of its awareness and social resilience tools.

Partnerships with NGOs and international organizations form a cornerstone of the funding strategy. Non-governmental organizations often have access to grants and donor funds for public education and risk communication. For example, Athens can collaborate with organizations like the Red Cross/Red Crescent Climate Center, local public health NGOs, or academic institutions on joint projects to run heat awareness campaigns or operate community helplines. These partners can contribute expertise and manpower, and importantly, they can bring in funding from their sponsors or dedicated EU-programs (such as EU Civil Protection or public health grants). One concrete case is the EXTREMA Global app for urban heat alerts, initially developed with EU-research funding, its rollout in Athens is facilitated by partnerships that include academic developers and city authorities. NGOs might assist by hosting workshops using the app in vulnerable neighborhoods, funded by their outreach budgets, while the city provides data and promotional channels. Such co-funding arrangements reduce the burden on the city alone and ensure the messaging is trusted (as NGOs often enjoy high credibility at the community level). Moreover, Athens has benefited from being part of EU-wide awareness campaigns (for instance, the European Climate Pact and similar initiatives) which come with communication budget support. EU communication budgets (like those from DG ECHO for civil protection awareness, or DG CLIMA for climate action campaigns) can provide grants for developing multilingual educational materials, running city-wide advertisement drives during heat season, or creating school curricula on climate health, all of which Athens can utilize to amplify its local efforts. By aligning city campaigns with EU priorities, it becomes easier to attract these

funds; for example, if the EU is promoting the “Early Warning for All” initiative, Athens can frame its early warning SMS system and helpline as a pilot for that goal, making it eligible for European support.

Impact investors and philanthropic funds focused on climate resilience and public health represent another financing avenue. Impact investors are entities (funds, foundations, or social enterprises) that invest in projects yielding social and environmental benefits alongside a modest financial return. In the context of Athens’ social innovations, this could involve social impact bonds or outcome-based financing for resilience. For instance, consider a “Climate Awareness Social Impact Bond”: private investors provide upfront capital to implement a comprehensive heat-health outreach program (including the helpline, door-to-door checks on the elderly during heatwaves, and school education modules). If the program achieves agreed metrics, say, a certain percentage increase in households signed up for heat alerts, or a reduction in heat-related illnesses as recorded by hospitals, then the investors receive a successful payment from public authorities or a foundation. This model, while novel, has been used in other social domains (like reducing homelessness or improving public health outcomes) and could be applied to climate risk communication. It essentially transfers the upfront cost and some risk to private actors, who are paid only upon delivering results, ensuring public money is well spent. Athens could seek out collaborations with European impact investment funds or development banks interested in urban resilience. Additionally, philanthropic grants (from entities like the Rockefeller Foundation, which is already engaged via Arsht-Rock, or the Bloomberg Philanthropies, etc.) can directly fund certain pilots, for example, a grant to develop a state-of-the-art climate-risk exhibit in a public space or to produce an innovative media campaign on heat preparedness. These grants usually don’t require repayment and are motivated by the desire to create model solutions that can be replicated elsewhere, which matches well with ARSINOE’s ethos of developing transferable innovation packages.

At the community and grassroots level, Athens is also utilizing crowd-sourced micro-grants and school-based funding channels to support hyper-local initiatives. Crowdsourced micro-grants refer to small grants that may be funded by pooling many small contributions, often facilitated by online platforms or community fundraising drives. For example, a neighborhood group might propose setting up a “community cooling center” in a local air-conditioned cafe or communal hall for use during heatwaves. Through a municipal platform (or in partnership with a civic crowdfunding site), residents could donate small amounts, and the total pooled, possibly matched by the city or a sponsor, becomes a micro-grant to that group to stock the cooling center with water, fans, first-aid kits, and run an awareness event. Similarly, micro-grants could fund a school’s climate education garden, where students learn about heat impacts by measuring temperatures in sun vs. shade after planting trees, a small budget for tools and seedlings that might be raised via parent-teacher associations and matched by an environmental NGO. Athens is encouraging the formation of these grassroots projects by simplifying application processes and providing visibility, for instance, an online portal listing current community resilience projects seeking support, which citizens can contribute to (financially or as volunteers). Meanwhile, school-based outreach programs offer funding opportunities through educational budgets and EU-programs like Erasmus+. Incorporating climate and health awareness into school curricula can attract Erasmus+ grants (which support educational exchanges and innovative teaching). Athens could partner its schools with others in Europe on a climate education project, bringing modest funding and intercultural learning. The Ministry of Education in Greece also supports pilot programs. If Athens develops a successful climate-health education module in some local schools, it might receive national funds to expand it regionally.

Furthermore, engaging schools unlock indirect resources: teachers and students become ambassadors of awareness in their families, multiplying the impact without additional funding. Some of the ARSINOE Living Lab engagements include youth, which provides a ready pipeline of enthusiastic participants for such programs.

To ensure long-term sustainability of these social innovation efforts, Athens can mainstream successful initiatives into municipal services. This means that after initial external funding helps launch tools like the heatwave helpline or the dedicated extreme heat section on the city's website, the city will allocate municipal budget to keep them running permanently. For example, if the helpline proves effective during a couple of summers with NGO or EU-support, Athens can then include funding for staffing and telecom costs for it in its annual public health budget. By institutionalizing these measures, the city avoids the common pitfall of pilot projects fading away when grant funding ends. One condition for adopting these into core services is demonstrating their effectiveness and demand. Hence, monitoring and evaluation are built into each project: usage statistics for the app, call volumes and response outcomes for the helpline, number of people attending workshops, etc. Measurable success will justify the city council's decision to dedicate funds to them ongoing. Additionally, policy alignment needs to be considered: looking into national and EU policies (like the EU Adaptation Strategy's emphasis on public awareness and the Sendai Framework for Disaster Risk Reduction's call for inclusive risk communication) to reinforce that funding such measures is not just optional charity, but a strategic necessity. This helps unlock or retain funding. For instance, if Greece's national climate adaptation plan mandates public awareness campaigns, then Athens can receive national funds or at least political backing to run them regularly.

In conclusion, the financial support for the Awareness/Social (Health) sector in Athens is characterized by blended, layered funding aimed at maximum reach and resilience. By drawing on EU and national grants, city-NGO collaborations, innovative impact finance, community crowdfunding, and incorporation into city budgets, Athens ensures that its critical risk communication and social engagement innovations are not only piloted but sustained and scaled. This flexible funding approach mirrors the innovation strategy's people-centered focus: just as the solutions involve the whole community (from mobile apps to school programs), the financing likewise comes from a broad community of contributors (from EU institutions down to neighborhood citizens). Such diversity in funding sources makes the overall effort more resilient to any single source drying up and embeds the notion that building climate awareness is a shared responsibility.

Policy & Governance Recommendations

Effective climate risk communication and community engagement hinge on interdepartmental coordination—particularly across education, health, and communications. Policies that promote open data, digital communication tools, and cross-sectoral collaboration enhance the reach and relevance of awareness campaigns. Partnerships with NGOs, academic institutions, and local schools offer trusted networks and technical input. Institutional investments in participatory program design and ongoing evaluation are necessary to build trust and ensure that all communities are informed and prepared.

To underscore the importance of the interventions in this sector, the authorities should integrate climate resilience and health into formal education curricula. In partnership with the Ministry of Education to develop and mainstream a curriculum module on climate change, extreme heat, and health resilience for primary and secondary schools. This should leverage educational tools like the **RESpring EDUPark** and be supported by programmes like Erasmus+. This would address the need for long-term behavioural change by embedding climate literacy in the education system. It builds on the success of the ARSINOE **T4T**

seminars and **Youth Assemblies** and addresses the barrier of "shifting priorities in education policies" by creating a formal, mandated programme.

A bold initiative would be to develop a unified and accessible public communication platform for climate risks. This would act as a vehicle to consolidate all official information, alerts, and resources related to climate hazards (heat, floods, etc.) into a single, multilingual municipal website and mobile application. This platform should integrate features from innovations like **I-REACT** and **EXTREMA Global** to provide real-time, personalised risk information and guidance. The platform should be co-managed by a cross-departmental team including Health, Civil Protection, and Communications. Such an intervention would directly aim at ameliorating fragmented communication and potential public mistrust. A unified platform ensures that citizens receive clear, consistent, and actionable information from a trusted source, which is critical for effective public preparedness and response.

4.0 CS2 Mediterranean Ports – Innovation Package

4.1 Overview of the Case Study

The Mediterranean Ports Case Study (CS2) focuses on three strategic ports: Piraeus in Greece, Limassol in Cyprus, and Valencia in Spain. These ports are major gateways for global trade and crucial nodes for regional connectivity, while also being highly exposed to climate change impacts including sea-level rise, storm surges, extreme winds, heatwaves, and heavy rainfall. Such hazards threaten the continuity of port operations, the safety of workers and communities, and the resilience of supply chains.

In parallel, ports are under increasing regulatory and market pressure to comply with the European Green Deal, Fit-for-55, and IMO decarbonisation strategies, which demand significant cuts in greenhouse gas emissions, adoption of cleaner energy systems, and integration with sustainable port-city development. This dual challenge requires innovations that both climate-proof critical port infrastructure and support decarbonisation and air quality improvements.

The ARSINOE Living Lab process in CS2 engaged stakeholders across port authorities, municipalities, national agencies, private operators, and local communities. Together, they identified key risks and designed innovation pathways supported by the Systems Innovation Approach (SIA), the Climate Innovation Window (CIW), and the Open Tenders for Innovations (OTIs). Three OTIs were prioritised for demonstration: EmbioAirBELD in Limassol, pollutant detection and control; the CLEVER Tool in Valencia, a climate event registry for decision support; and DIORAMA LET-Ports in Piraeus, satellite-based monitoring of GHGs and pollution.

The innovation packages are structured into four intervention sectors, each defined by a sectoral goal, innovation portfolio, timeline and milestones, barriers and enablers, and financing instruments: Port Operations and Infrastructure, Air Pollution and Emissions, Energy, and Decision-Support Tools. Together, these innovation pathways provide a roadmap for Mediterranean ports to become resilient, low-emission, and climate-adaptive infrastructures, supporting both regional trade resilience and global sustainability transitions.

4.2 Sectors

Port Operations / Logistics / Infrastructure

Sectoral Goals

The overarching goal in this sector is to ensure safe, resilient, and efficient port operations despite the increasing frequency of extreme weather events. Ports must reduce flood risks, minimise downtime, and embed climate-proofing standards into their infrastructure design and logistics planning. This involves upgrading port surfaces, drainage systems, and decision-support capacities, ensuring that the physical

backbone of operations can withstand the stress of climate change while supporting long-term sustainable growth.

Implementation Timeline & Milestones

In the short term up to 2030, ports will focus on piloting permeable pavements in high-risk areas, implementing the Road4Water approach to harvest and redirect runoff, and deploying early-warning systems that provide timely alerts for surges, winds, and heatwaves. The SACIP-Valencia forecasting system and the ALONGROUTE routing optimisation tool will be integrated into daily operations, while ports adopt standard operating procedures for weather-related disruptions. In the medium to long term, extending to 2050, these pilots will be scaled across all terminals. Resilient surfaces and drainage systems will become mainstreamed, and digital decision-support systems will be institutionalised in every major Mediterranean port. Climate-proofing standards will also be embedded into port masterplans and concession agreements, ensuring that future infrastructure follows resilience-based design principles.

Innovations in Focus

The innovations include Road4Water for runoff harvesting, permeable pavements for drainage control, early-warning systems and decision-support platforms for operational continuity, SACIP-Valencia for fine-grained meteorological forecasting, and ALONGROUTE for AI-assisted routing optimisation.

Barriers & Enablers

The political barrier lies in the limited prioritisation of adaptation in current investment agendas, but strong EU policy frameworks provide enabling conditions. Economically, high upfront costs and weak appraisal methods constrain adoption, though long-term cost savings and EU co-financing act as incentives. Socially, ports often face negative perceptions, yet engagement through Living Labs helps build acceptance. Technologically, integration remains a challenge due to legacy systems, but open standards offer a pathway forward. Legally, unclear permitting standards hinder climate-proof retrofits, while harmonisation across EU and national levels provides a solution. Environmentally, intensified extreme weather increases risks, but hybrid infrastructure design mitigates both flooding and pollutant runoff.

Financial Instruments

Short-term financing will rely on EU and national grants and technical assistance for pilots and feasibility studies. Medium-term financing is expected through public–private partnerships and concessional loans for infrastructure retrofits. In the long term, green port bonds linked to resilience performance and insurance-linked securities for surge and wind risks will play an essential role.

Policy & Governance Recommendations

To realise these innovations, a stronger policy framework for port adaptation must be institutionalised. This requires embedding climate resilience criteria into concession agreements, procurement procedures, and masterplans, ensuring that private operators are contractually bound to invest in resilient infrastructures. At the governance level, closer coordination between port authorities, municipalities, and national adaptation agencies is needed to align flood protection, stormwater management, and emergency planning. EU directives such as the TEN-T and CEF frameworks can serve as vehicles to mainstream climate-proofing standards, while national ministries should update permitting and design regulations to require resilient materials and integrated drainage systems. Regional governance mechanisms should further promote data sharing between ports and meteorological services, enabling early-warning systems to become operationally embedded rather than project-based pilots.

Air Pollution & Emissions

Sectoral Goals

This sector aims to monitor, reduce, and ultimately eliminate emissions from vessels, yard equipment, and port-related traffic. By 2050, the vision is to achieve near-zero emissions at berth and introduce differentiated port tariffs that reward clean technologies while penalising polluting practices.

Implementation Timeline & Milestones

From the present to 2030, ports will install EmbioAirBELD systems for localised detection, roll out Libelium and AirNode sensors for continuous monitoring, and operationalise DIORAMA LET-Ports for satellite-based detection of GHG plumes. Enforcement against non-compliant fuels will be strengthened using Marine Hound, and ports will begin publishing transparent emissions dashboards. By 2030–2050, these systems will be institutionalised through concession agreements and tariff schemes, embedding emissions-based incentives into the economic model of ports.

Innovations in Focus

The portfolio includes EmbioAirBELD for pollutant detection, AirNode and Libelium air-quality stations for real-time monitoring, DIORAMA LET-Ports for satellite-based verification, Marine Hound for enforcement against non-compliant fuels, Navisense for AIS-based emissions tracking, and Solumar for on-site filtering technologies capable of reducing emissions by over 90 percent.

Barriers & Enablers

The absence of harmonised EU-wide MRV criteria represents a legal and political barrier, while standardisation efforts provide an enabling condition. Economic costs of monitoring and abatement are significant, but emissions-based port fees can support adoption. Public mistrust and misperceptions about port emissions remain social barriers, but transparency through dashboards and community engagement are powerful enablers. Technologically, integrating diverse data sources is challenging, yet interoperable MRV protocols provide solutions. Environmental conditions such as heatwaves worsen pollution, but adaptive monitoring systems enable targeted responses.

Financial Instruments

Initial investment will come from grants and technical assistance to establish MRV networks. In the medium term, sustainability-linked bonds and loans tied to verified emission reductions will provide capital. In the longer term, differentiated port dues will recycle revenues into abatement measures, and blue finance instruments will link emissions mitigation to biodiversity and marine ecosystem benefits.

Policy & Governance Recommendations

Effective governance of port emissions requires the adoption of harmonised monitoring, reporting, and verification (MRV) frameworks at both EU and national levels. Policies should align port MRV requirements with maritime decarbonisation regulations, ensuring consistency between IMO rules, EU ETS expansion, and local port policies. Governance recommendations include integrating emissions monitoring obligations into concession agreements and port authority regulations, establishing cross-port data-sharing platforms for emissions inventories, and promoting differentiated tariff schemes through clear legal mandates. Municipal and regional authorities should embed port emissions data into air quality plans, creating accountability between ports and surrounding communities. Governance mechanisms should also foster collaboration with customs, coast guard, and maritime police to enforce compliance with fuel standards, while EU funding programmes can support the institutionalisation of emissions dashboards and transparency systems.

Energy

Sectoral Goals

The energy sector seeks to decarbonise port operations by electrifying vessels at berth, modernising yard equipment, and integrating renewable energy and storage systems. The long-term goal is to create ports that operate as climate-neutral energy hubs for both shipping and local communities.

Implementation Timeline & Milestones

By 2030, priority berths will be equipped with onshore power supply (OPS), OBREC devices will be tested for wave-energy generation, Quantum Marineworks optimisation tools will be used to improve voyage efficiency, and REELEASE pilots will explore recycling and upcycling of marine waste. By 2030–2050, OPS coverage will expand to all major terminals, hybrid coastal-energy infrastructures will become standard, and port-wide electrification and microgrids will be fully operational.

Innovations in Focus

The main innovations are OPS for clean shore-side electricity, OBREC as a dual-purpose breakwater and renewable energy generator, Quantum Marineworks as an optimisation tool for shipping efficiency, and REELEASE as a circular economy solution that creates energy and material value from waste.

Barriers & Enablers

Politically, a lack of long-term commitments slows progress, but EU CEF and TEN-T programmes provide an enabling framework. Economically and technologically, high capital expenditure and grid constraints are barriers, while EU funding and collaboration with grid operators enable progress. Legally, concession contracts rarely mandate OPS, but updated terms can accelerate electrification. Environmentally, substations face risks from extreme events, but resilient siting and construction standards mitigate vulnerabilities.

Financial Instruments

Short-term support will come from EU and national grants for feasibility and early OPS deployment. Medium-term financing will rely on PPPs and project finance structures, complemented by green and transition bonds linked to measurable CO₂ savings. Long-term stability will be supported by insurance and risk-transfer mechanisms, revenue-backed OPS tariffs, and power purchase agreements with shipping lines.

Policy & Governance Recommendations

Policy frameworks should prioritise the mandatory deployment of OPS across EU ports by embedding electrification requirements into the Alternative Fuels Infrastructure Regulation (AFIR) and port concession agreements. Governance structures should facilitate joint planning between port authorities, transmission system operators, and municipalities to integrate OPS into wider energy transition strategies. Policies should establish tariff structures that incentivise shipping companies to use OPS, complemented by subsidies for early adopters. At the governance level, ports should be encouraged to form energy clusters with surrounding urban areas, sharing renewable generation and storage capacities to create local resilience. EU-level coordination is also needed to harmonise technical standards for OPS and renewable integration, ensuring interoperability across ports.

Decision-Support Tools

Sectoral Goals

The aim is to embed data-driven, climate-smart decision-making into everyday port operations and long-term planning. Decision-support tools must provide risk analytics, operational forecasting, and sustainability metrics to guide investments, concessions, and resilience planning.

Implementation Timeline & Milestones

In the short term, up to 2030, ports will deploy the CLEVER Tool in Valencia for climate event logging, adopt AE4RIA metrics for ESG and SDG reporting, and implement the Metronamica Vulnerability Index for spatial risk assessment. ALONGROUTE will also be integrated into operational systems. By 2030–2050, decision-support will become fully mainstreamed, with data flows institutionalised across concessions, masterplans, insurance pricing, and stakeholder reporting.

Innovations in Focus

Key tools include CLEVER for climate event integration into workflows, AE4RIA metrics for sustainability performance measurement, Metronamica for vulnerability mapping, and ALONGROUTE as a routing optimisation tool connected to DSS frameworks.

Barriers & Enablers

Politically and legally, the absence of systematic adaptation requirements and concerns about data privacy represent barriers, while governance frameworks for secure data sharing provide enabling conditions. Economically, benefits are distributed and hard to monetise, but linking DSS outputs to avoided-loss metrics and insurance pricing creates value. Technological barriers stem from legacy system incompatibility, while open data standards offer a solution. Socially, stakeholder buy-in is needed to legitimise transparency, and the Living Lab process provides an enabling mechanism for co-design and trust-building.

Financial Instruments

Short-term financing will rely on grants and technical assistance for DSS development and training. Medium-term investments will come from PPPs to expand sensor networks and permanent decision-support services. In the long term, sustainability-linked financial instruments tied to resilience indicators such as reduced downtime or avoided losses will become a major pathway, supported by hybrid financing portfolios identified in ARSINOE's financing strategies.

Policy & Governance Recommendations

Governance frameworks must institutionalise the use of decision-support tools in concession agreements, port authority planning, and insurance pricing. Policy should mandate the integration of DSS outputs into port masterplans, ensuring that resilience and sustainability metrics are systematically considered in investment decisions. Data governance frameworks are required to regulate secure sharing of port, environmental, and shipping data, protecting privacy while enabling cross-sectoral collaboration. EU programmes should provide guidance on standardising DSS methodologies, while national ministries can embed DSS into adaptation planning. At the governance level, Living Labs should be formalised as participatory platforms for continuous stakeholder engagement, linking local priorities to EU and international port resilience frameworks.

5.0 CS3 Main River – Innovation Package

5.1 Overview of the Case Study

The Main River Basin in Germany is a complex socio-ecological system that faces multiple climate-related risks and sectoral pressures. As a densely populated and economically significant region, the basin is home to major cities, extensive agricultural land, hydropower plants, and important ecosystems. Climate change intensifies these pressures by increasing the frequency of floods and droughts, altering precipitation patterns, and degrading water quality. At the same time, competing demands for water, land, and energy create conflicts between economic growth, ecological protection, and social well-being.

The ARSINOE project identified the Main River Basin as a key case study to demonstrate how multi-sectoral integration and stakeholder-driven innovation can enhance resilience. The Living Lab process engaged a broad spectrum of actors, including municipalities, water authorities, farmers, energy companies, conservation groups, and civil society. Using the Systems Innovation Approach and tools such as the Climate Innovation Window and Open Tenders for Innovations, stakeholders co-designed innovation pathways that bridge ecological, technical, and governance solutions. The innovation packages developed are organised into four main sectors: Water Management, Agriculture, Energy, and Governance & Decision-Support Tools. Each sector is presented below through detailed analysis of goals, innovations, barriers, financing instruments, and policy and governance recommendations.

5.2 Sectors

Water Management

Sectoral Goals

The central goal of water management in the Main River Basin is to secure resilience against hydrological extremes while ensuring good ecological status in line with the EU Water Framework Directive. This involves protecting communities and infrastructure from floods, securing reliable water supplies during droughts, and reducing pollution loads to maintain ecosystem health. Achieving these goals requires a balanced approach that combines traditional grey infrastructure with nature-based solutions, alongside improved governance and monitoring.

A second goal is to embed water management within a broader resilience framework that recognises the interconnectedness of flood protection, drought mitigation, and water quality. Restoring floodplains and wetlands not only reduces flood risks but also improves groundwater recharge and filters pollutants, thereby strengthening resilience across multiple dimensions. This integrated approach shifts the focus from reactive responses to proactive, multifunctional strategies that deliver ecological and socio-economic benefits simultaneously.

Implementation Timeline & Milestones

By 2030, priority actions will include piloting early-warning systems for floods and droughts, restoring selected wetlands and riparian zones, and upgrading municipal wastewater treatment plants. These measures will demonstrate how technological and ecological innovations can complement each other in strengthening resilience. Municipalities and water utilities will also begin implementing buffer strips along agricultural areas to reduce nutrient runoff, providing early improvements in water quality.

Between 2030 and 2050, the focus will shift to scaling these measures across the basin. Large-scale floodplain restoration projects will be implemented to create multifunctional retention areas that mitigate floods, improve biodiversity, and support groundwater recharge. Adaptive infrastructure such as modular dams and smart reservoirs will be deployed, while water utilities and municipalities will institutionalise advanced wastewater treatment and ecosystem service monitoring. By mid-century, water management in the basin will be guided by integrated planning frameworks that ensure cross-sectoral coordination and long-term sustainability.

Innovations in Focus

The innovation portfolio for water management includes digital early-warning platforms that integrate meteorological and hydrological data, allowing faster and more accurate responses to floods and droughts. These platforms will be linked with civil protection protocols to ensure timely mobilisation of resources. Nature-based solutions such as wetland restoration, reforestation, and buffer strips are equally central, as they reduce runoff, filter pollutants, and improve ecological resilience.

Advanced wastewater treatment technologies also form part of the portfolio, targeting the removal of nutrients, pharmaceuticals, and microplastics. Complementing these are ecosystem service valuation

methods that provide decision-makers with tools to quantify the economic and social benefits of ecological restoration. Together, these innovations demonstrate how technical, ecological, and institutional measures can reinforce each other in achieving water resilience.

