TransformAr

Accelerating and upscaling transformational adaptation in Europe: demonstration of water-related innovation packages

Sustainability profiles of solutions

Deliverable 5.2

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EXECUTIVE SUMMARY

This report provides sustainability profiles for validated solutions implemented within the TransformAr demonstrators, assessed both individually and at the region-specific portfolio (RSP) level. It presents a structured approach to evaluating the environmental, economic, and social sustainability impacts of each demonstrator, incorporating risk assessments (RA) encountered during implementation.

We first introduce the Sustainability Rating Method (SRM), a comprehensive framework designed to assess and enhance sustainability performance. The SRM is a crucial tool given the rising demand for effective sustainability assessments. Its alignment with Sustainable Development Goal (SDG) specific indicators ensures relevance for stakeholders aiming to meet global sustainability targets. It integrates the approaches of Life Cycle Thinking (LCT) and Handprint Thinking (HT) to effectively transfer the sustainability framework into practical assessment. Its structured four-phase approach (Scoping, Implementation, Data Process, and Assessment) provides detailed, actionable guidance for assessments. The method is applied and tested in each demonstrator to generate sustainability profiles for validated solutions and RSP in this report.

The report presents sustainability profiles of each validated solution and RSP across the six demonstrators: Lappeenranta (Finland), Westcountry Region (UK), Galicia (Spain), Oristano (Italy), Guadeloupe (France), and Egaleo (Greece). A total of 19 tested and demonstrated solutions are assessed, encompassing a diverse range of nature-based solutions, innovative technologies, financing mechanisms, insurance and governance models, and awareness and behavioural change solutions. Each demonstrator's sustainability performance is evaluated through a combination of common and tailored performance categories that reflect local context and real conditions, ensuring comparability and transparency for further adaptation and upscaling efforts. The structured profile assessment includes results and interpretation, uncertainties and actions for improvement and next steps, facilitating the adoption and replication of these solutions in other regions, promoting the wider dissemination of transformational adaptation practices.

The insights gathered from these demonstrators will contribute to the ongoing development of the SRM methodology in the forthcoming deliverable D5.9, further refining sustainability metrics and validating the methodology's scalability and applicability across diverse operational environments. This will support future institutions in applying the method, enhancing decision-making and the implementation of adaptation solutions. This iterative process strengthens the robustness and adaptability of SRM, ensuring its continued relevance for future sustainability assessments.

LIST OF ABBREVIATIONS

AAS	Actionable adaptive solutions
AF	Adaptation Fund
AI	Artificial intelligence
AWAR	Awareness-raising modules
BNG	Biodiversity Net Gain
CAF/CAE	Citizen app
CEI	Choice experiment
CCA	Climate change adaptation
CC	Climate Change
CIH	Climate innovation hub
COAST	Coastal Contract
DSI	Demand analysis for social services and infrastructures
GB	Green bonds
GHG	Greenhouse gas
HT	Handprint thinking
ICW	Integrated Constructed Wetlands
ICWM	Integrated Constructed Wetlands Monitoring
INTERM	Intertidal Monitoring
KCS	Key community system
LCT	Life cycle thinking
LWO	Local Wetland Observatory
ML	Machine learning
MRM	Mussel Raft Monitoring
NBS	Nature-based solution
NN	Nutrient Neutrality
NUDG	Nudging
RA	Risk assessment
RI	Resilience Index
RSP	Region-specific portfolio
SAC	Special Area of Conservation
SCS	Smart Climate Stations

SD	Sustainable development
SDG	Sustainable Development Goal
SG	Smart gate
SRM	Sustainability rating method
SWMM	Stormwater monitoring
URB	Nature-based urban stormwater solution
TA	Transformational adaptation
TSP	Technical Support Partners
WRT	Westcountry Rivers Trust

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1.0 INTRODUCTION

1.1 Background

Climate change presents unprecedented challenges across Europe, impacting ecosystems, economies, and communities. The increasing frequency and intensity of climate-related hazards, such as floods, droughts, and rising sea levels, necessitate a transformational adaptation approach that extends beyond incremental solutions. The TransformAr project is designed to accelerate and upscale adaptation through the demonstration of water-related innovation packages across diverse geographic, climatic, and socio-economic contexts.

The project spans six demonstrator regions, including Lappeenranta (Finland), the Westcountry (UK), Galicia (Spain), Oristano (Italy), Guadeloupe (France) and Egaleo (Greece). Through these demonstrators, TransformAr seeks to share knowledge, replicate successful initiatives, and identify common barriers to adaptation. Among 22 pre-identified actionable adaptive solutions (AAS) (Figure 1.1, their abbreviated names, more details in each demonstrator's Section), 19 have been tested and demonstrated - ranging from nature-based interventions to innovative technologies and governance models. The project provides pathways for reducing climate risks. The insights gathered from these efforts will contribute to a broader understanding of how to implement large-scale transformational adaptation, both within Europe and globally.

	Behavioural change and awareness-raising solutions	**Governance schemes**	**Nature-Based Solutions**	**Technological and digital solutions**	**Insurance, financial and economic schemes**
Lappeenranta	Citizen app (CAF)		NBS for urban stormwater management (URB)	Stormwater monitoring (SWMM)	Choice experiment (CEI)
Westcountry Region			Integrated Constructed Wetlands (ICW)	ICW monitoring (IWCM)	Green bonds (GB)
Galicia		Resilience Index (RI)		Mussel raft monitoring (MRM), Intertidal monitoring (INTERM)	
Oristano		Coastal contracts (COAST)	Smart Grid for coastal management (SG)		
Guadeloupe	Nudging (NUDG)				Adaptation Fund (AF)
Egaleo	Citizen app (CAE), Awareness-raising and behavioural change modules (AWAR)	Demand analysis for social services/infrastructures (DSI), Climate Innovation Hub (CIH)		Smart climate stations (SCS)	

*The Grant Agreement mentions two solutions SWM and SWMM for Lappeenranta, yet both refer to the monitoring of stormwater management solutions. The 'SWMM' was proposed as the solution for digital monitoring (in full: Stormwater monitoring). The Insurance Mechanism (INSUR) is not included, as it is primarily based on feasibility analysis rather than direct implementation.

Figure 1.1 Actionable adaptive solutions of TransformAr

1.2 Objectives and scope

The primary goal of this report is to provide holistic and integrated sustainability profiles for the validated solutions implemented in the TransformAr demonstrators, at an individual level and for each region-specific portfolio (RSP), and their contributions to Sustainable Development Goals (SDGs). These sustainability profiles aim to evaluate and quantify the environmental, economic, and social impacts of the TA solutions, while also assessing the risks encountered during their implementation.

The Sustainability Rating Method (SRM) has been developed as a systematic framework to evaluate the sustainability impacts of the validated solutions, integrating Life Cycle Thinking (LCT) and Handprint Thinking (HT). This approach ensures a comprehensive assessment by considering both minimization of negative impacts and maximization of positive contributions throughout the lifecycle of each solution.

The evaluation process involves collecting and analyzing data from multiple sources, including monitoring reports, field data, experimental results, life cycle inventories, modeling analysis, participatory interviews, and cost-benefit analyses. LCT ensures that the full environmental, economic, and social footprint of each solution is considered across its entire lifecycle, from design, implementation to long-term operation. HT focuses on enhancing sustainability benefits, measuring how solutions contribute to positive environmental and social change beyond just impact reduction.

The sustainability profiles are developed using both qualitative and quantitative evaluations, offering a holistic assessment of benefits, risks, and trade-offs associated with implementing adaptive solutions in each demonstrator. The SRM is applied as a relative sustainability assessment, measuring performance against defined targets while identifying opportunities for amplifying handprints and optimizing life cycle efficiencies to support scalable and transformational adaptation.

The scope of this report is adaptive and comprehensive, providing detailed contextual information for each demonstrator. It encompasses the scoping of challenges, objectives, baseline conditions, and solutions, ensuring that projected sustainability targets are aligned with regional priorities and stakeholder interests for effective and context-specific adaptation. The assessment framework considers local socio-economic conditions, climate risks, and policy landscapes, allowing for a flexible yet structured evaluation. By integrating quantitative and qualitative sustainability metrics, the report offers insights into the effectiveness, scalability, and replicability of tested solutions. This approach supports evidence-based decision-making, enabling stakeholders to refine adaptation strategies and drive wider transformational change across diverse environments.

1.3 Target audiences

This report is designed for a broad spectrum of stakeholders, each playing a crucial role in implementing, evaluating, and scaling transformational adaptation solutions. By offering evidence-based sustainability assessments, it provides insights for local governments, urban planners, researchers, businesses, financial institutions, NGOs, and local communities.

Municipal authorities and regional policymakers are central to climate adaptation planning and decision-making. This report offers tested adaptation strategies, such as Lappeenranta's Stormwater Monitoring System (SWMM), which provides real-time water quality data for urban flood management. Similarly, Oristano's Coastal Contract (COAST) guides policymakers in coastal protection planning, addressing climate risks through legal frameworks and governance models. Policymakers in Guadeloupe can explore Adaptation Funds (AF) as a model for financing small-scale resilience projects, enabling direct investments in community-based solutions.

Urban planners can apply nature-based solutions (NBS) and green infrastructure to design climate-resilient cities. Lappeenranta's Nature-based Urban Stormwater Solution (URB) showcases how NBS can be integrated into urban stormwater management, reducing flood risks and improving water quality. Egaleo's Smart Climate Stations (SCS) offer planners real-time urban heat monitoring, allowing for improved urban greening and heat mitigation strategies.

Academic institutions and research organizations can utilize this report's data-driven assessments to refine climate modeling, sustainability metrics, and resilience indicators. Galicia's Resilience Index (RI) provide scientific tools to support the mussel farming sector in adapting to climate change while the Intertidal Monitoring (INTERM) system serves as a model for analyzing coastal sedimentation patterns and sea-level rise.

Companies in agriculture, aquaculture, energy, and infrastructure can benefit from innovative adaptation solutions and investment opportunities. Westcountry's Green Bonds (GB) demonstrate how private sector investments can finance sustainable agriculture and water management projects. Guadeloupe's

Nudging (NUDG) model highlights how behavioral science can drive corporate sustainability strategies. The fisheries and aquaculture sector in Galicia have now three tested solutions (MRM, RI and INTERM) that enhance the understanding and manage climate risks affecting mussel production and shellfish harvesting.

Banks, insurance providers, and green investment funds can explore climate finance mechanisms that support resilience-building initiatives. Guadeloupe's Adaptation Fund (AF) showcases a community-driven financing model, while Wes Country's Green Bonds offer insights into scalable financial instruments for nature-based solutions.

Environmental organizations, advocacy groups, and NGOs play a key role in mobilizing communities, shaping policies, and implementing local adaptation projects. Westcountry Rivers Trust (WRT) exemplifies how NGOs can drive community-led adaptation efforts by implementing solutions such as Integrated Constructed Wetlands (ICW) to enhance water quality and ecosystem restoration. Additionally, Green Bonds (GB) provide a financial mechanism to support sustainable land management and riparian habitat conservation, ensuring long-term resilience.

Public participation is essential for the success of adaptation efforts. This report highlights engagement tools, such as Egaleo's CAE, which enables citizens to contribute climate data and provide feedback on adaptation measures. Lappeenranta's Choice Experiment for Investors (CEI) assesses private citizens' willingness to support green investments, while Guadeloupe's behavioral change initiatives (NUDG) encourage climate-resilient lifestyles. By involving local populations, these demonstrators ensure adaptive solutions are community-driven and widely accepted.

By addressing diverse stakeholder needs, this report enhances knowledge-sharing, supports policy development, and promotes investment in sustainable adaptation solutions. The insights gained from six demonstrators provide replicable models that guide climate adaptation efforts worldwide.

2.0 METHODOLOGY

We apply a holistic and integrated framework. The method will be further developed to deliver in D5.9 for wider applications.

2.1 Sustainability and SDG Alignment

2.1.1 Sustainability framework

Sustainability was defined by the United Nations Brundtland Commission in 1987 "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987). The report proposed addressing poverty and unsustainable consumption patterns through a strategy that integrated economic development with environmental sustainability, which collectively formed the foundation for the three pillars of sustainability: society, environment, and economy (Giddings et al., 2002). It's essential to recognize that the three-pillar concept of sustainability didn't originate from a single source. Instead, it gradually emerged from early academic critiques of the economic status quo, considering both social and ecological perspectives. Additionally, the United Nations' efforts to reconcile economic growth with solutions to social and environmental issues played a significant role in its development (Purvis et al., 2019). Different forms have been found and presented: three intersecting circles (often described as a 'Venn diagram'), or literal 'pillars' and a concentric circles approach (Lozano, 2008; Purvis et al., 2019), as shown in Figure 2.1.

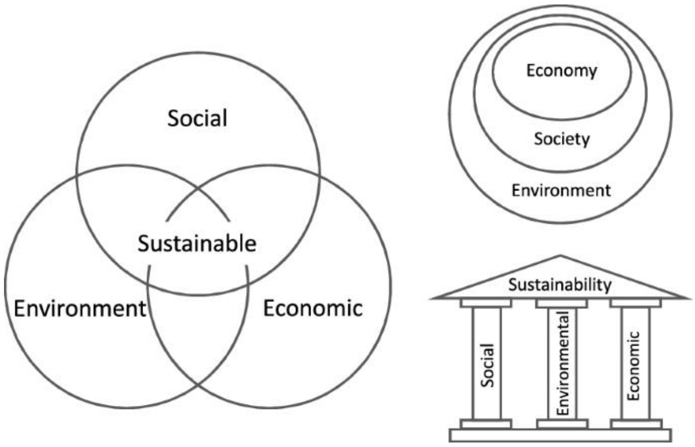


Figure 2.1 Forms of sustainability pillars

Sustainable development (SD) refers to the principle of meeting human development goals while ensuring that natural systems can continue to supply the resources and ecosystem services essential for the economy and society (Mensah, 2019). As part of the development roadmap, the United Nations' Sustainable Development Goals (SDGs) call for action to protect the planet, end poverty and guarantee the well-being of people (Taylor, 2016). Although conceptions of sustainability and SD are distinguishable, much of the contemporary sustainability literature centers around the SDGs (Purvis et al., 2019; Ruggerio, 2021). On the other hand, the most often cited definition with respect to SD is the one proposed by the Brundtland Commission Report (Emas, 2015a). Nevertheless, the three pillars of sustainability were explicitly embedded in the formulation of the SDGs, as evidenced by the public's understanding and the UN's multidimensional description (Dalampira & Nastis, 2020). Overall, sustainability and SD are closely related concepts, and could be described as the goal or endpoint of a process (Mebratu, 1998), or a state and process for achieving this state (Gray, 2010).

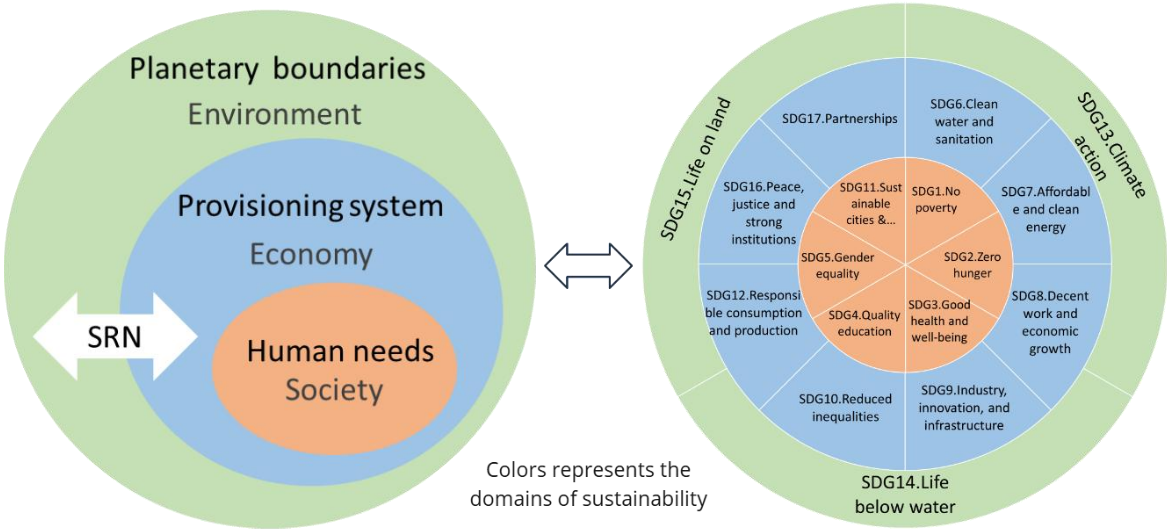
2.1.2 SDG Implementation

The SDGs are widely regarded as the most suitable global framework for advancing holistic sustainable development, due to their foundational democratic principles, broad global recognition, and the internationally standardized indicator framework that allows for consistent comparisons (Emas, 2015b; Mishra et al., 2024a). There is a growing consensus that the SDGs are an appropriate global framework for addressing various global challenges (Adenle et al., 2023a; Mishra et al., 2024b; Nhamo et al., 2020).

Local and Regional Governments (LRGs) worldwide are using Voluntary Local Reviews (VLRs) to track and report on SDG progress, which is growing exponentially (Unhabitat, 2024). LRGs have proven themselves capable of accelerating SDG implementation, particularly in climate action (Mohieldin et al., 2022). For example, 39 cities and regions submitted their VLR reports to UN in 2020 (Mohieldin et al., 2022) while 48 VLR reports were published by LRGs in 2023 alone, reflecting the increasing engagement of local governments in SDG documentation (Ortiz-Moya & Kataoka, 2024). Their roles in raising public awareness, maintaining basic public services, and responding rapidly to emergencies are critical and showcased their ability to scale up contributions effectively (UN, 2020). The business sector has also showed a significant commitment towards integrating the SDGs into their strategic planning and reporting processes. For instance, based on a sample of over 200 companies around the world, in 2020, four out of five companies (83%) assessed included a commitment to the SDGs in their reports, yet, fewer than half (40%) set measurable targets for how their actions contribute towards achieving the Goals (Global Reporting Initiative., 2023). Some impact ranking systems, such as the Times Higher Education (THE) Impact Rankings, evaluate universities' contributions to the SDGs (Nogueiro & Saraiva, 2023). These rankings highlight how universities promote the SDGs through various initiatives, including research, teaching, and outreach (Avelar & Pajuelo-Moreno, 2024). The crucial roles of non-governmental organizations (NGOs) in implementing the SDGs deserve recognition (Paužuolienė et al., 2024). They advocate for policy changes, hold governments and businesses accountable, raise public awareness, and implement grassroots projects. Additionally, NGOs provide training and technical assistance to enhance community capacity (Hege & Demailly, 2017, 2018). Citizens are already contributing to the monitoring of five SDG indicators, and citizen science has the potential to support 76 indicators, together accounting for approximately 33% (Fraisl et al., 2020).

2.1.3 Holistic Assessment

While the SDGs outline a broad global agenda, they are not directly applicable to local assessments. Though they touch on various aspects of holistic SD, they are not guided by a founded theory and fall short of providing a thorough understanding of societal and environmental systems, lacking a clear means-ends continuum (Costanza et al., 2014; Nilsson & Costanza, 2015). Thus, Societal Relations to Nature (SRN) as a founded theory is taken to complement SDGs towards a holistic sustainability assessment (Becker et al., 2011; Görg, 2011; Hummel et al., 2017). SRN emphasizes the deep interconnections and mutual constitution of social, environmental, and economic sustainability. Following the suggestion from holistic and integrated life cycle sustainability assessment (Zeug et al., 2020), the sustainability assessment (SA) framework will be used as the basis for the evaluation of sustainability performance (Figure 2.2.a). In this framework, specific SDGs and their corresponding sub-goals are assigned in specific sustainability aspects. Social sustainability is defined as the long-term and global fulfillment of human needs and social well-being as an end (human needs, social, SDG1-5 &11); economic sustainability stands for technologies and economic structures which are efficient, effective and just provisioning systems relating human needs and environment (provisioning system, economic, SDG6-10, 12, 16 &17); and ecological sustainability as the long-term stability of our environment as a basis of reproduction within planetary boundaries (planetary boundaries, environmental, SDG13-15), seen in Figure 2.2.b. In the framework application, indicators are linked to SDGs via sub-goals as end point impact categories.



a) Framework based on the Societal Relations to Nature (SRN)

b) Relational entities, aspects, and assigned SDGs of Sustainability Assessment

Figure 2.2 Sustainability assessment framework and relational entities, aspects, and assigned SDGs

2.2 Sustainability Rating Method

2.2.1 Integration Approaches

The sustainability rating method (SRM) is constructed upon the sustainability assessment framework, which is designed to evaluate and validate solutions through a comprehensive and objective approach. To effectively transfer the sustainability framework into practical assessment, we integrate two key approaches: life cycle thinking (LCT) and handprint thinking (HT).

Life Cycle Thinking (LCT) is an approach that evaluates the environmental, social, and economic impacts of a product or service throughout its entire life cycle—from raw material extraction to production, use, and disposal. This holistic perspective helps identify opportunities to improve sustainability performance at each stage of the product's life (de Fátima Maciel et al., 2024). By considering the full life cycle, LCT ensures that sustainability assessments capture all relevant impacts, avoiding the shifting of burdens from one stage to another.

In SRM, LCT strengthens sustainability assessments by providing a comprehensive view of the impacts associated with a solution throughout its entire life cycle. This approach ensures that all stages of a solution are considered, allowing for a thorough evaluation of environmental, social, and economic impacts. By identifying hotspots and opportunities for improvement at each stage, LCT helps in developing more sustainable solutions.

Handprint thinking (HT) focuses on the positive impacts that actions can have on sustainability. It encourages proactive measures to create beneficial outcomes, complementing the traditional focus on reducing negative impacts. HT emphasizes the importance of actions that contribute positively to social and environmental well-being. This approach helps in identifying and promoting practices that generate positive sustainability impacts, thereby enhancing the overall sustainability profile of solutions (Husgafvel, 2023).

Handprint Thinking (HT) complements LCT by focusing on the positive contributions that solutions can make towards sustainability. It aids in assessing the sustainable level of solutions by measuring the extent of positive contributions made. Furthermore, HT is instrumental in the generation of indicators that reflect the positive impacts of solutions, providing a balanced view of both the benefits and risks associated with their implementation.

By integrating LCT and HT, the sustainability assessment framework becomes more robust, capturing both the comprehensive life cycle impacts and the positive contributions of solutions. This dual approach ensures a holistic and rigorous evaluation of sustainability performance, facilitating informed decision-making and promoting the adoption of sustainable practices.

2.2.2 Stakeholder participation

The SRM involves linking indicators through classification, normalization, weighting, and aggregation within the framework aligned with the SDGs and sub-goals as endpoint impact categories. However, it is essential to recognize that not every globally relevant SDG indicator is applicable to local assessments, even when accounting for international or external impacts (Adenle et al., 2023b; Meschede, 2020). Decision-making on sustainable actions is inherently complex, involving uncertainty, divergent values, competing interests, and an urgency that requires holistic approaches drawing from multiple fields of knowledge and diverse stakeholder perspectives (Fonseca et al., 2021; Waas et al., 2014). In this context, a structured and systematic approach to stakeholder engagement can provide essential insights for tackling complex sustainability challenges in a way that is equitable, inclusive, and responsive to diverse social, economic, and environmental concerns (Nonet et al., 2022; Waas et al., 2014; Wells et al., 2020).

The TransformAr project develops a community-based innovation process to foster citizens' and stakeholders' engagement and ensure the co-ownership of solutions, allowing to co-design, co-test and co-finance solutions. Eight Work-Packages (WPs) are implemented to achieve the objectives (Figure 2.3), where a multi-stakeholder framework for building and managing TransformAr Innovation Ecosystems (IEs) acts as the basis for Transformational Adaptation (TA) of demonstrators (WP1).

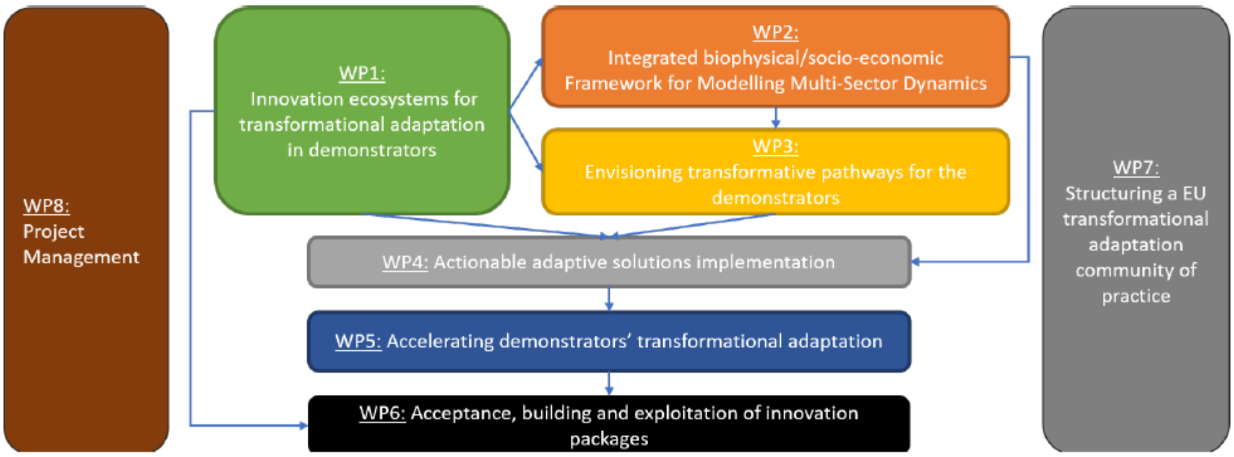


Figure 2.3 Overall strategy of the work plan

Stakeholder communities are built through multi-level activities with citizens and target stakeholders to ensure a co-creation process at the demonstrator level where technical and socio-economic aspects are well-encompassed, including citizenship acceptance. From the moment the project starts, communities and innovation ecosystems (IE) are set up and built as the basis for all activities with stakeholders transformational adaptation. Stakeholders' engagement guidelines (D1.1) were developed to ensure stakeholders' and public engagement, outlining (1) Composition of potential target stakeholders' groups

(2) Detailed rules for stakeholders' engagement, and (3) Operational management procedures at regional/EU levels (FEUGA, 2022).

In TransformAr, main activities of stakeholder engagement have been conducted across different WPs, serving as a critical cross-checking resource for this deliverable. Demo Facilitators design and coordinate activities to mobilize stakeholder relationships at the regional/national level, with support from WP leaders and Technical Support Partners, ensuring smooth engagement and communication with regional communities. This includes activities throughout the project (face-to-face or online), round tables, short surveys and questionnaires, trainings, and other participatory activities, which are done with stakeholders during the project in the frame of IEs. Demonstrators' interactions are organized at a steady pace when all pilots have initiated operations. For each demonstrator, a stakeholder matrix (D1.2) is developed to select relevant stakeholders (institutional, social, economic) within the IE (Khamis, 2022). This matrix contains a variety of profiles under the target stakeholder groups, relevant for the different Key Community Systems (KCS) targeted by the project (policymakers, industry, financial institutions, climate and sector experts, research organizations, NGOs, civil society organizations) and information concerning their interests and decision/policy making influence. Based on the stakeholder matrix, a Stakeholders' Advisory Board (SAB) is created to support the engagement and dissemination activities and strengthen TransformAr's reach. Consultation Workshops are organized in each demonstration region coordinated by WP leader with the Demo facilitators to envision transformative pathways for demonstrators. Another set of Consultation Workshops will be organized during the last year of the project to bring together information from different stakeholders and KCS, coming up with relevant information completing the specific conclusions from transformative pathways. Stakeholders' involvement (logistics, level of engagement) is monitored to evaluate the activities performed (effectiveness, impact, usefulness), potential deviations and contingency measures to the multi-stakeholder strategy through regular one-to-one online contacts with the Demo Facilitators to follow planned activities with stakeholders within each demonstrator. The stakeholder's attitudes and beliefs that hinder or facilitate the adoption of the behaviors that lead to transformative change are assessed and mapped (D1.4), which lays down a robust groundwork to analyze social acceptance (Sabucedo, 2023). Specific activities for citizens and stakeholders are designed and implemented to trigger change in their behavior towards the solutions to be tested based on the barriers identified. The inter-community exchange of best practices can not only help address ongoing challenges but also proactively prevent implementation obstacles. Task leaders together with Demo Facilitators coordinate the communication between the different demonstrators' teams to share experiences and identify common challenges (Michaux & Passalaqua, 2024).

In WP2, stakeholder feedback is integrated into the Modelling Customization and Implementation Report (D2.2), which outlines the customization and application of the modelling chain for each of the six demonstrators. This report addresses the need for high-resolution, detailed representation of key processes and the interdependencies among risk factors, and includes the assessment of adaptation measures. WP3 applies and uses the methodologies developed for the stakeholder approach in WP1. It takes into account individual stakeholder threats, needs and strengths in regard to the economic, ecological and societal impact of change, which leads to a shared vision and socio-economic pathways of a climate resilient future. Based on the results of the previous assessments and stakeholder consultations, partners come up with a preferred shared vision and pathway that maximizes benefits from transformational adaptation and minimizes costs and losses (Pathways Deliverables).

Based on the co-creation process prepared in WP1, solutions for citizens and stakeholders to trigger change in their behavior and raise awareness on the transformational process ongoing in demonstrators are implemented (D4.1). Concrete regulatory frameworks are provided to demonstrators to foster transformational adaptation and new or enhanced governance schemes to empower stakeholders in the process (D4.2). The information gathered and modelled, and the prioritization carried out through consultation processes with experts and stakeholders have been used in different demonstrators with a specific purpose. For example, it is compiled in a resilience index, associating main risks and vulnerabilities with resilience factors and recommendations, which aims to stimulate behavioral change. Stakeholder preferences for climate adaptation in stormwater management system are conducted through choice experiments. The outcome is modelled to integrate knowledge and related services into the design of new policy instruments and business models and the co-design and test policy tools as part of new adaptation standards jointly with stakeholders, through behavioral economic experiments in the different regions (D5.4 Report on willingness to pay for solutions).

2.2.3 Process and steps

The implementation of SRM follows a structured approach to assess and enhance the sustainability performance of solutions. The process begins with identifying and defining the criteria, indicators, and boundaries for each demonstrator case. These elements are context-specific and risk-based, ensuring that sustainability profiles effectively capture key challenges and highlight opportunities for improvement. "Risk-based" refers to risk assessment (RA) as a core component of the process, integrated within participatory interviews, where stakeholders actively contribute to identifying risks and defining relevant indicators. The process is supported by information and evidence from various sources such as project monitoring reports, modeling analyses, and experimental field data, ensuring a systematic, transparent, and ethical evaluation. This approach facilitates a performance-driven assessment, ensuring that sustainability solutions are evaluated holistically and continuously refined to support practical implementation and achieve long-term impact (Figure 2.4).

There are two different applications linking the SDGs to life cycle assessment (LCA): 1) linking existing LCA results to SDGs as endpoints in a qualitative way, 2) quantitatively integrating the SDG indicators into an LCA impact pathway framework (Weidema et al., 2020). For our research, we are applying the first approach to select and determine each indicator and whether they contribute to each of the SDGs. We evaluate the solutions' ”performance to the targets (PTT)” to determine how effectively they meet sustainability goals and identify where potential risks may arise. This evaluation highlights areas where mitigation strategies are needed to address challenges and risks. At the same time, it emphasizes opportunities for positive change, paving the way for future improvements. Additionally, this approach fosters the scalability and replicability of adaptive solutions, ensuring that successful strategies can be expanded or applied to new contexts, driving long-term sustainability and resilience.

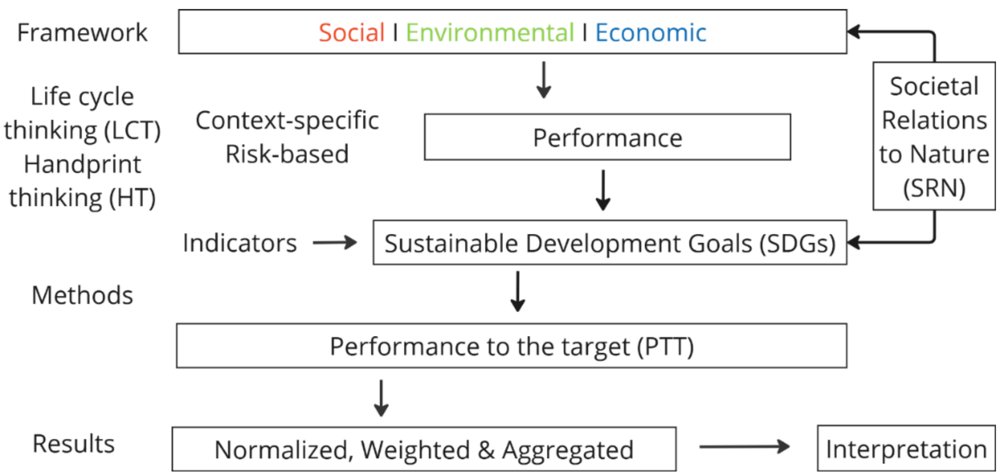


Figure 2.4 Sustainability rating method implementation

At the same time, we develop the methodological steps for implementing the assessment (Figure 2.5). We develop a guide for the local demonstrator in terms of actions for an assessment process. It identifies four distinct phases: scoping, implementation, data process, and assessment. Each phase includes a set of unique steps that can be performed. The method and guide will be further developed based on observed outcomes from this report and delivered in D5.9 (Sustainability Rating Method).

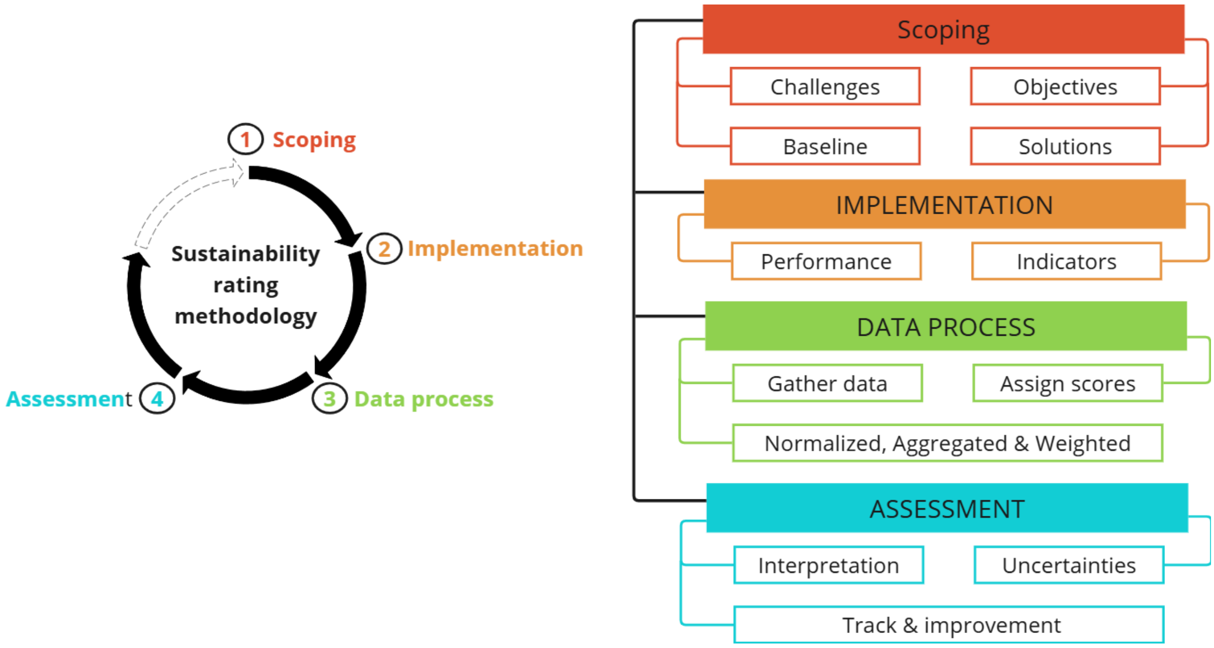


Figure 2.5 Phases and steps of sustainability rating method

Phase 1: Scoping

Scoping within the TransformAr project is a strategic assessment process aimed at fostering transformational adaptation to climate change across Europe. This process is essential for identifying and promoting sustainable strategies, tailored to the unique challenges faced by each of demonstrators. The scoping process entails a comprehensive, long-term approach that equips city leaders and stakeholders with the tools needed to map out strategic decisions for the future. This involves developing a clear "road map" that guides decision-makers in prioritizing sustainable interventions, whether for entire regions or specific locales. It incorporates the use of analytical tools to assess the complex issues these regions face, setting the groundwork for effective adaptation strategies.

The TransformAr project applies scoping to diverse scenarios, such as improving infrastructure for flood mitigation, enhancing water quality, and integrating nature-based solutions (NBS). This adaptive scoping process is rooted in empirical data and participatory planning, ensuring that decisions are inclusive and responsive to the specific needs of each demonstrator. The combination of quantitative and qualitative data underpins the planning process, offering a robust foundation for sustainable decision-making that aligns with the SRM framework.

<u>The four steps of scoping:</u>

1. **Challenges**: This step involves a thorough identification of the specific climate risks and socio-economic challenges that each demonstrator region faces. This phase includes evaluating both immediate and long-term pressures impacting these regions, ensuring that stakeholders have a comprehensive understanding of the current and anticipated obstacles.
2. **Objectives**: Setting clear, strategic goals for transformational adaptation is crucial in guiding the process. These objectives focus on reducing identified climate risks, enhancing resilience, and

promoting sustainable development. The goals should be designed to harness innovative solutions tailored to each region, incorporating adaptive technologies and methods like nature-based solutions (NBS) and advanced water management systems. Establishing objectives ensures that stakeholders share a unified vision for the path forward.

3. **Baseline**: Creating a baseline is essential for understanding the current status of environmental, economic, and social conditions within each demonstrator. This step requires collecting and analyzing data to assess vulnerabilities, resource availability, and existing adaptation measures. The baseline provides a reference point against which future progress can be measured, enabling a structured and data-driven approach to adaptation planning.
4. **Solutions**: In this step, actionable adaptive solutions (AAS) are developed and selected, focusing on the specific needs of each demonstrator region. The solutions range from nature-based interventions, which support ecosystem resilience, to advanced technologies and robust governance models that address water-related challenges and other climate risks. By tailoring solutions to local conditions and capabilities, TransformAr ensures that interventions are both effective and sustainable, promoting large-scale transformational change.

The scoping process supports the development of sustainability profiles for each demonstrator, which illustrate the progress toward achieving the SDGs. Furthermore, scoping fosters broad community engagement, encouraging dialogue that carefully considers the social, economic, and environmental impacts of potential paths forward. This dual-focused process—both forward-looking in preparing for future challenges and backward-looking in learning from the unique historical and social contexts of the demonstrators—helps ensure that climate adaptation efforts are resilient, effective, and community-centered.

Phase 2: Implementation

The implementation phase evaluates adaptive solutions' performance across environmental, economic, and social dimensions using Handprint Thinking (HT) integrated with Life Cycle Thinking (LCT) and risk-based performance assessment. It assesses effectiveness, scalability, and sustainability, aligning with SDGs. Tailored indicators measure progress, ensuring adaptability and strategic resilience. This approach enhances stakeholder engagement, social acceptance, and replicability, driving transformational adaptation.

<u>The two steps of implementation:</u>

5. **Performance**: Conducting a comprehensive evaluation of the performance of the selected adaptive solutions across environmental, economic, and social dimensions. This step involves assessing the effectiveness, efficiency, and scalability of each solution, while aligning indicators with specific SDGs, sub-targets, and broader sustainability domains. By ensuring alignment with global and local sustainability frameworks, the evaluation provides a holistic view of how well the solutions are meeting sustainability objectives. five common categories

Unlike traditional evaluations that rely on static baselines or business-as-usual comparisons, HT combines LCT and risk-based performance assessment to foster continuous improvement and maximize positive impacts. HT evaluates the environmental, social, and economic contexts in which solutions operate, identifying opportunities for proactive enhancement throughout the solution’s lifecycle. By incorporating risk-based performance metrics, HT anticipates potential challenges and opportunities, ensuring adaptive management and strategic resilience. It then outlines necessary actions and plans to optimize performance while maximizing positive impacts. This dynamic and adaptive approach measures positive changes against the baseline, offering stakeholders forward-looking insights that reflect current outcomes and predict future potential.