Barriers & Enablers

Political fragmentation is one of the main barriers, as responsibilities for water, land, and flood management are distributed across multiple administrative levels. This slows coordination and creates inefficiencies. However, EU directives such as the Floods Directive, Water Framework Directive, and Biodiversity Strategy provide strong enabling frameworks by requiring integrated and cross-sectoral approaches. Economically, high upfront costs of restoration and monitoring systems are a barrier, but long-term avoided damages and EU co-financing act as incentives.

Social barriers include land-use conflicts, especially where agricultural land is needed for floodplain restoration or buffer zones. Resistance can be reduced through participatory processes that ensure stakeholders are engaged in decision-making and benefit-sharing. Technologically, integrating data across monitoring systems remains challenging, but advances in digital modelling and IoT provide strong enablers. Legally, permitting procedures are often lengthy, but reforms to streamline approvals can accelerate implementation. Environmentally, climate change amplifies risks, yet also creates urgency and political momentum for transformative water management.

Financial Instruments

In the short term, EU adaptation funds, Horizon Europe projects, and national resilience grants will support pilots and demonstration projects. These resources will de-risk innovation and provide municipalities with financial support to experiment with new approaches. In the medium term, public-private partnerships will mobilise investment in large-scale retention projects, wastewater treatment upgrades, and monitoring networks. Concessional loans from the European Investment Bank will also be critical to scaling innovations.

In the long term, resilience bonds and insurance-linked securities will provide new financing pathways, linking investment returns to avoided losses. Payments for ecosystem services will compensate farmers and landowners for adopting practices that improve water quality and flood protection. Biodiversity credits and nutrient trading schemes may also emerge as innovative financing mechanisms, embedding ecosystem benefits into market systems.

Policy & Governance Recommendations

Policy reforms must prioritise the integration of flood, drought, and water quality management into a unified governance framework. National legislation should require municipalities to designate flood retention zones, while CAP subsidies should incentivise farmers to implement nutrient reduction measures and riparian buffers. River basin authorities should be empowered with stronger enforcement capacity, enabling them to align land-use planning with hydrological resilience. At EU level, greater alignment between the Floods Directive, Water Framework Directive, and Biodiversity Strategy is essential to ensure coherence and maximise co-benefits.

Governance recommendations include institutionalising stakeholder platforms that bring together farmers, municipalities, utilities, and conservation groups to co-design water management strategies. Early-warning systems should be embedded into civil protection frameworks, supported by formalised data-sharing agreements between meteorological services and river authorities. Transparency is equally critical: monitoring data should be made publicly accessible, empowering communities to hold authorities accountable. Insurance regulators should reform premium structures to reward preventive measures, incentivising uptake of ecosystem-based solutions. Collectively, these reforms will transform water management in the Main Basin from fragmented and reactive to integrated, proactive, and adaptive.

Agriculture

Sectoral Goals

The goal of the agricultural sector is to transition towards climate-resilient farming systems that reduce pressures on water resources, improve soil health, and secure food production. Agriculture is a major driver of nutrient pollution in the basin, and its high water demand exacerbates drought risks. At the same time, farming communities depend on the river system for irrigation, livestock, and livelihoods, making them vulnerable to climate variability. Sustainable agriculture is therefore central to both environmental protection and socio-economic stability.

Another important goal is to strengthen the role of agriculture in providing ecosystem services, not only food. By adopting agroecological practices, farmers can reduce erosion, increase soil fertility, and support biodiversity. Agriculture can thus shift from being a source of pressure on the basin to a contributor to resilience, creating synergies between economic productivity and ecological sustainability.

Implementation Timeline & Milestones

By 2030, the agricultural sector will pilot precision farming technologies that optimise fertiliser and pesticide use, reducing nutrient runoff. Efficient irrigation systems will be introduced to reduce water demand, while conservation tillage and cover cropping will improve soil health. Farmers will also participate in demonstration projects that showcase the benefits of agroecological practices.

Between 2030 and 2050, these practices will be scaled through CAP subsidies and regional policies that reward sustainable farming. Digital monitoring tools for soil health and nutrient management will be mainstreamed, and drought-resistant crop varieties will be widely adopted. By mid-century, agriculture in the Main Basin is expected to be largely climate-resilient, with sustainability integrated into both practices and governance.

Innovations in Focus

The innovation portfolio includes precision farming technologies such as sensors, drones, and AI-assisted platforms that optimise inputs and reduce runoff. Efficient irrigation systems, including drip irrigation and smart scheduling, will reduce water consumption while maintaining yields. Agroecological practices such as crop diversification, cover crops, and conservation tillage are also central, as they build soil resilience and reduce erosion.

Digital soil monitoring platforms will provide real-time data on soil moisture, nutrient content, and organic matter. Combined with breeding programmes for drought-resistant crops, these innovations create a farming system that is both productive and resilient under climate stress.

Barriers & Enablers

Political barriers include conflicting policy signals between agricultural subsidies and environmental regulations. While CAP reforms are moving towards sustainability, legacy frameworks still incentivise intensive practices. Economically, the costs of transitioning to sustainable systems are high for farmers, but subsidies and efficiency gains provide enabling conditions. Socially, resistance to changing traditional practices remains strong, though demonstration projects and farmer cooperatives can improve acceptance.

Technological barriers relate to access and affordability of precision farming tools, particularly for smallholders. However, rapid innovation and cost reductions are making these technologies more accessible. Legally, enforcement of environmental standards is uneven, but EU compliance requirements are pushing national governments towards stricter implementation. Environmentally, soil erosion and water scarcity present urgent challenges, making sustainability not only desirable but necessary.

Financial Instruments

Short-term financing will rely on CAP subsidies, national grants, and EU innovation funds for pilot projects. These instruments will de-risk adoption and provide financial incentives for early adopters. In the medium term, cooperative loans and blended finance schemes will enable scaling across farming communities.

In the long term, carbon and soil credits will provide additional revenue streams, compensating farmers for ecosystem services such as carbon sequestration and erosion prevention. Green credit lines from banks and sustainability-linked finance instruments will further incentivise adoption. By embedding agriculture into emerging environmental markets, long-term sustainability can be financially rewarded.

Policy & Governance Recommendations

Policy reforms should ensure full alignment between CAP subsidies and water quality goals. Conditionality mechanisms must be strengthened to link subsidies directly to sustainable practices such as nutrient management, soil conservation, and efficient irrigation. National agricultural policies should harmonise with water and biodiversity frameworks, preventing contradictions and ensuring coherence. Legal frameworks should also support cooperative models, enabling farmers to pool resources and share the benefits of sustainable practices.

Governance recommendations include institutionalising farmer participation in basin-level planning. Living Labs should evolve into permanent advisory bodies where agricultural cooperatives and conservation authorities jointly design strategies. Training programmes and extension services should be expanded to help farmers adopt precision and agroecological practices. Monitoring systems should be transparent, allowing farmers and authorities to track progress towards sustainability. These governance reforms will empower agriculture to shift from being a source of environmental pressure to a cornerstone of resilience in the Main Basin.

Energy

Sectoral Goals

The goal of the energy sector is to decarbonise production and consumption while reducing conflicts with water and land use. Hydropower, solar, and bioenergy are all significant in the basin, but poorly planned deployment can create tensions with ecosystems and agriculture. The aim is therefore to maximise renewable energy potential while safeguarding water quality, biodiversity, and land productivity.

A second goal is to improve energy efficiency and resilience by upgrading existing hydropower plants, integrating renewables into the grid, and adopting circular energy systems. The energy transition in the Main Basin must be designed not only to reduce emissions but also to strengthen the ecological and socio-economic systems on which communities depend.

Implementation Timeline & Milestones

By 2030, pilots will focus on hydropower efficiency retrofits, testing agrivoltaics on agricultural land, and circular bioenergy systems that use residues rather than dedicated crops. Municipalities will also experiment with renewable microgrids that increase resilience during extreme events.

Between 2030 and 2050, renewable energy deployment will scale significantly, guided by spatial planning frameworks that balance energy expansion with biodiversity protection. By 2050, the energy system in the Main Basin is expected to be largely climate-neutral, integrated with agriculture and water management to provide co-benefits.

Innovations in Focus

Key innovations include agrivoltaic systems that allow solar generation alongside crop production, protecting crops from weather extremes while generating electricity. Circular bioenergy systems will rely on agricultural residues, reducing waste and avoiding land competition. Hydropower retrofits will

improve efficiency while reducing ecological impacts, and renewable microgrids will strengthen resilience.

Complementing these are digital planning tools that integrate ecological, hydrological, and energy data, allowing transparent and evidence-based decision-making. These tools will help avoid land-use conflicts and ensure that renewable deployment supports resilience.

Barriers & Enablers

Political silos between energy, water, and agricultural authorities create barriers, but EU renewable energy frameworks provide enabling support. Economically, high upfront costs and uncertain returns challenge adoption, though efficiency gains and EU funding provide incentives. Social barriers include local opposition to renewable installations, but participatory planning can build trust.

Technological barriers include grid integration challenges, but advances in smart grids and storage solutions are enablers. Legally, unclear permitting slows renewable deployment, but reforms to planning and permitting processes can resolve this. Environmentally, renewable expansion can threaten ecosystems if poorly planned, but careful governance can prevent trade-offs.

Financial Instruments

Short-term subsidies and innovation grants will fund pilots. In the medium term, PPPs and concessional loans will finance larger projects, supported by EU green transition programmes.

In the long term, green bonds, renewable energy certificates, and sustainability-linked finance will support the scaling of integrated systems. Farmers and cooperatives may access credit lines for agrivoltaics, while utilities can issue bonds tied to carbon reduction and biodiversity outcomes.

Policy & Governance Recommendations

Policy frameworks must explicitly support integrated renewable energy deployment. National renewable energy targets should be aligned with biodiversity and agricultural policies, while legal reforms should clarify permitting for agrivoltaics and bioenergy. EU directives should require biodiversity safeguards in renewable deployment, ensuring ecological and social co-benefits.

Governance recommendations include creating collaborative energy–land planning platforms where utilities, farmers, and conservation authorities co-develop strategies. Digital planning tools should be institutionalised to provide transparency in decision-making. Incentives should reward multifunctional land uses, and basin-level governance should coordinate across municipalities to prevent fragmented development. By embedding renewable energy into a nexus governance framework, the Main Basin can decarbonise while enhancing resilience.

Governance & Decision-Support Tools

Sectoral Goals

The aim of this sector is to strengthen governance capacity by institutionalising decision-support tools that integrate climate risks, hydrology, land use, and energy data. These tools will provide evidence-based guidance for planning, investment, and emergency response. By embedding DSS into statutory frameworks, governance can shift from fragmented and reactive to integrated and proactive.

A second goal is to institutionalise participatory processes within governance. Decision-support must be transparent and inclusive, creating legitimacy and trust among stakeholders. This ensures that DSS is not only a technical tool but also a social process that empowers communities and aligns with broader resilience strategies.

Implementation Timeline & Milestones

By 2030, pilot DSS platforms will be deployed to integrate hydrological and climate data into planning. Stakeholder engagement platforms will also be tested to ensure inclusivity. By 2030–2050, DSS will be

institutionalised at basin scale, guiding water management, land-use decisions, and energy planning. Insurance companies and investors will also adopt DSS outputs in risk assessments.

By 2050, DSS will be a governance standard across the basin, embedded into statutory planning, financial regulation, and community decision-making. Transparency and participation will be fully institutionalised.

Innovations in Focus

Innovations include integrated modelling platforms, vulnerability assessment tools, participatory digital platforms, and sustainability metrics aligned with SDGs and ESG frameworks. These tools provide both technical accuracy and social legitimacy, ensuring evidence-based and accountable governance.

By combining technical and participatory innovations, the sector ensures that governance is guided by both robust evidence and inclusive processes.

Barriers & Enablers

Political fragmentation and overlapping mandates create governance inefficiencies, but EU directives and national reforms provide strong enabling conditions. Economically, DSS benefits are diffuse and hard to monetise, but avoided losses and efficiency gains create indirect value. Social barriers include mistrust of digital systems, but participatory design and transparency can build trust.

Technological barriers include interoperability challenges, but open data standards and digital platforms enable integration. Legally, data governance frameworks are still evolving, but mandates for integrated planning provide momentum. Environmentally, climate change creates urgency, making DSS indispensable.

Financial Instruments

Short-term funding will come from EU and national grants for DSS development and training. Technical assistance will build capacity at local level. Medium-term financing will involve PPPs between municipalities, utilities, and regional authorities.

In the long term, sustainability-linked finance tied to resilience indicators will ensure stable funding. Insurance companies and investors will increasingly rely on DSS outputs, embedding them into financial decision-making and creating long-term sustainability.

Policy & Governance Recommendations

Policy reforms must mandate the use of DSS in statutory planning and investment decisions. River basin authorities should integrate DSS outputs into water management plans, while municipalities should align land-use planning with vulnerability assessments. EU cohesion funding should be conditional on DSS integration, ensuring resilience is mainstreamed.

Governance recommendations include institutionalising Living Labs as permanent advisory councils for basin governance. Data governance frameworks must clarify responsibilities for sharing and privacy, creating trust and accountability. National and EU programmes should standardise DSS methodologies to ensure interoperability. Financial regulators should also embed DSS outputs into risk assessments for insurance and investment, reinforcing their value. By embedding DSS into governance at all levels, the Main Basin can achieve proactive, integrated, and resilient decision-making.

6.0 CS4 Prespa/Ohrid Lakes– Innovation Package

6.1 Overview of the Case Study

CS Ohrid and Prespa is located in the Western Balkans, in a cross-border region that spans three countries: North Macedonia, Greece, and Albania.

The lake region lies within Europe's most ecologically valuable aquatic ecosystems, famous for extraordinary biodiversity and also home to a UNESCO-protected cultural heritage area.

The main aim of the Ohrid and Prespa Lakes Case Study is to strengthen climate resilience across environmental, social, and economic sectors that rely on water. It concentrates on reducing the effects of declining rainfall and rising temperatures that cause water shortages. The resilience-building process unfolds across three phases: identifying risks, projecting impacts, and designing responses (adaptation), with targets in the social sector (households), economic sectors (industry, agriculture, tourism), and the energy sector (cascade hydropower plants). The importance of this focus stems from water's essential role in the survival and sustainable development of these sectors, making it crucial to address water scarcity driven by climate change.

Activities carried out in CS4, in line with the Arsinoe Resilience Framework and System Innovation Approach, were designed to lead to informed decisions for development of strategy for optimal climate adapted water resource use and management in the region, considering different climate scenarios.

Innovation pathways established with stakeholders through consequential sessions of national and transboundary Living labs, closed the identified gaps in sustainable water management and set the ground for implementation of innovative solutions that lead to an improved availability and accessibility of measured data and impact thereof on the behavioural and consumption patterns towards water as a scarce resource.

Throughout the ARSINOE project, the SIA has been applied to ensuring a sustainable and continuous collaboration with the stakeholders groups and the process of understanding and identifying the needs related to climate risks, national, international and transboundary strategies, priorities, and innovation potential. Within the SIA approach CS4 has gone through a series of National and Transboundary Living Lab (LL), workshops and follow-up engagements, aiming to build strong stakeholder engagements with the main sectors affected by climate change effects such as water, energy, tourism, biodiversity, urban development and planning, social and health sector.

The participatory process started with mapping major players and pinpointing climate-related pressures, obstacles, and systemic bottlenecks. In a series of workshops, participants jointly examined potential futures, crafted a shared 2050 vision, and outlined innovation pathways organized around milestone years (2030, 2040, 2050). These pathways aren't fixed implementation plans; they function as adaptable roadmaps for rolling out innovation portfolios, tackling cross-cutting barriers, and harmonizing sectoral objectives with long-term resilience.

Activities carried out in CS4, contributed to a development of strategy for climate adapted water management in the region, considering different climate scenarios. Innovation pathways established with stakeholders through consequential sessions of national and transboundary Living labs set the ground for implementation of innovative solutions that lead to an improved availability of measured data and impact thereof on the behavioural and consumption patterns towards water as a scarce resource.

The CS4 Innovation Package offers a locally grounded, context-specific approach to strengthening resilience. It blends stakeholder-driven priorities with technical innovations, proposing a suite of interventions that address real-world vulnerabilities while establishing a foundation for integrated, adaptive, and inclusive development.

6.2 Sectors

Water Governance & Transboundary Management

Sectoral Goals

Water shortages create major challenges by shaping how water is used and by fueling conflicts among different sector interests and policies. They affect farming, fishing, manufacturing, and household water use, driving competing demands and intricate management choices. The scarce supply also threatens biodiversity conservation and the health of delicate ecosystems and species that depend on steady water sources. Tackling water scarcity calls for balancing human needs with environmental protection to secure long-term resilience for both people and nature.

The Ohrid and Prespa Lakes Case Study implemented the Integrated Water Management Model in multi-sector coupled systems (IWaMM). This model provides an analytical planning framework supported by system-based numerical modelling and simulation tools, aimed at enhancing the climate resilience of environmental, economic, and social water-use sectors within complex systems. IWaMM helped ensure a balanced allocation of the region's water resources and bridged social and economic dimensions in addressing climate-change impacts on the transboundary Ohrid and Prespa lake ecosystem, which is shared by Greece, Albania, and North Macedonia. The CS4 in Arsinoe project seeks to enhance the climate resilience of environmental, economic, and social water-related sectors by delivering an intelligent, comprehensive, and innovative package of long-term planning solutions. It focuses on ensuring a sufficient, quality water supply for all users, while balancing and respecting their interests and development needs.

The CS4 will help ensure a balanced use of the region's water resources and connect the social and economic sectors affected by climate change within the Ohrid and Prespa transboundary watershed (approximately 3,000 km²). It addressed the following core systems: Environment (biodiversity and ecosystems), Society (citizens, households, water utilities, policymakers), Economy (agriculture, fishery, tourism, industry), and Hydropower.

Implementation Timeline & Milestones

By 2030, efforts will focus on creating transboundary governance platforms that bring together authorities from North Macedonia, Albania, and Greece. Pilot joint monitoring systems will be established, using harmonised indicators for water quality and ecosystem health. Local-level water user associations will also be strengthened to ensure community participation in governance.

Between 2030 and 2050, these structures will be institutionalised into formal transboundary governance mechanisms with legal mandates and stable financing. By mid-century, governance is expected to be harmonised across the three countries, with integrated water management plans that align with EU directives and international agreements.

Innovations in Focus

Innovations include digital monitoring platforms that provide real-time, harmonised data on water quality and availability across borders. Participatory governance tools will support stakeholder engagement in transboundary decision-making, ensuring inclusivity and legitimacy. Scenario-modelling platforms will enable joint planning by simulating climate and socio-economic impacts under different management options.

These innovations create a foundation for cooperative governance, providing the evidence, participation, and foresight necessary for joint management of the lakes.

Barriers & Enablers

Political barriers include diverging national interests and institutional fragmentation across the three countries. However, EU accession processes for North Macedonia and Albania provide strong enabling conditions by requiring alignment with EU water and environmental directives. Economically, limited

national budgets constrain transboundary cooperation, but international funding mechanisms create opportunities.

Social barriers include mistrust between communities across borders, but joint projects and participatory platforms can build trust. Technologically, data harmonisation is a challenge due to varying monitoring capacities, but digital platforms offer enabling solutions. Legally, transboundary governance agreements are weak or absent, though international conventions such as the UNECE Water Convention provide enabling frameworks.

Financial Instruments

Short-term financing will come from EU pre-accession funds, bilateral cooperation projects, and international donors such as GEF and UNEP. These resources will support pilot monitoring systems and initial governance platforms. Medium-term financing will rely on joint funds created by the three governments, supported by international financial institutions.

In the long term, sustainable financing will be achieved through transboundary water funds supported by ecosystem service payments and contributions from sectors such as tourism and hydropower. These funds will ensure long-term operation of governance institutions and monitoring systems.

Policy & Governance Recommendations

Policy reforms must prioritise the establishment of a legally binding transboundary governance mechanism for Ohrid and Prespa Lakes. National water laws should be harmonised with EU directives, particularly the Water Framework Directive, and aligned across the three countries. Shared monitoring protocols should be institutionalised, and transboundary water agreements should include enforcement mechanisms.

Governance recommendations focus on creating permanent transboundary councils with representation from governments, municipalities, civil society, and the private sector. These councils should oversee joint planning, data sharing, and conflict resolution. Participatory mechanisms should ensure that local communities have a voice in decision-making. International organisations should provide technical support and oversight to ensure compliance and build trust.

Biodiversity & Ecosystem Services

Sectoral Goals

The goal of this sector is to protect and restore the unique biodiversity of Ohrid and Prespa Lakes while safeguarding the ecosystem services that support local livelihoods. The lakes host a high number of endemic species and provide cultural, recreational, and provisioning services that are vital to surrounding communities. However, eutrophication, habitat degradation, and invasive species are threatening biodiversity.

Another goal is to embed ecosystem services into economic and governance frameworks. By recognising the economic value of biodiversity and ecological functions, policymakers can justify long-term investments in conservation. Protecting ecosystems also enhances resilience to climate change, as wetlands and forests regulate water flows, store carbon, and buffer against extreme events.

Implementation Timeline & Milestones

By 2030, conservation efforts will prioritise reducing nutrient inflows through buffer zones, upgrading wastewater treatment plants, and restoring degraded wetlands. Pilot projects on ecosystem service valuation will be initiated to integrate biodiversity into planning. Public awareness campaigns will strengthen community engagement in conservation.

Between 2030 and 2050, large-scale restoration projects will be undertaken, including reforestation, invasive species management, and re-naturalisation of river inflows. Ecosystem service valuation will be institutionalised in decision-making, guiding land-use and investment choices. By 2050, biodiversity

protection will be mainstreamed across sectors, ensuring that ecological and economic resilience reinforce each other.

Innovations in Focus

Innovations include advanced wastewater treatment systems capable of removing nutrients and pollutants. Riparian buffer zones and wetland restoration are key ecological innovations that filter pollutants and provide habitats. Digital biodiversity monitoring tools will provide real-time data on species and ecosystem health.

Ecosystem service valuation methods are equally important, providing decision-makers with evidence of the economic benefits of biodiversity. These innovations ensure that conservation is not only ecologically sound but also economically justified.

Barriers & Enablers

Political barriers include weak enforcement of environmental laws and conflicting land-use priorities. However, international frameworks such as Natura 2000 and UNESCO World Heritage status provide strong enabling conditions. Economically, conservation is often underfunded, but ecosystem service valuation can mobilise new resources.

Social barriers include limited awareness of biodiversity's value, though education and awareness campaigns can address this. Technologically, monitoring systems are underdeveloped, but digital platforms offer scalable solutions. Legally, enforcement of conservation laws is weak, but international oversight provides pressure for improvement.

Financial Instruments

Short-term financing will rely on EU LIFE programmes, UNESCO conservation funds, and national biodiversity programmes. Medium-term financing will include PPPs for eco-tourism and biodiversity credits to mobilise private capital.

In the long term, payments for ecosystem services and biodiversity offsets will provide sustainable financing. Tourism taxes and hydropower contributions could also feed into biodiversity funds. By embedding ecosystem services into financial systems, conservation will be secured over the long term.

Policy & Governance Recommendations

Policy reforms should integrate ecosystem service valuation into statutory planning and investment frameworks. CAP subsidies should incentivise practices that protect biodiversity, and national biodiversity strategies should be aligned across the three countries. Legal frameworks must strengthen enforcement of protected areas and ensure compliance with international obligations.

Governance recommendations include creating joint biodiversity councils across the three countries to coordinate conservation. Participatory mechanisms should involve local communities in restoration and monitoring projects. Transparent monitoring systems should make biodiversity data publicly accessible, creating accountability and trust. By embedding biodiversity into governance, the lakes' ecological uniqueness can be preserved for future generations.

Agriculture & Food Systems

Sectoral Goals

The goal of this sector is to transition to sustainable agriculture that reduces nutrient inflows into the lakes while ensuring food security and rural livelihoods. Intensive farming practices around the lakes contribute to eutrophication, threatening water quality and biodiversity. Climate change further exacerbates risks by increasing droughts and reducing water availability. Sustainable agriculture is therefore critical for ecological and socio-economic resilience.