Given the complex and region-specific nature of climate adaptation, five common categories are identified through the process: Stakeholder Engagement and Participation, Monitoring, Evaluation and Adaptation, Management and Coordination, Financial Viability, and Risk and Resilience. To maximize impact, each category can be tailored to address the unique needs of specific solutions. For instance, Readiness and Feasibility categories were created to support the Nudging Solution in Guadeloupe, focusing on fostering behavioral change and ensuring effective community engagement. This approach keeps the assessment practical, informative, and aligned with the demonstrator's challenges and opportunities, while ensuring transparency and enabling comparison and evaluation of solutions for their adoption potential across different operating environments

6. **Indicators**: Establishing indicators that effectively measure the progress and success of the adaptive solutions is crucial. These indicators are tailored to reflect specific sustainability targets, such as reductions in flood risk, improved water quality, and social engagement levels. The indicator development process is risk-based, ensuring that indicators are identified by evaluating potential risks and challenges in collaboration with key implementation stakeholders. This participatory approach ensures that the indicators are relevant, context-specific, and adaptable to diverse operational environments. Regular monitoring of these indicators guarantees that the solutions are on track to meet their objectives and can be adjusted as needed to maximize impact and mitigate risks. The process is designed to enhance the potential for adoption in different operating environments, accounting for local social, economic, and environmental conditions.

LCT is applied across all solutions to assess sustainability impacts throughout the entire life cycle, from design and implementation to end-of-life management. By evaluating environmental, social, and economic impacts at each stage, LCT ensures comprehensive sustainability assessments. HT is strategically integrated to focus on the positive contributions of adaptive solutions, promoting actions that generate social and environmental benefits. This combined approach not only evaluates risks and negative impacts but also highlights opportunities for positive change. The simultaneous integration of LCT, HT, and risk identification enables early detection of potential risks and negative impacts, allowing for proactive mitigation strategies. This cohesive framework ensures that data gaps, resource constraints, and operational challenges are considered, maintaining the feasibility and effectiveness of assessments.

For TransformAr, the integration of HT into indicator development and sustainability assessment enhances the project's transformative potential. By actively measuring positive impacts, HT supports the project's goal of accelerating transformational adaptation across diverse European regions. This approach enables the identification of value-adding actions that contribute positively to environmental and social sustainability. The combined use of LCT and HT, alongside risk-based assessments, ensures a holistic evaluation of sustainability, driving continuous improvement and adaptation of solutions. This methodology not only increases stakeholder engagement and social acceptance but also fosters the scalability and replicability of adaptive solutions. By promoting a forward-looking perspective that focuses on positive impacts, TransformAr is better positioned to inspire proactive behavior, enhance community resilience, and achieve its overarching sustainability objectives.

After the indicators were selected, they were assigned to the relevant SDGs. This process involved mapping each indicator to the most applicable SDG sub-targets by evaluating its measured outcome and identifying the corresponding objectives within the 169 SDG sub-targets. Because many indicators have cross-cutting impacts, additional sub-targets were examined to see if they might also be supported. Once the most relevant sub-targets were identified, a concise rationale was provided to explain how each indicator's measured progress relates to the corresponding SDG objective. Finally, if an indicator linked to multiple goals, the strongest connections were prioritized, typically listing only one or two sub-targets where its impact was most direct, thereby ensuring the mapping remained clear and focused.

Phase 3: Data process

The data process phase is essential for building comprehensive sustainability profiles for adaptive solutions across the six demonstrator regions. This phase ensures that collected data is robust, scored effectively, and appropriately normalized and aggregated to inform decision-making and strategic planning.

<u>The three steps of data process:</u>

7. **Gather Data**: The first step involves systematically collecting data from various reliable sources to inform the sustainability profiles of the adaptive solutions. Data collection focuses on multiple dimensions, such as environmental, economic, and social impacts, aligning with the goals of transformational adaptation.

Key data sources include:

- Monitoring reports: Periodic assessments that evaluate the effectiveness of implemented solutions, documenting key insights such as lessons learned, and challenges encountered. A variety of existing deliverables from the TransformAr project are available to support these evaluations.
- Field data and experimental results: Data gathered from monitoring systems and laboratory-tested samples, tracking key performance indicators such as runoff, nutrient loading, and water quality. These measurements offer real-world validation of adaptive solutions, supporting precise performance assessments and ongoing improvements.
- Modelling analysis: Modeling analysis utilizes various datasets, such as Morphodynamic Modelling to evaluate sediment transport and climate impacts on sandbank dynamics, and habitat biodiversity assessed using the Shannon-Weaver index, among others. These analyses provide insights into environmental changes, species distribution, and ecosystem resilience under varying conditions.
- Participatory Interviews: This method engages stakeholders in an iterative process, with multiple rounds of interviews to gather in-depth insights into region-specific contexts and challenges. Stakeholders actively contribute to identifying risks, co-designing indicators, and validating findings, ensuring that the results are informed, accurate, and comprehensively reflected in the profile through continuous feedback.
- Cost-benefit analyses (CBAs): Financial evaluations that quantify the economic viability of each adaptive solution by comparing implementation costs against projected benefits, including long-term savings and societal gains. These analyses are conducted in collaboration with D5.5 Bankability Reports (scheduled for completion in June 2025).
- Secondary Data Sources: Published research papers, books, industry reports, databases, government publications, and online articles. These resources provide synthesized, analyzed, and interpreted information from primary data sources and are useful for understanding broader trends, supporting decision-making, or supplementing primary research with contextual insights.

The environmental impacts of Nature-Based Solutions (NBS) implemented by LAPP and WRT are analyzed using Life Cycle Assessment (LCA), following ISO standards (EN ISO 14044, 2006). The LCA process includes goal and scope definition, life-cycle inventory analysis, life-cycle impact assessment, and interpretation. LCA modeling is conducted using Sphera LCA for Experts software, with data from literature and databases (Sphera, Ecoinvent). Further details on the assessment methodology will be provided in deliverable D5.7 – Ex-post Assessment of Solution Reports (completion June 2025). Additionally, the Cost-Benefit Analysis (CBA) focuses on NBS, using only the relevant indicators generated in this process.

Data provided by demonstrators serves as a key source of information, covering technical, financial, and performance-related data on implemented solutions. This includes construction records used to build life cycle inventories (LCIs), detailing materials and activities carried out during the construction. Additionally, technical and financial data provide insights into design specifications, investment costs, operational expenses, and maintenance requirements. Performance data from monitoring and field assessments track key indicators such as efficiency, durability, and participation rates. Collectively, these documents enable data-driven decision-making, guiding further improvements and optimization of the solutions.

This data-gathering phase is essential for understanding baseline conditions, tracking actual on-going performance outcomes, guiding further development, and supporting post-project progression towards target objectives for each solution. This ensures a comprehensive evaluation framework that drives continuous improvement and strategic alignment with sustainability goals.

8. **Assign Scores**: Scoring the solutions based on their performance against the established indicators. Once data is collected, the next step is to assign scores that quantify the effectiveness and impact of the adaptive solutions. This scoring process translates raw data into standardized metrics that facilitate comparison and analysis.

This involves both qualitative and quantitative assessments. Metrics for quantitative assessments are developed to represent tangible outcomes, such as reductions in flood risk, improvement in water quality and economic returns. Qualitative evaluations include factors that cannot be directly measured, such as community engagement levels and public perception. These factors are scored based on survey results and expert judgment using an established qualitative scale.

In the SRM, a rating score of 0 represents no improvement towards the target, indicating no progress of the solutions towards sustainability goals. Conversely, a score of 5 signifies the solutions’ performance in achieving the target, but it does not mean that sustainability has been fully achieved. Instead, these scores reflect the distance or performance process towards the target based on the index criteria. The dynamic nature of SRM means that as conditions change and more data is collected, the targets and ratings can be adjusted, ensuring continuous improvement and accuracy in sustainability assessments.

9. **Normalize, Weight and Aggregate**: The next step in the data process phase involves normalizing and applying weights to quantitative indicators, followed by aggregation to produce a sustainability profile for each adaptive solution and region-specific portfolio (RSP). Normalization is applied only to quantitative data to ensure comparability, while qualitative indicators are considered directly in the evaluation.

To assess progress across different indicators in a standardized manner, all quantitative indicator values are converted to a 0 to 5 scale, where 0 represents no progress and 5 represents full achievement of the target. This method ensures comparability between indicators that measure both reductions (e.g., flood hazards) and increases (e.g., event attendance) as progress toward a target. The normalized score is calculated as follows:

$$S_{normalized} = \frac{|V_{baseline} - V_{AAS}|}{|V_{baseline} - V_{target}|} \cdot 5$$

Where

$S_{normalized}$ - Normalized score of the indicator (0-5)

$V_{baseline}$ - Initial value of the indicator

V_{AAS} - Current measured value of the indicator.

V_{target} – target value of the indicator

This method is applicable to two types of indicators:

a. Reduction-based indicators (where progress means a decrease from the baseline to the target). Example:
   - Flood hazards: A reduction in the number of floods per year.
   - Response time: A reduction in the time taken to respond to an event.
b. Increase-based indicators (where progress means an increase from the baseline to the target). Example:
   - Event attendance: An increase in the number of participants.
   - Solution implementation completeness: The proportion of a project, strategy, or intervention successfully executed.

Although straightforward, this formula can obscure the direction of progress, potentially misrepresenting improvements or deteriorations relative to the baseline. To avoid this issue, additional conditions are applied consistently across both indicator types: a score of 0 is assigned whenever performance shows no improvement or represents a deterioration compared to the baseline. Conversely, a maximum score of 5 is assigned when performance meets or exceeds the target, indicating full achievement or surpassing of the desired outcome. These conditions provide clarity and robustness to the normalized scores.

After all indicators have assigned or calculated scores, these scores are aggregated to evaluate the overall contribution of the solution to the assigned SDGs. The aggregation is performed using the weighted sum method, which allows for a flexible and transparent assessment by considering the relative importance of each indicator. The overall contribution score for each SDG is calculated as follows:

$$S_{SDG} = \sum_{i=1}^{n} w_i \cdot S_i$$

Where

S_{SDG} – final aggregated score, 0 to 5 scale,

n – total number of indicators contributing to the SDG,

S_i – normalized score of indicator i,

w_i – weight assigned to the indicator

The weight assigned to each indicator is calculated as:

$$w_i = \frac{1}{N_{SDG}}$$

Where

w_i – weight assigned to indicator i,

N_{SDG} - the total number of indicators contributing to a specific SDG.

This ensures that the sum of assigned weights for each SDG is always 1. Later, the demonstrators can customize weightings to test their own assumptions and explore different scenarios, enabling flexible and context-specific evaluations. This participatory approach enhances the model's relevance and adaptability, ensuring accurate reflection of stakeholder priorities and local contexts in performance assessment.

Phase 4: Assessment

The assessment phase is integral to its mission of accelerating transformational adaptation to climate change across Europe. During this phase, a comprehensive assessment is conducted to gather insights into the environmental, economic, and social impacts of these adaptive solutions. This phase emphasizes a 'portfolio-approach' that allows for the evaluation of both individual solutions and RSPs. This methodology rates sustainability progress from the baseline towards targeted outcomes, ensuring a detailed understanding of how solutions perform within different geographic and socio-economic contexts.

A critical aspect of this phase is to identify risks encountered during the implementation of solutions. This includes understanding challenges such as resource allocation, technical feasibility, and community engagement. Furthermore, the assessment phase provides an opportunity to quantify how well the solutions align with SDGs, helping stakeholders make informed decisions based on a blend of qualitative and quantitative data. The assessment phase outputs are tailored for various audiences. It is pivotal for delivering a holistic understanding of the impacts and feasibility of the tested solutions within the TransformAr project. It lays the groundwork for scaling successful adaptation strategies across Europe and beyond, fostering a collaborative approach to addressing water-related climate risks and other climate challenges.

This phase involves a structured approach that can be articulated through three main steps: uncertainties, interpretation, and track and improvement. These steps play a pivotal role in guiding the implementation and evaluation of transformational adaptation solutions across the demonstrators.

<u>The three steps of assessment:</u>

10. **Interpretations**: The interpretation step focuses on analyzing data to extract meaningful insights from the implementation of adaptive solutions across all regions. By leveraging life cycle performance evaluation reflected in the sustainability profile, stakeholders can assess how effectively each solution aligns with relevant SDGs, identifying strengths and areas for improvement.

This targeted analysis enables strategic actions that accelerate progress toward SDG targets, enhancing operational sustainability and maximizing positive impacts through handprint thinking. By pinpointing where adaptive solutions are performing well and where enhancements are needed, stakeholders can set clear directions for future actions, driving more effective contributions to climate resilience and sustainable development. Furthermore, this approach provides valuable insights for replicators, enabling them to learn from implemented solutions and tailor strategies to local contexts, thereby ensuring broader applicability and increased effectiveness of climate resilience measures.

11. **Uncertainties**: Understanding and managing uncertainties is crucial for accurately interpreting results and extracting meaningful insights from sustainability profiles, ensuring that they effectively guide strategic actions. Properly addressing uncertainties helps stakeholders understand the underlying dynamics of each profile, enabling them to make informed decisions

and prioritize actions that drive progress toward climate resilience and sustainable development goals.

Each demonstrator region faces unique water-related climate risks and socio-economic challenges, compounded by inherent uncertainties in data collection—particularly when piloting innovative solutions in a learning process. In the context of nature-based solutions, for instance, accurately measuring inlet and outlet flows is technically challenging due to the complexity of natural hydrological dynamics, leading to potential uncertainties in data accuracy and reliability. Additionally, uncertainties arise from the methodologies used to develop performance indicators, necessitating rigorous correlation analysis to identify potential dependencies among variables and to understand causal relationships between different indicators. Continuous monitoring and reassessment of uncertainties enable adaptive solutions to evolve and maintain their effectiveness and relevance, ensuring they make meaningful contributions to climate resilience and the achievement of sustainable development goals.

12. **Track & Improvement**: The track and improvement phase ensures ongoing monitoring, continuous learning, and refinement of implemented solutions. This involves the continuous collection and updating of actual results using tools such as the SWMM system in Lappeenranta, combined with community-based monitoring to sustain adaptive measures. By regularly evaluating outcomes, stakeholders can validate the performance of sustainable practices, identify barriers, and adapt strategies to optimize impact. This iterative approach allows for the dynamic adjustment of targets, ensuring they remain relevant and ambitious in light of real-world performance and evolving climate challenges. From a methodological perspective, the track and improvement phase fosters enhancement through an iterative learning process. This continuous development loop strengthens the methodology, improving data accuracy, indicator reliability, and overall evaluation effectiveness. By embracing this adaptive approach, stakeholders can refine analytical frameworks, incorporate new insights, and ensure that methodologies remain robust and responsive to changing environmental and socio-economic conditions.

Through these three steps—addressing interpretation, uncertainties, and tracking and improving solutions—the assessment results of sustainability profiles are significantly enhanced, amplifying their benefits. Interpretation of life cycle performance data reveals how effectively solutions align with SDGs, enabling strategic actions that maximize positive impacts through handprint thinking. Managing uncertainties ensures accurate interpretations by addressing data quality challenges and refining indicator methodologies, thereby maintaining reliable assessments. The track and improvement phase drives continuous learning and refinement, allowing adaptive targets and methodologies that respond to evolving dynamics. Together, these steps maximize operational sustainability, climate resilience, and positive contributions to sustainable development.

In the following sections, we will apply the SRM using the four-phase approach: Scoping, Implementation, Data Processing, and Assessment. For the assessment, sustainability profiles are presented, along with results, their interpretation, uncertainties, and actions for improvement and next steps. In the interpretation, we use symbols (+, ++, +++) to illustrate score levels: 0-1 (+), 2-3 (++), and 4-5 (+++), making it easy to read.

3.0 LAPPEENRANTA (FINLAND)

3.1 Scoping

Lappeenranta (61°06’N, 28°19’E) is a city in southeastern Finland, situated in the South Karelia region near the Russian border (Figure 3.1). It spans an area of 1,724 km² and has a population of approximately 73,000. The city lies on the shores of Lake Saimaa, the largest lake in Finland and the fourth largest in Europe, which is crucial for the city's water supply but has been affected by algal blooms. The terrain is dominated by the First Salpausselkä ridge, an ice-marginal formation composed mainly of sand and gravel, housing extensive groundwater reserves.

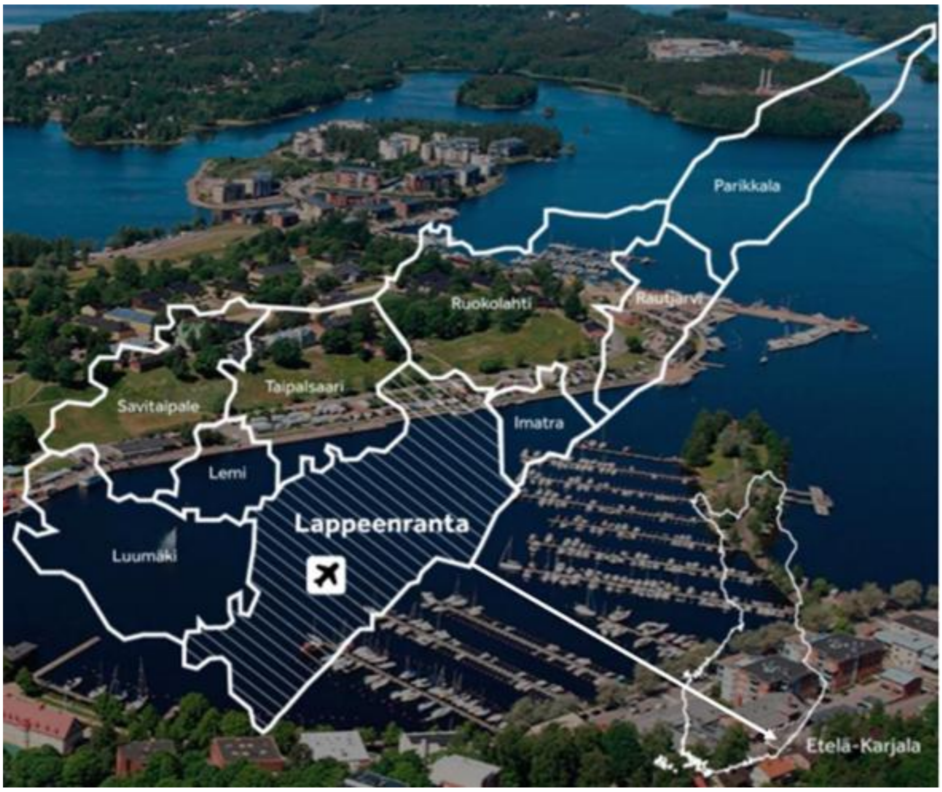


Figure 3.1 Lappeenranta’s boundaries within South Karelia in relation to the map of Finland

The city experiences a continental subarctic/boreal climate, characterized by four distinct seasons. Winters are notably longer than summers, with an annual precipitation average of 614 mm, about half of which falls as snow. Snowmelt typically occurs in April and May, contributing to flood risks. The climate is influenced by Lake Saimaa, the Gulf of Finland, and the Salpausselkä ridge, leading to significant local climate variations.

Specific challenges faced by the city in adapting to the impacts of climate change have been comprehensively identified through the Adaptation Pathway development (refer to D3.9 - Compendium of Pathways and Actions for detailed insights). To effectively address these challenges, the TransformAr project focuses on two critical Key Community Systems (KCS): water management and urban planning. The objectives and solutions designed to overcome these challenges are outlined in Table 3.1, providing a strategic framework for sustainable adaptation. To enhance the understanding of this report - focused on the sustainability profiles of the solutions - a review of the solutions and their interconnections is included here (illustrated in Figure 3.2). This ensures that readers grasp the contextual background and strategic approach. More detailed baseline analysis, additional insights and data can be found in the D5.8 - Intermediary Monitoring Report.

Table 3.1 Challenges and objectives in relation to solutions demonstrated

Challenges and objectives	Actionable adaptive solutions (AAS)*			
	URB	SWMM	CAF	CEI
• Increased flood risk due to increased rainfall and temperature in winter and spring: urban surface runoff and flood mitigation, mitigation of the risk	x	x		x
• Increase of peak events in precipitation: addressing the conveyance runoff water pipelines capacity issues	x	x		
• Environmental assessment of emission load to recipient lake and groundwater caused by runoff and infiltration: increasing awareness, mitigation of the load	x	x	x	
• Adaptation relevant data and information availability to all stakeholders: improvement to present state via real-time monitoring and novel data	x	x	x	
• Facilitation of the choice of alternative options, e.g., green infrastructure: increase awareness of stakeholders	x	x	x	x
• Climate change impacts in this region: Increase awareness of stakeholders via empirical data and forecasts from reliable sources.		x	x	

* URB: Nature-based urban stormwater solution, SWMM: Stormwater monitoring, CAF: Citizen App Finland, CEI: Choice Experiment survey.

The four actionable adaptive solutions (AAS) implemented in TransformAr are designed to address urban flood risks, water quality degradation, and climate change awareness. These solutions are strategically interconnected, forming a cohesive system that enhances urban resilience and community engagement (Figure 3.2). The review of each solution and its performance evaluations is presented.