A second goal is to diversify rural economies through sustainable food systems that integrate value-added products, eco-labelling, and agro-tourism. By creating alternative income streams, farming communities can reduce dependence on intensive practices and contribute to conservation.

Implementation Timeline & Milestones

By 2030, pilot projects will introduce precision fertilisation, efficient irrigation, and organic farming practices. Farmers will be supported through training programmes and subsidies for sustainable practices. Demonstration farms will showcase the benefits of agroecology.

Between 2030 and 2050, sustainable farming practices will be mainstreamed, supported by CAP subsidies and regional policies. Eco-labels and value chains for sustainable products will be established, while agro-tourism will expand as a complementary income source. By 2050, agriculture around the lakes will be largely sustainable and integrated with conservation goals.

Innovations in Focus

Key innovations include precision farming technologies, efficient irrigation systems, and agroecological practices such as crop rotation, cover cropping, and organic fertilisation. Agro-tourism and eco-labelling are social and market innovations that diversify rural incomes.

Digital platforms for soil and nutrient monitoring will support decision-making, ensuring efficient and sustainable farming. Together, these innovations reduce ecological pressures while maintaining economic viability.

Barriers & Enablers

Political barriers include inconsistent agricultural policies across the three countries, but EU alignment provides enabling conditions. Economically, transition costs are high for farmers, but subsidies and market incentives such as eco-labels provide support. Socially, resistance to change remains a challenge, but demonstration projects and cooperative models can build acceptance.

Technologically, access to precision farming tools is limited, but costs are falling. Legally, enforcement of agricultural regulations is weak, but EU accession processes create pressure for compliance. Environmentally, soil degradation and water scarcity create urgency, making sustainability indispensable.

Financial Instruments

Short-term financing will come from CAP subsidies, national agricultural funds, and international donors. Medium-term financing will include cooperative loans and blended finance for scaling sustainable practices.

In the long term, carbon and soil credits will provide new revenue streams, while eco-tourism and sustainable value chains will create diversified income. Payments for ecosystem services may also compensate farmers for conservation practices.

Policy & Governance Recommendations

Policy reforms should align agricultural subsidies with water quality and biodiversity goals. CAP conditionality mechanisms must link subsidies directly to sustainable practices. National agricultural policies across the three countries should be harmonised to prevent inconsistencies.

Governance recommendations include institutionalising farmer cooperatives in basin-level planning. Participatory platforms should empower farmers to co-design solutions, supported by training and extension services. Monitoring systems must be transparent, allowing progress to be tracked and creating accountability. By embedding sustainability into agricultural governance, the lakes' ecosystems and communities can thrive together.

Clean Energy & Hydropower

Sectoral Goals

The goal of this sector is to balance hydropower generation with ecological and social sustainability. Hydropower is a major source of renewable energy in the region, but poorly managed dams disrupt ecosystems, alter water flows, and threaten fish populations. Aligning energy production with ecological resilience is essential to achieving a just transition.

Another goal is to diversify energy systems by integrating solar, wind, and small-scale renewables. Reducing reliance on large dams decreases ecological impacts while enhancing energy security and resilience to climate variability.

Implementation Timeline & Milestones

By 2030, pilot projects will focus on retrofitting hydropower plants with fish passages and ecological flow management. Solar and wind projects will be initiated in suitable areas, supported by community energy cooperatives.

Between 2030 and 2050, hydropower operations will be fully aligned with ecological requirements, supported by digital monitoring systems. Renewable diversification will be scaled, reducing reliance on large dams. By mid-century, the region will have a balanced, climate-neutral energy system.

Innovations in Focus

Key innovations include fish passages, ecological flow management systems, and digital monitoring of hydropower impacts. Solar and wind projects integrated into rural areas provide diversification. Community energy cooperatives represent social innovations that empower local stakeholders.

These innovations ensure that renewable energy contributes to sustainability rather than undermining ecosystems. By combining ecological retrofits with diversification, the region can achieve a just transition.

Barriers & Enablers

Political barriers include strong reliance on hydropower revenues, which may discourage diversification. However, EU decarbonisation targets and just transition funding provide enabling conditions. Economically, retrofits and diversification require significant investment, but long-term resilience and cost savings create incentives.

Socially, communities dependent on hydropower may resist changes, but cooperative models and participatory planning can build support. Technologically, retrofitting hydropower is complex, but innovations are advancing. Legally, ecological flow requirements are often weakly enforced, but EU frameworks provide pressure for compliance.

Financial Instruments

Short-term financing will come from EU decarbonisation and just transition funds, supporting pilots and retrofits. Medium-term financing will include PPPs for renewable diversification and concessional loans for hydropower upgrades.

In the long term, green bonds and renewable energy certificates will support large-scale investments. Community cooperatives may access credit lines for small-scale renewables. Sustainability-linked finance instruments will tie investments to ecological performance.

Policy & Governance Recommendations

Policy reforms must require ecological flows and fish passages in hydropower operations. National energy policies should prioritise diversification and support community renewables. Legal frameworks should align hydropower operations with EU environmental standards.

Governance recommendations include creating basin-level councils where energy companies, conservation groups, and communities jointly plan operations. Participatory monitoring should be institutionalised to ensure transparency and trust. Community energy cooperatives should be supported through policy and financial incentives. By embedding ecological sustainability into energy governance, the region can achieve a just and resilient transition.

7.0 CS5 Canary Islands– Innovation Package

7.1 Overview of the Case Study

The ARSINOE Case Study 5 focuses on the Canary Islands, a Spanish archipelago located in the Atlantic Ocean, off the northwestern coast of Africa. Despite its image as a tourist haven, the region faces acute systemic risks tied to water scarcity, energy dependency, waste management, biodiversity loss, and climate-induced hazards such as drought and wildfire. These risks are magnified by insularity, limited resource self-sufficiency, and the increasing pressure of urbanization and mass tourism.

The islands' fragile ecosystems and socio-economic structures are particularly sensitive to climate change, requiring adaptive and systemic approaches that go beyond isolated interventions. With its diverse topography, dispersed population, and sectoral interdependence, the region serves as a representative testbed for developing cross-sectoral innovations in climate resilience.

Stakeholders from regional and local governments, academia, civil society, and the private sector have emphasized the need for an integrated vision that enhances environmental protection while also safeguarding economic viability and social equity. A major bottleneck is the fragmented governance structure and the perceived lack of coherence across sustainability plans, which often remain disconnected from operational capacities and long-term investments.

Under the ARSINOE project, the SIA has been applied to foster a collaborative process that integrates climate risks, regional development priorities, and innovation potential. The co-creation process was structured through a series of Living Lab (LL) workshops and follow-up engagements, aiming to build consensus among diverse stakeholders across sectors such as water, energy, waste, tourism, biodiversity, and urban resilience.

The participatory journey began by mapping key actors and identifying climate-related pressures, challenges, and systemic bottlenecks. Through workshops, stakeholders collectively explored possible futures, developed a common vision for 2050, and articulated innovation pathways structured around milestone years (2030, 2040, 2050). These pathways are not static implementation plans but serve as dynamic roadmaps for deploying innovation portfolios, addressing cross-cutting barriers, and aligning sectoral goals with long-term resilience.

Central to this process was the recognition that interlinked sectors—such as water and energy, or waste and tourism—require coordinated innovation packages. Innovations were selected from the Climate Innovation Window and through stakeholder input, with attention to feasibility, systemic impact, and alignment with regional strategies and funding opportunities.

The CS5 Innovation Package thus represents a contextualized, locally grounded approach to resilience-building. It synthesizes stakeholder-driven priorities with technical innovations, proposing a portfolio of interventions that respond to real-world vulnerabilities while laying the foundation for integrated, adaptive, and inclusive development.

7.2 Sectors

Water

Water availability and management represent one of the most pressing resilience challenges across the Canary Islands. The region's unique geographic and climatic conditions—marked by low rainfall, high evapotranspiration, and growing urban and agricultural demand—have placed increasing strain on existing water systems. Overreliance on energy-intensive desalination, outdated irrigation infrastructure, and fragmented water governance further compound the problem. As climate change intensifies, ensuring equitable and efficient access to water has become a strategic priority for regional sustainability and socio-economic cohesion.

Sectoral Goals

The main goals of the water sector in CS5 are increasing resilience, efficiency, and sustainability in the face of mounting climatic and resource pressures. The innovation package aims to increase water reuse and efficiency across both urban and agricultural settings, reduce dependence on conventional freshwater sources, and promote nature-based and circular solutions tailored to local ecological contexts. At the same time, early detection and management of drought risk are prioritised through improved monitoring systems and digital tools. Finally, stronger integration between water, energy, and food systems is seen as essential to reduce systemic vulnerabilities and ensure the long-term viability of water resources in the archipelago.

Implementation Timeline & Milestones

By 2030, initial actions focus on piloting decentralized greywater reuse systems, small-scale desalination, and circular irrigation technologies to address immediate vulnerabilities and build institutional capacity. From 2030 to 2040, the aim is to scale up these innovations while operationalising monitoring tools for drought risk, improving irrigation efficiency, and expanding water reuse across sectors. For the following 20 years (2040–2050), the focus shifts to mainstreaming nature-based and circular solutions, supported by integrated governance and long-term planning for regional water resilience.

Innovations in Focus

The selected innovations in the water sector reflect efforts to enhance resilience through low-impact technologies and decentralised systems. Emphasis is placed on improving water quality, supporting circular resource use, and addressing infrastructure challenges linked to water loss and treatment. Each innovation complements broader goals of sustainable water management adapted to local needs.

- **NBS for domestic wastewater treatment (DEPURANAT – Teno):** An experimental pilot in the Parque Rural de Teno uses decentralized nature-based systems to treat domestic wastewater through constructed wetlands and planted substrates. Designed for low maintenance and energy use, the system supports local water reuse for agricultural and irrigation purposes.
- **Utilization of brine for resource generation, ceasing to be a waste product:** This innovation focuses on the sustainable management of brine produced by seawater reverse osmosis (SWRO) desalination systems. By characterising the chemical composition and exploring industrial reuse options, it supports circular economy goals while reducing the environmental impact of desalination in the Canary Islands.
- **Swarm Robotics Systems (MATRIX) for Pipeline Inspection:** An autonomous swarm-robotic system designed to inspect water and wastewater pipelines using multiple small robots. These robots work together to detect leaks and structural issues, improving maintenance efficiency and reducing water loss within narrow or hard-to-access pipe networks.

Barriers & Enablers

Water governance in the Canary Islands presents a complex interplay of challenges and opportunities, shaped by the archipelago's geographic isolation, increasing climate pressures, and institutional context.

A central barrier lies in the fragmentation of responsibilities across regional, local, and sectoral authorities, which hinders the development of integrated water strategies. This issue is compounded by limited coordination mechanisms and gaps in data sharing, affecting both short-term interventions and long-term resilience planning.

Economic constraints remain significant, especially in terms of sustaining large-scale hydraulic infrastructure and upgrading outdated water systems. Many municipalities face budgetary limitations, and investment is often dependent on national or European funding instruments. The high energy intensity of desalination processes, which are vital in the region, also places strain on local resources and calls for more energy-efficient innovations in water production and reuse.

From a social perspective, low public awareness regarding water stress and its link to climate change continues to pose a barrier to behavioural shifts and stakeholder mobilisation. At the same time, water-related policies are not always well-aligned with local capacities for implementation, particularly in smaller or rural communities across the islands.

Despite these challenges, a number of key enablers support systemic innovation in the sector. The existence of regional water plans and alignment with the EU Water Framework Directive provide a strong regulatory foundation. Moreover, increasing awareness of the islands' ecological vulnerability is fostering greater political will and citizen interest in water-related climate adaptation.

Technological innovations, such as modular desalination, and nature-based solutions for water retention, offer promising entry points for accelerating impact. Additionally, the availability of pilot projects through ARSINOE and other EU-funded programmes enhances institutional learning and creates space for replicability and scale-up.

Financial Instruments

Financing water-sector innovations in the Canary Islands is challenging due to high upfront costs and limited local budgets. Many critical water projects (like desalination plants or water reuse systems) require substantial investments that small municipalities cannot cover alone. Funding often depends on external sources, which can be competitive and subject to shifting policies. There is also fragmentation in local governance and limited experience with blended finance (mixing public and private funds), making it hard to fully utilize available funding. Key financial instruments and opportunities for the water sector include:

- **European Regional Development Fund (ERDF):** Provides EU structural funds for improving water infrastructure and efficiency projects. ERDF grants have been used to upgrade outdated water systems and support new technologies for water savings and reuse.
- **LIFE Programme:** An EU funding program supporting environmental and climate action projects. In the Canary Islands, LIFE funds can back nature-based solutions (like ecosystem restoration for water retention) and pilot projects in integrated water management.
- **Recovery and Resilience Facility (RRF):** Part of the EU's post-COVID recovery plan, the RRF offers significant funding for green and resilient investments. It has been tapped to boost financing for critical water and climate adaptation projects in the islands (e.g. modernizing desalination with renewable energy).
- **Green Bonds and Climate Adaptation Bonds:** Local authorities are exploring these bond instruments to raise capital for large-scale water infrastructure. By issuing green bonds, the Canary Islands can attract investors to finance projects like new desalination plants or expanded water reuse facilities, with the bond proceeds dedicated to sustainability goals.

- PPP's and dedicated funds: To scale up innovations such as smart water metering and efficient irrigation systems, municipalities consider PPPs. These partnerships leverage private investment alongside public funds for projects that have revenue potential or community benefits. Dedicated local investment funds can also be created to pool resources for small-scale water initiatives (for example, community rainwater harvesting or greywater recycling programs).
- Research and innovation programs: Programs like Horizon Europe and the Innovation Fund provide grants for research, feasibility studies, and demonstration projects. These instruments support multi-stakeholder collaborations in the water sector, allowing testing of new technologies (such as modular desalination units or advanced drought monitoring tools) before scaling up.

Together, these financial instruments aim to bridge the gap between short-term funding cycles and long-term infrastructure needs. Streamlining access to EU funds, improving coordination among authorities, and providing technical assistance in grant applications are all measures suggested to maximize the impact of these financial tools on water resilience.

Policy and Governance Recommendations

The overarching governance challenge for the Canary Islands is the need for a quantitative, qualitative, open, participatory, and intersectional database that includes environmental, agronomic, economic, and social aspects to facilitate cross-cutting governance. This is aimed at adapting the primary as well as the tourism sector to climate change and fostering its ecological transformation and sustainability. The future vision is for the Canary Islands to be a territory adapted to climate change with a completed ecological transition, guaranteed food security, and a fair, green, ethical, and accessible government.

An overarching however ambitious action, would be for the regional government to create an innovation-friendly regulatory sandbox allowing temporary derogations from rigid rules for pilots in areas such as robotic inspection, recycled materials, and data-driven agriculture. This should be coupled with capacity-building initiatives in vocational schools and universities, dedicated innovation funding facilities (pooling EU, regional, and private sources), and impact monitoring frameworks tracking water savings, waste reductions, soil health improvements, and rural job creation. These overarching measures will provide the enabling environment for the individual innovation packages to thrive and scale sustainably.

The water sector faces challenges from rising temperatures, the need for sustainable supply, and aging infrastructure. Public authorities, specifically the Cabildos and Island Water Councils, should prioritise investment in modernising public water networks to address significant leakage rates, which can be as high as 30-40%. The reshaping of the legal framework should abide by the principles of water circularity, integrating regulations that actively promote and simplify the use of treated wastewater and the commercialisation of brine from desalination plants, transforming them from waste products into resources. This addresses the barrier of "illegal discharges of brine" and restrictions on wastewater use. In addition, classifying brine-derived minerals as "resources" (not waste) under environmental law if quality standards are met can contribute to the development of circular solutions in the regional economy. A more ambitious approach could include the revision of the regional legal framework to create a market for brine and establish clear quality standards for reused water in agriculture, thus facilitating the inclusion innovations in NbS for wastewater treatment.

To pave the way for the development of the necessary desalination plans, the authorities should consider introducing policies that provide incentives, such as tax breaks or subsidies, for private and public water

operators to invest in renewable energy sources like solar or wind to power desalination and pumping, a key part of the region's energy transition. Moreover, the regional authorities could introduce licence conditions for desalination plants requiring resource recovery plans and create a regional registry and traceability system for brine reuse.

A publicly accessible platform with high-resolution climate data and projections is material in promoting transformational adaptation in the Canary islands. This can be addressed by officially integrating the SICMA CANARIAS tool into the decision-making processes of the Island Water Councils. Furthermore, data on water extraction, aquifer levels, and water quality should be made public to overcome the current lack of up-to-date, reliable data and increase transparency, a key concern raised by stakeholders.

Agri-Food

The Agri-Food sector in the Canary Islands combines elements from both the primary sector—focusing on food production and consumption—and agriculture, reflecting the interdependent nature of these domains in the region. For the purposes of this Innovation Package, we have merged these two sectors to address their shared challenges and interconnected opportunities under a unified framework. This integrated approach allows for a more coherent analysis of innovation needs, barriers, and enabling conditions, particularly in the context of sustainable food systems, land use, and climate resilience. Given the geographical and climatic particularities of the Canary Islands, including water scarcity and fragmented agricultural plots, addressing agri-food innovation is central to ensuring long-term food security, ecosystem health, and economic viability.

Sectoral Goals

The overall goal for the Agri-Food sector in the Canary Islands is to transition towards a more sustainable, resilient, and integrated food production and consumption system. This includes enhancing agricultural productivity while maintaining environmental integrity, reducing dependency on food imports, and promoting circular practices such as waste valorisation and resource efficiency. A key objective is to develop and apply nature-based and digital solutions that can optimize local production, ensure food safety, and preserve biodiversity. Further goals involve strengthening regional food value chains, encouraging stakeholder collaboration, and increasing awareness and participation among consumers to support more sustainable dietary habits and local economies.

Implementation Timeline & Milestones

By 2030, the focus is on promoting precision agriculture, improving the sustainability of food production, and supporting local supply chains. Key actions include piloting circular approaches for organic waste, raising awareness among producers and consumers, and encouraging climate-smart agricultural practices tailored to the island's conditions. Between 2030 and 2040, these initiatives are scaled up. More producers adopt sustainable farming techniques, digital tools are expanded, and new partnerships are formed to support soil regeneration, biodiversity protection, and climate adaptation in crop planning. For the period 2040 to 2050, the goal is to establish an integrated agri-food system that combines local production with circularity, equity, and resilience. Innovations are embedded into policy frameworks and linked to broader food and climate strategies for the Canary Islands.

Innovations in Focus

Innovation pathways in the agri-food sector aim to strengthen the sustainability of production systems while promoting rural regeneration and circular resource flows. The highlighted solutions prioritise farmer empowerment, data-driven decision-making, and the valorisation of agricultural by-products, contributing to more resilient food systems and community-based innovation.

- **Smart Field Notebook:** A tool enabling farmers to maximize the utility of generated information and facilitate its transmission to public administrations through telematic methods

- **Greenhouse Plastics for 3D Printing of Agri-Equipment:** This innovation explores the recovery and transformation of agricultural plastic waste, particularly from greenhouses, into eco-composite materials suitable for 3D printing. By combining recycled plastic with cellulose fibres and additives, the resulting material offers improved mechanical properties for producing agricultural tools and components, contributing to circular economy practices in the agri-food sector.
- **AgTech (smart agriculture technologies):** These technologies encompass tools such as sensors, AI, IoT, blockchain and remote data systems used in agriculture to improve productivity, resource efficiency, and environmental sustainability. AgTech enables farmers to make more informed decisions about irrigation, pest management, forecasting, and supply chain management while also helping reduce waste and environmental impact.
- **Apadrina un Olivo (Adopt an Olive Tree):** A social innovation that reconnects individuals with rural heritage by enabling them to sponsor abandoned olive trees, supporting ecological restoration, sustainable olive oil production, and local job creation in depopulated areas.
- **On-Farm Experimentation (OFE):** Promotes collaborative research directly on farms, empowering farmers and scientists to co-develop practical innovations tailored to local agricultural conditions.

Barriers & Enablers

The agri-food sector in the Canary Islands combines primary production and local food systems, both essential for regional sustainability but shaped by persistent limitations. Fragmented farming landscapes, limited water availability, and a high reliance on imports make food production particularly vulnerable. Many producers face challenges related to aging infrastructure, low profit margins, and limited access to innovation or training. These factors make it harder to transition to more sustainable and climate-resilient practices.

At the same time, the region benefits from a strong sense of local identity, growing support for food sovereignty, and a willingness to explore alternatives. Public initiatives are increasingly focused on supporting local producers, enhancing soil and water management, and building circular systems. Research institutions are active in piloting innovative approaches, and new funding opportunities are becoming available to support small-scale transitions. Collaboration between producers, consumers, and institutions is seen as a critical enabler for progress.

Financial Instruments

The Agri-Food sector (encompassing agriculture and local food systems) in the Canary Islands also faces significant financial hurdles. Many farms and food producers are small-scale and struggle with accessing funding for innovation or expansion. Challenges include complex grant application processes, limited administrative capacity, and financial models that don't fit well with small or circular agriculture projects. To support a transition to sustainable and resilient agri-food systems, the following financial instruments are identified:

- **Common Agricultural Policy (CAP) Funds:** The EU's CAP is a primary funding source for farmers. Especially through its Rural Development Program, CAP provides grants and subsidies for modernization, training, and environmentally friendly farming practices. In the Canary Islands, these funds can help farmers invest in efficient irrigation, soil conservation, or organic farming methods.
- **PDR-Canarias (Regional Rural Development Program):** This is a Canary Islands-specific program aligned with the CAP, offering tailored financial support to local producers. It can fund initiatives like improving irrigation infrastructure on farms, developing local seed

varieties, or cooperative processing facilities, thus strengthening the regional food value chain.

- **EU Innovation and Environment Programs:** Funding instruments such as the LIFE Programme and Horizon Europe are available to agri-food stakeholders. LIFE can co-finance pilot projects in sustainable agriculture or food waste valorization, while Horizon Europe grants support research and innovation (for example, precision farming technology adapted to island conditions or climate-resilient crop trials). These programs help de-risk innovative practices by covering part of the costs and facilitating knowledge transfer.
- **Micro-financing and Cooperative Funding Models:** Because traditional bank loans and investors often overlook small or low-profit agriculture ventures, micro-finance schemes and cooperative funds are emerging as alternatives. Micro-loans can provide farmers with capital for small improvements (like rainwater tanks or greenhouse upgrades). Cooperative models—where groups of producers pool resources or community investors support local farms—also offer financial backing for niche products (such as indigenous crops or artisanal goods) and community-supported agriculture projects.

While these funding options exist, the text emphasizes the need for better coordination and accessibility. Simplifying application procedures for EU and regional funds, offering technical assistance to help farmers apply for grants, and encouraging collaborative investment (public-private or farmer cooperatives) could greatly improve financial support. Strengthening the financial foundation in this way is crucial for the Canary Islands to achieve a sustainable, climate-resilient agri-food system that reduces reliance on imports and preserves local agriculture.

Policy and Governance Recommendations

The primary sector in the Canary Islands is the largest water user and is highly vulnerable to climate change, particularly temperature increases affecting its unique subtropical crops like bananas. Governance reforms should focus on creating an enabling environment for sustainable practices, technological adoption, and strengthening local food systems.

It is of material importance to enhance knowledge co-creation and sharing to disseminate best practices in transformational adaptation in the agri-food sector. To this end, stakeholders should focus on creating a formal programme managed by public agricultural institutions like the Canary Islands Institute for Agricultural Research (ICIA) for traditional knowledge sharing. This programme should facilitate On-Farm Experimentation (OFE) as a collaborative learning model between farmers and scientists. Incentives for promoting these models of collaboration could include integrating them in the procedures around agricultural expansion for farmers and small enterprises.

Integrating digital technologies through the enhancement of digital knowledge is material for the sustainable transformation of the sector in the region. This can be achieved through the development of subsidy programmes and technical assistance hubs to support the adoption of AGTECH (smart agriculture technologies), including crop mapping systems and Smart Field Notebooks. Vocational training and life-long learning especially for young farmers should be prioritized to ensure that practitioners include digital solutions in their operations to boost productivity and environmental resilience. A bold reform encompasses establishing a public-private partnership to create a regional data infrastructure that supports these technologies.