The URB solution demonstrates a biofiltration area designed to harvest urban runoff and stormwater from streets and sidewalks. This NBS integrates plants and greenery to reduce urban runoff, enhance water retention, and filter pollutants before the water reaches Lake Saimaa or infiltrates into groundwater. The design also delays stormwater flow to the drainage system, functioning as a buffer zone to prevent flooding during severe rainfall events. Real-time sensors are deployed within the biofiltration area to monitor water volume flow and environmental emissions, including nutrient and heavy metal concentrations. This monitoring is complemented by water sampling campaigns, offering detailed insights into stormwater quality and pollution levels. The data collected from URB is integrated into the SWMM, where it is transformed into actionable information through predictive models and visual analytics.

SWMM is a scalable digital platform that collects and analyzes data from real-time sensors installed within the biofiltration area, urban drainage systems, and other strategic locations across the city. This system monitors water flow volumes, surface levels, and stormwater quality, generating high-resolution data on stormwater dynamics. This system's design ensures that information is presented in an accessible format for city planners through the Street AI platform and for citizens via the CAF. SWMM provides real-time monitoring of the URB biofiltration area, validating its effectiveness in pollution control and water retention.

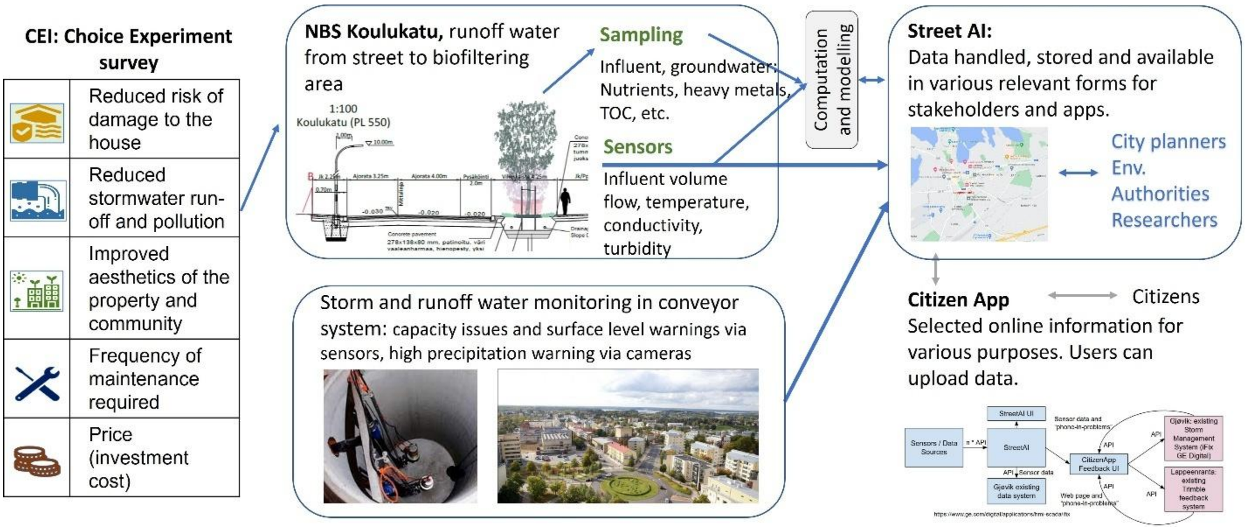


Figure 3.2 Actionable adaptive solutions (AAS) in Lappeenranta

CAF is a crowd-sensing and real-time monitoring platform designed to enhance public awareness of climate change and urban stormwater management. It provides up-to-date information on air quality, weather conditions, stormwater quality, and drainage system flooding. The app also supports community engagement by enabling citizens to report urban flooding, drainage issues, and other climate-related events, which are integrated into the Street AI system for municipal action. The CAF disseminates data generated from the SWMM platform, offering citizens real-time insights into the effectiveness of URB in stormwater management.

CEI is designed to evaluate stakeholder preferences and willingness to adopt green infrastructure for stormwater management. It gathers data from private landowners through surveys to understand community perceptions of NBS, willingness to pay for environmental improvements, and policy preferences for urban flood mitigation. Insights from CEI inform strategic decisions for upscaling NBS like URB and optimizing stormwater management infrastructure.

3.2 Implementation

The integration of Life Cycle Thinking (LCT), Handprint Thinking (HT), and Risk Assessment (RA) into the performance evaluation process offers a strategic approach to evaluating performance throughout the life cycle of solutions, guiding the development of relevant indicators. This section begins with a review of each solution and its applied methodology across four key solutions, followed by a list of indicators presented by performance categories. In general, LCT ensures that long-term effects, such as flood resilience, water quality, and system performance, are assessed across the entire life cycle. HT focuses on maximizing positive contributions, enhancing community engagement, and driving sustainable outcomes. At the same time, RA identifies potential risks, enabling proactive mitigation strategies to enhance the success and resilience of solutions.

Nature-based Urban Stormwater Solution (URB)

The performance evaluation of URB is structured into five tailored categories - Flooding Vulnerability, Water Quality, Environmental Impact, Biodiversity and Habitat, and Livability and Comfort - along with three common categories: Management and Coordination, Financial Viability, and Risk and Resilience. Table 3.2 outlines the performance categories and corresponding indicators for URB.

Table 3.2 Performance categories and indicators for Nature-based Urban Stormwater Solution (URB)

Performance categories	Indicator	Sub-indicator
Flood vulnerability	Reduced Flood Hazard	
	Reduced Runoff	
	Reduced Peak Flow	
	Reduction in Flood Damage	
Water Quality	Reduction in Nutrients	Reduction in Nitrogen (Nitrate (NO_3^-)) Loading
		Reduction in Phosphorus Loading
	Reduction in Metals	Reduction in Copper Loading
		Reduction in Zinc Loading
		Reduction in Antimony Loading
		Reduction in Cadmium Loading
Environmental Impact	Climate	Climate Change - total
		Resource use, fossils
	Water	Ecotoxicity, freshwater - total
		Eutrophication, marine
		Eutrophication, freshwater
	Air	Particulate matter
		Air Filtering
	Land	Eutrophication, terrestrial
	Human	Human toxicity. cancer - total
		Human toxicity. non-cancer - total
		Photochemical ozone formation, human health
Biodiversity and Habitat	Increase in Species Richness	
	Habitat Health	
Liveability and Comfort	Increase in Green Space	
	Residence Accessibility	
	Aesthetic Appreciation	
Management and Coordination	Internal Communication and Collaboration	
	Institutional Coordination	
	Commitment Fulfillment	
Financial Viability	Investment	Investment Cost
		Investment Cost Efficiency
	Maintenance	Cost
		Maintenance Cost Efficiency
	Avoided Cost	Value of real estate
		Cost of stormwater sewage drains
Risk and Resilience	Ice Mitigation Strategy	
	Snowmelt Overflow Prevention	

LCT, HT, and RA work together to develop indicators across various sustainability categories by integrating performance, risk, and positive impacts. Flooding Vulnerability: LCT, RA, and HT are embedded to identify indicators that measure flood resilience, such as Reduced Flood Hazard and Reduced Runoff, while RA anticipates risks like flood damage. HT focuses on enhancing flood resilience through water retention, and LCT tracks these impacts over time. Water Quality: HT and RA focus on reducing pollutants like nutrients and heavy metals. LCT evaluates the effectiveness of NBS in pollutant removal, ensuring improvements in water quality. Environmental Impact: HT selects indicators for positive environmental outcomes (e.g., Air Filtering), while RA anticipates risks like acidification and eutrophication. LCT integrates these to track long-term life cycle impact on the air, water, land, and human. Biodiversity and Habitat: HT promotes biodiversity by selecting indicators like Increase in Species Richness to ensure ecological health. LCT tracks biodiversity improvements throughout the solution lifecycle. Livability and Comfort: HT emphasizes Increase in Green Space and Aesthetic Appreciation to enhance social and environmental benefits, while RA addresses challenges like land-use conflicts. LCT ensures long-term benefits and tracks effective green space utilization. Management and Coordination: HT enhances social, environmental, and economic impacts by selecting indicators for community engagement and institutional coordination. RA anticipates communication breakdowns, ensuring effective management strategies, while LCT supports continuous impact monitoring. Financial Viability: HT selects indicators like Investment Cost Efficiency and Value of Real Estate to maximize economic benefits, while RA anticipates financial risks such as maintenance costs. LCT tracks financial impacts across the lifecycle, ensuring sustainability. Risk and Resilience: HT promotes proactive measures like Ice Mitigation Strategy and Snowmelt Overflow Prevention, ensuring adaptive flood management. RA identifies specific risks like blockages, and LCT monitors the effectiveness of mitigation strategies across the lifecycle. This integrated approach ensures that risks are proactively managed, positive contributions are maximized, and sustainability impacts are tracked over time for continuous improvement.

Stormwater Monitoring (SWMM)

The performance evaluation of SWMM is structured into two tailored categories - System Performance, Data Quality - along with three common categories: Stakeholder Engagement and Participation, Financial Viability, and Risk and Resilience. Table 3.3 outlines the performance categories and corresponding indicators for SWMM.

RA identifies risks in data governance, ensuring transparency, while HT fosters community involvement in Stakeholder Engagement and Participation. Indicators like Public Data Accessibility and Ease of Data Access ensure informed decision-making and stakeholder satisfaction. LCT ensures continuous improvement by monitoring operational and environmental impacts. System Performance: RA identifies vulnerabilities, guiding indicators like System Uptime and Scalability. HT enhances usability with indicators such as User Customization Options and Response Efficiency, ensuring stakeholder satisfaction. LCT fosters continuous improvement by contextualizing environmental and operational impacts. Data Quality: RA ensures data integrity through monitoring to mitigate contamination risks, while HT drives community involvement, enhancing Data Accuracy. Sampling Validation and Sampling Provider Match leverage HT's collaborative approach to optimize data quality and ensure robustness. Financial Viability: RA assesses financial risks to ensure cost-effectiveness, while HT aligns financial metrics with community needs, enabling strategic resource allocation. This minimizes economic risks and enhances long-term operational efficiency, fostering evidence-based financial decision-making. Risk and Resilience: RA anticipates data storage and partner dependencies, ensuring cloud capacity and local sustainability. HT encourages proactive strategies to mitigate risks through sensor coverage redundancy and stakeholder engagement. LCT ensures that governance aligns with sustainability goals, integrating environmental impacts into the resilience strategy. This integrated approach ensures holistic and adaptable assessments, driving sustainability, stakeholder engagement, and continuous improvement throughout the solution's life cycle.

Table 3.3 Performance categories and indicators for Stormwater Monitoring (SWMM)

Performance categories	Indicator	Sub-indicator
Stakeholder Engagement and Participation	Public Data Accessibility	
	Ease of Data Access	
	Data Usability Satisfaction	
System Performance	System Uptime	
	System Scalability	
	Integration Capability	
	Installation Requirements	
	User Customization Options	
	System Response	Response Efficiency
		Response Efficiency Satisfaction
	Tech-enabled Monitoring	Use of AI and ML
		Use of Energy
	Sensor Provider Match	
Data Quality	Continuous monitoring	
	Data Accuracy	
	Sampling Validation	
	Sampling Provider Match	
Financial Viability	Investment	Investment cost
		Investment cost efficiency
	Maintenance	Maintenance cost
		Maintenance cost efficiency
	Operation	Operational cost
		Operational cost efficiency
	Business Model Economic Risk	
Risk and Resilience	Cloud Data Capacity and Storage	
	Sensor Coverage Redundancy	
	Partner Dependency	

Citizen App Finland (CAF)

The performance evaluation of CAF is structured into five common categories: Stakeholder Engagement and Participation, Monitoring, Evaluation, and Adaptation, Management and co-ordination, Financial Viability, and Risk and Resilience. Table 3.4 outlines the performance categories and corresponding indicators for CAF.

RA assesses risks related to inclusivity and data accessibility, while HT promotes positive social outcomes through active participation in Stakeholder Engagement and Participation. Indicators like Event Attendance Rate and Event Attendance Satisfaction measure engagement success and quality of interactions. Monitoring, Evaluation, and Adaptation: RA helps identify risks in app accessibility, data accuracy, and usability, while HT focuses on community participation and feedback integration. Indicators like App Utilization Rate, Feedback Implementation Rate, and Coverage Area ensure the app adapts to local needs and fosters inclusivity. Management and Coordination: RA identifies risks in user support systems and engagement strategies, ensuring efficient responses, while HT fosters collaboration and sustainable behavior. Indicators like Timely Support Response and Engagement Strategy measure service efficiency and participation. Financial Viability: RA assesses financial risks and inefficiencies in costs, while

HT ensures stakeholder involvement in resource optimization. Indicators like Investment Cost, Cost Efficiency, and Operational Costs help evaluate the financial sustainability of the solution. Risk and Resilience: RA identifies vulnerabilities such as partner dependency and data hosting risks, while HT emphasizes local ownership and capacity building. Indicators like Partner Dependency and Local Control and Ownership ensure long-term sustainability and resilience.

Table 3.4 Performance categories and indicators for Citizen App Finland (CAF)

Performance categories	**Indicator**	**Sub-indicator**
Stakeholder Engagement and	Event Attendance	Event Attendance Rate
		Event Attendance Satisfaction
Monitoring, Evaluation, and Adaptation	Manual Language Diversity	
	Solution Implementation Completeness	
	Usability Satisfaction	
	App Utilization	App Utilization Rate
		App Utilization Satisfaction
	Feedback Implementation	Feedback Implementation Rate
		Feedback Implementation Satisfaction
	Coverage Area	
	Integration Capability	
Management and Coordination	Timely Support Response	
	Engagement strategy	
Financial Viability	Investment	Investment cost
		Investment cost efficiency
	Maintenance	Maintenance cost
		Maintenance cost efficiency
	Operation	Operational cost
		Operational cost efficiency
Risk and Resilience	Partner Dependency	
	Local Control and Ownership	
	Data Hosting and Accessibility	

Choice Experiment (CEI)

The performance evaluation of CEI is structured into five common categories: Stakeholder Engagement and Participation, Monitoring, Evaluation, and Adaptation, Management and co-ordination, Financial Viability, and Risk and Resilience. Table 3.5 outlines the performance categories and corresponding indicators for CEI.

RA is used to identify Risk and Resilience such as Partner Dependency, which assesses the reliance on external entities for survey design, distribution, and data collection. High dependency could expose vulnerabilities, while low dependency enhances resilience by fostering local self-sufficiency. HT emphasizes stakeholder empowerment, particularly through Survey Completion Rate and Survey Completion Satisfaction in Stakeholder Engagement and Satisfaction, ensuring that the survey is accessible, engaging, and designed to minimize participant effort while maximizing data quality. In

Monitoring, Evaluation, and Adaptation, Policy Impact Perception and Result Consistency reflect how well the survey results align with decision-making and institutional processes, boosting confidence in governance and the effectiveness of participatory mechanism.

Table 3.5 Performance categories and indicators for Choice Experiment (CEI)

Performance categories	Indicator
Stakeholder Engagement and Satisfaction	Survey Completion Rate
	Survey Completion Time
	Survey Completion Satisfaction
Monitoring, Evaluation, and Adaptation	Policy Impact Perception
	Result Consistency
Management and Coordination	Institutional Coordination
Financial Viability	Survey Investment
	Design and Data Resources
	Investment Cost Efficiency
Risk and Resilience	Partner Dependency

After the indicators were selected, they were assigned to the relevant SDGs by matching each indicator's measured outcome to the appropriate sub-targets, following methodology described in Section 2.2.3. For example, indicators

- "Reduced Flood Hazards" reflecting the effectiveness of NBS in decreasing the frequency of flood events
- "Response Efficiency Satisfaction" reflecting the SWMM system's response efficiency in addressing urgent issues,
- "Continuous Monitoring" reflecting the capability of a water management system to provide uninterrupted, real-time data on water quality, flow, and flood risks,

They are all connected to SDG 11: Sustainable cities and communities, specifically sub-goal 11.5, which aims to "significantly reduce the number… of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters,..". At the same time, the indicators "Reduced Flood Hazards" and "Response Efficiency Satisfaction" also contribute to SDG 13 Climate action, via sub-goal 13.1, which aims to "strengthen resilience and adaptive capacity to climate-related hazards...". Meanwhile, "Continues Monitoring" contributes to SDG 6: Clean water and sanitation, via sub-goal 6.3, which aims to "improve water quality by reducing pollution,..".

3.3 Data process

The data process stepinvolves several stages starting with data gathering, followed by assigning scores for qualitative indicators, and calculating and normalizing scores for quantitative indicators. After that, the scores are trasnferred to relevant SDG sub-goals, and the corresponding SDGs are then used for assessment. Next, the indicator scores are combined to generate aggregate scores for SDGs. The goal is to ensure that the collected data is consistently evaluated, standardized, and presented in a way that aligns with sustainability goals.

The project employs a systematic data gathering process, integrating iterative participatory interviews with supporting sources, such as monitoring reports, field studies, and institutional documentation. This multi-source approach ensures a comprehensive and evidence-based assessment of adaptation solutions, enhancing both qualitative and quantitative evaluations. Multiple sources are cross-checked, covering key deliverables such as:

- Stakeholders Matrix and IE Baseline Profiles (D1.2)
- Six Region-Specific Portfolios of Solutions (D3.8)
- Compendium of Pathways and Action Plans (D3.9)
- Intermediary Monitoring Report (D5.8)
- Replicable socio-economic impact assessment tools of transformational pathways (D3.6)
- Learning Stories on Awareness-raising and Behavioral Change Solutions (D4.1)
- Learning Stories on Nature-Based Solutions and Book of Nature-Based Solutions (D4.3)
- Learning Stories on Digital and Technological Solution (D4.4)
- Learning Stories on Insurance and Financial Solutions (D4.5)

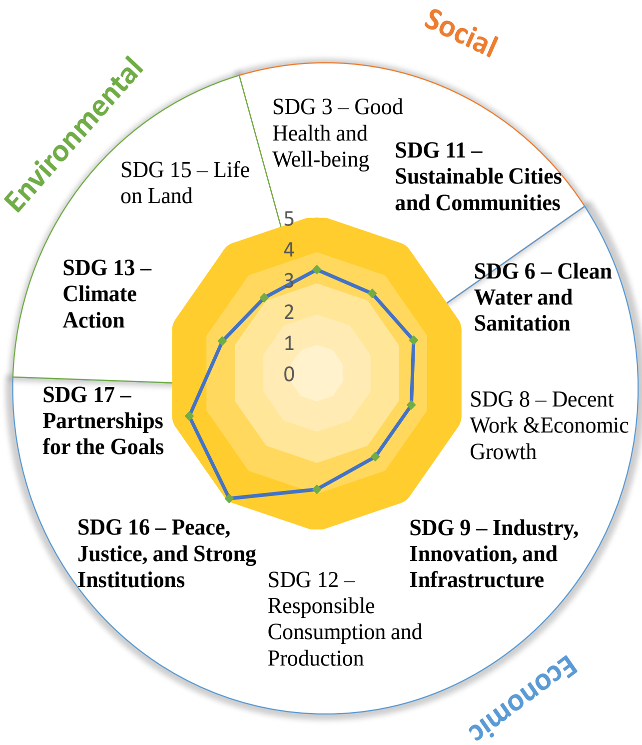
Institutional documentation plays an important role in supporting data collection and validating adaptation solutions, such as cost records related to investment, maintenance, and operation, as well as stakeholder engagement tracking records to monitor participation and impact. Additionally, it encompasses action plans and supporting literature that contribute to estimation. Field data and experimental results are gathered from monitoring systems and laboratory-tested samples, tracking indicators such as runoff, nutrient loading, and water quality. Documentation on NBS construction provides information on resource consumption and the work carried out during construction. This information, along with laboratory sample results, is used to develop life cycle inventories and conduct LCA assessing environmental impacts. Secondary data resources are also used, including literature data on maintenance requirements to complete life cycle inventories and LCA databases (Sphera and Ecoinvent) to calculate environmental impact. This integrated, multi-source approach ensures a comprehensive and accurate evaluation of the solutions' effectiveness.

The normalization is carried out using the general approach in the SRM described in Section 2.2.3. Furthermore, after all indicators have been assigned scores in a range from 0 to 5, the scores are allocated to the relevant SDG sub-goals identified for each indicator, and the final contribution to each SDG is aggregated using the weighted sum method, assuming equal weights for all indicators. However, the importance of each indicator or solution can be adjusted based on project goals, stakeholder input, or the specific context of Lappeenranta. Some indicators may need adjustment or weighting based on contextual factors. For instance, the socio-economic impact of stormwater management solutions might be weighted more heavily in areas with high flooding risks but lower engagement, ensuring that the evaluation balances both environmental and societal dimensions.

3.4 Assessment

The sustainability profiles of each solution and region-specific portfolio (RSP) are presented here. They align with SDG goals, as well as the sustainability domains of social, economic, and environmental aspects. The assessment begins with an evaluation of each solution, followed by the RSP, addressing three key aspects: results and their interpretation, uncertainties, and actions for improvement and next steps.

3.4.1 Sustainability profile of NBS for urban stormwater management (URB)



URB (Nature-based urban stormwater solution)

Primary targeted SDGs*:

Co-benefit SDGs:

* Targeted SDGs are black bordered.

The interpretation of the profile should focus on **Primary targeted SDGs** with multiple indicator contributions, while co-benefit SDGs typically have limited contributions from specific indicators.

Social domain

Relevant performance categories (indicators):

Flood Vulnerability (Reduced Flood Hazard, Runoff, Peak Flow, Flood Damage) – SDG 11, Liveability and Comfort – SDG 11 & 3, Management and Coordination (Internal Communication and Collaboration) – SDG 11, Financial Viability (Maintenance, Avoided Cost), and Risk and Resilience – SDG 11 & 3

Interpretation:

+++ Effective cross-department collaboration ensures sustainable urbanization and holistic management of nature-based solutions.

++ Managing peak flows decreases flood severity and reduces disaster-related losses in urban areas, while lowering the number of flooded structures mitigates economic and social damages, enhancing urban resilience.

\+ Cost savings from reduced stormwater drainage expenses highlight benefits in strengthening urban resilience and promoting sustainable infrastructure management, while green infrastructure improves public spaces and social well-being, though no increase in green space or residential accessibility has occurred, as the area remains unchanged from pre-intervention levels.

+ Proactive measures against ice blockages and rapid snowmelt enhance climate adaptation by protecting urban infrastructure from stormwater surges, and as a pilot Nature-Based Solution (NBS), the city has recently recognized ice mitigation risks and is considering a strategy guide to ensure resilience.

Effective cross-department collaboration ensures sustainable urbanization (SDG 11) and holistic management of nature-based solutions. Managing peak flows and reducing stormwater drainage costs enhance urban resilience, while green infrastructure fosters inclusivity and well-being (SDG 3).

Economic domain

Relevant performance categories (indicators):

Flood Vulnerability (Reduced Runoff) - SDG 6, Water Quality (Reduction in Nutrients and Metals) – SDG 6 & 12, Management and Coordination – SDG 16 & 17, Financial Viability - SDG 9 and SDG 17, Financial Viability – SDG 8

Interpretation:

+++ There is strong evidence of substantial runoff reduction, with noticeable positive impacts.

+++ Internal management, communication, and institutional coordination have been effective, strengthening institutional capacity and fostering the development of accountable and transparent institutions at all levels.

++ Water quality has improved, as shown by comparisons of inlet and downstream groundwater samples, although nearby summer construction activities may have potentially influenced upstream water parameters.

+ The investment shows moderate efficiency, contributing to green infrastructure development and reducing costs associated with stormwater drainage systems, however the intended benefits require further exploration and supporting evidence.

Overall, LAPP has been successful in contributing to SDG 16 and SDG 17 by strengthening institutional capacity and fostering accountable institutions. The green infrastructure investment (SDG 8, 9) shows positive impacts, although further evidence is needed. The system improves water quality (SDG 6), but upstream construction activities (SDG 12) may impact the results, requiring further exploration.

Environmental domain

Relevant performance categories (indicators):

Flood Vulnerability (Reduced Flood Hazard and Peak Flow) – SDG 13, Biodiversity and Habitat – SDG 15; Risk and Resilience (ice mitigation strategy), Liveability and Comfort (Increase in Green Space) – SDG 15, Risk and Resilience (Ice Mitigation Strategy) - SDG 13

Interpretation:

+++ Flood hazard has been significantly reduced, enhancing ecosystem resilience and mitigating climate-induced degradation, as highlighted in the Department Report from the city.

++ Peak flow has a moderate reduction with noticeable improvements in flood management, enhancing ecosystem resilience against climate-induced water extremes, though occasional high-flow events still occur, as observed by technicians on-site.

+ The Nature Smart Cities Business Model (NSC-BM) indicate an increase in species richness and improvements in habitat health, enhancing ecosystem resilience and contributing to the conservation and restoration of freshwater and terrestrial ecosystems.

+ As a pilot, this initiative has underscored the city's need to address ice mitigation risks to enhance resilience, ensuring ecosystem adaptability to climate change.

Overall, flood hazard reduction has strengthened ecosystem resilience and mitigated climate-induced degradation (SDG 13), with moderate peak flow reductions improving flood management. Increased species richness and habitat health support SDG 15. However, ice mitigation risks require further adaptation efforts.

Uncertainties

Several main issues should be considered when interpreting the results:

- Water quality data was obtained from laboratory analysis of manual samples. Inlet samples are considered reliable, whereas outlet samples were unavailable. Instead, downstream groundwater measurements served as proxies, introducing uncertainty due to complex groundwater processes. Additionally, nearby summer construction activities may have negatively influenced groundwater parameters, potentially biasing the evaluation of the NBS's effectiveness. Since no specific guidelines for stormwater exist in Finland yet, we used groundwater and lake water limits as the target reference.
- Biodiversity and Habitat: Results are derived from the NSC-BM modeling, which includes certain assumptions (for details, see D3.6 - Replicable socio-economic impact assessment tools of transformational pathways).

*Life Cycle Assessment (LCA): The results of the LCA performed for NBS show that water treatment by NBS results in improvements in the impact category of freshwater eutrophication due to a decrease in phosphorus concentration, and in human toxicity, due to the decrease in heavy metal concentration. Although these results are supported by literature showing improvements in water quality after filtration NBSs, the uncertainty of these results is rather high, as there is no measurement of water quality immediately after the NBS, as mentioned above.

At the same time, various emissions from the lifecycle of NBS (construction, maintenance, and demolition) lead to impacts in the following categories: climate change, freshwater ecotoxicity, human toxicity, and fossil resource use. The main impact comes from material production (biochar and growing media), which are background processes outside the influence of the demonstrator.

A weighted comparison of the results using the Environmental Footprint 3.0 methodology shows that the overall impact from the NBS lifecycle outweighs the benefits from water treatment. This may suggest that the NBS is a structure causing more harm than benefits, which is not entirely correct, as there are other environmental benefits (e.g., flood reduction), as well as social and economic advantages, that demonstrate the value of NBS. These environmental benefits cannot be fully estimated by LCA due to its inherent methodological limitations.

Ideally, the NBS lifecycle and benefits from water treatment should be compared with the current stormwater management infrastructure, which requires upgrades to effectively manage increased water flows resulting from climate change. These upgrades would inevitably generate additional construction emissions. However, reliable comparative data (both primary and from literature) is unavailable, and conducting an LCA based solely on assumptions for the construction introduces uncertainty to a level where the results are no longer reliable.

The results of the performed LCA can serve as guidance on critical processes (biochar and growing media) to focus on when replicating or constructing new NBS. However, due to limitations mentioned above, these results are not included in the sustainability profile of LAPP. At the same time, the improvement of water quality caused by NBS implementation is reflected in indicators "Reduction in Nutrients" and "Reduction in Metals".

Overall, uncertainties include water quality variations due to proxy data and nearby construction biases, and biodiversity estimates based on NSC-BM modelling assumptions.

Improvement and next steps

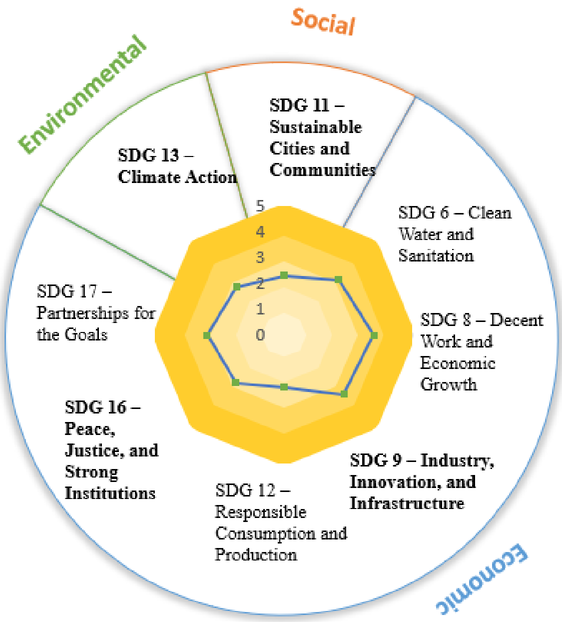
Several ongoing initiatives and planned actions are in place to enhance the effectiveness and resilience of NBS:

- Computations are currently underway to estimate water quality conditions at the NBS outlet. Continuous monitoring and data collection are essential to accurately assess the benefits of NBS. These efforts are closely linked with SWMM and CAF.

- Ice Mitigation and Snowmelt Overflow Prevention: Guidelines are being developed to improve risk management and resilience, ensuring the effectiveness of NBS under winter conditions.
- Life Cycle Impact Considerations: Taking into account not only benefits of NBS but also the environmental impacts caused by its life cycle is crucial for the sustainability of stormwater management in Lappeenranta. Therefore, the results of LCA should be included in a later version of the LAPP sustainability profile. To achieve this, additional data should be collected, and both the scope of the LCA and its results should be harmonized with the sustainability assessment method.
- BALTFLOOD Project: LAPP has launched a new three-year project, Baltic Flood Resilience and Digital Solutions (BALTFLOOD), funded by Interreg (3/2025–2/2028), to gain a more holistic understanding of the benefits and potential risks of NBS.

In summary, water quality validation is advancing through ongoing modeling efforts, ensuring accurate assessment of Nature-Based Solutions (NBS) benefits. Ice mitigation and snowmelt overflow guidelines are being developed to enhance resilience. Sustainable material selection prioritizes permeable surfaces and bio-based composites. The BALTFLOOD project (2025–2028) will further refine NBS effectiveness and risk management.

3.4.2 Sustainability profile of Stormwater monitoring (SWMM)



SWMM (Stormwater monitoring)

* Targeted SDGs are black bordered.

The interpretation of the profile should focus on **Primary targeted SDGs** with multiple indicator contributions, while co-benefit SDGs typically have limited contributions from specific indicators.

Social domain

Relevant performance categories (indicators):

System Performance (System Uptime, System Response), Data Quality (Continuous monitoring), Financial Viability (Maintenance) and Risk and Resilience (Sensor Coverage Redundancy).

Interpretation:

+++ The monitoring system has consistently remained operational, ensuring continuous data collection and analysis, which strengthens disaster resilience.

+ Regular maintenance ensures the long-term feasibility and effectiveness of the system.

+ The two-hour delay in sending monitoring results to the cloud and the reliance on a single set of sensors at the URB inlet for continuous data collection pose challenges for real-time responsiveness and create a risk of data gaps due to sensor failures.

Overall, the monitoring system remains operational, supporting disaster resilience, while regular maintenance ensures long-term feasibility. However, a two-hour data transmission delay affects real-time responsiveness, impacting hazard detection and pollution prevention. Additionally, reliance on a single sensor set risks data gaps from potential sensor failures, challenging SWMM's effectiveness.

Economic domain

Relevant performance categories (indicators):

Stakeholder Engagement and Participation – SDG 16 &17, System Performance (System Uptime, Scalability, Integration Capability, Installation Requirement – SDG 9, 16, & 17, Tech-enabled Monitoring – SDG 7, 9, 12, Sensor Provide Match, SDG 12 & 16), Data Quality – SDG 6, 9, 11, Sampling Provider Match - SDGs 12, 16 & 17, Financial Viability - SDG 8, 9, 11 & 12, Risk and Resilience – SDG 9, 11 & 16

Interpretation:

+++ The monitoring system has consistently remained operational and available for data collection and analysis. It is capable of efficiently adjusting to fluctuations in demand, configuration changes, or evolving operational needs. Additionally, it integrates seamlessly with external systems and technologies, ensuring smooth data exchange, interoperability, and synchronization.

++ Monitoring data has been validated consistency of data collected through manual sampling to ensure the reliability, accuracy, particularly in mitigating risks such as contamination and human error.

++ The city can effectively manage, scale, and secure data storage, handling current and future volumes while adapting to changing demands.

\+ The data is easily accessible by citizens through the CitySen.app (CAF); however, additional processing is required to make the information readable and understandable for the public. Currently, it is only accessible to city and technical partners, as the data is too technical.

\+ Sensors require modifications to the manholes, with some needing to remain underwater, and manhole leakage incidents have resulted in data loss; additionally, reliance on a single sensor and manual sampler collection provider may pose challenges and risks due to dependency on one supplier.

The monitoring system enhances SDG 9 by ensuring resilient, scalable, and interoperable infrastructure, efficiently adapting to operational changes and integrating with external systems. It supports SDG 16 through data reliability and transparency, validated by manual sampling to mitigate risks like contamination and human error. Accessible via CitySen.app (CAF), the platform promotes SDG 17 but requires addition efforts in data presentation. Data security and scalability reinforce SDG 6, while supplier dependency risks highlight procurement challenges impacting SDG 12 and SDG 8.

Environmental domain

13 CLIMATE ACTION

Relevant performance categories (indicators):

System Performance (System Uptime, System Scalability, System Response, Tech-enabled Monitoring)

Interpretation:

++ High system uptime ensures uninterrupted data flow, while strong scalability allows quick adaptation to changing requirements or increased demand with minimal disruption, strengthening overall resilience.

\+ The two-hour delay in sending monitoring results to the cloud/data platform hinders real-time responsiveness, reducing the system's ability to rapidly detect and address climate-driven hazards, such as extreme weather events, flooding, or contamination.

\+ The system relies on batteries, with no evidence of environmentally friendly technologies or advanced data analytics in water management, limiting its potential to enhance climate resilience through predictive analytics.

Overall, while high system uptime and strong scalability ensure uninterrupted data flow and adaptability, a two-hour data delay limits real-time hazard detection, reducing responsiveness to flooding and contamination. Reliance on battery-powered sensors without eco-friendly technology or advanced analytics restricts the system's potential to enhance climate resilience through predictive adaptation.

Uncertainties

Issues should be considered when interpreting the results:

- The development of user-friendly data modeling is in its final validation stage, with improved engagement anticipated once the validated results are integrated into the StreetAI system for enhanced accessibility and usability.
- The manhole leakage, which caused data loss early in the pilot, was resolved during project development, incorporating lessons learned and implemented improvements to enhance system reliability and resilience.

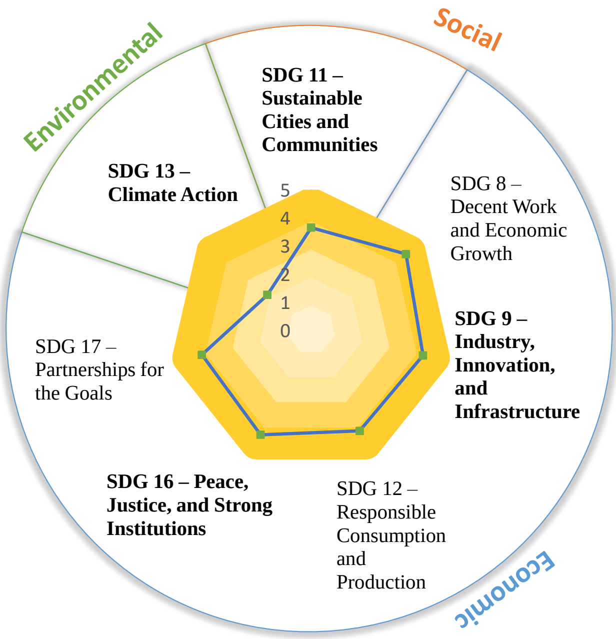
Improvement and next steps

Several ongoing initiatives and planned actions are in place to enhance the monitoring system:

- The integration of monitoring data is nearing completion, aiming to improve accessibility for the public and facilitate data usage.
- A new local provider has been identified by technical support partner for manual sampler collection, which could help mitigate some of the risks associated with the data validation to ensure the data quality of the monitoring system.
- BALTFLOOD Project: LAPP has launched a new three-year project, Baltic Flood Resilience and Digital Solutions (BALTFLOOD), funded by Interreg (3/2025–2/2028), to further advance data system integration.

Overall, the integration of monitoring data is nearing completion, enhancing public accessibility and usability. A new local provider has been secured for manual sampler collection, ensuring data validation and quality. The BALTFLOOD project (2025–2028) has been launched to advance flood resilience and digital solutions, further strengthening data system integration.

3.4.3 Sustainability profile of Citizen app (CAF)



CAF (Citizen App Finland)

Primary targeted SDGs*:

Co-benefits SDGs:

* Targeted SDGs are black bordered.

The interpretation of the profile should focus on **Primary targeted SDGs** with multiple indicator contributions, while co-benefit SDGs typically have limited contributions from specific indicators.

Social domain

Relevant performance categories (indicators):

Stakeholder Engagement and Participation, Monitoring, Evaluation, and Adaptation, Management and coordination (Timely Support Response)

Interpretation:

- +++ The stakeholder feedback process ensures inclusivity, with four suggestions made and implemented, demonstrating a commitment to integrating stakeholder input into decision-making.
- ++ The majority of app features are developed, with some remaining to be finalized by the project's end, ensuring full functionality.
- \+ Citizens can upload water quality data using citizen science toolkits, with the city collaborating with schools to promote environmental awareness, though application utilization remains limited, primarily concentrated in the western part of the city, indicating a need for broader engagement and coverage.
- \+ Stakeholder engagement is estimated through the one-day TransformAr Open Day event; the app's availability only in Finnish may limit accessibility and inclusivity (around 10% non-Finnish speakers), though English may be added in the future.

Overall, these contributions support progress toward SDG 11 by fostering inclusive and sustainable urbanization through stakeholder engagement, participatory planning, and continuous app improvements. Ensuring accessibility for non-Finnish speakers and expanding usage will further enhance its impact and reach.

Economic domain

Relevant performance categories (indicators):

Monitoring, Evaluation, and Adaptation, Financial Viability and Management and Risk and Resilience – SDG9 & 16, Management and Coordination (Timely Support Response) – SDG 16, Financial Viability – SDG 8, Stakeholder Engagement and Participation (Manual Language Diversity) – SDG 10, Monitoring, Evaluation, and Adaptation (Feedback Implementation, Integration Capacity), Management and Coordination (Engagement Strategy) and Risk and Resilience (Local Control and Ownership) – SDG 17

Interpretation:

+++ Based on the real-time data shared through the app, citizens can actively participate in citizen science initiatives, engage with the platform (e.g., reporting water quality measurement), contribute to local data collection, and enable local teams to develop data analysis skills. This process raises public awareness, enhances trust and engagement, strengthens research and innovation capacities, and fosters a robust infrastructure for climate monitoring, stormwater management, and informed decision-making.

+++ Localized data hosting enhance public access to information and increase institutional transparency.

++ The project ensures that investments in climate adaptation are optimized, reducing waste and fostering sustainable economic activity.

\+ Making critical environmental data available in multiple languages ensures inclusivity, allowing marginalized communities to participate in climate action decision-making.

Overall, this solution supports SDG 9 by fostering robust climate monitoring infrastructure through real-time data sharing, citizen science participation, and local data analysis skills. It enhances SDG 16 by promoting transparency, trust, and inclusive decision-making. Additionally, it advances SDGs 8, 10, 12, and 17 by optimizing climate adaptation investments and ensuring equitable access to environmental data.

Environmental domain

Relevant performance categories (indicators):

Stakeholder Engagement and Participation

Interpretation:

+ A one-day event was organized to promote the app, encountering challenges in communication and facilitating discussions on climate issues.

Overall, promoting the citizen app to enhance public engagement in raising awareness and understanding of climate risks requires further efforts to effectively contribute to local adaptation strategies.

Uncertainties

Main issues should be considered when interpreting the results:

- The stakeholder's engagement is estimated based on a single TransformAr Open Day event, including multi pupil groups for citizen science projects, which may not comprehensively represent the overall involvement and impact.
- As the pilot phase of the citizen app focuses on engagement, the primary target audience is Finnish-speaking citizens.