Promoting circularity in the agri-food value chain can be achieved by creating separate collection systems and extended producer responsibility schemes for agricultural plastics, and supporting SMEs to produce recycled plastic-based 3D printing filaments and eco-composite tools. This can be further supported by the establishment of green procurement rules prioritising local 3D-printed equipment.

Tourism

Tourism plays a central role in the Canary Islands' economy, bringing jobs and investment, but also creating pressure on natural resources and local infrastructure. Climate change is already affecting the sector, with rising temperatures, extreme weather, and stress on water and energy systems impacting both the environment and the visitor experience.

To respond to these challenges, the tourism innovation pathway promotes a shift toward more sustainable and climate-resilient tourism. The focus is on reducing emissions, improving resource efficiency, and diversifying tourism activities. The pathway also encourages stronger links between tourism and local communities, while protecting the natural landscapes that make the islands a unique destination.

Sectoral Goals

The general goal is to support a transition towards more sustainable, resilient, and inclusive tourism models. This includes shifting away from mass tourism toward approaches that value local ecosystems, cultural heritage, and year-round community well-being. Environmental sustainability, circular practices, and responsible resource management form the core of this transition.

Implementation Timeline & Milestones

By 2030, the goal is to increase energy and water efficiency in tourist accommodations, promote off-season and inland tourism to reduce pressure on coastal areas, and integrate sustainability standards into tourism services. By 2040, the pathway seeks to expand circular economy practices in the sector, foster partnerships between tourism businesses and local producers, and introduce digital tools to monitor and reduce environmental impacts. Looking ahead to 2050, the long-term ambition is to position the Canary Islands as a leading model for climate-resilient tourism in Europe, supported by strong community participation, adaptive infrastructure, and a clear alignment with regional sustainability goals.

Innovations in Focus

Tourism-related innovation in CS5 remains limited but offers targeted opportunities to advance circular practices and reinforce local value chains. The focus is on early-stage actions with high potential for cross-sectoral impact.

- **Tourism Organic Waste for Agricultural Compost:** Converts biorresidues from hotel kitchens and gardens into high quality compost to regenerate soils, reduce waste, and create synergies between tourism and local agriculture via circular economy practices.

Barriers & Enablers

The transition toward climate-resilient tourism in the Canary Islands faces several structural and operational barriers. Seasonality, dependence on external markets, and the dominance of mass tourism models pose challenges to diversification and innovation uptake. Environmental pressures, particularly water scarcity and ecosystem degradation, further constrain adaptive capacity. Institutional fragmentation and limited coordination between tourism operators, local authorities, and environmental agencies may slow the integration of sustainability measures.

Despite these challenges, several enablers support a shift toward more sustainable practices. The region benefits from high awareness of climate risks and growing interest in alternative tourism models among both residents and visitors. Existing infrastructure for digital tools and renewable energy provides a foundation for innovation. EU and regional funding mechanisms are increasingly aligned with green

transition objectives, offering opportunities for investment. In addition, ongoing collaborations between research institutions, public bodies, and tourism stakeholders create a supportive environment for testing and scaling new solutions.

Financial Instruments

Tourism is the economic backbone of the Canary Islands but making it sustainable and climate-resilient requires significant investment. The innovation package for tourism focuses on greener infrastructure, resource efficiency, and community-based initiatives, all of which need funding support. Unlike water and agriculture, the tourism sector's financial discussion is centered more on available funding tools than on specific barriers, but it implicitly addresses the challenge of redirecting investments towards sustainability. Key financial instruments for the tourism sector include:

- **European Funding programs:** The Canary Islands can leverage general EU funds for sustainable development in tourism. Notably, ERDF and LIFE Programme grants can finance projects like eco-friendly transport for tourists, energy and water efficiency upgrades in hotels, or preservation of natural sites used for tourism. The Recovery and Resilience Facility is another source that can support digital innovation in tourism (such as smart tourist flow management systems) or green infrastructure, aligning with post-pandemic recovery and climate goals. These EU funds have been used in similar regions and provide a strong basis for new project proposals.
- **Local government support and public-private partnerships:** Island councils and municipal authorities can co-finance sustainability initiatives in tourism through local grant schemes or by forming partnerships with tourism businesses. For example, a local government might offer a matching grant for hotels that install solar panels or water-saving devices, sharing the cost with the private sector. Public-private partnerships can also develop larger projects such as sustainable theme parks or electric public transit for tourists, combining public oversight with private investment.
- **Green Bonds and Revolving Funds:** To finance medium-sized projects (too large for small grants, but too small to attract big investors), tools like green bonds or dedicated revolving funds can be utilized. A green bond issued by the regional government could raise capital earmarked for tourism-related environmental projects (e.g. coastal restoration or building a network of electric vehicle charging stations for rental cars). Revolving funds, which reinvest returns from funded projects back into new projects, can support ongoing improvements, such as a fund that loans money for energy efficiency upgrades in resorts and uses the energy cost savings (paid back by the businesses) to fund new loans.
- **Crowdfunding and impact investment:** Smaller, community-led tourism initiatives often benefit from alternative financing. Crowdfunding can engage citizens and visitors to contribute to projects with visible local benefits (for instance, a community solar-powered eco-lodge or a cultural heritage site preservation). Impact investors (who seek social and environmental returns alongside profit) might finance projects like a social enterprise training locals in sustainable tourism guiding, or an eco-tourism startup. These avenues not only bring in funds but also raise public awareness and support for sustainable tourism.

By utilizing these financial instruments, the Canary Islands aim to steer the tourism sector toward a more resilient and eco-friendly model. Investments will focus on reducing the environmental footprint of tourism (through energy/water savings and waste reduction), promoting year-round and inland tourism to ease pressure on hotspots, and strengthening links between tourism and local communities (so that tourism revenue supports local development). The combination of EU funds, local government initiatives, and innovative financing (bonds, crowdfunding, etc.) creates a diverse funding portfolio to drive the transformation of the tourism industry in line with climate resilience goals.

Policy and Governance Recommendations

While tourism is a major economic driver, the future vision sees it becoming less fundamental, creating more space for the primary sector. This requires a shift towards a more sustainable tourism model that contributes positively to the islands' environmental and social resilience. A key political barrier is the reluctance to promote transformative initiatives that could be interpreted as "disturbing" tourists.

Acknowledging the political barriers at play, a dedicated tourism tax for climate adaptation activities is the most ambitious regulatory (and economic) reform the region could undertake. It involves the creation of a transparent and participatory governance body, including community representatives, to oversee the allocation of these funds. This will build public trust and ensure the funds address priority needs, such as financing NBS or upgrading water infrastructure. The legal framework must also address challenges such as application to vacation rentals. In tracking the use of tax revenues for earmarked adaptation projects, a strong set of KPIs should be set to monitor their progress and justify the tax burden on tourists.

The regional authority should consider mandating the separate collection and traceability of bio-waste generated by tourism activities, including waste from hotel kitchens and garden maintenance. To support this initiative, the authority must provide grants, technical assistance, and streamlined permitting processes for local composting facilities. Additionally, the regional authority should develop comprehensive quality standards and certification schemes for compost production to build trust and confidence among local farmers in using these organic materials.

Progressing towards a circular tourism economy warrants the establishment of a formal platform for collaboration between tourism operators, hotel associations (like Ashotel), municipalities, and agricultural cooperatives to implement a system for collecting tourism organic waste for agricultural compost. Having said that, to strengthen the link between tourism and agriculture, moving beyond pilot projects to a systemic solution, the authorities could consider introducing municipal ordinances or regional policies that incentivise or mandate waste separation in hotels and restaurants. Identifying this as a cross-cutting topic can allow the local stakeholders to promote sustainable agritourism through the development of a strategic plan. This should include updating territorial planning regulations to facilitate the development of small-scale, sustainable agritourism ventures, helping to rebalance the economy as envisioned by local stakeholders and ensuring tourism contributes to the appreciation and viability of the primary sector.

8.0 CS6 Black Sea– Innovation Package

8.1 Overview of the Case Study

The Black Sea region represents one of Europe's most complex transboundary socio-ecological systems. It connects upstream land uses, riverine dynamics, and coastal ecosystems in a basin that spans multiple countries and administrative levels. The region provides vital ecosystem services including fisheries, tourism, agriculture, and biodiversity, but it is also one of the most vulnerable areas in Europe to climate-

related hazards. Floods, droughts, and coastal erosion are increasingly frequent, compounded by anthropogenic pressures such as land degradation, nutrient inflows from agriculture, and urbanisation. These drivers interact to undermine both environmental health and socio-economic stability.

The ARSINOE project selected the Black Sea as a case study to demonstrate how integrated watershed management and nature-based solutions can address multi-level risks. The Living Lab process involved stakeholders from upstream catchments, riverine zones, and coastal areas, including ministries, municipalities, port authorities, farmers, tourism operators, NGOs, and research institutions. Through the Systems Innovation Approach, supported by the Climate Innovation Window and the Open Tenders for Innovations framework, stakeholders co-developed innovation pathways. These pathways address the headwater, riverine, and coastal nexus through four main sectors: Integrated Watershed Management, Coastal Protection & Marine Ecosystems, Agriculture & Rural Development, and Governance & Decision-Support Tools.

8.2 Sectors

Integrated Watershed Management

Sectoral Goals

The primary goal of this sector is to create an integrated approach to watershed management that reduces flooding, prevents droughts, and limits nutrient inflows into the Black Sea. Currently, upstream land use practices such as deforestation, intensive agriculture, and poorly planned urbanisation increase runoff, reduce infiltration, and contribute to both extreme hydrological events and water quality problems. Integrated watershed management aims to restore ecological functions in upstream and midstream areas, thereby reducing pressures downstream.

Another important goal is to align watershed management with EU directives such as the Water Framework Directive and the Floods Directive, ensuring compliance while strengthening resilience. By embedding ecosystem-based approaches in watershed governance, the sector aims to create co-benefits for biodiversity, carbon sequestration, and local livelihoods.

Implementation Timeline & Milestones

By 2030, pilot projects will focus on upstream reforestation, wetland restoration, and green infrastructure in urban catchments. These measures will reduce runoff, increase groundwater recharge, and filter pollutants before they reach rivers and the sea. Digital early-warning systems for floods and droughts will also be deployed, supported by improved hydrological monitoring.

Between 2030 and 2050, integrated watershed management will be scaled across the basin. Large-scale floodplain reconnection and wetland networks will be restored, creating multifunctional landscapes that reduce risks and improve ecosystem health. By mid-century, watershed management is expected to be guided by basin-wide strategies that integrate ecological restoration, agricultural practices, and urban planning.

Innovations in Focus

Key innovations include nature-based solutions such as upstream afforestation, wetland restoration, and floodplain reconnection. Green infrastructure in cities, such as permeable pavements and green roofs, will reduce stormwater runoff. Digital hydrological models and early-warning systems will provide real-time data for proactive management.

Complementary innovations include nutrient trading schemes and ecosystem service valuation tools that integrate ecological benefits into economic decision-making. These innovations ensure that watershed management delivers both environmental resilience and economic value.

Barriers & Enablers

Political barriers include fragmented responsibilities across multiple countries and administrative levels. However, EU directives and regional cooperation frameworks provide enabling conditions. Economically, restoration projects require high upfront investment, but avoided damages and EU funding provide strong incentives.

Socially, land-use conflicts with farmers and developers can hinder restoration, but participatory processes and compensation schemes provide enabling conditions. Technologically, data gaps and inconsistent monitoring systems are a barrier, though advances in digital tools enable integration. Legally, weak enforcement of environmental laws is a barrier, but EU accession processes and international agreements provide momentum.

Financial Instruments

In the short term, EU cohesion funds, Horizon Europe projects, and international donor programmes (e.g. GEF, UNEP) will finance pilots. Medium-term financing will include PPPs for restoration projects and concessional loans from IFIs for infrastructure upgrades.

In the long term, ecosystem service payments, resilience bonds, and biodiversity credits will provide sustainable financing. Tourism and agriculture sectors may also contribute to watershed funds, ensuring stable revenues for long-term management.

Policy & Governance Recommendations

Policy reforms must prioritise basin-wide integration of land, water, and ecosystem management. National policies should align with EU directives and harmonise across borders. Incentives for sustainable land use, such as CAP subsidies tied to watershed services, should be institutionalised. Legal frameworks must also enforce ecological flow requirements and land-use restrictions in floodplains.

Governance recommendations include establishing permanent transboundary watershed councils with representation from governments, municipalities, farmers, and NGOs. Data-sharing agreements should be formalised to create transparent monitoring systems. Participatory governance mechanisms should empower local communities to engage in watershed planning, ensuring legitimacy and ownership. These reforms will transform watershed governance from fragmented and reactive to integrated and adaptive.

Coastal Protection & Marine Ecosystems

Sectoral Goals

The goal of this sector is to strengthen resilience of Black Sea coasts and marine ecosystems against sea-level rise, erosion, and pollution. Coastal zones are particularly vulnerable to climate change, as rising seas and intensifying storms damage infrastructure, tourism facilities, and habitats. Protecting coasts is essential for safeguarding both economic and ecological assets.

A second goal is to restore and protect marine ecosystems that provide essential services such as fisheries, biodiversity support, and carbon sequestration. Addressing eutrophication, habitat degradation, and overfishing is critical to ensuring that marine ecosystems continue to provide long-term benefits.

Implementation Timeline & Milestones

By 2030, pilot projects will focus on nature-based coastal protection measures such as dune restoration, wetland buffers, and oyster reefs. Ports and coastal cities will test hybrid infrastructure solutions that combine grey defences with ecological restoration. Marine protected areas will also be expanded, and monitoring systems for pollution and biodiversity will be strengthened.

Between 2030 and 2050, large-scale coastal restoration and protection will be implemented across the Black Sea. Hybrid solutions will become the norm, combining seawalls with restored wetlands and dunes. Fisheries management will be aligned with ecological targets, and marine protected areas will be expanded into a coherent regional network. By mid-century, coastal protection will be guided by integrated land-sea strategies.

Innovations in Focus

Innovations include hybrid coastal protection systems, oyster reef restoration, dune stabilisation, and wetland buffers. Marine monitoring systems using remote sensing and IoT devices will provide real-time data on pollution, biodiversity, and ecosystem health. Marine protected area networks represent governance innovations that safeguard ecosystems.

Ecosystem service valuation tools will provide evidence of the economic benefits of marine restoration, supporting investment and policy alignment. These innovations combine ecological and technological approaches to deliver sustainable coastal protection.

Barriers & Enablers

Political barriers include fragmented governance across countries and sectors, but regional cooperation frameworks such as the Black Sea Commission provide enabling conditions. Economically, restoration projects require significant investment, but avoided damages and eco-tourism revenues create incentives.

Social barriers include resistance from coastal developers and fishers, though participatory processes can build support. Technologically, scaling nature-based solutions requires new expertise, but advances in engineering and ecology provide enabling conditions. Legally, enforcement of marine protection is weak, but EU and international conventions provide pressure for compliance.

Financial Instruments

Short-term financing will come from EU adaptation funds, national coastal protection programmes, and donor grants. Medium-term financing will involve PPPs for hybrid infrastructure and eco-tourism projects that support marine protection.

In the long term, blue bonds, biodiversity credits, and payments for ecosystem services will create sustainable financing streams. Tourism taxes and fisheries contributions may also feed into marine protection funds. These instruments embed ecosystem resilience into financial systems.

Policy & Governance Recommendations

Policy reforms should embed nature-based solutions into coastal protection strategies. National coastal management laws should require hybrid approaches that combine grey and green infrastructure. Fisheries policies must align with biodiversity conservation, ensuring sustainable catches. EU and regional frameworks should harmonise coastal and marine policies across the Black Sea.

Governance recommendations include establishing transboundary marine councils to coordinate marine protected areas and fisheries management. Participatory governance mechanisms should engage fishers, tourism operators, and communities in coastal protection. Data transparency is critical, with marine monitoring data made publicly accessible. These reforms will create resilient coasts and sustainable marine ecosystems.

Agriculture & Rural Development

Sectoral Goals

The goal of this sector is to transition agriculture towards sustainable practices that reduce nutrient runoff and soil erosion, thereby protecting water quality and ecosystems in the Black Sea. Agriculture is a major source of nutrient inflows, driving eutrophication and ecological degradation. Sustainable practices are therefore central to ecological resilience.

Another goal is to promote rural development that diversifies incomes and strengthens community resilience. Agro-tourism, eco-labels, and cooperative models can provide farmers with alternative revenue streams while supporting conservation.

Implementation Timeline & Milestones

By 2030, pilot projects will introduce precision fertilisation, conservation tillage, and efficient irrigation. Farmer cooperatives will be supported, and demonstration farms will showcase sustainable practices.

Between 2030 and 2050, sustainable agriculture will be scaled, supported by CAP subsidies and rural development funds. Agro-tourism and eco-labels will become mainstream, and soil carbon credits will create new income streams. By 2050, agriculture will be fully integrated with ecological and economic resilience strategies.

Innovations in Focus

Key innovations include precision farming technologies, efficient irrigation systems, conservation tillage, and crop diversification. Agro-tourism and eco-labelling are market innovations that diversify income and reward sustainability. Digital soil monitoring platforms provide data for sustainable practices.

Carbon and soil credits create financial innovations that embed ecosystem services into agricultural systems. Together, these innovations create sustainable and resilient rural communities.

Barriers & Enablers

Political barriers include inconsistent agricultural policies across countries, but EU alignment provides enabling conditions. Economically, transition costs are high, but subsidies and ecosystem service payments provide support. Socially, resistance to changing practices is a barrier, but demonstration projects and cooperatives create enabling conditions.

Technologically, access to precision tools is limited, but costs are declining. Legally, enforcement of agricultural standards is weak, but EU directives provide pressure for compliance. Environmentally, soil degradation and water scarcity increase urgency for sustainability.

Financial Instruments

Short-term financing will come from CAP subsidies, rural development funds, and donor programmes. Medium-term financing will include cooperative loans and blended finance for scaling sustainable practices.

In the long term, carbon and soil credits will provide revenue, while agro-tourism and eco-labels will diversify incomes. Payments for ecosystem services will compensate farmers for conservation practices.

Policy & Governance Recommendations

Policy reforms must align agricultural subsidies with water and biodiversity goals. CAP conditionality should tie payments to sustainable practices such as nutrient management and conservation tillage. National agricultural laws should harmonise across the basin to prevent inconsistencies.

Governance recommendations include institutionalising farmer cooperatives in basin planning and creating participatory governance structures. Training programmes and extension services should support adoption of innovations. Transparent monitoring systems should track progress and create accountability. By embedding sustainability into agricultural governance, rural communities can thrive while protecting ecosystems.

Governance & Decision-Support Tools

Sectoral Goals

The goal of this sector is to strengthen governance capacity by institutionalising decision-support tools that integrate hydrological, agricultural, coastal, and socio-economic data. These tools will provide evidence-based guidance for planning, investment, and risk management across the basin.

Another goal is to create participatory governance frameworks that enhance trust and legitimacy across borders. Decision-support must not only provide technical accuracy but also empower stakeholders and create accountability.

Implementation Timeline & Milestones

By 2030, pilot DSS platforms will be deployed to integrate watershed, agricultural, and coastal data. Participatory platforms will be tested to ensure inclusivity. By 2050, DSS will be institutionalised across the basin, guiding integrated land-sea governance.

Between 2030 and 2050, DSS will expand to integrate financial and risk data, enabling insurers and investors to incorporate resilience metrics. By mid-century, DSS will be a governance standard across the basin.

Innovations in Focus

Innovations include integrated modelling platforms, vulnerability assessment tools, participatory governance platforms, and ESG-aligned sustainability metrics. These tools combine evidence and participation to strengthen governance.

By embedding DSS into statutory planning and investment frameworks, the region can achieve proactive and adaptive governance.

Barriers & Enablers

Political fragmentation across countries is a major barrier, but EU accession processes and regional cooperation provide enabling conditions. Economically, DSS benefits are diffuse and hard to monetise, but avoided losses and efficiency gains create incentives. Social barriers include mistrust across borders, but participatory processes can build trust.

Technologically, interoperability challenges exist, but open data standards provide solutions. Legally, weak enforcement of environmental laws is a barrier, but international conventions provide enabling conditions. Environmentally, climate change urgency underscores the need for DSS.

Financial Instruments

Short-term financing will come from EU and donor grants for DSS pilots. Medium-term financing will involve PPPs and joint investments by municipalities, utilities, and regional authorities.

In the long term, sustainability-linked finance tied to resilience indicators will embed DSS into financial markets. Insurers and investors will increasingly rely on DSS outputs in risk assessments, reinforcing adoption.

Policy & Governance Recommendations

Policy reforms must mandate DSS use in planning and investment decisions. National and regional strategies should require DSS integration in watershed, agriculture, and coastal governance. EU funding should be conditional on DSS adoption.

Governance recommendations include establishing permanent transboundary governance councils that use DSS for decision-making. Data governance frameworks must clarify responsibilities for data sharing and transparency. Standardisation of DSS methodologies across the basin is essential. Financial regulators should embed DSS outputs into insurance and investment risk assessments. These reforms will institutionalise evidence-based, participatory governance in the Black Sea.

9.0 CS7 Southern Denmark– Innovation Package

9.1 Overview of the Case Study

The ARSINOE case study in Southern Denmark focuses on the region's low-lying coastal areas, which are highly vulnerable to flooding from multiple sources, including extreme sea levels, storm surges, intense rainfall, and high groundwater levels. The key area of focus is the city and port of Esbjerg, a major economic hub and an international centre for renewable energy infrastructure in the North Sea. The region's key systems—including its communities, critical infrastructure (transport, energy, water), primary production (agriculture, fisheries), and the unique ecosystems of the UNESCO World Heritage Wadden Sea—are all under increasing threat from climate change.

The central challenge identified by local stakeholders is to ensure efficient and sustainable flood risk management that guarantees the safety of citizens and protects both existing and future investments in the city, its enterprises, and other valuable assets. A significant barrier is the Danish governance structure, where local municipalities and utility companies, rather than regional or national bodies, are legally and financially responsible for climate adaptation, making coordinated, large-scale solutions difficult to implement.

The ARSINOE project has applied the Systems Innovation Approach (SIA) in Southern Denmark to move beyond isolated, sector-specific solutions towards a holistic and co-created strategy for resilience. This has been implemented through a Living Lab (LL) in Esbjerg, which serves as an open innovation space for stakeholders from academia, the private sector, public authorities, and civil society. The LL focused on developing an "emergency preparedness plan in flooding extremes".

The participatory process began with stakeholder mapping to identify key actors, from municipal planners and utility companies to the police, private businesses, and local councils. The first LL workshop, held in October 2022, brought these stakeholders together to create a mental map of the interconnected challenges, including flood risks, urban development, economic financing, and citizen involvement. This exercise shifted the mindset from purely technical problems to a systemic view that highlighted social and governance dimensions.

Based on this shared understanding, the LL participants refined a problem statement that acknowledged the need for proactive, collaborative planning to overcome the limitations of reactive responses and fragmented systems. In the second workshop, held in January 2023, stakeholders co-developed a shared future vision for 2050: a green, sustainable, and climate-resilient Esbjerg where the city and port are closely connected, and solutions are implemented through robust dialogues involving citizens and public and private sectors. The third workshop in October 2023 used a backcasting methodology, starting from this 2050 vision to identify the concrete steps, milestones, and innovations needed to achieve it, forming the basis of the innovation package.

9.2 Sectors

Water and flood risk management

Sectoral Goals

The primary goal is to develop and implement robust, multifunctional, and sustainable flood risk management solutions that protect citizens, critical infrastructure, and economic assets from coastal, pluvial, and fluvial flooding.

Implementation Timeline & Milestones

The innovation pathway for this sector includes short-term actions to improve risk assessment and management by 2025, mid-term implementation of protection infrastructure by 2030, and long-term strategic enhancements towards 2050. A key project is the multifunctional storm surge barrier, with its first phase already in place and a second phase planned over the next 20-30 years.

Innovations in Focus

The innovation package combines both 'hard' infrastructure and 'soft' digital tools to create a comprehensive defense system. The SIA process for CS7 spurred one innovation to support medium and long-term objectives in water and wastewater management.

- **Saferplaces:** A cloud-based Digital Twin solution for flood risk intelligence in urban areas. This tool, selected through the ARSINOE Open Tender, delivers precise flood hazard assessments and damage predictions, allowing stakeholders to simulate various flood scenarios and test the effectiveness of adaptation measures like the planned Green Flood Barrier.

Having said that, local stakeholders identified areas amenable to innovative solutions as follows:

- **Improved Storm Surge and Flood Models** through the development of advanced models using machine learning and AI to provide more accurate flood forecasts and risk assessments, supporting both emergency response and long-term planning.
- **Novel Pumping Systems:** New technologies to manage compounding flood risks from backwater and high groundwater levels, particularly in low-lying urban areas.

Barriers and Enablers

A significant political barrier is the fragmentation of responsibility, with local authorities bearing the financial burden for adaptation. Economic barriers include the high upfront costs for large infrastructure and uncertainty over long-term benefits, which can reduce the willingness of private actors to invest. However, the direct threat of flooding acts as a powerful enabler, creating a sense of urgency.

Financial Instruments

Southern Denmark's low-lying coastal geography and flood-prone areas demand substantial upfront investment in protective infrastructure and adaptive measures. A mix of public and innovative financial instruments can support these needs:

- **EU Structural and Investment Funds:** European cohesion funds (e.g. ERDF, Cohesion Fund) prioritize climate adaptation, risk prevention and management. Southern Denmark can tap these for dike construction, coastal defenses, and nature-based solutions. EU funds are well-suited to large-scale public goods like flood protection, and the EU has earmarked an increasing share of its budget to climate action (20% in 2014–2020, rising to 25% for 2021–2027). A barrier is the co-financing requirement and competition for these funds, which necessitates strong project preparation capacity and alignment with EU priorities. The region's high income status may limit eligibility for some cohesion funds, but targeted programs (e.g. the LIFE program's climate adaptation stream) can provide grants for ecosystem-based adaptation and capacity building.

- **Public–Private Partnerships (PPPs):** PPPs can leverage private capital and expertise to design, build, and maintain flood infrastructure (e.g. storm surge barriers, levees, urban drainage systems). This approach can ease public budget constraints by attracting investors with a steady return (such as availability payments or user fees). However, suitability depends on revenue models, flood defenses are pure public goods and don't inherently generate cash flow, so PPP contracts often require government payment guarantees. Regulatory frameworks must enable long-term contracts, and risk allocation (especially for extreme event damage) must be clearly defined. In Southern Denmark, PPPs could be viable for multi-purpose projects (for example, a flood barrier integrated with a harbor redevelopment that yields commercial revenue). A key barrier is the complexity of structuring such partnerships for climate resilience; uncertainty in climate projections and lack of precedent can deter private investors. Ensuring that PPP consortia truly share risks and co-develop solutions, rather than focusing only on finance, is critical for success.
- **Green Bonds and Climate Bonds:** Issuing green bonds (debt securities earmarked for environmental projects) can mobilize institutional investors for flood risk management. Municipalities or utilities in Southern Denmark could issue green bonds to finance seawalls, wetlands restoration, or resilient water infrastructure, capitalizing on investors' appetite for sustainable assets. Green bonds provide upfront capital repaid over time through taxes or utility revenues. This instrument aligns with long-term adaptation goals, and international experience shows growing support for such bonds as a stable financing source. The challenge is ensuring project pipelines and meeting reporting standards to avoid "greenwashing." Southern Denmark's strong credit and governance make it a good candidate, but smaller municipalities may need aggregation mechanisms or backing (for instance, Denmark's KommuneKredit pool) to access bond markets at reasonable rates.
- **Catastrophe bonds and Insurance-linked securities:** Catastrophe bonds (cat bonds) transfer disaster risk to capital markets, providing a payout to the issuer (e.g. a regional authority) if a defined catastrophe (storm surge, extreme flood) occurs. For Southern Denmark, cat bonds or parametric insurance could be used as contingent financing, ensuring rapid funds for recovery and rebuilding of flood defenses after a major event. This instrument suits the region's goal of financial resilience against low-probability, high-impact storms. A cat bond could, for example, be structured to trigger if coastal water levels exceed a threshold, supplying tens of millions of euros for emergency response. The suitability lies in protecting public finances from ruinous losses and providing quick liquidity. However, cat bonds do not finance preventive measures: they are essentially post-disaster relief tools. They also face barriers: high transaction costs, complexity in modeling trigger events, and a limited investor base willing to take Danish flood risk. In practice, catastrophe bonds have seen more use at national scales or in regions with higher risk profiles; for Southern Denmark, they could complement (not replace) upfront investments. Insurance-linked instruments also include reinsurance arrangements or insurance pools. Notably, Denmark already operates a public disaster compensation scheme funded by a levy on property insurance, which ensures all properties are covered for flood damage. This tax-financed insurance model spreads risk nationally and aids recovery climatechange.post.com, but it does not fund adaptation, it pays for damages after floods. To encourage prevention,

authorities could explore premium discounts or payouts for risk reduction (e.g. insurers or the Danish Storm Council funding wetlands restoration to reduce future claims, similar to a pilot in Spain where an insurer funds wetland conservation as natural flood protection).

- **Community funds and local co-financing:** Engaging the community through local funding mechanisms can bolster both finances and buy-in. Community resilience funds could be established, allowing citizens and local businesses to contribute to flood protection projects (through crowdfunding, cooperative schemes, or special levies). For example, a municipality might set up a fund for upgrading dikes, with voluntary donations or a small climate adaptation surcharge on local taxes. This can create a sense of shared ownership and awareness. Southern Denmark's experience, however, shows barriers in practice: when coastal municipalities attempted to have local landowners pay annual fees for beach nourishment and dike maintenance, many resisted the cost. Willingness to pay among citizens can be low for collective goods, especially if benefits are diffuse or long-term. Thus, while community funding is suitable for smaller-scale measures (like rain gardens, elevating homes or improving the "Climate Ready Esbjerg" app for flood alerts), it requires intensive engagement and transparent benefit-sharing. Any community-based financing must address equity (who pays vs who benefits) to gain broad support.

In summary, a diverse portfolio of instruments: blending grants, public financing, market-based tools, and community contributions is available to support water and flood risk management. Each comes with trade-offs: grants and public funds are most straightforward but limited; private capital via bonds or PPPs can fill the gap if projects are structured to generate returns or public repayments; and risk-transfer instruments like cat bonds address residual risk but don't replace investment in prevention. The choice of instruments must match Southern Denmark's goals of reducing flood risk, ensuring financial sustainability, and overcoming implementation barriers like unclear cost responsibility and public acceptance.

Financial Instruments

A phased financial strategy is needed to deploy these instruments effectively over time, aligning with immediate needs, medium-term plans, and long-term resilience goals. For CS7 Southern Denmark, the strategy can be outlined in short-, medium-, and long-term pathways:

1. **Short-term (next 1–3 years):** Focus on quick wins and capacity building. Leverage available grants and existing budgets to implement no-regret measures and preparatory actions. For example, pilot projects funded by EU programs (LIFE, Horizon Europe) or national climate funds can demonstrate effective solutions, such as nature-based shoreline protections or the enhancement of the "Climate Ready Esbjerg" app for early warning. These relatively modest investments (often grant-funded) build local know-how and public support. Concurrently, conduct rigorous risk assessments and project scoping for larger interventions, this groundwork is crucial to access bigger funding streams later. Early on, the region should establish a dedicated task force or financing working group to coordinate proposals for EU structural funds and to engage stakeholders (municipalities, landowners, investors) in funding plans. Given the current legislative context that places primary responsibility on private landowners, convening

stakeholders to negotiate cost-sharing agreements is an immediate priority. In the short term, the financial strategy also includes contingency planning: ensuring that disaster response funds or insurance are in place. For instance, the region can collaborate with the National Storm Council to verify that insurance/compensation mechanisms will swiftly cover any flood damages, preventing ad-hoc budget crises. This period is about creating “shovel-ready” adaptation projects and interim risk financing so that Southern Denmark is prepared both to invest and to respond.

2. Medium-term (3–10 years): Scale up investment through blended finance and structured programs. In this phase, major capital projects for flood protection should be rolled out, backed by a combination of funding sources. The region will aim to secure EU structural funds in the 2027–2033 programming cycle by including coastal resilience in Denmark’s and the region’s operational programs. Structural funds could co-fund large infrastructure (e.g. a sea wall, sluice gates, or elevated harbor quays) with national or municipal match-funding. To cover the local share, municipalities might issue green bonds or take low-interest loans via institutions like KommuneKredit, repaying over decades through general revenues or earmarked taxes. Public-private partnerships can be structured for multi-use projects – for example, a PPP where a private consortium designs and builds a storm surge barrier in exchange for availability payments from the government over 20–30 years. Careful contract design will be needed to ensure performance (perhaps with bonus payments for on-time delivery or penalties for flooding). By the mid-2020s, Southern Denmark should also explore innovative bonds and insurance: possibly a resilience or environmental impact bond where investors’ returns depend on achieved flood risk reduction (as demonstrated in a US city that raised \$12 M via an outcome-based bond for green infrastructure to reduce flooding). While such instruments are new in Europe and entail legal and technical hurdles, piloting them could attract new capital and attention to Southern Denmark’s adaptation efforts. Insurance-linked solutions might also emerge in this period; for instance, the region could partner with insurers on a parametric insurance policy that pays the city a fixed sum if an extreme storm tide occurs, providing rapid funds for recovery and rebuilding. During the medium term, mainstreaming adaptation into budgets and regulations is key. Regular municipal budgets should start allocating annual funds for maintenance of dikes and pumps, not just emergency fixes. Utility companies (water, electricity) serving the region should be mandated (and financially enabled) to climate-proof their infrastructure, with costs recouped via rates or government support. Critically, by 2030 Southern Denmark should have in place a clear cost-sharing framework for coastal protection – potentially through updated legislation or local agreements that define what costs are borne by landowners, municipalities. This clarity will give private investors and the public confidence that big projects have a sustainable financing and governance model.
3. Long-term (2030s and beyond): Achieve financial sustainability and climate resilience by institutionalizing funding mechanisms. In the long run, the aim is for Southern Denmark to have self-replenishing financing streams for flood risk management, reducing reliance on extraordinary one-off grants. This could include the creation of a permanent regional Climate Resilience Fund – seeded by national government transfers and local contributions, that continuously invests in adaptation upgrades (e.g. raising dikes higher as sea levels rise, maintaining wetlands, relocating at-risk assets) and can also act as a reserve for disaster recovery. By 2040 and beyond, innovative market instruments should complement public funding. For

example, if climate risks continue to escalate, Denmark or a pool of North Sea regions might issue sovereign catastrophe bonds as insurance against mega-disasters, as some climate-vulnerable countries have done. These would provide a backstop for truly extreme events while day-to-day resilience is handled by built infrastructure. In parallel, insurance pricing and land-use policy should work in tandem: in the long term, risk-based insurance premiums (or risk taxes) can send signals to discourage building in floodplains, and the proceeds of such premiums/taxes could be funneled into adaptation investments (a form of solidarity that charges risk-takers and rewards risk reduction). The long-term strategy also anticipates that private-sector involvement becomes routine – by making adaptation investments “bankable” and quantifying their benefits, Southern Denmark can attract institutional investors at scale. Over decades, one expects advances in measuring resilience dividends, which would help monetize benefits like avoided flood losses and thus unlock more private financing. Ultimately, by mid-century, financing for flood risk management should transition from ad-hoc projects to a continuous improvement model, where each budget cycle and business plan includes climate resilience components. This aligns with European calls for “adaptation pathways” that allow iterative investments as climate evolves.

Conditions for implementation and adoption: Successfully executing this financial strategy requires certain enabling conditions:

- **Governance and coordination:** A clear governance structure must be in place to manage funds and projects across multiple jurisdictions. Southern Denmark’s case shows fragmentation in responsibility (state vs municipalities vs landowners) can stall action. A coordinated regional coastal authority or a formal agreement between national and local governments is needed to oversee adaptation financing. This body should have the mandate to plan long-term, prioritize investments, and blend funding sources. High-level political commitment (at the Danish national level) to support Southern Denmark’s resilience will help unlock state co-funding and regulatory fixes.
- **Stakeholder buy-in:** Securing stakeholder buy-in is paramount. Landowners, citizens, and businesses need to perceive the strategy as fair and necessary. This may involve extensive community engagement and transparent cost-benefit communication. For example, if new local taxes or fees are introduced for flood protection, residents should see how those contributions directly enhance their safety. Past experience of fee proposals being rejected underscores the need for early and meaningful consultation. Public education about the rising risks and the cost of inaction (estimated to potentially reach 7% of EU GDP under high warming) can build support for proactive financing. Likewise, private investors and utilities need confidence in the regulatory environment – they will buy in if they see stable policies and a commitment that investment costs can be recovered reasonably (through tariffs, tax incentives, or credits).
- **Institutional capacity:** Administering blended finance and complex projects requires strong institutional capacity. Local authorities must be equipped with skills in project finance, grant applications, and PPP contract management. It may be necessary to train municipal staff or hire specialized experts to manage EU fund applications and to structure innovative instruments. Capacity gaps can be addressed by partnering with national agencies, consulting firms, or knowledge networks. For instance, preparing a green bond issuance or a cat bond deal will involve legal and financial expertise beyond routine public administration – acquiring this

capacity (perhaps via Denmark's finance ministry or advisors) is a prerequisite. The World Bank and EU have noted that detailed data and analytics are also needed to target investments effectively and make the economic case for adaptation. Building an evidence base (hazard maps, cost–benefit analyses for projects, etc.) is an institutional task that underpins successful financing.

- **Regulatory and policy framework:** Several regulatory conditions must be aligned. If PPPs are pursued, Denmark's procurement and concession laws should accommodate long-term, climate-focused contracts, possibly adjusting standard procurement rules to account for lifecycle resilience benefits rather than just upfront cost. For bond financing, adherence to the upcoming EU Green Bond Standard will ensure credibility, and Danish law must permit municipalities or regions to take on the necessary debt (Danish municipalities have access to low-cost loans via KommuneKredit, which is a helpful existing mechanism). Policy updates may include planning regulations that mandate integrating climate adaptation in new developments (ensuring private developers finance protective measures) and reforms to cost-sharing laws so that municipalities can more easily levy local contributions or spend general revenues on multi-municipal projects. Additionally, any innovative insurance solutions would require regulatory approval (e.g. the insurance regulator allowing parametric products or insurers investing in nature-based projects). The EU policy landscape is also a factor – aligning Southern Denmark's plans with EU priorities (such as the EU Adaptation Strategy and Disaster Risk Reduction policies) can smooth access to funding and technical support.
- **Monitoring and flexibility:** A condition often overlooked is the need for monitoring of how funds are used and the outcomes achieved. Financiers (whether public or private) will demand accountability that the money results in reduced flood risk. Key performance indicators, such as hectares of wetlands restored, number of homes protected, or flood damage avoided in euros should be tracked. This not only maintains trust with funders and the public, but also allows adaptive management of the financial strategy. If certain instruments underperform or risks change faster than expected, the strategy should be revisited. Flexibility to incorporate new instruments is also important. For example, if in five years a new EU resilience bond or a national climate fund is created, Southern Denmark should be ready to integrate it.

Citizen & Community Engagement and Education

Sectoral Goals

To foster a climate-resilient community by improving education, raising risk awareness, and actively engaging citizens, civil society, and the private sector in co-designing and implementing adaptation solutions.

Implementation Timeline & Milestones

By 2025, the goal is to have digital platforms for citizen engagement fully operational. By 2030, new economic models to motivate private and citizen contributions will be developed, and by 2050, education on climate risks will be integrated into schools and adult learning programs.

Innovations in Focus

This sector relies heavily on social and digital innovations to build capacity and foster collaboration.

- **CitizenLab:** A digital platform selected through the Open Tender to ensure representative and inclusive citizen engagement. It supports both digital and physical participation, allowing citizens to provide input on planning processes through features like interactive mapping and AI-powered feedback summaries.
- **Flood-MapEx:** A multi-stakeholder workshop concept, also selected via the Open Tender, that combines vulnerability assessments with crisis management exercises to build shared risk awareness among citizens, businesses, and authorities.

During the consultation process, local stakeholders also highlighted the need for economic models for shared investment. Specifically, they recognized the need for new financial models that clarify the economic measures needed and create incentives for citizens and the private sector to contribute financially to common protection solutions. Finally, a visitor center was envisaged, to create a physical space for sharing knowledge on climate, energy, and disaster preparedness, further embedding resilience in the local culture.

Barriers & Enablers

Social barriers include a lack of risk awareness in some groups and challenges in integrating diverse communities. However, Denmark's strong tradition of citizen involvement and the co-creation process of the LL act as powerful enablers. A key financial barrier is the poor identification of funding opportunities.

Financial Instruments

The financial strategy for citizen and community engagement in climate resilience will emphasize sustained support, scaling successful initiatives, and creating enabling environments over time. A phased approach can ensure that engagement efforts grow from ad-hoc projects to an ingrained part of Southern Denmark's climate strategy:

1. **Short-term (1–2 years): Initiate and Demonstrate.** In the immediate term, the focus is on initiating pilot programs and demonstrating the value of community engagement. This involves utilizing readily available funds and channels:
 - *Launch pilot projects with grant support:* For example, use an EU-funded project (such as ARSINOE's living labs or a Horizon Europe grant) to run a series of community workshops on flood preparedness in vulnerable neighborhoods. Similarly, tap small national grants (or climate-related research programs at the University of Southern Denmark) to develop educational materials and school activities about local climate risks. These pilots should be relatively low-cost but high-visibility, creating success stories that can be publicized.
 - *Leverage existing institutions:* Work through established structures – e.g. integrate climate topics into ongoing adult education courses, or add a climate resilience module to emergency services volunteer training – using existing municipal or regional budgets. The short-term strategy might reallocate a modest sum from environment or civil protection budgets specifically to community outreach (a few percent of infrastructure project costs devoted to public engagement can be justified as part of project effectiveness).

- *Community fund kickoff:* If pursuing a community resilience fund or crowdfunding campaign, start small with a clear, tangible goal (“raise €50k to equip local flood response teams with mobile pumps and first-aid kits” or “crowdfund the planting of 500 trees for urban cooling”). Early success in meeting a funding goal can galvanize confidence. Even a symbolic contribution from citizens demonstrates interest and can be parlayed into lobbying for more public funds.
- Throughout the short term, tracking and publicly highlighting quick wins is crucial. For instance, if 100 households sign up to a new flood alert SMS service after a community drive, or if a school competition on climate solutions draws many participants, celebrate these as milestones. This not only builds community momentum but also helps convince decision-makers that engagement has real impacts (e.g. more informed citizens, potentially less damage in the next storm due to better preparedness).
- 2. **Medium-term (3–5 years): Institutionalize and Scale Up.** In the medium term, the strategy shifts to scaling up successful initiatives and embedding them into institutions so that engagement is not reliant on one-off projects:
 - *Secure dedicated funding streams:* Advocate for and establish a stable budget line for climate education and engagement within municipal and regional budgets. For example, by year 3, the City of Esbjerg or the Region of Southern Denmark could allocate a fixed annual amount (perhaps increased incrementally) to fund ongoing community programs (such as citizen advisory panels, climate ambassadors in each town, or maintenance of digital engagement tools). At the same time, seek multi-year funding from national programs – e.g. Denmark could launch a “Climate Aware Communities” scheme, offering matching funds to municipalities that invest in local adaptation engagement. By showing early pilot successes, Southern Denmark can make a strong case for such funding.
 - *Public-private synergies:* Expand partnerships with local businesses, NGOs, and educational institutions. For instance, medium-term could see the creation of a Climate Resilience Learning Hub in Southern Denmark – a center (physical or virtual) where resources, training, and events for the public are coordinated. This could be co-funded: a local university provides expertise, companies sponsor events, and the government covers operational costs. Such a hub could train community leaders, support volunteer climate groups, and serve as a focal point for citizen science (like coastal water level monitoring by volunteers). By institutionalizing a hub or network, the engagement effort gains permanence beyond political cycles.
 - *Curriculum integration and youth engagement:* Work with the education system to formally integrate climate resilience into school curricula and extracurricular activities. In the 3–5 year span, aim to have climate adaptation and sustainability taught in schools across the region – a change that might be supported by the national education ministry. Funding for teacher training and materials might come from a mix of the Education Ministry and environment agencies. Engaging youth is a long-term investment, and Denmark’s strong education sector can absorb these themes given resources.
 - *Scaling community funding mechanisms:* If a local climate fund was launched, evaluate and refine it. Perhaps establish a matching scheme where for every krone raised by the community, the municipality matches it – this can incentivize greater participation.

Consider expanding the model region-wide if one town's approach worked. Medium-term could also explore innovative insurance incentives for communities: for example, if a whole neighborhood undertakes flood-proofing actions (like installing backflow valves), an insurance company might agree to lower premiums for that area, effectively freeing up household money that could be pooled into a community emergency fund. Such arrangements require negotiation but illustrate creative blending of community action with financial incentives.

3. Long-term (6+ years): Mainstream and Sustain. Over the longer term, the aim is to mainstream citizen engagement into the fabric of climate resilience planning, ensuring it is continuous and self-sustaining:
 - *Make engagement a formal part of governance:* Southern Denmark's climate adaptation governance by year 6–10 should have permanent channels for citizen input and co-creation. This could mean institutionalizing the living lab approach – e.g. a standing Community Climate Council that meets regularly and has representation in regional planning processes. These structures need modest funding for coordination, which should be built into the operating budgets of local governments. The financial strategy should account for stipends, meeting resources, or outreach materials to support citizen representatives. When citizen engagement is seen as a *standard component* (like public hearings or consultations are), funding it will become non-controversial.
 - *Long-term program funding:* Just as libraries or emergency services have steady funding, community resilience programs should too. For example, maintain an ongoing public awareness campaign (via media, social networks, local radio) about climate risks and preparedness – funded as part of the regional risk management strategy. Over time, these costs can potentially be absorbed into larger adaptation projects (many funding guidelines by now require stakeholder engagement, meaning future infrastructure grants may include a budget for public engagement activities by default).
 - *Outcome-based evaluation and adjustment:* In the long run, financial support should flow to the most effective engagement initiatives. This means setting up a system to evaluate which approaches yield results – e.g. increased volunteerism, adoption of household adaptation measures, etc. Those that work (say, a community flood warden program that demonstrably improves emergency response) should receive more funding, while less effective ones might be phased out. This performance focus will reassure funders that money is well spent and adapt efforts to changing societal needs.
 - *Resilience culture and private sector buy-in:* Culturally, the goal is that local businesses and citizens come to see resilience as a shared responsibility. By 2030 and beyond, one hopes to see private investments in community resilience normalized – e.g. real estate developers routinely contribute to local adaptation funds as part of projects, insurers actively partner with municipalities on risk awareness (because it reduces claims), and community groups integrating climate action into their regular activities (with only light financial support from authorities). If achieved, the financial burden on the government can plateau or even decrease as society takes on more of the load (supported by economic incentives). However, this scenario hinges on maintaining trust: people will

contribute time or money if they see that their contributions lead to real improvements and if everyone (including government) is doing their part.

Resilience of Critical Systems (Utilities, Private Sector, Governance)

Sectoral Goals

To enhance the resilience of critical infrastructure (energy, water, transport) and businesses by identifying cascading risks, improving risk management, and motivating private investment in protective measures.

Implementation Timeline & Milestones

The focus until 2025 is on identifying cascading risks and developing pathways for private investment. By 2030, the aim is to have improved climate risk management tools and new technologies for protecting critical assets.

Innovations in Focus

Stakeholders in CS7 did not zero-in on specific innovations, however identified key areas for intervention to shape a climate-resilient pathway underpinned by innovative solutions:

- Cascading Risks Model: A model being adapted from CS8 to identify and analyse the potential knock-on effects of flooding on interdependent systems like electricity, water supply, and transport in Esbjerg.
- Damage Cost Assessment and Modelling (DCAM): An open-source tool used to assess the economic risks of flooding across multiple sectors, providing the quantitative basis for cost-benefit analyses of adaptation options.
- Innovative Building Protection and Off-Grid Solutions: Future-oriented solutions to make buildings and essential services less vulnerable to infrastructure failures during extreme events.