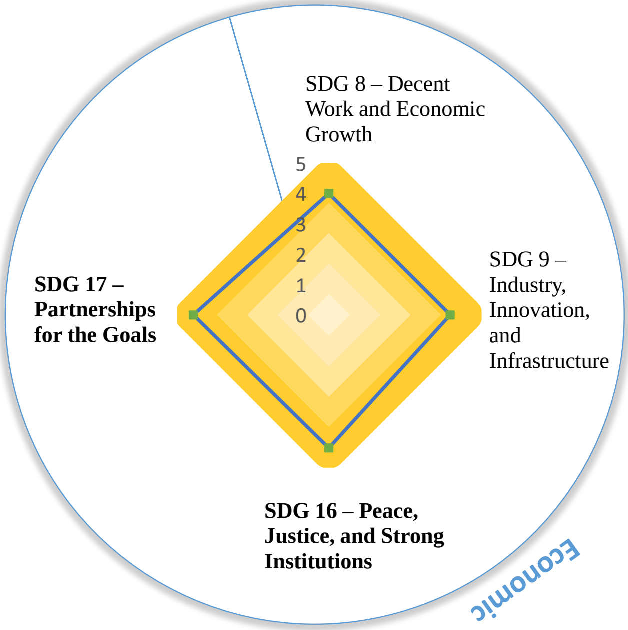
Improvement and next steps

Several ongoing initiatives and planned actions are in place to enhance the effectiveness and resilience of CAF:

- The app's development will continue, incorporating the latest alerting feature to enhance functionality, user engagement, and real-time responsiveness.
- The engagement strategy will be enhanced to attract more public participation and expand coverage across the city.
- BALTFLOOD Project: LAPP has launched a new three-year project, Baltic Flood Resilience and Digital Solutions (BALTFLOOD), funded by Interreg (3/2025–2/2028), to engage citizens, such as co-designing public services, crowdsourcing and citizen science.

Overall, improvements focus on enhancing the app's functionality to improve engagement and responsiveness. Public participation will be increased through a strengthened engagement strategy. The BALTFLOOD Project (2025–2028) will foster citizen involvement in co-designing services, crowdsourcing, and citizen science to enhance flood resilience and digital solutions.

3.4.4 Sustainability profile of Choice experiment for investors (CEI)



CEI (Choice Experiment)

Primary targeted SDGs*:

Co-benefits SDGs:

* Targeted SDGs are black bordered.

The interpretation of the profile should focus on **Primary targeted SDGs** with multiple indicator contributions, while co-benefit SDGs typically have limited contributions from specific indicators.

Economic domain

Relevant performance categories (indicators):

Stakeholder Engagement and Satisfaction, Monitoring, Evaluation, and Adaptation, Management and Coordination – SDG 16 & 17, Financial Viability – SDG 8 & 9, Risk and Resilience – SDG 9 & 16

Interpretation:

+++ Strong coordination among institutional partners across survey design, testing, data collection, analysis, and reporting enhances timely communication, role clarity, and informed decision-making.

++ High survey completion rates reflect effective citizen participation mechanisms, fostering responsive, participatory decision-making, and encouraging evidence-based, inclusive policymaking, with 19% of respondents believing their input will influence decision-making, highlighting institutional accountability, public trust, and efficient resource allocation for sustainable governance.

++ There is strong evidence of alignment, with most monitoring and assessment results remaining consistent despite differences in methodologies.

- Investing in survey tools and analysis platforms strengthens data-collection infrastructure for climate resilience, while the city relies on external partners for survey development and critical data analysis.

Through transparent data collection, inclusive governance, and strong partnerships, CEI supports institutional integrity (SDG 16) and fosters multi-stakeholder collaboration for sustainable decision-making (SDG 17), while also contributing to economic efficiency (SDG 8) and innovation in climate and stormwater solutions (SDG 9).

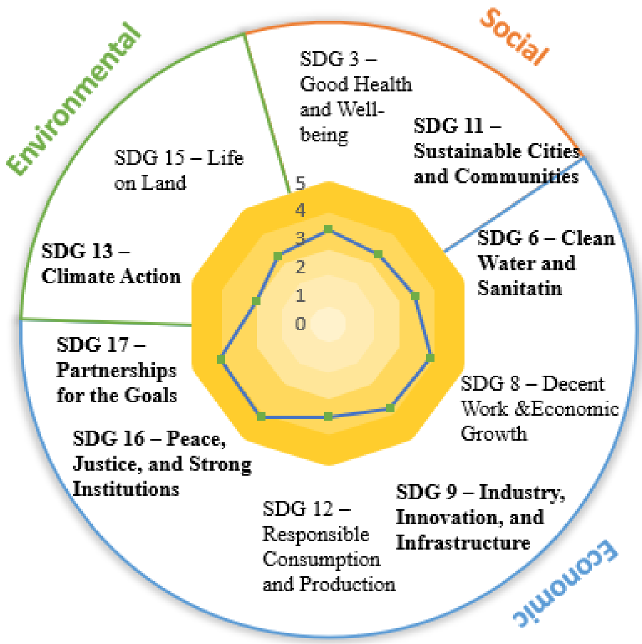
Uncertainties

The main uncertainty of the survey is that it analyses citizens' willingness to pay for solutions based on a hypothetical scenario, which may not accurately reflect real implementation. Consequently, Policy Impact Perception could vary in actual cases, influenced by real-world feasibility, cost implications, and public acceptance.

Improvement and next steps

The next steps will involve using the results to engage with decision-makers, aligning with other evidence to support policy development. This may include prioritizing flood risk reduction and runoff control, addressing citizens' concerns about maintenance costs and timing, and incorporating diverse preferences. Future efforts should also explore effective communication strategies to enhance public engagement and awareness of NBS benefits.

3.4.5 Sustainability profile of Region-specific portfolio (RSP)



Region-specific portfolio (RSP)
Include four solutions: URB (Nature-based urban stormwater solution), SWMM (Stormwater monitoring), CAF (Citizen App Finland) and CEI (Choice Experiment survey for citizens)

Primary targeted SDGs*:

* Targeted SDGs are black bordered.

The interpretation of the profile should focus on **Primary targeted SDGs** with multiple indicator contributions, while co-benefit SDGs typically have limited contributions from specific indicators.

Social domain

Relevant performance categories (indicators):

URB: Flood Vulnerability (Reduced Flood Hazard, Runoff, Peak Flow, Flood Damage) – SDG 11, Liveability and Comfort – SDG 11 & 3, Management and Coordination (Internal Communication and Collaboration) – SDG 11, Financial Viability (Maintenance, Avoided Cost), and Risk and Resilience – SDG 11 & 3

SWMM: System Performance (System Uptime, System Response), Data Quality (Continuous monitoring), Financial Viability (Maintenance) and Risk and Resilience (Sensor Coverage Redundancy) – SDG 11

CAF: Stakeholder Engagement and Participation -SDG 4 & 11, Monitoring, Evaluation, and Adaptation, Management and co-ordination (Timely Support Response) – SDG 11

Stakeholder Engagement and Satisfaction, Monitoring, Evaluation, and Adaptation, Management and Coordination – SDG 16 & 17, Financial Viability – SDG 8 & 9, Risk and Resilience – SDG 9 & 16

Interpretation:

- +++ Effective coordination across departments has ensured sustainable urbanization and improved nature-based solutions (URB, CAF and CEI)
- ++ Managing peak flows and reducing stormwater drainage costs (URB) enhance flood resilience and disaster prevention.
- \+ Stakeholder engagement and participatory planning (CAF) can be strengthened through a structured engagement strategy, enhancing inclusivity, resilience, and long-term project success, while limited accessibility for non-Finnish speakers and lack of expansion restricts the broader impact of urban resilience initiatives.
- \+ The monitoring system remains functional, supporting disaster resilience through regular maintenance and ensuring long-term usability (SWMM), however, a two-hour data transmission delay impacts real-time hazard detection and pollution prevention, and reliance on a single sensor set increases the risk of data loss, challenging SWMM's effectiveness in urban flood management.

In summary, effective coordination across departments has improved sustainable urbanization and nature-based solutions (URB, CAF, CEI), supporting flood resilience and disaster prevention (SDG 11). Stakeholder engagement and participatory planning enhance inclusivity and resilience, while the monitoring system (SWMM) ensures disaster resilience, but data transmission delays and sensor reliance pose challenges to real-time hazard detection (SDG 3, 11).

Economic domain

Relevant performance categories (indicators):

URB: Flood Vulnerability (Reduced Runoff) - SDG 6, Water Quality (Reduction in Nutrients and Metals) – SDG 6 & 12, Management and Co-ordination – SDG 16 &17, Financial Viability - SDG 9 and SDG 17

SWMM: Stakeholder Engagement and Participation – SDG 16 &17, System Performance (System Uptime, Scalability, Integration Capability, Installation Requirement – SDG 9, 16, & 17, Tech-enabled Monitoring – SDG 7, 9, 12, Sensor Provide Match, SDG 12 & 16), Data Quality – SDG 6, 9, 11, Sampling Provider Match - SDGs 12, 16 & 17, Financial Viability - SDG 8, 9, 11 & 12, Risk and Resilience – SDG 9, 11 & 16

CAF: Monitoring, Evaluation, and Adaptation, Financial Viability and Management and Risk and Resilience – SDG9 & 16, Management and co-ordination (Timely Support Response) – SDG 16, Financial Viability – SDG 8, Stakeholder Engagement and Participation (Manual Language Diversity) –

SDG 10, Monitoring, Evaluation, and Adaptation (Feedback Implementation, Integration Capacity), Management and co-ordination (Engagement Strategy) and Risk and Resilience (Local Control and Ownership) – SDG 17

CEI: Stakeholder Engagement and Satisfaction, Monitoring, Evaluation, and Adaptation, Management and Coordination – SDG 16 & 17, Financial Viability – SDG 8 & 9, Risk and Resilience – SDG 9 & 16

Interpretation:

- +++ Runoff reduction has had noticeable positive impacts on stormwater management, while water quality improvements are evident from sample comparisons (URB, SWMM).
- +++ Internal management, communication, and institutional coordination have enhanced institutional capacity (URB, CAF, CEI), while high survey completion rates reflect effective citizen participation and evidence-based policymaking (CEI).
- ++ The monitoring system (SWMM) and citizen app (CAF) integrate with StreetAI, ensuring data interoperability and synchronization, while manual sampling validation enhances data reliability and accuracy (SWMM).
- ++ The majority of app features are developed (CAF), but data accessibility via StreetAI needs improvement (SWMM, CAF), and 19% of respondents believe their input influences institutional decisions (CEI).
- \+ Investment in green infrastructure has helped reduce stormwater drainage costs, but long-term benefits need to be further explored (URB).
- \+ Application usage (CAF) remains low, with the app's Finnish-only availability limiting accessibility for non-Finnish speakers (10% of the population), while reliance on a single sensor and sampler provider poses supplier dependency risks, and manhole leakage issues have caused data loss and required sensor modifications (SWMM).

Overall, URB shows significant stormwater management improvements (SDG 6), reducing runoff and enhancing water quality. Investments in green infrastructure and cost reductions contribute to sustainable growth (SDG 8, SDG 9). Institutional coordination, transparency, and public trust (SDG 16) are fostered (URB, CEI), while global cooperation (SDG 17) supports data-sharing. Supplier dependency (SWMM) and app accessibility (CAF) challenges hinder broader impact, requiring further optimization to achieve sustainable, inclusive, and resilient urban development (SDG 12, SDG 10).

Environmental domain

Relevant performance categories (indicators):

URB: Flood Vulnerability (Reduced Flood Hazard and Peak Flow) – SDG 13, Biodiversity and Habitat – SDG 15; Risk and Resilience (ice mitigation strategy), Liveability and Comfort (Increase in Green Space) – SDG 15, Risk and Resilience (Ice Mitigation Strategy) - SDG 13

SWMM: System Performance (System Uptime, System Scalability, System Response, Tech-enabled Monitoring) – SDG 13

CAF: Stakeholder Engagement and Participation – SDG 13

Interpretation:

+++ Significant flood hazard reduction has strengthened ecosystem resilience, improved urban flood management, and supported long-term climate adaptation (URB).

++ Increased species diversity and improved habitat conditions contribute to freshwater and terrestrial ecosystem conservation, promoting biodiversity protection (URB).

+ Ice-related risks pose challenges to infrastructure resilience, requiring adaptive strategies (URB), while reliance on non-sustainable energy and lack of advanced analytics limit predictive climate adaptation and long-term sustainability (SWMM).

+ Limited community participation in the climate risk awareness app weakens public-driven adaptation efforts (CAF), while a two-hour data transmission delay reduces real-time responsiveness to flooding and contamination risks (SWMM).

Overall, Significant flood hazard reduction strengthens ecosystem resilience (URB, SWMM), supporting long-term climate adaptation (SDG 13) and promoting biodiversity conservation (SDG 15). However, challenges such as ice-related risks (URB), data submission delay (SWMM), and limited community participation (CAF) hinder predictive climate adaptation and public-driven efforts.

Uncertainties

Uncertainties exist across multiple areas, impacting the assessment of water quality, biodiversity, stakeholder engagement, and data modeling.

- Water quality data relies on manual sampling with proxies for inlet and outlet locations, potentially influenced by construction activities and the absence of stormwater guidelines in Finland (URB, SWMM).
- Biodiversity assessments are based on Nature Smart Cities Business Model (NSC-BM) modeling, incorporating assumptions that may affect accuracy (URB).
- Data modeling improvements are underway, with anticipated enhanced engagement upon integration into the StreetAI system (URB, SWMM), while manhole leakage issues that caused early data loss have been resolved, highlighting system reliability concerns (URB).

- Stakeholder engagement estimates are based on a single event, which may not fully capture public involvement (CAF), and survey results influenced by hypothetical willingness-to-pay scenarios may not accurately reflect real-world adoption or feasibility (CEI).

* The LCA results indicate key processes causing impact during the lifecycle of NBS, but these results are not included in the profile due to a lack of reliable comparative data and missing data on water quality after NBS. Thus, they primarily serve as guidance on critical processes to focus on when replicating or constructing new NBS

Overall, the uncertainties in water quality data stem from indirect measurements, that may be affected by construction activities. Biodiversity assessments rely on assumptions within NSC-BM modeling, and LCA results lack reliable comparative data. Additionally, stakeholder engagement estimates and survey results may not fully reflect real-world adoption.

Improvement and next steps

To enhance climate adaptation and urban resilience, several key initiatives are underway:

- Modeling tools are being developed to validate water quality data (SWMM), ensuring accurate assessment of NBS benefits through continuous monitoring and improved data accessibility.
- Ice mitigation guidelines and overflow prevention strategies are being implemented to enhance winter resilience, while sustainable materials like permeable surfaces and bio-based composites are prioritized to minimize environmental impact (URB).
- The CAF app is being upgraded with new alerting features for improved real-time responsiveness, while an expanded engagement strategy aims to boost citywide participation, and Citizens' willingness to pay (CEI) will engage decision-makers, aligning evidence with flood risk reduction, maintenance concerns (URB), and stakeholder preferences, while enhancing public awareness of NBS benefits.
- The BALTFLOOD Project (2025–2028) will drive flood resilience and digital solutions, with ongoing monitoring data integration improving public accessibility and usability, exploring the long-term benefits of NBS (URB, SWMM, and CAF).

In summary, LAPP will continue its development, focusing on enhancing water quality validation and improving NBS benefit assessments within the BALTFLOOD Project (2025–2028), and strengthening flood resilience, public data accessibility, and decision-making.

4.0 WESTCOUNTRY REGION (UK)

4.1 Scoping

The South West region covers an area of 23,800 km², bordered by the Atlantic Ocean to the north and west and the English Channel to the south and east. The Westcountry Rivers Trust (WRT) is exploring emerging ecosystem services markets as a mechanism to compensate landowners for restoring wetlands and riparian buffers along river corridors. The demonstrator sites are all located in the south-west of England (Figure 1). Each site falls within a catchment designated as either a Special Area of Conservation (SAC) (Camel and Axe) or Ramsar site (Somerset Levels and Moors), where water quality and quantity issues have been identified.

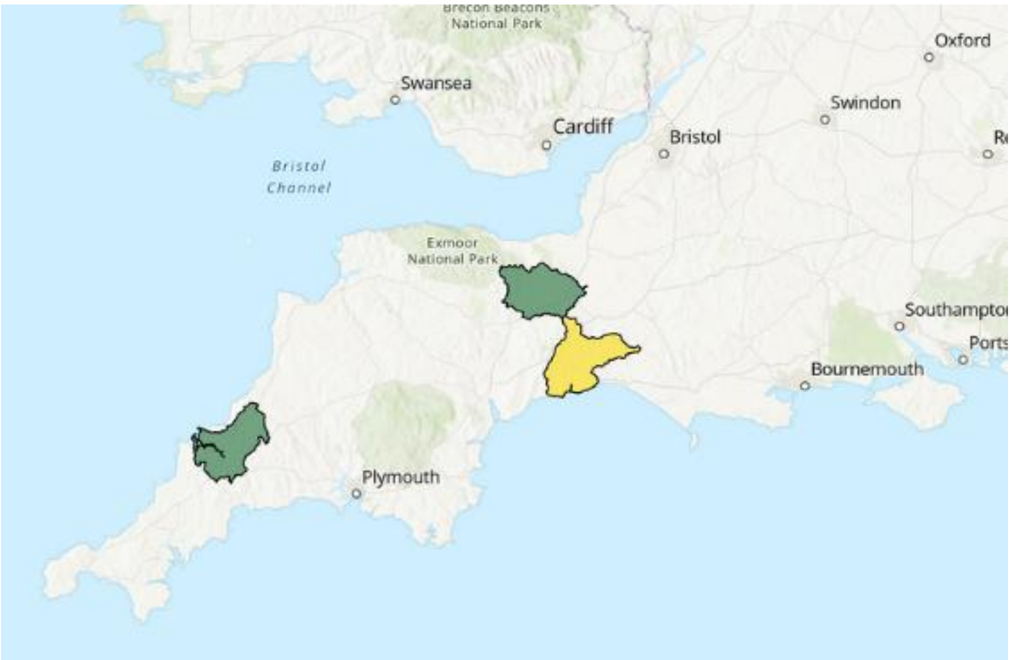


Figure 4.1 Demonstrator sites in the south-west of England

The Westcountry is expected to experience drier summers and more frequent extreme weather events, including droughts and intense rainfall, leading to water quality concerns. The UK Met Office projects several climate-related impacts for the region, such as increased river and surface water flooding, warmer and wetter winters affecting crop management, and hotter, drier summers impacting water quality and supply. Extreme weather events, including flooding, droughts, landslides, and heatwaves, may disrupt essential services and affect public health. Additionally, rising sea levels threaten coastal communities and infrastructure.

In TransformAr, WRT aims to tackle the challenges through the development of integrated constructed wetlands (ICW), monitoring of integrated constructed wetlands (ICWM) and green bonds (GB). Its objectives focus on implementing nature-based solutions such as riparian buffers, floodplain wetlands, and ponds to capture sediment, reduce nutrient loading in rivers, and enhance water storage and riparian habitats in key catchments. To ensure long-term adoption, compensation is needed for landowners who set aside agricultural land. WRT is testing Phosphate credits, allowing housing developers to fund ecosystem services for long term (30-80 years), enabling sustainable development in the catchment (Figure 4.2). Key Interventions include 1) Riparian Buffers and Floodplain Wetlands: Nature-Based Solutions (NBS) are used to create riparian buffers and floodplain wetlands, which filter pollutants from agricultural runoff before they reach waterways. These interventions aim to restore habitats and enhance the connectivity between ecosystems, promoting biodiversity; 2) Citizen Science Initiatives: Local communities are actively involved in monitoring water quality and biodiversity through citizen science programs. These initiatives not only collect valuable data but also engage the public in environmental stewardship; and 3) Ecosystem Services Markets: The Phosphate Credits and Biodiversity Net Gain credits are financial incentives designed to align the interests of farmers, developers, and environmentalists. By leveraging these credits, stakeholders are incentivized to adopt sustainable practices that benefit both agriculture and the environment.