Barriers & Enablers

A technological barrier is limited access to detailed data on infrastructure interdependencies, while a major political barrier is the lack of public requirements to drive private-sector adaptation.

Financial Instruments

Resilience of Critical Systems in Southern Denmark spans essential utilities (such as energy, water supply, wastewater, telecommunications), the private sector economy (industries, SMEs, supply chains), and governance mechanisms (emergency services, municipal operations). These systems underpin the region's functionality, and their resilience is vital during climate stress (storms, floods, heatwaves). Financing their resilience requires instruments that can support large-scale infrastructure upgrades, encourage private investment in risk reduction, and ensure continuity of services. Key financial instruments include:

1. Short-term (1–3 years): Prioritize risks and secure quick wins. In the immediate horizon, the strategy focuses on risk assessment, planning, and high-urgency fixes:
 - *Conduct comprehensive resilience audits:* The very first step is identifying vulnerabilities in all critical systems. Southern Denmark should carry out (or update) climate risk and

vulnerability assessments for its utilities, transportation links, digital networks, and key industrial facilities. This analytical phase, which can be funded by modest allocations or technical assistance grants, will inform where to direct funds first. Many critical sectors may already have some risk data, but integrating it into a regional overview is important.

- *Emergency preparedness investments:* Allocate funding for low-regret, high-impact improvements that can be done quickly. For example, purchase backup generators for critical pump stations or shelters, improve emergency communication systems for first responders, and ensure redundant power or water supply connections to hospitals. These relatively small investments (often using local emergency funds or national civil protection grants) can significantly boost resilience in the short term. Given recent European disaster experiences, there may be EU civil protection funding available to co-finance such emergency equipment and planning enhancements.
 - *Secure contingent financing:* Establish financial mechanisms to provide liquidity in case of a disaster, before major events strike. In the short term, this could mean arranging an emergency reserve fund at the municipal or regional level dedicated to critical infrastructure repairs, or setting up agreements with the Finance Ministry for rapid disbursement of funds if needed. Even negotiating credit lines with commercial banks or multilateral lenders as a standby facility is worthwhile. Essentially, ensure that if a storm or flood hits next year, money will not be the bottleneck in restoring power, water, or transport. This might include working with the national government to tap the EU Solidarity Fund if criteria are met for disasters – knowing the process and requirements in advance.
 - *Engage operators and the private sector:* Immediately convene a Critical Infrastructure Resilience Council with representatives from utilities (electric, water, telecom), major companies (e.g. port operators, large manufacturers), and government agencies. In the short term, this council serves to coordinate efforts and share information about vulnerabilities and planned upgrades. Financially, it sets the stage for co-financing opportunities – for example, a utility might say “we plan to reinforce substation X if the city raises the dike in that area,” allowing joint planning. This coordination ensures that short-term fixes by one actor aren’t negated by inaction from another. It also builds trust needed for PPPs or blended projects down the line.
2. **Medium-Term (4–10 years):** Invest and implement at scale. In this phase, armed with risk data and plans, Southern Denmark will deploy major investments to strengthen critical systems, using a mix of public funding, private investment, and partnerships:
- *Execute priority infrastructure projects:* By this stage, specific big-ticket projects should be ready to go – for example, elevating main road connections that flood, flood-protecting the region’s power distribution hubs, enhancing drainage and cooling in industrial zones, or relocating extremely vulnerable facilities. These can be multi-year projects financed through the capital instruments identified. For instance, suppose the assessment found that a certain water treatment plant is at flood risk – the medium-term action is constructing flood barriers around it or moving key equipment to higher ground, funded by a combination of a national grant and a loan that the water utility will repay

via tariffs. Another example: if the Port of Esbjerg (an economic linchpin) needs climate-proofing, a financing package might involve port revenues, an EIB loan, and perhaps a PPP with a private port operator for new resilient infrastructure. This period likely coincides with tapping into the EU's 2021–2027 and 2028–2034 budget cycles, meaning Southern Denmark should secure and then utilize EU co-financing for these projects by around 2025–2030.

- *Public-private financing models:* Start implementing innovative financing models. For example, issue a regional resilience bond to raise capital for a bundle of projects (the bond could be marketed highlighting Southern Denmark's climate adaptation program, appealing to ESG-focused investors). Alternatively, launch at least one pilot PPP – perhaps on a new piece of critical infrastructure like a “smart grid initiative” where a private firm builds a more weather-resilient power storage system and the cost is recouped through energy savings and reliability payments from the grid operator. The medium term is a proving ground for such models, and successes or failures will teach lessons. It's important to ensure regulatory support here: e.g. if a PPP delivers more reliable power, the energy regulator should allow the costs to be recovered via rates.
- *Encourage private sector adaptation:* Through the medium term, implement incentive schemes for the broader private sector. This could take the form of a resilience grant program for SMEs – small matching grants or low-interest loans to help businesses elevate machinery, install flood barriers, or improve cooling in heat-prone workplaces. A portion of EU Regional Development Funds or national regional aid could be allocated for this, branding it as a climate adaptation competitiveness program (keeping businesses running in face of climate stress is an economic goal). Likewise, consider tax incentives: for instance, allow accelerated depreciation or tax credits for companies that invest in climate adaptation measures, lowering their tax burden in the short run as a reward for making climate-resilient capital expenditures. These financial incentives can significantly boost private investment. The uptake of these measures should be monitored – if few companies use them, adjust the approach (perhaps the issue is awareness, which means coupling incentives with technical advisory services to businesses).
- *Strengthen governance and policy:* By mid-decade, aim to have stronger policies mandating resilience. For example, update building codes to require that critical facilities (hospitals, telecom centers) are built or retrofitted to withstand projected climate extremes. Ensure that utility regulators formally incorporate resilience metrics: a water company could be required to maintain service in a 100-year storm, and be evaluated on that. While this is not a direct financial instrument, it drives financing by making adaptation investments non-optional. Utilities will then budget for them as part of compliance. In tandem, emergency management protocols and training should be enhanced, potentially funded by national civil protection budgets, to ensure that even if some failures occur, response is effective (a resilient system is not only about hard infrastructure but also the “software” of crisis response).
- *Leverage regional cooperation:* Southern Denmark can also look outward in the medium term – cooperating with other regions or countries on financing resilience. For instance,

join forces with other North Sea regions to lobby for a dedicated EU resilience fund or to set up a regional insurance pool for storm impacts. Such broader initiatives could bring additional resources or risk-sharing to the table by the end of this period, reinforcing what the region can do alone.

3. Long-Term (10+ years): Integrated and adaptive resilience Financing. Looking a decade and beyond, the strategy aims for integration and foresight – resilience financing becomes part of regular investment cycles, and the region stays proactive as risks evolve:
 - *Lifecycle funding and renewal*: Critical systems require ongoing investment, not a one-off effort. The long-term strategy envisions that every time infrastructure is replaced or upgraded at end-of-life, it is done to climate-resilient standards and financed accordingly. For example, if in the 2030s a major bridge or sewage plant is due for renewal, it's automatically planned with climate projections in mind and financing is arranged (via bonds, PPP, or budget) to build it to those specifications. This creates a continuous pipeline of resilience investment where financing needs are predictable and spread out over time, avoiding both the “too late” and “too sudden” pitfalls.
 - *Dynamic adaptation pathways*: Adopt a financing approach that supports “adaptation pathways,” meaning it's flexible to ramp up or adjust as climate science updates. For instance, if sea level rise accelerates more than expected by 2040, Southern Denmark might need to upgrade coastal defenses sooner or to a higher level. The financing strategy should have contingency for that – possibly a mix of savings in the resilience fund and the ability to issue additional bonds or secure emergency EU funds. Essentially, maintain financial agility. One idea is to keep debt capacity or bonding authority in reserve for climate contingencies, rather than using up all borrowing room on non-climate projects. Also, pricing climate risks into long-term capital planning (using tools like scenario analysis) will help avoid stranded assets and ensure money isn't wasted on things that climate impacts will render obsolete.
 - *Private sector mainstreaming*: By this stage, the goal is that private companies and utilities independently prioritize resilience because it makes business sense and is demanded by stakeholders. Banks might incorporate climate resilience into lending criteria (businesses that lack adaptation plans might face higher loan interest or insurance costs), creating a market-driven push for investment. The role of public finance can then gradually shift to filling gaps (e.g. protecting assets that are critical but not profitable, like certain public goods) and to subsidizing the most vulnerable. Weaning off heavy public subsidies is possible if the private sector fully takes up its role – for example, if insurers heavily incentivize or even require certain protective measures for coverage, companies will invest their own funds. The public sector in long-term might act more as an enabler and regulator, with direct financing focused on truly public-interest or equity aspects.
 - *Next-generation instruments*: Explore and utilize advanced financial instruments that may emerge. For instance, by the 2030s, there could be robust markets for resilience credits or adaptation outcome swaps. If metrics improve, perhaps cities could trade “resilience bonds” where investors get paid based on reduction in climate risk indices. While speculative now, staying abreast of financial innovation will ensure Southern

Denmark can benefit from any tools that provide cheaper capital or better risk sharing. Insurance markets might also evolve – we may see climate risk insurance pools at the EU level, or new parametric products for municipalities. The strategy should periodically reassess the landscape of instruments (e.g. every few years via that Critical Infrastructure Resilience Council or similar forum) and be ready to pilot promising options.

- *Human and social capital:* Long-term resilience funding isn't just about hard cash; it's also about human capital. Investing in the education and training of the next generation of engineers, planners, and emergency managers in climate resilience will pay financial dividends by leading to cost-efficient solutions and avoiding costly mistakes. Part of the strategy could include funding university programs or vocational training focused on climate-proof infrastructure management. Over decades, this builds a workforce for whom considering climate risk is second nature – effectively reducing the incremental cost of resilience because it's embedded in standard practice.

Policy and Governance Recommendations

Southern Denmark faces increasing climate risks, notably storm surges and sea-level rise in coastal areas such as Esbjerg and the Wadden Sea. To ensure resilience, the region requires coordinated action across governance levels, private sector investment, and knowledge-driven innovation

At the epicenter of horizontal policy and governance interventions lies the need for the development and fostering of integrated financing mechanisms. The region should seek to establish regional climate investment platforms pooling EU, national, municipal, and private capital. In addition, blended finance models that reduce risk for private investors and safeguard green innovation are of high priority. Having said that, the region will benefit from strengthening cross-Sector Partnerships, through formalizing long-term collaboration agreements between municipalities, universities, and industry clusters to accelerate pilot projects. A joint innovation lab focused on climate resilience can further support public-private knowledge transfer.

The foundation for climate resilience in Southern Denmark also requires developing a comprehensive regional data hub that centralizes climate, hydrology, and socio-economic impact data related to storm surges. This hub must ensure open access for all stakeholders, creating transparency and enabling informed decision-making across sectors. To maximize effectiveness, the region should align with established EU knowledge platforms such as Copernicus and Horizon Europe projects, facilitating continuous learning and benchmarking against best practices throughout Europe.

Effective climate adaptation demands coordinated governance structures that bridge multiple administrative levels. Southern Denmark should establish a "Resilience Board" that creates formal linkages between local municipalities, the Region of Southern Denmark, national authorities, and EU institutions. This governance framework must be inherently adaptive, incorporating flexible project planning cycles spanning from 2025 to 2050 while maintaining regular monitoring mechanisms and meaningful citizen input to ensure democratic legitimacy and community buy-in.

Public Authorities (Municipality, National, EU)

Public authorities at municipal, national, and EU levels bear primary responsibility for storm surge barrier planning and implementation. The immediate priority involves finalizing both technical specifications and financial arrangements for Phase 1 short-term interventions and Phase 2 long-term infrastructure

development. These barriers must incorporate multifunctional design principles that serve transportation needs, recreational opportunities, and biodiversity enhancement beyond their primary flood protection function.

Investment planning requires publishing comprehensive phased roadmaps for 2025, 2030, and 2050 that strategically integrate EU Cohesion Funds, Denmark's national climate budget, and regional development resources. Authorities should develop innovative procurement models that actively incentivize low-carbon construction methods and nature-based solutions. Additionally, regulatory clarity becomes essential through establishing legal frameworks for land-use allocation related to storm surge defenses and streamlining permitting processes for multifunctional coastal infrastructure to minimize project delays.

Private Sector (Industry, Enterprises, Investors)

The private sector's involvement spans financing, corporate engagement, and blue economy development. Financial innovation should focus on developing green bonds and specialized climate resilience funds specifically tailored to coastal defense projects. Insurance-linked instruments such as catastrophe bonds offer mechanisms for sharing storm surge risks across broader financial markets, reducing the burden on individual stakeholders.

Corporate engagement strategies should incentivize industry co-investment in protective infrastructure that simultaneously secures industrial zones and critical energy hubs. Small and medium enterprises require targeted support to develop adaptation technologies including advanced water pumping systems and resilient construction materials. The tourism and blue economy sectors present opportunities for promoting investments in sustainable harbor and tourism facilities that integrate flood protection with economic development, creating dual-purpose infrastructure that serves both protective and commercial functions.

Knowledge Institutions

Academic and research institutions play a crucial role in applied research, knowledge transfer, and public education. Research priorities should include conducting comprehensive scenario-based modeling of Wadden Sea ecosystem responses to proposed storm surge barriers, ensuring environmental considerations remain central to planning decisions. Support for applied research and development on multifunctional infrastructure that combines traditional grey infrastructure with nature-based green solutions will drive innovation in coastal protection.

Knowledge transfer mechanisms must systematically collect and disseminate lessons learned from international best practices, particularly drawing from successful examples like the Netherlands' Delta Works program. Providing open training programs for public officials and private sector engineers in adaptive coastal management builds local capacity and expertise. Citizen education initiatives, developed in partnership with municipalities, enhance public understanding of climate risks and build community support for necessary adaptation measures.

The transformation toward climate resilience follows a structured timeline with clear milestones. By 2025, Southern Denmark must establish essential financing mechanisms, complete Phase 1 barrier planning, and launch the regional data hub infrastructure. The 2030 target involves operationalizing public-private investment partnerships, implementing multifunctional harbor and flood protection designs, and expanding international knowledge exchange networks. By 2050, the region aims to achieve

a fully integrated, adaptive, and resilient coastal defense system supported by strong public trust and effective shared governance across all stakeholder groups.

A climate-resilient Southern Denmark ultimately depends on coordinated governance structures, innovative financing mechanisms, and evidence-based decision-making processes. By leveraging strategic partnerships between public authorities, private investors, and knowledge institutions, the region can effectively safeguard its vulnerable coastal zones while simultaneously fostering sustainable economic opportunities that benefit local communities and contribute to broader regional development goals.

10.0 CS8 Torbay/Devon (UK)– Innovation Package

10.1 Overview of the Case Study

Torbay, located in South Devon on the southern coast of the United Kingdom, is highly exposed to multiple climate-related hazards. Its coastal towns, critical infrastructure, and natural assets face risks from sea-level rise, storm surges, riverine flooding, and extreme rainfall. These hazards interact with socio-economic vulnerabilities such as ageing infrastructure, reliance on tourism, and pockets of social deprivation, creating a complex risk landscape. Beyond physical hazards, climate change poses cascading risks to health, water supply, biodiversity, and critical infrastructure systems, including transport, energy, and telecommunications.

The ARSINOE project chose Torbay as a case study because of its integrated climate risks and the opportunity to demonstrate how multi-sectoral innovations and governance reforms can build resilience in a coastal-urban system. The Living Lab process engaged Torbay Council, the Environment Agency, local water and energy utilities, transport authorities, business associations, and civil society. Supported by the Systems Innovation Approach, the Climate Innovation Window, and the Open Tenders for Innovations framework, stakeholders co-created innovation pathways. These are structured into four key sectors: Flood Risk Management, Health & Social Resilience, Critical Infrastructure & Utilities, and Governance & Decision-Support Tools.

10.2 Sectors

Flood Risk Management

Sectoral Goals

The main goal of this sector is to reduce the risks of coastal, riverine, and pluvial flooding in Torbay through an integrated set of measures that combine grey infrastructure, nature-based solutions, and digital decision-support. Flooding is the most pressing hazard for the region, regularly disrupting transport, damaging property, and posing threats to life and economic stability. Reducing flood risk is therefore fundamental to ensuring the resilience of both local communities and critical infrastructure.

A second goal is to embed adaptive flood management into long-term urban planning. This means moving away from reactive emergency responses towards anticipatory strategies that integrate climate projections, ecosystem services, and community-based preparedness. By mainstreaming resilience into planning processes, Torbay can protect its socio-economic fabric and reduce long-term costs.

Implementation Timeline & Milestones

By 2030, pilot projects will prioritise upgrading existing sea walls and drainage systems, while also testing innovative nature-based solutions such as wetland restoration, green roofs, and permeable surfaces. Digital flood forecasting platforms will be deployed, enabling early warnings for communities and

businesses. Community-based preparedness campaigns will also be initiated to build awareness and capacity.

Between 2030 and 2050, large-scale floodplain restoration, managed realignment of vulnerable coasts, and expansion of nature-based drainage systems will be undertaken. Smart infrastructure, such as adaptive barriers and automated pumping systems, will be integrated into flood defences. By mid-century, Torbay aims to operate with a fully adaptive flood risk management system that balances engineered protections with ecological resilience.

Innovations in Focus

Innovations include hybrid flood defences that combine traditional barriers with ecological restoration. Digital forecasting systems integrate meteorological, hydrological, and social data to provide real-time flood warnings. Adaptive infrastructures such as modular seawalls and automated drainage systems offer flexible responses to extreme events.

Nature-based solutions, including wetlands, permeable pavements, and green roofs, reduce runoff and provide co-benefits for biodiversity and recreation. Together, these innovations represent a shift from rigid defences to flexible, multi-functional systems that reduce risks while enhancing ecological and social value.

Barriers & Enablers

Political barriers include fragmented responsibilities between local councils, national agencies, and private infrastructure owners. However, UK flood policy and national adaptation programmes provide strong enabling conditions. Economically, high upfront costs for flood defences are a barrier, but avoided damages and national funding programmes incentivise action.

Social barriers include limited public awareness of flood risks and resistance to relocation in managed realignment schemes. These can be mitigated through participatory planning and compensation mechanisms. Technologically, integrating data from different sources is challenging, but advances in digital platforms are enabling progress. Legally, complex planning procedures can delay projects, though reforms to streamline adaptation approvals are underway.

Financial Instruments

Short-term financing will come from the UK Flood and Coastal Resilience Innovation Programme and EU structural funds available during transition. Local authorities will also leverage municipal bonds to finance pilot projects. Medium-term financing will include PPPs and insurance-backed investments for large-scale defences.

In the long term, resilience bonds, catastrophe insurance pools, and payments for ecosystem services will provide sustainable financing. By linking financial instruments to avoided damages and ecological co-benefits, Torbay can stabilise long-term investment flows.

Policy & Governance Recommendations

Policy reforms should prioritise integrating flood risk projections into statutory planning, ensuring that new developments avoid high-risk zones. National policies should provide clear frameworks for managed realignment and nature-based solutions, supported by subsidies and legal certainty. Legal reforms should also streamline permitting for resilience projects.

Governance recommendations include creating permanent multi-stakeholder councils for flood risk management. These councils should include local authorities, utilities, businesses, and communities to coordinate investments and manage trade-offs. Participatory platforms should empower communities to shape decisions, ensuring legitimacy and accountability. Transparent monitoring systems should also make flood risk data publicly accessible.

Health & Social Resilience

Sectoral Goals

The main goal of this sector is to strengthen health systems and social resilience in the face of climate hazards. Flooding, heatwaves, and extreme weather events pose risks to physical health, mental wellbeing, and social stability in Torbay. Vulnerable groups, including the elderly, low-income households, and people with pre-existing health conditions, are disproportionately affected. Protecting these populations is central to equitable resilience.

A second goal is to embed health considerations into climate adaptation planning. This requires integrating health data, social vulnerability assessments, and resilience measures into urban planning and emergency response. By linking health and climate policies, Torbay can build a holistic resilience framework that protects both communities and ecosystems.

Implementation Timeline & Milestones

By 2030, pilot projects will focus on establishing early-warning systems for heatwaves and floods that integrate health risk data. Health services will be trained to respond to climate-related emergencies, and public campaigns will raise awareness of health risks. Social resilience projects, such as community hubs and peer support networks, will also be initiated.

Between 2030 and 2050, health infrastructure will be climate-proofed, including upgrades to hospitals and care facilities. Climate-health data platforms will be institutionalised, allowing real-time monitoring of risks and vulnerabilities. By mid-century, health and social resilience will be fully embedded into adaptation planning, ensuring systemic protection of communities.

Innovations in Focus

Innovations include integrated climate-health early-warning systems that link meteorological data with health indicators. Climate-proof hospital designs and resilient supply chains ensure continuity of care. Community-based innovations such as resilience hubs and peer support networks strengthen social capital.

Digital health monitoring platforms enable the integration of real-time data into planning and emergency response. Together, these innovations link physical infrastructure with social systems, creating comprehensive resilience.

Barriers & Enablers

Political barriers include the siloed nature of health and climate policy. However, the UK's NHS Net Zero and adaptation strategies provide enabling conditions. Economically, health adaptation projects face funding gaps, but cost-benefit analyses show high returns in avoided healthcare costs.

Social barriers include limited public awareness of climate-health links, but education campaigns and participatory initiatives provide enabling conditions. Technologically, integrating health and climate data is challenging, though digital platforms are advancing. Legally, health and adaptation frameworks are not fully aligned, but reforms can bridge this gap.

Financial Instruments

Short-term financing will rely on NHS adaptation funds, local authority budgets, and UK resilience programmes. Medium-term financing will include PPPs for health infrastructure upgrades and insurance products for climate-health risks.

In the long term, social impact bonds and resilience funds will finance community-based resilience projects. By embedding health adaptation into financial systems, sustainable funding for vulnerable groups can be secured.

Policy & Governance Recommendations

Policy reforms should embed climate-health risks into statutory planning and NHS adaptation strategies. National policies should mandate integration of health data into climate resilience planning. Subsidies should support climate-proofing of hospitals and care facilities.

Governance recommendations include creating local climate-health councils to coordinate between health services, local authorities, and community groups. Participatory governance should empower vulnerable groups to shape adaptation strategies. Transparent data systems should integrate climate and health indicators, supporting evidence-based policy.

Critical Infrastructure & Utilities

Sectoral Goals

The goal of this sector is to increase the resilience of critical infrastructure systems in Torbay, including energy, water, transport, and telecommunications. These systems are highly interconnected, and disruptions in one sector often cascade into others. Strengthening resilience is therefore essential to maintaining the functioning of society and the economy.

A second goal is to modernise infrastructure systems through digitalisation, redundancy, and decentralisation. By creating flexible and adaptive systems, Torbay can reduce vulnerability to shocks and enhance long-term sustainability.

Implementation Timeline & Milestones

By 2030, pilot projects will focus on upgrading vulnerable assets such as water treatment plants, power substations, and transport nodes. Redundancy measures, such as backup power systems and alternative transport routes, will be introduced. Digital monitoring platforms will be deployed to detect risks in real time.

Between 2030 and 2050, large-scale infrastructure modernisation will be undertaken. Decentralised energy systems, smart grids, and resilient transport networks will be fully integrated. By mid-century, Torbay's infrastructure will operate as an adaptive, flexible system capable of withstanding compound risks.

Innovations in Focus

Innovations include smart grids, resilient water supply systems, and digital infrastructure monitoring platforms. Decentralised energy systems, such as community microgrids, enhance resilience and sustainability. Redundant transport systems and alternative supply chains reduce vulnerability to disruption.

Complementary innovations include cross-sectoral risk assessment platforms that identify cascading vulnerabilities. Together, these innovations strengthen the resilience of critical systems.

Barriers & Enablers

Political barriers include siloed infrastructure governance, but UK resilience frameworks provide enabling conditions. Economically, modernisation requires high investment, but cost-benefit analyses show strong returns. Social barriers include limited awareness of infrastructure interdependencies, though participatory platforms can build understanding.