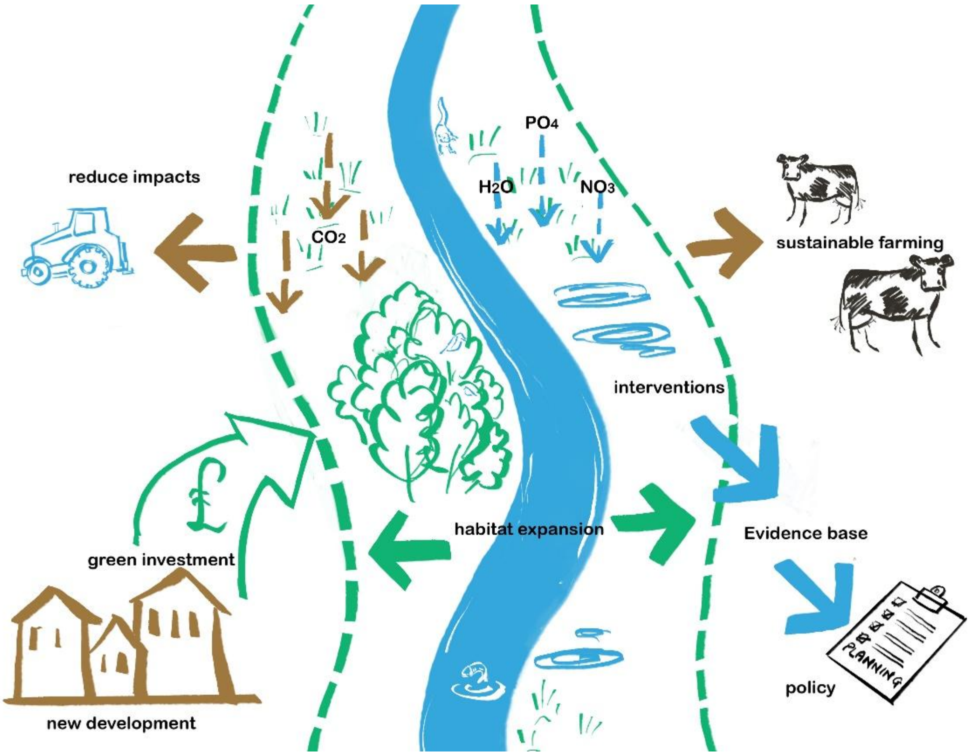


Figure 4.2 Infographic demonstrating benefits of green bond model

4.2 Implementation

The ICW, ICWM, and GB solutions are evaluated using a structured approach that incorporates Risk Assessment (RA), Handprint Thinking (HT), and Life Cycle Thinking (LCT). RA identifies potential risks, HT measures positive sustainability impacts, and LCT ensures long-term viability. These methods work together to provide a comprehensive assessment across multiple indicators. By integrating risk analysis, sustainability benefits, and life cycle considerations, this approach supports informed decision-making and enhances resilience. The structured evaluation ensures consistency in measuring each solution's performance, sustainability, and long-term impact, promoting effective and responsible implementation across various contexts.

Integrated Constructed Wetlands (ICW)

The performance evaluation of ICW is structured into six tailored categories – Readiness and Feasibility, Flood vulnerability, Water quality, Environmental Impact, Biodiversity and Habitat, Livability and Comfort, along with four common categories: Stakeholder Engagement and Participation, Management and Coordination, Financial Viability, and Risk and Resilience. Table 4.1 outlines the performance categories and corresponding indicators for ICW.

Table 4.1 Performance categories and indicators for Integrated Constructed Wetlands (ICW)

Performance categories	Indicator	Sub-indicator
Readiness and Feasibility	Methods Applied	
Stakeholder Engagement and Participation	Meeting Attendance	Meeting Attendance
		Meeting Engagement Satisfaction
	Workshop Attendance	Workshop Attendance
		Workshop Participation Satisfaction
	Event Attendance	Event Attendance
		Event Attendance Satisfaction
	Feedback Submission	Feedback Submission
		Feedback Submission Satisfaction
	Local Landowners Engaging	
Flood vulnerability	Water Retention Capacity	
Water quality	Reduction in Nitrogen Loading	
	Reduction in Phosphorus Loading	SNOWDON HILL FARM
	Improvement in pH level	SNOWDON HILL FARM
	Improvement in dissolved oxygen level	SNOWDON HILL FARM
Environmental Impact	Climate	Climate Change - total
		Resource Use, Fossils
	Water	Eutrophication, freshwater
	Land Use Change	
Biodiversity and Habitat	Increase in species richness	
Livability and Comfort	Community Resilience	Community Resilience
		Community Resilience Satisfaction
Management and Coordir	Communication Strategy Readiness	
	Stakeholder Coordination	
	Internal Communication and Collaboration	
	Commitment Fulfillment	Commitment Fulfillment
		Commitment Fulfillment Satisfaction
Financial Viability	Investment	Investment cost
		Scrapes & Sediment Traps
		Leaky Dams
		Brash Bundles & Scrapes
		Scrapes, Leaky Dams, Tree Coppicing & Tree Planting
		Investment cost efficiency
	Maintenance	Maintenance Cost
		Maintenance Cost Efficiency
Risk and Resilience	Landowner Maintenance Willingness	
	Phosphate Credit Calculation Change	
	Local Authority Permission	
	Sediment Management	

In Stakeholder Engagement and Participation, RA identifies risks related to low engagement, participation barriers, and feedback inefficiencies, HT encourages inclusive and proactive participation strategies, and LCT ensures that stakeholder involvement remains sustainable over time. For Flood Vulnerability, Water Retention Capacity assesses the role of riparian buffers and wetlands in flood mitigation. In Water Quality, RA identifies risks related to contamination persistence, HT fosters pollution reduction strategies, and LCT ensures that water management remains effective over time. For Environmental Impact, RA identifies risks related to greenhouse gas emissions, resource depletion, and ecological damage, HT enhances sustainable resource use strategies, and LCT ensures long-term environmental benefits. In Biodiversity and Habitat, RA identifies risks related to biodiversity loss and ecosystem fragmentation, HT promotes strategies to support species richness, and LCT ensures that interventions contribute to long-term ecological resilience. Within this category, Increase in Species Richness and Habitat Health assesses the ecological effectiveness of NBS. For Livability and Comfort, Community Resilience and Community Resilience Satisfaction assess the effectiveness of NBS in enhancing local adaptation capabilities. In Management and Coordination, RA identifies risks related to poor stakeholder coordination and commitment gaps, HT promotes engagement and trust-building strategies, and LCT ensures that coordination remains structured and sustainable. In Financial Viability, RA identifies financial risks related to high costs and funding constraints, HT emphasizes cost-effective solutions, and LCT ensures long-term financial sustainability. For Risk and Resilience, RA identifies risks related to landowner maintenance willingness, regulatory constraints, and sediment management, HT fosters policies and incentives to enhance maintenance engagement, and LCT ensures that resilience strategies remain scalable and sustainable.

Integrated Constructed Wetlands Monitoring (ICWM)

The performance evaluation of ICWM is structured into two tailored categories – System Performance, Data Quality, along with four common categories: Stakeholder Engagement and Participation, Management and Coordination, Financial Viability, and Risk and Resilience. Table 4.2 outlines the performance categories and corresponding indicators for ICWM.

Table 4.2 Performance categories and indicators for Integrated Constructed Wetlands Monitoring (ICWM)

Performance categories	Indicator	Sub-indicator
Stakeholder Engagement and Participation	Private Investment Attracted	
	Citizen Science Engagement	
	Training Participation	Training Participation
		Training Participation Satisfaction
	Training Completion	Training Completion
		Training Completion Satisfaction
	CSI Community Resilience	
System Performance	System Uptime	Continuous Phosphate Monitor
		Monitoring Staff
	System Uptime Satisfaction	
	System Scalability	
	Integration Capability	
	Installation Requirements	
	User Customization Options	
	Response Efficiency	Response Efficiency
	Sensor Lifespan	Sensor Lifespan
		Sensor Lifespan Satisfaction
	Tech-enabled Monitoring	Use of AI and machine learning (ML)
		Use of energy
	Sensor Provider Match	
	Computing Power	
	Sensor Maintenance Frequency	
	Software Update Frequency	
Data Quality	Continuous monitoring	
	Sampling Validation	
	Monitoring Data Accuracy	
	Sampling Data Matching	
	Sampling Provider Match	
	Sensor Coverage Redundancy	
Management and Coordir	Citizen Science Program	
	Stakeholder Coordination	
	Monitoring Spot Accessibility	
Financial Viability	Investment	Investment Cost
		CSI Sampling Toolkits
		Modelling Analysis
		Investment Cost Efficiency
	Maintenance	Maintenance Cost
		Maintenance Cost Efficiency
	Operational	Operational Cost
		Operational Cost Efficiency
	Business Model Economic Risk	
Risk and Resilience	Cloud Data Capacity and Storage	
	Partner Dependency	

In Stakeholder Engagement and Participation, RA identifies risks related to low participation, resource allocation inefficiencies, and community disengagement. HT fosters active participation in citizen science initiatives and training programs, while LCT ensures that engagement strategies remain sustainable over time. For System Performance, RA identifies risks related to downtime, integration challenges, and maintenance issues. HT promotes technological innovation, such as AI-driven monitoring and user customization, while LCT ensures that system upgrades and expansions remain sustainable. In Data Quality, RA identifies risks related to data inconsistencies, environmental influences, and discrepancies in sampling. HT fosters robust data validation strategies, including citizen science initiatives, while LCT ensures the long-term integration of accurate and diverse data sources. In Management and Coordination, RA identifies risks related to poor coordination, accessibility issues, and inconsistent community engagement. HT fosters active citizen participation in data collection, while LCT ensures that management frameworks support long-term operational sustainability. For Financial Viability, RA identifies financial risks related to investment constraints and operational expenditures, HT emphasizes cost-effective resource allocation, and LCT ensures that financial strategies remain sustainable over time. In Risk and Resilience, RA identifies risks related to reliance on external partners and infrastructure limitations, HT fosters local capacity-building to enhance resilience, and LCT ensures that infrastructure investments support long-term climate adaptability.

Green bonds (GB)

The performance evaluation of GB is structured into two tailored categories – Readiness and Feasibility, Governance and Policy, along with five common categories: Stakeholder Engagement and Participation, Monitoring, Evaluation, and Adaptation, Management and Coordination, Financial Viability, and Risk and Resilience. Table 4.3 outlines the performance categories and corresponding indicators for GB.

Table 4.3 Performance categories and indicators for Integrated Constructed Wetlands Monitoring (ICWM)

Performance categories	Indicator	Sub-indicator
Readiness and Feasibility	Phosphate Credit Implementation Readiness	
	Policy Interventions	
Stakeholder Engagement and Part	Event Participation	
	Private Sector Investment Engagement	
Governance and Policy	Flexible Financing Models	
Monitoring, Evaluation, and Adap	Legal Mechanism Effectiveness	
	Ethical Brokerage Coordination	
	Credit Revenue Generation	
	Payment Realization	
	Landowner Satisfaction	
	Investor Satisfaction	
	Ethical Broker Satisfaction	
Management and Coordination	Stakeholder Communication and Collaboration	
Financial Viability	Setup	Green Bond Setup Cost
		Green Bond Setup Efficiency
	Operational	Operational Costs
		Operational Cost Efficiency
Risk and Resilience	Conservation Covenant Compliance	
	Credit Calculation Impact	
	Market Demand Uncertainties	

In Readiness and Feasibility, RA identifies risks related to regulatory alignment, infrastructure readiness, and stakeholder coordination. HT emphasizes the role of policy-driven incentives to mobilize investment, while LCT ensures that financing models remain adaptable and scalable over time. For Stakeholder Engagement and Participation, RA identifies risks related to low investment attraction and ineffective stakeholder communication. HT fosters private sector participation through incentives and awareness, while LCT ensures that engagement strategies remain sustainable for long-term financial participation. In

Governance and Policy, Flexible Financing Models evaluates the adaptability of financing models for landowner compensation. In Monitoring, Evaluation, and Adaptation, RA identifies risks related to weak legal enforcement and payment inconsistencies, HT fosters ethical financial coordination, and LCT ensures that revenue models support sustainable conservation. For Management and Coordination, RA identifies risks related to inefficient coordination and misalignment of adaptation efforts, HT promotes engagement among local institutions, and LCT ensures that collaborative strategies enhance long-term financial sustainability. In Financial Viability, RA identifies risks related to high setup and operational costs, HT emphasizes efficiency in green finance management, and LCT ensures that financial models are scalable and impactful. For Risk and Resilience, RA identifies risks related to conservation covenant enforcement, fluctuating credit calculations, and market demand uncertainties. HT supports financial models that enhance investor confidence, while LCT ensures that market mechanisms remain adaptable to evolving conservation needs.

After the indicators were selected, they were assigned to relevant SDGs by matching each indicator's measured outcome to appropriate sub-targets, following the methodology described in Section 2.2.3. For example:

- Maintenance Cost Efficiency, reflecting efficient resource use in maintaining digital infrastructure and monitoring equipment, contributes to sub-goal 8.4, which aims to "improve progressively, through 2030, global resource efficiency in consumption and production and endeavours to decouple economic growth from environmental degradation." Optimized maintenance helps systems operate reliably with minimal environmental and financial costs, directly supporting sustainable economic growth.
- Phosphate Credit Calculation Change assesses adjustments to phosphate credit systems and their impact on landowners' willingness to adopt sustainable practices. It is linked to sub-goal 8.3, which seeks to "promote development-oriented policies that support productive activities, decent job creation, entrepreneurship, creativity, and innovation, and encourage the formalization and growth of micro-, small- and medium-sized enterprises." By influencing economic incentives, this indicator promotes entrepreneurship and productivity in sustainable land management.
- Landowner Satisfaction evaluates stakeholders' experiences with green bonds as financing tools for conservation projects. This indicator contributes to sub-goal 8.3 by ensuring green bonds are accessible, effective, and financially appealing, thereby fostering the growth of conservation-based enterprises and sustained participation in sustainable development.

Together, these indicators support SDG 8 – Decent Work and Economic Growth – by promoting resource efficiency, innovation in land management practices, and inclusive financial tools, strengthening the economic viability of nature-based solutions and sustainable rural economic activities. Additionally, each indicator also aligns with other SDGs: Maintenance Cost Efficiency aligns with SDG 9.4, which calls for sustainable infrastructure upgrades and resource-use efficiency. By ensuring maintenance budgets are used wisely, the indicator supports the responsible development of nature-based infrastructure. Phosphate Credit Calculation Change is connected to SDG 6.3, which focuses on improving water quality by reducing pollution and minimizing nutrient runoff. Encouraging sustainable land management practices reduces phosphorus discharge, enhancing aquatic ecosystems' health. Landowner Satisfaction supports SDG 15.1, promoting conservation and sustainable use of terrestrial and freshwater ecosystems. Positive stakeholder experiences with green bond mechanisms encourage continued investment in biodiversity preservation and ecosystem restoration. Overall, the selected indicators bridge SDGs 6, 8, 9, and 15, by emphasizing resource efficiency, sustainable economic incentives, and stakeholder engagement in nature-based solutions.

4.3 Data process

The data process involves several stages starting with data gathering, followed by assigning scores for qualitative indicators, while scores for quantitative indicators are calculated and normalized. After that, the scores are transferred to relevant SDG sub-goals, and the corresponding SDGs are then used for assessment. Next, the indicator scores are combined to generate aggregate scores for SDGs. The goal is to ensure that the collected data is consistently evaluated, standardized, and presented in a way that aligns with sustainability goals.

The project employs a systematic data gathering process, integrating iterative participatory interviews with supporting sources, such as monitoring reports, field studies, and institutional documentation. This multi-source approach ensures a comprehensive and evidence-based assessment of adaptation solutions, enhancing both qualitative and quantitative evaluations. By synthesizing diverse data sources and refining indicator processing methods, this methodology strengthens the robustness of evaluations and advances effective climate resilience strategies, ensuring that adaptation solutions are well-validated, context-specific, and responsive to stakeholder needs.

Multiple sources are cross-checked, covering key deliverables such as:

- Stakeholders Matrix and IE Baseline Profiles (D1.2)
- Six Region-Specific Portfolios of Solutions (D3.8)
- Compendium of Pathways and Action Plans (D3.9)
- Intermediary Monitoring Report (D5.8)
- Learning Stories on Nature-Based Solutions and Book of Nature-Based Solutions (D4.3)
- Green Bonds: Innovative financial solutions for nutrient pollution (EU Missions – Adaptation to Climate Change)
- TransformAR NBS Impact Assessment
- Snowdon Hill Wambrook Biodiversity Metric Assessment

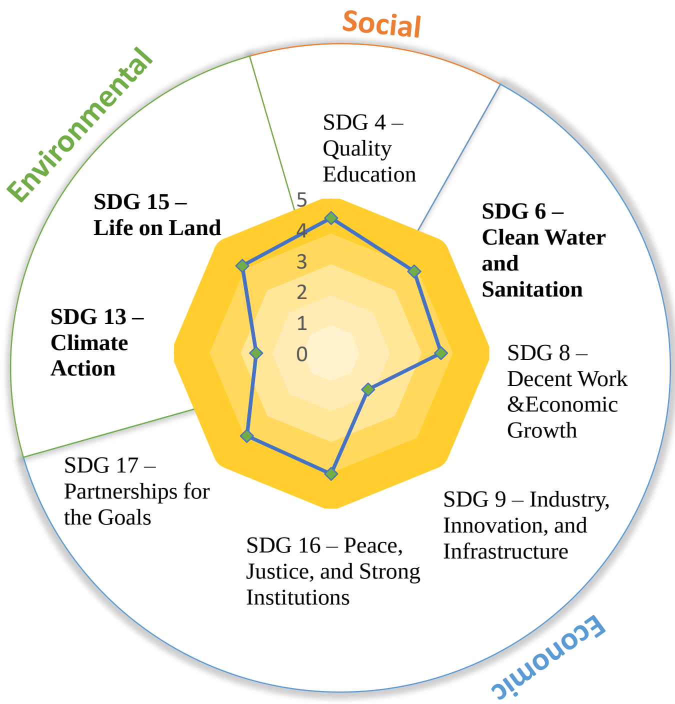
Institutional documentation plays an important role in supporting data collection and validating adaptation solutions, such as cost records related to investment, maintenance, and operation, as well as stakeholder engagement tracking records to monitor participation and impact. Field data offer critical insights by assessing environmental changes and ecosystem resilience. By integrating these elements, the project ensures a data-driven, evidence-based approach that strengthens the effectiveness and scalability of adaptation strategies. Documentation on NBS construction provides information on resource consumption and the work carried out during construction. This information, along with water quality monitoring results, is used to develop life cycle inventories and conduct LCA assessing environmental impacts. Secondary data resources including literature information about maintenance requirement, runoff volume, and efficiency of nutrients removal by different types of NBS, are also used to complete life cycle inventories. Background data were collected from LCA databases (Sphera and Ecoinvent). LCA for Experts by Sphera was used to model the life cycle NBSs and calculate their environmental impact. This integrated, multi-source approach ensures a comprehensive and accurate evaluation of the solutions' effectiveness.

After all relevant information for quantitative indicators has been collected, it was normalized to ensure comparability both among the quantitative indicators themselves and with the qualitative indicators. Normalization is carried out using the general approach in the SRM described in Section 2.2.3. Furthermore, after all indicators have been assigned scores in a range from 0 to 5, the scores are allocated to the relevant SDG sub-goals identified for each indicator, and the final contribution to each SDG is aggregated using the weighted sum method, assuming equal weights for all indicators. However, the importance of each indicator or solution can be adjusted based on project goals, stakeholder input, or the specific context of WRT. Some indicators may need adjustment or weighting based on contextual factors. For instance, the socio-economic impact of stormwater management solutions might be weighted more heavily in areas with high flooding risks but lower engagement, ensuring that the evaluation balances both environmental and societal dimensions.

4.4 Assessment

The sustainability profiles of each solution and region-specific portfolio (RSP) are presented here. They align with SDG goals, as well as the sustainability domains of social, economic, and environmental aspects. The assessment begins with an evaluation of each solution, followed by the RSP, addressing three key aspects: results and their interpretation, uncertainties, and actions for improvement and next steps.

4.4.1 Sustainability profile of Integrated constructed wetlands (ICW)



ICW (Integrated Constructed Wetlands)

Primary targeted SDGs*:

Co-benefits SDGs:

* Targeted SDGs are black bordered.

The interpretation of the profile should focus on **Primary targeted SDGs** with multiple indicator contributions, while co-benefit SDGs typically have limited contributions from specific indicators.

Social domain

Relevant performance categories (indicators):

Stakeholder Engagement and Participation (Workshop Attendance, Event Attendance)

Interpretation:

+++ Workshops and public events focused on ICW solutions educate local communities on sustainable practices, and evaluating participant satisfaction helps ensure that learning objectives—such as sustainable agriculture and flood mitigation—are effectively achieved.

Economic domain

Relevant performance categories (indicators):

Readiness and Feasibility – SDG 6, Stakeholder Engagement and Participation – SDG 16 & 17, Flood Vulnerability – SDG 6, Water quality (Reduction in Phosphorus Loading) – SDG 6, Environmental Impact (Climate) – SDG 9, (Water) – SDG 6, Liveability and Comfort -SDG 16, Management and Coordination (Communication Strategy Readiness, Commitment Fulfilment) – SDG 16 & 17, Financial Viability (Investment) – SDG 8 & 9, Risk and Resilience (Landowner Maintenance Willingness) – SDG 17, (Phosphate Credit Calculation Change) – SDF 6 & 8, (Local Authority Permission) – SDG 16 & 17, (Sediment Management) – SDG 9

Interpretation:

+++ High meeting attendance and active stakeholder engagement support inclusive, responsive decision-making in wetland management. Landowner commitment to implementing riparian buffers and wetlands is evident, while timely local authority approvals are likely due to clear regulatory alignment and strong collaborative relationships.