Technologically, integration across sectors is complex, but advances in digitalisation enable progress. Legally, regulatory frameworks lag behind technological developments, but reforms can bridge this gap. Environmentally, climate change urgency provides momentum for action.

Financial Instruments

Short-term financing will come from UK infrastructure resilience funds and local authority budgets. Medium-term financing will involve PPPs for infrastructure upgrades and insurance products for risk-sharing.

In the long term, green bonds, resilience bonds, and sustainability-linked loans will finance systemic modernisation. These instruments embed resilience into financial markets, ensuring long-term investment.

Policy & Governance Recommendations

Policy reforms should embed resilience criteria into infrastructure regulation and investment frameworks. National strategies should mandate climate-proofing of infrastructure assets. Legal frameworks must support decentralisation and digitalisation.

Governance recommendations include creating cross-sectoral resilience councils that bring together utilities, transport authorities, and regulators. Participatory platforms should involve communities in infrastructure planning. Transparent data systems should map vulnerabilities and monitor progress.

Governance & Decision-Support Tools

Sectoral Goals

The goal of this sector is to strengthen governance capacity through decision-support tools that integrate climate, infrastructure, and social data. These tools enable evidence-based planning, investment, and emergency response. By embedding decision-support into statutory processes, Torbay can ensure that resilience and sustainability are systematically considered.

A second goal is to institutionalise participatory governance processes, ensuring legitimacy and inclusivity. By combining technical tools with participatory platforms, governance can balance accuracy with social acceptance.

Implementation Timeline & Milestones

By 2030, pilot DSS platforms will be deployed, integrating climate projections, infrastructure vulnerabilities, and social indicators. Participatory governance platforms will also be tested. By 2050, DSS will be institutionalised across Torbay's governance systems, guiding investment and planning.

Between 2030 and 2050, DSS will expand to integrate financial and risk data, enabling insurers and investors to incorporate resilience metrics. By mid-century, DSS will be standard in Torbay's governance.

Innovations in Focus

Innovations include digital twins, integrated modelling platforms, and participatory decision-support systems. ESG-aligned metrics enable integration with financial systems. Together, these innovations create governance that is both evidence-based and participatory.

By linking predictive modelling with stakeholder engagement, DSS platforms create resilient governance ecosystems.

Barriers & Enablers

Political barriers include fragmented governance and competing mandates, but UK climate policy provides enabling conditions. Economically, DSS benefits are diffuse, but avoided losses and efficiency gains create incentives. Social barriers include mistrust of digital tools, but participatory processes can build acceptance.

Technologically, interoperability is a challenge, but open standards provide solutions. Legally, data governance frameworks are underdeveloped, but reforms can address this. Environmentally, climate urgency provides momentum.

Financial Instruments

Short-term financing will come from UK innovation funds and local budgets. Medium-term financing will involve PPPs and joint investments by utilities and municipalities.

In the long term, sustainability-linked finance tied to resilience metrics will embed DSS into financial systems. Insurers and investors will increasingly use DSS outputs in risk assessments.

Policy & Governance Recommendations

Policy reforms should mandate DSS use in planning and investment. National adaptation strategies should require integration of DSS in governance. EU-UK collaboration post-Brexit can also support knowledge sharing and funding alignment.

Governance recommendations include institutionalising Living Labs as permanent advisory platforms. Data governance frameworks must clarify responsibilities and ensure transparency. Standardisation of DSS methodologies across regions will ensure interoperability. Regulators should embed DSS outputs into risk assessments, aligning governance with financial systems.

11.0 CS9 Sardinia– Innovation Package

11.1 Overview of the Case Study

The Sardinian Case Study (CS9), led by AGRIS, addresses a complex set of interconnected climate resilience challenges within the region of Southern Sardinia, Italy. The region, which includes the metropolitan area of Cagliari and the province of South Sardinia, covers 32.3% of the island's surface and 47.7% of its population. It experiences a typical Mediterranean climate with warm, dry summers and mild winters, and is classified as semi-arid with an average annual rainfall of approximately 450 mm, concentrated in autumn and early spring.

The primary challenge for Sardinia is to enhance and stabilise sustainable and resilient food production in the face of climate change and limited production inputs such as land, water, and energy. Staple food production, particularly durum wheat, is projected to be severely impacted by increasing air temperatures, decreasing and erratic rainfall, and land degradation. This threatens the stability of local food chains, affecting both the primary agricultural sector and downstream activities like milling, bread-making, and pasta-making, potentially leading to food insecurity and social instability. Water scarcity is a critical issue, with climate change expected to increase the demand for irrigation, leading to groundwater depletion and salinisation.

The innovation pathways developed for CS9 aim to support a transition towards a more adaptive and climate-resilient agricultural and food system. The overarching future vision for Sardinia, with a time horizon of 2050, is to ensure food security, promote sustainable food production based on local chains, stimulate sustainable food processing, and encourage healthy and sustainable food consumption habits. This involves optimising water and land management for agricultural use, especially for durum wheat, to preserve soil fertility and ensure balanced water resource management for all sectors.

These pathways were co-developed with local stakeholders through a participatory Living Lab process, which followed a Systems Innovation Approach (SIA). The SIA methodology focuses on integrating multi-faceted technological, digital, business, governance, and environmental aspects with social innovation to develop adaptation pathways. The innovations included in this package are a blend of technological,

social, and institutional solutions. Many identified milestones for Sardinia do not solely depend on new technologies but also on policy measures. The distribution of innovations across milestone years (e.g., Present-2030, 2040-2050) reflects stakeholder prioritisation rather than a rigid implementation plan. Innovations marked in green are funded within the ARSINOE framework, while those in red indicate an innovation gap.

ARSINOE contributes to the development of these innovation packages by financing selected innovations through dedicated open calls. Four innovations are currently being tested in the Sardinian case study: Innovative biostimulants for plants (CONCIMI BIOLOGICI), smart agriculture technologies (Lobelia-AgroClimate), Integrating Rain harvesting and solar pumping (SOLAR PUMPING), and a participatory certification system (COCCOI IGP).

The Systems Innovation Approach (SIA) was specifically applied to the Sardinian Case Study (CS9) as a comprehensive methodological framework to address complex, interconnected climate resilience challenges. This involved a highly participatory process through Living Labs, engaging quadruple helix stakeholders from academia, the private sector, public authorities, and civil society.

At the initial stage, stakeholders co-defined the central challenge: "How to enhance and stabilize sustainable and resilient food production under conditions of climate change and limited production inputs, such as land, water, energy?". This involved a detailed understanding of the regional context and main issues. Through a visioning exercise, stakeholders co-developed a "Sardinia 2050" vision, aiming for food security, sustainable local food chains, processing, and consumption habits, alongside optimised water and land management. This built a shared positive future, moving beyond current limitations. A portfolio of key innovations—technological, social, and institutional—was co-designed to achieve this vision. This included four specific innovations being tested in CS9: innovative biostimulants, smart agriculture technologies, integrating rain harvesting and solar pumping, and a participatory certification system. The process concluded with identifying barriers hindering implementation and enablers supporting it, often utilising the PESTLE framework. Sardinia also underwent a governance assessment to understand how existing governance supports or restricts resilience development, focusing on durum wheat production and its local chains.

11.2 Sectors

Sustainable Agriculture

Sectoral Goals

The main challenge in sustainable agriculture is the increasing threat to staple food production and yield stability, particularly for durum wheat, due to climate change impacts such as increasing temperatures, decreased and erratic rainfall, and land degradation. The region faces projected average yield declines of 16-19% for durum wheat in southern growing areas, exacerbated by EU decoupling policies and low commodity prices. This necessitates innovative approaches to preserve soil fertility, optimise water and nutrient inputs, and adapt crop management practices.

Implementation Timeline & Milestones

The implementation of the sustainable agriculture innovation pathway is structured to deliver progressive impacts from 2030 to 2050, gradually transitioning the regional farming sector towards climate-smart and carbon-neutral production. In the short term, by 2030, priority actions focus on stabilising and improving food production (MS1) through the uptake of digital decision-support systems such as , the introduction of innovative biostimulants (CONCIMI BIOLOGICI), and the spread of

conservative agronomic practices. These will be complemented by the deployment of precision farming equipment (e.g. driver-assisted tractors, precision drills) and the development of soil ecosystem service monitoring protocols to establish reliable baselines.

By 2040, the emphasis will shift towards enhancing the competitiveness of farms (MS8) and ensuring hydrogeological safety (MS12) through regulatory reforms, targeted RDP incentives, and investments in training and advisory services. These measures will embed climate risk management, strengthen resilience to drought and extreme weather, and improve long-term productivity.

By 2050, the sector is expected to achieve carbon-neutral agriculture (MS9) through the full integration of regenerative practices, ecosystem-based payments, and circular nutrient flows, completing the transformation towards a resilient, low-emission, and competitive agricultural system aligned with Sardinia's sustainability vision.

Innovations in focus

The innovation pathway for sustainable agriculture focuses on several key areas, spanning from present to 2050. It incorporates both technological and social innovations to achieve resilience.

- **Smart agriculture technologies (Lobelia-AgroClimate)**, funded by ARSINOE, enable continuous monitoring of soil and water parameters, allowing farmers to adjust practices and reduce the use of water, pesticides, and fertilisers. There is also an emphasis on new seed varieties and fertilisers, conservative agronomic practices like minimum tillage and sod seeding, and remote sensing technologies to optimise irrigation and nutrient inputs.
- ARSINOE also supports the use of **innovative biostimulants for plants (CONCIMI BIOLOGICI)**, derived from protein hydrolysates of slaughterhouse waste, to preserve and enhance long-term soil fertility.

Barriers and Enablers

Several barriers and enablers influence agricultural innovation adoption. Economic barriers include limited purchasing power among farmers, high costs of new technologies, and preferences for more profitable crops, while social and cultural resistance stems from general inertia towards innovations among both producers and consumers, cultural resistance to change particularly in lower-education classes, and reluctance to adopt new nitrogen fertilizers from animal by-products due to established habits. Some farmers also refuse aided irrigation for rainfed crops, considering it unnecessary. Technological barriers encompass low average knowledge levels, limited access to new technologies, and potential transmission problems from technological devices such as mobile networks in rural areas. Additionally, persisting in unfavorable growing conditions due to climate change can distract farmers from sowing activities.

However, several enablers can facilitate adoption. Economic enablers focus on low interest rates for capital investments and implementing innovative solutions, while social and cultural enablers include investments in education and enhanced access to social communications to overcome resistance, with ARSINOE's demonstrative actions aiming to convince farmers of new approaches' effectiveness. Technological enablers emphasize data availability, disruptive technologies, processes, and low-cost technology innovation. Legal enablers involve incentives and supporting regulations for sustainable practices such as conservative and precision agriculture, use of circular economy amendments and fertilizers, alongside soil protection regulations. Environmental enablers promote long-term soil fertility

conservation and restoration, low-input agronomic practices like minimum tillage and sod seeding, and enhanced information about production sustainability.

Financial Instruments

Implementing climate-resilient sustainable agriculture in Sardinia requires tailored financial tools and funding sources. A combination of European Union funds, national/regional subsidies, and private investment is essential to support farmers and stakeholders in adopting the innovations and practices described above. Key financial instruments include:

- **Common Agricultural Policy (CAP) Funds:** The CAP provides significant support through its Rural Development Programmes (RDPs). In Sardinia, the RDP co-finances grants for sustainable farming practices and farm modernization. These funds support precision agriculture equipment, water-saving irrigation systems, and soil conservation measures. For example, Sardinia's RDP has funded cooperative projects for climate change adaptation in farming. At least 30% of RDP funding is reserved for environmental and climate-related actions, such as agri-environmental schemes paying farmers to adopt minimum tillage, crop rotation, or organic farming. The RDP also supports risk management measures, including crop insurance schemes and mutual funds, to buffer farmers against droughts or extreme weather losses, aligned with calls to expand farm insurance coverage.
- **Public Grants and subsidies:** Beyond the CAP, regional authorities can deploy grants or low-interest loans to encourage innovation uptake. Innovation grants (such as those from ARSINOE's own funding calls) help pilot new technologies like smart agriculture sensors or biostimulants. Subsidies can lower the cost of biostimulants and new seed varieties, making it easier for farmers to try these climate-resilient inputs. Moreover, payment for ecosystem services schemes are envisioned by 2050 (e.g. paying farmers for soil carbon sequestration or maintaining landscape features) as part of achieving carbon-neutral agriculture. These ecosystem-based payment programs would financially reward farmers for delivering environmental benefits, creating a new income stream for climate-friendly practices.
- **Loans and blended finance:** Farmers and agri-businesses may access credit to invest in infrastructure (e.g. rainwater harvesting systems or solar pumps for irrigation). The European Investment Bank (EIB) and national banks play a role by offering soft loans or guarantee schemes for climate adaptation projects. The EIB, for instance, supports agriculture via direct loans, guarantees, and financing of rural infrastructure. Blended finance mechanisms can combine public funds with private capital, for example, using RDP grants or guarantees to attract bank loans for purchasing precision machinery. Such instruments reduce the risk for private lenders and help mobilize additional investment into the agricultural sector.
- **Insurance and risk transfer products:** To enhance resilience, financial instruments also include insurance solutions. Crop insurance (with government support or premium subsidies) can compensate yield losses due to drought or extreme weather, encouraging farmers to invest in higher-risk innovative crops. At a larger scale, innovative instruments like catastrophe bonds or climate risk insurance pools could provide rapid funds in disaster years. These risk-transfer tools, supported by public-private partnerships, ensure that farmers can recover quickly from

climate shocks. EU policymakers are encouraging Member States to launch such new financial instruments in their CAP Strategic Plans to better protect farmers from climate risks.

In summary, the sustainable agriculture pathway will leverage a mix of public funding (CAP/RDP grants for innovation and environmental services), private financing (loans and investments facilitated by guarantees), and market-based instruments (insurance and carbon finance). These financial instruments are crucial enablers, lowering the economic barriers for farmers and aligning economic incentives with climate-resilient farming. By 2040, targeted RDP incentives and regulatory reforms are expected to improve farm competitiveness, and by 2050, schemes like ecosystem payments and carbon credits will help achieve carbon-neutral, regenerative agriculture. All these instruments work together to ensure that farmers have the necessary financial support and risk protection to adopt sustainable practices at scale.

Policy & Governance Recommendations

Effective implementation of innovation pathways in Sardinia requires targeted policy and governance interventions. The overall strategy involves creating a supportive regulatory environment that incentivises sustainable practices and addresses existing market failures.

To ensure the successful implementation and long-term impact of the Innovation Packages developed under the project, a coherent policy and governance framework is needed to connect technological and organisational innovations with enabling institutions, incentives, and long-term planning. Overarching priorities should focus on strengthening cross-sectoral governance, mobilising blended finance, and building the institutional capacity to integrate innovations into existing regional development plans. The regional government should establish a multi-stakeholder innovation coordination platform, bringing together public authorities, research institutions, cooperatives, and farmers' organisations to steer the rollout of innovations, monitor their impacts, and align them with milestones such as MS1 (stabilising food production), MS7 (improving water efficiency), and MS9 (achieving carbon neutrality). Dedicated funding lines, combining resources from the Rural Development Programme (RDP), the 's cohesion funds, and private investors, should be created to de-risk investments in sustainable agriculture, local food chains, and integrated water–energy systems. At the same time, consumer awareness campaigns and educational programmes must be launched to stimulate social demand for sustainable products and practices, thereby accelerating behavioural change and fostering political support (MS5).

Within the agricultural sector, policy should prioritise the mainstreaming of climate-smart and regenerative farming practices as identified through innovations such as for digital decision support, the introduction of innovative biostimulants (CONCIMI BIOLOGICI), and the spread of conservative agronomic techniques. These measures directly support milestones on stabilising food production (MS1) and improving farm competitiveness (MS8). The regional government should adapt the RDP to provide targeted subsidies and performance-based payments for soil ecosystem services, rewarding farmers who enhance soil fertility, biodiversity, and carbon sequestration (MS12). Regulations and land tenure frameworks should be updated to remove obstacles to adopting precision farming equipment—such as driver-assisted tractors and precision drills—and to enable cooperative models that share machinery and data. The establishment of an agro-climate governance board is recommended to coordinate the deployment of innovations, monitor their performance, and align risk management planning with Early Warning Systems for climate extremes. Parallel investments in training and advisory services are crucial

to build farmers' capacity to adopt new technologies, integrate soil ecosystem monitoring protocols, and plan for climate resilience.

Local Food Chain

Sectoral Goals

The instability of durum wheat production, exacerbated by climate change, negatively affects local food chains. Sardinia currently imports durum wheat to meet demand (54,000 tons produced vs. >160,000 tons demanded), making the region vulnerable to external supply shocks and increasing greenhouse gas emissions from long-distance transport. This imbalance, if occurring in poorer Mediterranean regions, could threaten food and social security and trigger migration processes.

Implementation Timeline & Milestones

The implementation timeline for the "Local Food Chains" sector in CS9 Sardinia aims to strengthen local short chains, reduce dependence on imported durum wheat, and enhance food security.

The transition of the region's local food systems is envisioned as a phased process extending from 2030 to 2050, aiming to build resilient, transparent, and circular value chains rooted in local production. By 2030, early actions will focus on improving access to information on sustainable food (MS2), reducing food waste (MS3), and increasing local production (MS4). This will involve deploying blockchain-based traceability and participatory certification tools (as proposed for the COCCOI IGP supply chain), combined with consumer information campaigns and local public procurement schemes to boost market demand for Sardinian products.

By 2040, the focus will expand to enhancing farm competitiveness (MS8) and increasing agricultural employment (MS13). Policy support will include regional branding strategies, collective logistics and marketing infrastructures, and fiscal incentives for small producers joining certified local supply networks. These measures aim to consolidate local agri-food clusters, strengthen market positioning, and ensure fair income distribution across the value chain.

By 2050, the sector is expected to deliver fully circular and low-emission food production systems (MS11), closing nutrient loops, valorising food waste, and embedding sustainability criteria across all stages of the food chain. This will position Sardinia as a leader in resilient, climate-aligned regional food systems.

Innovations in Focus

The innovation pathway for the local food chain is designed to enhance local food production and infrastructure, supporting the "farm to fork" EU perspective.

- **The participatory certification system (COCCOI IGP)** for Pane Coccoi, which is being tested within ARSINOE. This system aims to strengthen local chains for conventional and organic staple food production. Efforts are also geared towards fostering collaboration between primary producers (farmers), first-level processors (millers), second-level processors (bakers and pasta makers), traders, and final consumers.

Barriers and Enablers

Several barriers impede the development of local food systems, including economic challenges such as low commodity prices for local products that impact profitability, along with social and cultural inertia from both consumers and producers towards adopting new practices and supporting local products.

However, multiple enablers can facilitate local food system development. Economic enablers focus on local chains that ensure income for farmers and food security for citizens while encouraging innovative agronomic techniques under sustainable agriculture and circular economy principles. Legal enablers include regulations that encourage and support agreements between different actors in the food chain. Environmental benefits arise from reduced greenhouse gas emissions due to decreased dependence on long-distance imports. Social enablers involve enhanced information about production sustainability that can drive consumer demand for local products.

Financial Instruments

Strengthening Sardinia's local food chains and reducing dependence on imports will also require supportive financial instruments. Building resilient, local "farm-to-fork" value chains involves investment in infrastructure, market development, and coordination among producers, processors, and retailers. The following financial tools are integral to this innovation pathway:

- Rural development and regional funds: Just as in farming, RDP and regional funds are directed to bolster local food systems. Sardinia's RDP provides support for short supply chains and local markets, helping fund projects that connect farmers to consumers more directly. For instance, grants can co-finance the creation of local processing facilities (mills, bakeries) or storage and logistics centers to handle local durum wheat and other products. The RDP also encourages farmers to join quality schemes or cooperatives; in fact, it has targeted support for hundreds of farms to participate in certified quality schemes (like PDO/PGI products) and strengthen supply chain organization. Additionally, EU structural funds or regional development funds might be used to invest in food hub infrastructure and improve transportation or digital platforms that connect local producers with urban consumers.
- Financial incentives for collaboration: Policy measures by 2030 and 2040 include fiscal incentives and subsidies to encourage actors to participate in local supply networks. This might take the form of tax breaks or reduced fees for small producers, millers, or bakers who join certified local chains (such as the *Pane Coccoi* IGP participatory certification). Public procurement schemes also act as financial incentives, for example, schools, hospitals, or government canteens may receive budgetary incentives or mandates to source a percentage of food locally, guaranteeing a stable market and income for local farmers. Such procurement policies indirectly finance local production by creating secure demand. Likewise, branding and marketing support (potentially funded by regional programs) is provided to promote Sardinian products, which can increase their market value and revenue for the local chain.
- Cooperative financing and micro-credits: Many local food initiatives rely on collective action. Cooperatives or producer groups can access micro-credit programs or cooperative loans tailored to small-scale agri-food businesses. These financing programs, sometimes backed by public guarantees, help local entrepreneurs, young farmers, artisanal millers, bakers, to obtain capital for starting or expanding their operations.

- **Market-based instruments and circular economy incentives:** As the local food chain moves toward circular and low-emission systems by 2050 (e.g., recycling waste, closing nutrient loops), there may be opportunities for circular economy incentives. This could include revenue from selling by-products (like compost from food waste) or participating in carbon credit markets if the local supply chain reduces emissions. While these are emerging mechanisms, they can provide supplementary funding. Moreover, reduced transport distances (due to local sourcing) save costs and may qualify businesses for green financing (such as lower-interest loans or grants for projects that cut carbon emissions). Environmentally minded financial instruments (for example, grants for renewable energy use in food processing or for electric vehicles in food distribution) further support the economic viability of sustainable local food chains.

Policy & Governance Recommendations

For local food systems, governance reforms should aim to enhance transparency, traceability, and consumer trust, while strengthening the resilience and competitiveness of local value chains. Regional authorities should promote the use of blockchain-based traceability and participatory certification systems, as envisaged for the COCCOI IGP bread supply chain, to ensure product authenticity and reduce fraud (MS2, MS10). These digital tools should be embedded into wider strategies to increase local food production and reduce waste (MS3, MS4), supported by regional branding initiatives and local procurement policies that prioritise Sardinian products in public canteens and institutions. To institutionalise coordination, a Sardinia Sustainable Food Council could be established to align producers, processors, retailers, and municipalities in developing shared logistics systems, market intelligence platforms, and consumer awareness campaigns. This council would also monitor the progress of local food systems towards milestones such as MS11 (developing circular food production systems) and MS13 (enhancing agricultural employment), ensuring alignment with broader regional economic development objectives. Incentive mechanisms—such as tax breaks or preferential financing—should be designed to support small producers joining these digital and organisational systems, while education and dissemination actions continue to shift consumer demand towards seasonal, low-impact diets.

Water and Energy

Sectoral Goals

Water scarcity is a chronic issue in Southern Sardinia, compounded by climate change projections of increased average temperatures, longer hot and dry periods, and more intense but fewer rainfall events, leading to a reduction in total water volume. The projected increase in water required for irrigation is expected to cause groundwater depletion and salinisation, negatively affecting soil fertility. Water supply relies significantly on both surface (57%) and groundwater (43%), with agriculture consuming 46% of the withdrawn total water. The energy required to pump and distribute water for irrigation is also a major cost for the agricultural sector, projected to increase with climate change.

Implementation Timeline & Milestones

Present to 2030: The initial focus involves Integrating Rain harvesting and solar pumping (SOLAR PUMPING) an ARSINOE-funded initiative. This milestone includes creating and appropriately sizing above-ground water reservoirs to establish an irrigation system fully powered by autonomous renewable sources with green energy storage. This system is designed to enable simultaneous water storage and renewable energy generation. Concurrently, efforts are directed at optimising the use of irrigation water

during critical plant growth stages by monitoring crop vegetative state through remote sensing and utilising probabilistic weather forecasts.

2040 to 2050: The long-term pathway anticipates the full operation of irrigation systems in an "energy island" mode, powered by clean energy for both grid-connected and off-grid fields. This period will also focus on optimising the energy required for water movement, aligning with robust water-energy nexus principles. The implementation process for such innovations is gradual, allowing for continuous evaluation and adjustment over time to ensure effectiveness [ARSINOE_D6.8_CS1_040925.pdf, Section 1.1].

Innovations in Focus

The innovation pathway for water and energy aims at a rational and efficient use of these resources, focusing on sustainable management and renewable energy integration.

- **Integrating Rain harvesting and solar pumping (SOLAR PUMPING).** This innovation involves creating and sizing above-ground water reservoirs to develop an irrigation system powered entirely by autonomous renewable sources with green energy storage. This system will enable simultaneous water storage and energy generation from renewables.

Barriers and Enablers

Political and economic barriers hinder sustainable agricultural and water management initiatives, with frequent changes in government creating challenges in the effective implementation of regulations such as the Water Framework Directives, while substantial investment requirements for new energy and water infrastructure and technologies present significant economic obstacles.

However, several enablers support these initiatives. Political enablers include the European Green Deal, which provides a supportive policy framework for sustainable practices. Technological enablers emphasize data availability and low-cost technology innovation that facilitates the spread and implementation of innovations. Environmental enablers focus on long-term soil fertility conservation, low-input agronomic practices, and low greenhouse gas emissions as crucial drivers for sustainable agricultural development.

Policy & Governance Recommendations

On water and energy systems, governance efforts must accelerate the transition to resource-efficient and climate-resilient infrastructures while embedding circularity principles into agricultural production. Public investment should be directed towards the development of solar-powered pumping systems combined with rainwater harvesting, as well as smart irrigation controls to reduce losses and optimize water allocation (MS7). Building on stakeholders identified needs, a regional plan for interconnected reservoirs, aquifer recharge schemes, and water reuse infrastructure should be developed to safeguard hydrogeological stability and drought resilience (MS12). At the same time, policies must enable the emergence of farm-based renewable energy generation systems, including energy communities and in-farm hydrogen micro-generators, supported by clear regulatory pathways for permitting, grid integration, and self-consumption incentives (MS6). Establishing a cross-sector Water–Energy–Agriculture Coordination Platform within the regional administration would help harmonise planning processes, permitting procedures, and funding allocations across departments. Furthermore, irrigation consortia and farm cooperatives should be required to include climate risk assessments and energy

performance reporting as conditions for accessing public subsidies, ensuring alignment with the long-term goal of carbon-neutral agriculture (MS9).

Through this integrated policy and governance architecture, it can effectively steer the uptake of the proposed innovations, meet its ARSINOE milestones, and position itself as a European frontrunner in climate-resilient and resource-efficient agri-food systems.

12.0 Inter-case differences in maturity and specificity

Differences in the maturity and specificity of Innovation Packages across case studies are expected and reflect how ARSINOE's Systems Innovation Approach and Living Lab process progressed in each context. First, Innovation Pathways were co-created during Living Lab Workshop 3, but not all Living Labs completed the full pathway outlining within the workshop timeframe; in several cases, pathway completion and detailing continued post-workshop, depending on the capacity of Living Lab leaders and the availability of stakeholders (see ARSINOE D2.4).

Second, case studies entered the innovation-sourcing pipeline (e.g., Open Tender for Innovations) at different moments, based on their progress in defining challenges and Innovation Packages and their willingness/capacity to engage early. This staging means that some cases were “ready earlier” and therefore could identify and test concrete innovations sooner, while others were expected to develop specificity later in the project timeline.

Third, the level of concreteness depends on the availability and fit of innovations emerging from the tender/market pipeline. In some contexts, early rounds did not yield a selected innovator because applications did not sufficiently match requirements or thematic needs, which naturally delays convergence on specific implementable solutions and keeps pathways at a higher, enabling level until the pipeline improves (D5.1).

A further reason for differences in maturity across Innovation Packages is the uneven depth of governance assessment available across case studies: some case studies benefited from additional governance analysis and institutional preparation (D2.3), which naturally enables more concrete, implementation-oriented packaging (e.g., clearer decision-making responsibilities, institutional feasibility, and readiness conditions), whereas other case studies did not have the same level of governance-detail coverage at the time of reporting and therefore remain more enabling/high-level in parts of the innovation selection and implementation pathway.

13.0 IP Transferability Potential

CS1 – Metropolitan Athens

The CS1 innovation package for Metropolitan Athens demonstrates strong transferability to other Mediterranean and heat-exposed metropolitan regions, particularly where climate stressors include urban heat islands, water scarcity, energy poverty, and socio-economic inequality. Its integrated framework—combining urban greening, decentralised non-potable water reuse, energy efficiency retrofits, and heat-health early-warning systems—provides a modular template that can be adopted by cities with varying capacities. The inclusion of digital decision-support tools such as Kausal (collaborative planning), CityClimateX (micro-climate modelling), WEO (satellite-based monitoring), and MINKA (citizen science engagement) ensures adaptability across institutional contexts, as these tools standardise evidence collection, transparency, and participatory governance. This makes the package not just locally relevant but also scalable to urban areas in Southern Europe, North Africa, and even megacities in Asia experiencing similar climate pressures.

The financing architecture identified for Athens in D7.5 further reinforces its transferability. The innovation package outlines a phased financing approach: (i) early reliance on EU and national grants, Horizon Europe pilots, and technical assistance to build capacity and prepare bundled projects; (ii) scaling through blended finance platforms, public–private partnerships, and concessional loans; and (iii) long-term institutionalisation of resilience bonds, Social Climate Fund instruments, and insurance-linked products. Importantly, Athens frames financing not just as a technical matter but also as a social one, embedding equity by targeting vulnerable households through a proposed Energy Poverty Office / one-stop shop that integrates energy efficiency and cooling measures into municipal services. This approach makes the innovation package highly adaptable for cities where climate adaptation must go together with social policy, offering a replicable model for equitable urban resilience.

CS2 – Mediterranean Ports (Cyprus, Greece, Spain)

The Mediterranean Ports package offers high transferability to port cities globally that face climate risks such as sea-level rise, storm surges, and air pollution. Innovations around hybrid port infrastructure, digital emission monitoring, and energy diversification are not limited to the Mediterranean but resonate with ports worldwide, especially in the context of global shipping decarbonisation goals. The governance mechanisms tested, including stakeholder engagement and port-city integration, also provide replicable frameworks.

However, transferability requires sensitivity to differences in institutional capacity and financial access. Large EU ports may adopt these packages more readily than smaller ports in developing regions. Nevertheless, by linking financing pathways to blue economy frameworks and EU Green Deal priorities, the Mediterranean Ports package serves as a replicable model for coastal infrastructure resilience and decarbonisation.

CS3 – Main River Basin (Germany)

The CS3 innovation package is highly transferable to other river basins across Europe, particularly those struggling with multi-sectoral pressures on water resources. Its integrated approach, linking water management, agriculture, energy, and governance, provides a model for balancing competing demands under climate stress. The reliance on DSS platforms and participatory governance strengthens adaptability, as these tools can be recalibrated to different hydrological and institutional contexts.

Transferability is also supported by its compatibility with EU-level strategies and financing mechanisms. The lessons on harmonising agricultural subsidies, embedding ecological flows in energy policy, and institutionalising cross-sectoral councils can be scaled across river basins in accession countries or other transboundary systems. Adaptations may be required in contexts with weaker institutions, but the innovation pathways provide a strong blueprint.

CS4 – Ohrid & Prespa Lakes (North Macedonia, Albania, Greece)

The innovation package for the Ohrid and Prespa Lakes has significant transferability to other transboundary lake systems that face pressures from agriculture, tourism, biodiversity loss, and governance fragmentation. Its emphasis on joint governance institutions, ecosystem service valuation, and sustainable agriculture can inform management strategies in other Balkan and global freshwater systems.

Transferability is particularly relevant for UNESCO-listed or otherwise internationally significant lakes, where cross-border cooperation and ecological uniqueness create both opportunities and challenges. The combination of ecological innovations, financial instruments, and participatory governance makes this package a replicable framework for balancing conservation and development.

CS5 – Canary Islands (Spain)

The Canary Islands package is transferable to island systems worldwide that face compounded vulnerabilities from water scarcity, energy dependence, and climate change. Its innovation pathways around aquifer protection, desalination, renewable integration, and sustainable agriculture are highly relevant to other volcanic or semi-arid islands.

Transferability is strengthened by its systemic framing of the water-energy-food nexus, which is applicable beyond islands to many semi-arid regions globally. Financing innovations such as water reuse credits and renewable cooperatives also provide replicable models. Tailoring will be needed to local governance and cultural contexts, but the Canary Islands case provides a valuable template for insular and resource-scarce environments.

CS6 – Black Sea Region

The Black Sea innovation package is transferable to other large marine basins and semi-enclosed seas facing nutrient inflows, pollution, and climate-driven coastal risks. Its emphasis on integrated watershed management, coastal protection, and governance tools offers lessons for regions such as the Baltic Sea or the Gulf of Mexico. The combination of nature-based solutions, DSS, and financial mechanisms makes it broadly adaptable.

Transferability is reinforced by the governance structures proposed, including transboundary watershed councils and regional marine protection frameworks, which can be adapted to other multi-country basins. While institutional capacity may vary, the package provides a strong reference point for land-sea integration, ecological restoration, and cooperative marine governance.

CS7 – Southern Denmark

The Southern Denmark case offers strong transferability to coastal and deltaic regions vulnerable to compound flooding from sea-level rise, storms, and rainfall. Its innovation pathways around nature-based flood defences, intelligent water management, and rural-urban synergies are relevant across Northern Europe and beyond. The integration of cultural heritage protection also adds a transferable dimension for heritage-rich areas.

Transferability is supported by the emphasis on systemic resilience and cross-sectoral governance. Financing pathways that link resilience investments to avoid damages and cultural heritage value are replicable in similar contexts. With adaptation to local institutional capacity, the package provides a scalable model for flood-prone regions.

CS8 – Torbay, South Devon (UK)

The Torbay package demonstrates strong transferability to other small and medium-sized coastal urban areas facing compound climate risks. Its emphasis on flood management, health and social resilience, critical infrastructure, and DSS integration provides a holistic framework that can be applied in other UK

coastal towns and globally. The combination of technological and social innovations enhances adaptability.

Transferability is particularly strong for urban areas where socio-economic vulnerabilities interact with climate risks. While financing options may differ outside the UK, the use of resilience bonds, PPPs, and social impact financing provides models that can be replicated. The Torbay case highlights how integrated approaches can be adapted for vulnerable coastal towns worldwide.

CS9 – Southern Sardinia (Italy)

The Southern Sardinia package is highly transferable to Mediterranean and semi-arid agricultural regions facing pressures on the water-food-energy nexus. Its innovation pathways around durum wheat resilience, soil conservation, circular economy, and water-energy optimisation can be applied across Southern Europe, North Africa, and other semi-arid zones.

Transferability is reinforced by the alignment with CAP reforms, EU decarbonisation goals, and circular economy strategies, which provide scalable policy frameworks. While socio-economic contexts may differ, the emphasis on farmer cooperatives, bio-based fertilisers, and ecosystem service payments offers replicable mechanisms for resilient agricultural transitions.

14.0 Design of Financial Instruments

CS1 -Athens Metropolitan Area

This section illustrates the design of a financial instrument for Metropolitan Athens that is directly grounded on willingness-to-pay estimates and choice experiment results reported in the WP7 deliverables. The objective is to demonstrate how the quantified social value of urban greening and heat mitigation measures can be converted into a credible and investable structure, using shadow prices to justify the financing flows. The chosen instrument is a municipal green bond with a performance-linked component, issued to finance the establishment and maintenance of approximately fifty hectares of pocket parks, micro-forests, green roofs and cool surfaces across heat-stressed districts of the city. This worked example is not only a theoretical exercise in applying willingness-to-pay estimates and shadow prices, but also fully consistent with the innovation packages identified for Metropolitan Athens in the WP6 deliverable. In the Athens case study, financial pathways are integrated into each of the priority sectors, including water, energy, urban greening and infrastructure, and heat risk management. Among the instruments explicitly listed for these sectors are municipal green bonds, resilience bonds, and blended public-private partnerships. These were proposed as central vehicles to move beyond reliance on grants and subsidies and to mobilise larger, more sustained flows of capital into climate adaptation and urban resilience measures. In the urban greening and heat sector specifically, the innovation package stresses the need for scaling up small-scale pilots such as pocket parks and green corridors into city-wide infrastructure programmes, which requires capital market instruments like green bonds to complement EU and national funds.

The programme is assumed to require around sixty million euros in upfront capital expenditure and three million euros annually in operations and maintenance. Around three hundred thousand residents are expected to directly benefit from these interventions by living, working or studying in proximity to them.

The key step is to translate the expected improvements into monetary terms using the WTP estimates of WP7 deliverables. Deliverable 7.3 (D7.3) provides Athens-specific willingness-to-pay values for four relevant categories affected by urban greening: air pollution (€67.67 per person per year), mortality risks from heat (€85.65), living and working conditions (€92.84), and traffic and noise (€42.50). Summed

together, these categories represent an annual value of €288.66 per person if all impacts were fully resolved. In practice, greening is assumed to close about a quarter of the gap, a conservative improvement fraction of 25 percent. Applying this factor reduces the annual benefit to around €72.17 per person. For the three hundred thousand residents in the serviced areas, this corresponds to an aggregate annual benefit of roughly €21.65 million. Even if the programme performs weaker in its early years, for example by achieving only twenty-two percent of the potential impact while new plantings establish, the annual benefit will still reach approximately €19.05 million.

When comparing benefits to costs over a twenty-year horizon, the advantage of the programme becomes clear. Economists discount future flows to today's value, but even after applying a moderate social discount rate for non-market benefits and a market rate for costs, the results show that the present value of benefits is more than three times larger than the present value of costs. The discounted benefits amount to approximately €337.5 million, while the total discounted costs, including both the one-off capital outlay and the recurring operations and maintenance, amount to about €102.6 million. The difference yields a net positive balance of around €235 million, which indicates that the programme is highly attractive in social cost–benefit terms and creates significant headroom to structure financial instruments.

On this basis, Athens could issue a fifteen-year, sixty million euro municipal green bond with a fixed base coupon of 3.5 percent. The innovative feature is a performance-linked step-down of the coupon, tied directly to the annual monetised benefits derived from the shadow prices. Each year, an independent evaluator would verify the outcomes using tools such as satellite imagery, micro-climate modelling and public health data. If the annual social benefit measured with this method exceeds €12 million, the coupon would fall by 0.25 percentage points the following year. If it exceeds €15 million, the reduction would be 0.50 points, and if it exceeds €18 million, it would be 0.75 points. In the base case, where annual benefits are around €21.65 million, the programme would consistently trigger the maximum reduction, lowering the interest burden for the municipality. For example, on a €60 million bond, the annual interest bill at 3.5 percent is around €2.1 million. Achieving the top performance tier would reduce the coupon to 2.75 percent in the following year, cutting the interest payment to roughly €1.65 million and saving about €450,000 that year.

The attractiveness of this design lies in its simplicity and transparency. The public value of the intervention, expressed in euros through shadow prices, is vastly larger than the annual cost of servicing the debt and maintaining the assets. The bond's performance-linked feature ensures that the city pays less interest only when real, verified social outcomes are delivered, thereby aligning fiscal incentives with social objectives. To further secure sustainability, Athens could establish a small reserve fund by collecting a modest contribution from local beneficiaries, for instance ten euros per adult per year. This would generate around two million euros annually, comfortably below the reported willingness-to-pay values, while providing assurance to investors and covering maintenance costs.

In summary, this design shows how willingness-to-pay estimates and choice experiment evidence from WP7 can be operationalised into a real financing instrument for urban greening and heat mitigation. The numbers demonstrate that the social benefits far exceed the costs, that the annual benefits can be transparently measured and monetised, and that a municipal green bond with a performance-linked coupon is both feasible and desirable. The approach creates a credible link between climate adaptation outcomes and financial markets, turning shadow prices into the basis for sustainable, equitable investment in urban resilience.

Other CSs

Unlike the Athens Metropolitan Area example, which can draw directly on quantified social value estimates (e.g., willingness-to-pay/ shadow prices) produced within WP7 and therefore supports an

explicit “benefit-to-cashflow” calculation, the design of specific financial instruments can be showcased to other CSs also as methodological templates.

Port Resilience / Sustainability-Linked Facility

Mediterranean ports can translate resilience and decarbonisation investments into financeable value primarily through avoided losses and measurable operational performance. In this context, benefits are most credibly expressed as avoided or reduced (i) weather-related downtime and service disruption, (ii) damage to port assets and cargo, and (iii) compliance and transition costs associated with emissions monitoring and tightening regulatory expectations. These outcomes are especially relevant where the innovation package prioritises operational continuity, risk reduction, and improved planning/management under climate stress.

A suitable financial structure would be Sustainability-Linked Facility (loan or bond) issued by a port authority (or a jointly governed port programme vehicle), where the pricing is linked to pre-defined, verifiable KPIs. The margin/coupon can step down when KPIs are achieved and step up (or remain unchanged) if they are not. KPIs should be chosen to reflect what ports can monitor and control through the innovation package, such as reductions in disruption hours attributable to climate events, completion of resilience upgrades embedded in port asset plans, deployment and institutionalization of decision-support tools, and verified implementation of emissions monitoring and reporting practices.

The credibility of this approach depends on verification architecture. Ports are well-positioned to generate auditable data through operational logs, maintenance/asset records, sensor networks, and DSS outputs. A verification protocol can combine (i) baseline definition (historic disruption/damage records and exposure mapping), (ii) a monitoring plan (how disruptions, damages, and operational indicators will be tracked), and (iii) independent assurance (third-party verification of KPI achievement). This makes the “value-to-cashflow” logic investable because the instrument’s performance conditions are tied to routine port data and formal reporting cycles rather than one-off estimations.

Cashflow robustness can be strengthened by blending and sequencing finance: early-stage grant/technical assistance funds the set-up costs (DSS configuration, capacity building, monitoring protocols); medium-stage PPP arrangements support scaling of infrastructure and digital solutions; and the sustainability-linked facility provides the core capital for port-wide resilience and performance upgrades once indicators and governance routines are in place. This sequencing aligns incentives: the port lowers financing costs by delivering verified resilience and sustainability outcomes, while lenders/investors gain confidence through transparent KPI measurement and assurance.

To compute numeric cashflows and KPI-linked pricing steps, CS2 would need a combined avoided-cost and stated preference evidence base. On the avoided-cost side: (a) baseline and expected reduction in weather-related disruption hours and a unit economic cost per hour (throughput loss, contractual penalties, supply-chain delay costs), and (b) baseline and reduced asset/cargo damages (claims and repair costs). In addition a choice experiment or contingent valuation would be needed to estimate willingness-to-pay (WTP) for improved port service resilience, for example: WTP per shipment/user for reduced delay probability, WTP for fewer annual disruption days, and/or WTP for increased reliability of critical services (passenger/freight continuity), potentially differentiated by stakeholder group (shipping lines, logistics operators, passengers, local businesses).

Resilience Bond + Payments for Ecosystem Services

In river basins (CS3), innovation packages typically create financeable value through avoided flood and drought damages, reduced disruption to economic activity, and improved water quality and ecosystem conditions that lowers long-run treatment and compliance costs. Because many basin measures are multi-functional (combining digital early warning/monitoring with nature-based solutions and targeted infrastructure upgrades), the benefits are best framed as a portfolio of avoided-loss and performance

outcomes rather than a single revenue stream. This makes the basin a strong candidate for performance-linked programme finance.

A practical structure would be a Resilience Bond issued by a basin authority, a municipal consortium, or a programme that finances a defined package of measures (e.g., retention/restoration, buffer strips, upgraded treatment, monitoring/DSS integration). The bond proceeds with funds for capital works and programme costs, while repayment is supported by participating in public budgets and (where relevant) co-financing from utilities and other beneficiaries. The “resilience” feature is introduced by linking financing terms or performance payments to verified reductions in risk and improvements in basin function over time.

To strengthen performance and maintain measures on the ground, the resilience bond can be paired with Payments for Ecosystem Services (PES) contracts. PES agreements pay land managers or local actors for verified service delivery that underpins basin resilience (e.g., nutrient runoff reduction practices, maintenance of restored areas, retention capacity preservation). This pairing solves a common gap: bonds can finance capital measures, but basin outcomes often depend on ongoing PES creates a durable incentive and governance mechanism to sustain performance beyond construction.

Verification relies on an integrated monitoring framework: DSS outputs, hydrological and water-quality indicators, and documented completion/maintenance of interventions. The bond’s performance-linked element can reference a small set of auditable indicators (e.g., verified restoration completion, measured nutrient load reductions at monitoring points, documented retention capacity outcomes, operationalization of early-warning/monitoring systems). Finance sequencing can also be explicit: early-stage grants/technical assistance establish baselines and monitoring; concessional lending can de-risk scale-up; and longer-term sustainability-linked capital becomes feasible as governance, monitoring, and performance data mature and are institutionalized within basin decision-making.

Numeric parameterization of the above would require a choice experiment or contingent valuation to estimate WTP for basin resilience and ecosystem improvements, for example: WTP per household for reduced flood risk (probability/severity reductions), WTP for improved river water quality (e.g., bathing water status, ecological status), WTP for restored floodplains/wetlands and associated biodiversity/recreation benefits, and/or WTP for reduced drought impacts on water availability.

15.0 Conclusion

The ARSINOE Deliverable D6.8 consolidates the work undertaken across all nine case studies into a coherent framework of Innovation Packages, demonstrating how systemic, cross-sectoral approaches can be translated into actionable climate adaptation strategies. By combining insights from innovation pathways, financial design, and governance assessments, the deliverable provides a comprehensive toolbox that reflects both the diversity of regional challenges and the shared need for integrated solutions. Each case study highlights sector-specific pathways but embeds them in a common structure that ensures replicability, comparability, and scalability across Europe.

A central finding is that adaptation requires the alignment of technological advances, governance reforms, and financing instruments. Stand-alone interventions are not sufficient; only packages that bundle nature-based solutions, decision-support tools, and tailored financing mechanisms can effectively respond to climate-related risks. The innovation packages also demonstrate the importance of social innovations, from citizen engagement to inclusive governance, as enablers of technical and financial uptake. The cross-fertilisation between case studies further shows how innovations developed in one context can be adapted to others, building a European ecosystem of climate resilience.

Finally, the deliverable underlines the importance of long-term sustainability and policy coherence. The recommendations stress that innovation packages should not only be technically sound and financially viable but also embedded in institutional frameworks that guarantee their persistence over time. By linking with EU-level initiatives such as the Climate Innovation Window and aligning with Sustainable Development Goals, ARSINOE ensures that local innovations contribute to broader climate objectives. The conclusion is clear: systemic innovation packages are both feasible and necessary to operationalise resilience pathways, offering a blueprint that can guide European regions in navigating the complexities of adaptation of climate change.



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Systems Innovation Approach (SIA) addresses the growing complexity, interdependencies and interconnectedness of modern societies and economies, focusing on the functions of the cross-sectoral system? as a whole? and on the variety of actors. The Climate Innovation Window (CIW) is the EU reference innovations marketplace for climate adaptation technologies. ARSINOE shapes the pathways to resilience by bringing together SIA and CIW, to build an ecosystem for climate change adaptation solutions. Within the ARSINOE ecosystem, pathways to solutions are co-created and co-designed by stakeholders, who can then select either existing CIW technologies, or technologies by new providers (or a combination) to form an innovation package. This package may be designed for implementation to a specific region, but its building blocks are transferable and re-usable; they can be re-adapted and updated. In this way, the user (region) gets an innovation package consisting of validated technologies (expanding the market for CIW); new technologies implemented in the specific local innovation package get the opportunity to be validated and become CIW members, while the society (citizens, stakeholders) benefits as a whole. ARSINOE applies a three-tier, approach: (a) using SIA it integrates multi-faceted technological, digital, business, governance and environmental aspects with social innovation for the development of adaptation pathways to climate change for specific regions; (b) it links with CIW to form innovation packages by matching innovators with end-users/regions; (c) it fosters the ecosystem sustainability and growth with cross-fertilization and replication across regions and scales, at European level and beyond, using specific business models, exploitation and outreach actions. The ARSINOE approach is show-cased in nine widely varied demonstrators, as a proof-of-concept with regards to its applicability, replicability, potential and efficacy.



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