+++ There is good evidence of communication strategy readiness, with effective stakeholder engagement and generally cost-efficient investment; feedback from climate adaptation and consultation workshops was slightly above average, offering useful insights and reasonable detail.

+++ The reduction of phosphorus loading is significant, with a notable impact on water quality and ecosystem health.

++ Local landowner engagement remains stable, though concerns about phosphate credit calculation changes have raised economic uncertainties for some, requiring clearer communication or incentives; some landowners needing targeted outreach, capacity-building, or support to commit to and maintain long-term conservation interventions.

+ Five of seventeen targeted nature-based solutions have been implemented, improving water quality and supporting inclusive, evidence-based decision-making in environmental management, although quantifying their full impact on regional resilience remains challenging due to the complexity of resilience metrics.

+ Although the greenhouse gas (GHG) emissions from ICW construction and maintenance are relatively low and partially balanced out by land use changes, there is still no direct mitigation benefit. Simultaneously, sediment management remains insufficient, raising risks of leakage, structural stress, or water quality issues.

Overall, ICWs reduce phosphorus loading and improve water quality (SDG 6), support cost-efficient investment and landowner engagement in sustainable practices (SDG 8 and SDG 9), and foster inclusive decision-making, strong communication strategies, and collaborative governance in nature-based wetland management and climate adaptation efforts (SDG 16 and SDG 17).

Environmental domain

Relevant performance categories (indicators):

Readiness and Feasibility – SDG 13, Stakeholder Engagement and Participation (Event Attendance) – SDG 13, (Local Landowners Engaging) – SDG 15, Flood Vulnerability – SDG 13, Water quality (Reduction in Phosphorus Loading) – SDG 15, Environmental Impact – SDG 13 & 15, Biodiversity and Habitat – SDG 15, Liveability and Comfort – SDG 13, Risk and Resilience (Landowner Maintenance Willingness) – SDG 15, (Sediment Management) – SDG 13

Interpretation:

+++ Climate resilience is enhanced through increased water retention and flood risk reduction achieved by nature-based solutions (NBS). Freshwater ecosystems are restored, biodiversity is supported, and land use is adapted for long-term ecological health and nutrient management in riparian and agricultural areas.

++ Although GHG emissions from the construction are currently unmitigated, the land use change from arable land to wetlands or grasslands strongly contributes to carbon sequestration and ecosystem resilience, while improved water quality lowers eutrophication impact—together boosting local biodiversity.

\+ Landowner participation in installing and maintaining wetlands or buffer zones is inconsistent, with many requiring targeted outreach, capacity-building, or incentives. Limited evidence of effective sediment management highlights the need for improved maintenance to prevent leakage, protect water quality, and strengthen climate resilience.

\+ Five of seventeen targeted nature-based solutions have been implemented to create riparian buffers and floodplain wetlands that filter agricultural runoff; their contribution to overall regional resilience remains difficult to quantify due to broad metrics and complex attribution within wider systems.

Overall, ICWs enhance climate resilience through water retention, flood mitigation, and improved sediment management (SDG 13). They support ecosystem restoration, biodiversity promotion, and sustainable land use, though inconsistent landowner participation highlights the need for targeted support to secure long-term environmental benefits (SDG 15).

Uncertainties

Uncertainties in interpreting the results include:

- Five NBS have been implemented, but water quality and environmental impact assessments have primarily focused on a single site, which is being used as a representative case for overall results.
- Data on nitrogen loading, pH levels, and dissolved oxygen are not available in this analysis and have been excluded from the profiles.
- Assessments of stakeholder coordination, internal communication, and collaboration are also not included due to a lack of available evaluation.
- Maintenance cost targets are missing, and maintenance cost efficiency could not be assessed due to a lack of available evaluation.
- Climate change impact should be interpreted with the understanding that it was calculated using a “no action” baseline. For more accurate comparisons, implemented solutions should be contrasted with other alternatives that perform the same function.

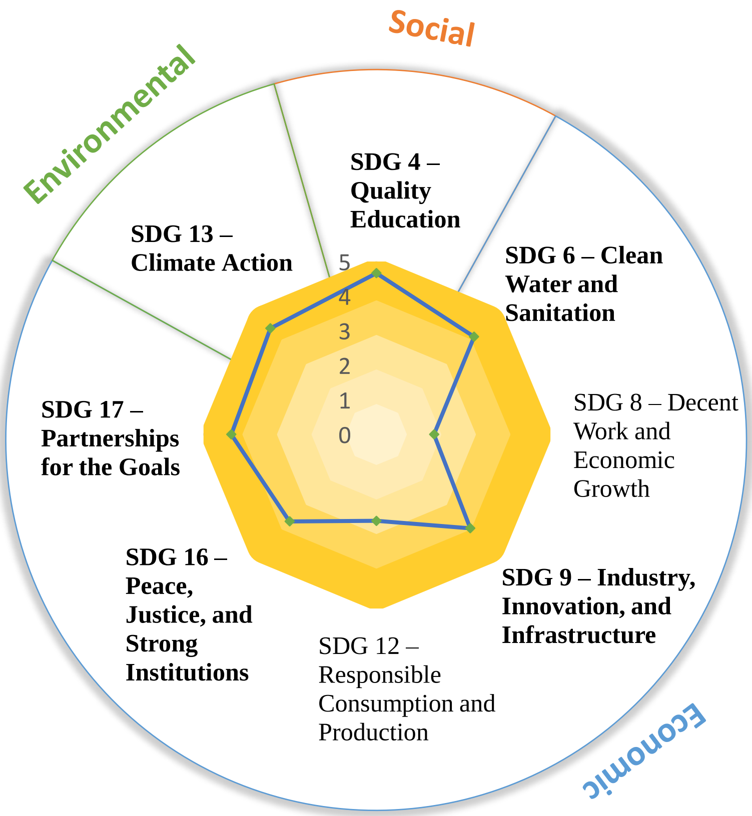
Improvement and next steps

Actions for the improvement and next steps:

- Expand environmental impact assessments beyond a single representative site and collect missing data on nitrogen loading, pH, dissolved oxygen, and maintenance costs to enable comprehensive analysis and improve evaluation accuracy.
- Address economic uncertainties related to phosphate credit calculations by improving communication, providing targeted outreach, and developing incentives or capacity-building programs to encourage sustained landowner participation in conservation practices.
- Conduct assessments of stakeholder coordination, internal communication, and collaboration to identify strengths and gaps, ensuring more cohesive and efficient delivery of nature-based solutions.
- Build on high meeting attendance and active stakeholder participation by integrating feedback mechanisms into decision-making processes and continuing to foster transparent, inclusive governance for wetland management.

Overall, environmental impact assessments will be expanded beyond a single site, addressing data gaps and economic uncertainties. Stakeholder coordination and collaboration will be assessed, ensuring efficient delivery and fostering inclusive, transparent governance for wetland management, with improved participation and communication strategies.

4.4.2 Sustainability profile of Integrated constructed wetlands monitoring (IWCM)



Primary targeted SDGs*:

Co-benefits SDGs:

* Targeted SDGs are black bordered.

ICWM (Integrated Constructed Wetlands Monitoring)

The interpretation of the profile should focus on **Primary targeted SDGs** with multiple indicator contributions, while co-benefit SDGs typically have limited contributions from specific indicators.

Social domain

Relevant performance categories (indicators):

Stakeholder Engagement and Participation (Training Participation, Training Completion), Financial Viability (Investment)

Interpretation:

+++ High attendance and completion rates in training sessions indicate effective skill-building and knowledge transfer, promote inclusive, quality education and lifelong learning opportunities essential for sustainable wetland and water resource management.

+++ Providing sampling toolkits through citizen science initiatives (CSI) fosters local education and awareness, actively involving communities in monitoring water quality and biodiversity.

Economic domain

Relevant performance categories (indicators):

Stakeholder Engagement and Participation – SDG 16 & 17, (Private Investment Attracted) – SDG 9, System Performance – SDG 9, (System Uptime Satisfaction, User Customization Options) – SDG 16, (Integration Capability, Sensor Provider Match) – SDG 17, Data Quality – SDG 9, (Sampling Validation, Sampling Data Matching) – SDG 16, Management and Coordination (Citizen Science Program) – SDG 16, (Stakeholder Coordination) – SDG 16 & 17, (Monitoring Spot Accessibility) – SDG 6 &9, Financial Viability – SDG 8, 9, 12 and 17, Risk and Resilience (Cloud Data Capacity and Storage) – SDG 9

Interpretation:

+++ Citizen science engagement fosters community ownership and resilience through local involvement in water sampling, while training enhances skills, collaboration, and informed decision-making.

+++ System uptime and satisfaction reflect the reliability and transparency of the monitoring infrastructure. The system demonstrates strong integration and scalability capabilities, with efficient response mechanisms that ensure real-time actions and improve decision-making.

+++ Continuous monitoring ensures real-time data collection for early detection and long-term sustainability, while high-precision data, scalable cloud storage, and robust sampling validation enhance data accuracy, support research, and strengthen overall monitoring reliability.

++ The use of intelligent analysis combined with sustainable energy solutions has the potential to enhance environmental monitoring, but issues with data downloading errors, variations between sampling and citizen science samples, and room for improvement in the Citizen Science Program's data consistency and validation remain.

+ System customization is challenging and requires technical expertise, with some features difficult to modify, while limited stakeholder coordination in monitoring water quality is further compounded by insufficient sensor coverage across the monitoring areas.

Overall, Citizen science engagement fosters community ownership and resilience through local involvement in water sampling (SDG 6), while training enhances skills and collaboration through innovation (SDG 9). System uptime and transparency ensure accountability (SDG 16), with strong integration achieved through partnerships (SDG 17). Continuous monitoring and real-time data collection strengthen decision-making processes (SDG 8) and support efficient resource management (SDG 12). However, challenges in system customization, data consistency, and stakeholder coordination remain.

Environmental domain

Relevant performance categories (indicators):

Stakeholder Engagement and Participation (Citizen Science Engagement, CSI Community Resilience), System Performance (Response Efficiency, Tech-enabled Monitoring, Computing Power), Data Quality (Continuous monitoring, Monitoring Data Accuracy, Sensor Coverage Redundancy), Management and Coordination (Citizen Science Program), Financial Viability (Investment)

Interpretation:

+++ Citizen science initiatives raise awareness of water and climate issues, empowering communities to adapt to environmental changes and strengthening local resilience to floods, droughts, and contamination through increased knowledge and preparedness.

+++ Reliable, real-time environmental data and continuous monitoring of wetland and water conditions enable early detection of climate and pollution stressors, enhancing early warning systems and supporting rapid adaptation strategies that strengthen community resilience to climate hazards.

\+ The use of intelligent analysis supports early detection of climate-related anomalies, enhancing community adaptation strategies, while citizen science programs—though supported by structured training and methodologies—require improvements in consistency and data validation.

\+ Improving sensor redundancy enhances the system's ability to detect anomalies or changing conditions more rapidly, reducing the risk of undetected climate events or pollution incidents and strengthening the overall adaptive response and resilience of environmental monitoring systems.

Overall, citizen science, intelligent analysis, and improved sensor redundancy enhance early detection of climate and pollution stressors. These tools support rapid adaptation, raise awareness, and empower communities to strengthen resilience against floods, droughts, and contamination through better data, preparedness, and environmental monitoring.

Uncertainties

Uncertainties in interpreting the results include:

- Assessments of some indicators are not included due to the lack of evaluation, including factors such as sensor lifespan, software update frequency, sampling provider match, business model economic risks, and partner dependency.
- Some indicators lack baselines or targets, relying on assumptions, which introduces uncertainties in the analysis and assessment process.

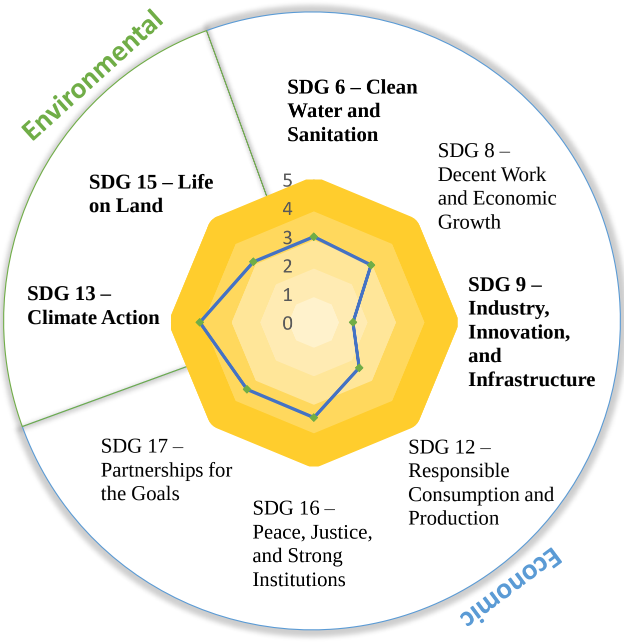
Improvement and next steps

Actions for the improvement and next steps:

- Improve data quality by addressing variations between citizen science samples and sensor data through better training, standardized protocols, and more robust validation methods to ensure reliable and consistent results.
- Expand sensor networks and improve redundancy to enhance the monitoring system's ability to detect anomalies more quickly, ensuring better real-time responses to climate-related events and pollution incidents.
- Invest in simplifying system customization and technical support to reduce dependence on external expertise, while fostering better coordination between stakeholders to optimize water quality monitoring and decision-making processes.

Overall, data quality should be improved by addressing variations between citizen science and sensor data, enhancing sensor networks for quicker anomaly detection, and simplifying system customization. Stakeholder coordination should be improved to optimize water quality monitoring and decision-making processes.

4.4.3 Sustainability profile of Green bonds (GB)



GB (Green Bonds)

Primary targeted SDGs*:

Co-benefits SDGs:

* Targeted SDGs are black bordered.

The interpretation of the profile should focus on **Primary targeted SDGs** with multiple indicator contributions, while co-benefit SDGs typically have limited contributions from specific indicators.

Economic domain

Relevant performance categories (indicators):

Readiness and Feasibility (Phosphate Credit Implementation Readiness) - SDG6 & 8, (Policy Interventions) – SDG 8, Stakeholder Engagement and Participation – SDG 8, 16 & 17, Governance and Policy – SDG 8 & 17, Monitoring, Evaluation, and Adaptation (Legal Mechanism Effectiveness, Ethical Brokerage Coordination) – SDG 16 & 17, (Credit Revenue Generation) - SDG 6 & 8, (Payment Realization) – SDG 8 & 16, (Landowner Satisfaction) – SDG 8, (Investor Satisfaction) – SDG 12 & 17, (Ethical Broker Satisfaction) – SDG 16 & 17, Management and Coordination -SDG 16 & 17, Financial Viability – SDG 8, 9 & 12, Risk and Resilience – SDG 8, 16 & 17 16

Interpretation:

+++ Supportive regulation like nutrient neutrality creates market demand, while ethical brokering and strong cross-sector coordination—despite some complexity—foster trust and transparency, enhancing green bond financing, especially from Development for housing (private) where legal phosphate offset requirements drive higher certainty than in other sectors.

++ Ethical broker satisfaction is overall positive, with promising solutions emerging despite slow progress and high initial legal and setup costs, which are expected to decline as the mechanism matures and standardized offset calculations need to be adopted to ensure consistency, transparency, and minimize risk.

\+ Phosphate credit implementation is progressing, with lessons from pilot areas informing broader rollout under nutrient neutrality schemes. While credit revenue potential is promising, constructed wetlands remain in design, delaying payment realization. Slow credit development affects landowner satisfaction.

\+ GB setup faced major delays due to the need for new contracts, frameworks, and payment rate design, while operational delays stemmed primarily from framework setbacks and changes in government legislation.

Overall, GB supports improved water quality (SDG 6) through phosphate offsetting, while stimulating rural employment and conservation-based income (SDG 8). It enables innovative financing and wetland infrastructure (SDG 9), promotes sustainable land management (SDG 12), fosters transparent and accountable governance (SDG 16), and relies on inclusive, cross-sector partnerships for effective implementation (SDG 17).

Environmental domain

Relevant performance categories (indicators):

Readiness and Feasibility (Policy Interventions) – SDG 13, Monitoring, Evaluation, and Adaptation (Legal Mechanism Effectiveness, Landowner Satisfaction) – SDG 15, Risk and Resilience (Conservation Covenant Compliance) – SDG 15

Interpretation:

+++ Effective policies for private sector climate investment, such as nutrient neutrality regulations, ensure that adaptation and mitigation strategies are embedded in national and regional frameworks, while also creating a defined market and demand for environmental credits.

++ Landowner satisfaction has been impacted by slow credit development and delays, yet fostering contentment is crucial, as satisfied landowners are more likely to uphold ecosystem stewardship, contributing to biodiversity protection and the conservation of wetland environments.

\+ Landowner compliance with legally binding conservation covenants is key to securing long-term ecosystem service commitments; while four sites are targeted, two are still in the process of being purchased and not yet under covenant protection.

Overall, GB embeds climate adaptation and mitigation into policy frameworks and creating markets for environmental credits (SDG 13), while promoting landowner stewardship, biodiversity protection, and long-term conservation through legally binding covenants and sustained ecosystem service commitments (SDG 15).

Uncertainties

Uncertainties in interpreting the results include:

- Early-stage implementation: many components are still in development or pilot phases, limiting the ability to fully assess the effectiveness of the solution.
- Revenue uncertainty: projected credit revenues remain unconfirmed and depend on the completion of infrastructure and actual market demand.
- Reliance on pilot data: current evaluations are based on a limited number of early cases, making it challenging to draw broadly applicable conclusions.

Improvement and next steps

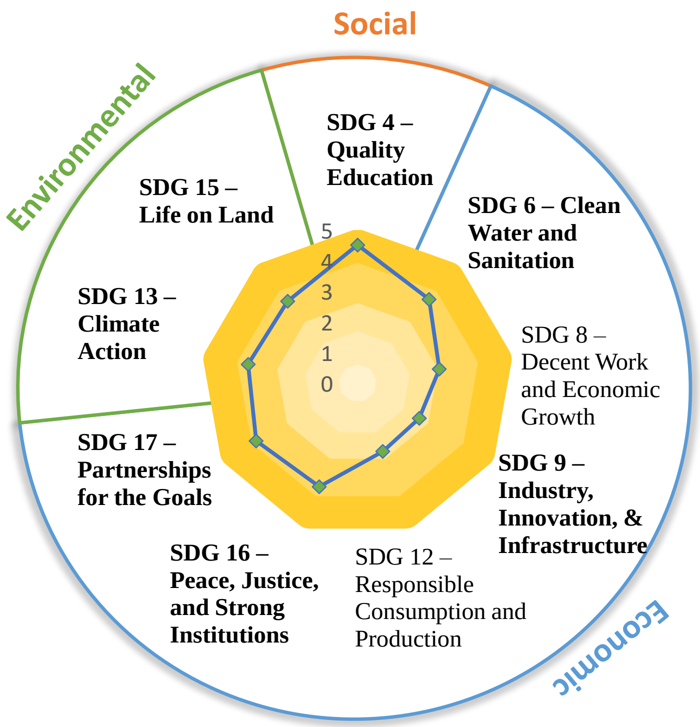
Several key actions from improvement and next steps:

- Scale up the rollout of nutrient neutrality and credit schemes by applying lessons from pilot areas. Finalize necessary frameworks, contracts, and payment structures to address current delays and meet delivery targets, including the progression of sites currently in the purchase phase.
- Reinforce regulatory certainty to support ongoing demand, particularly in housing development, while exploring additional sectors. Promote consistent offset calculations and expedite infrastructure delivery—such as constructed wetlands—to unlock credit sales and revenue generation.

- Address landowner concerns by reducing scheme delays, clarifying financial incentives, and advancing legally binding conservation covenants. Tailor support to improve satisfaction and ensure long-term commitment to ecosystem services and biodiversity protection.
- Lower entry costs as the mechanism matures by sharing case examples and standardizing processes. Build on the effective role of trusted brokers to streamline coordination, improve clarity, and sustain cross-sector collaboration essential for green bond success.

In summary, expanding rollout, strengthening market confidence, enhancing landowner engagement, and improving coordination are key next steps to accelerate green bond implementation, reduce delays, and ensure long-term environmental and economic impact.

4.4.4 Sustainability profile of Region-specific portfolio (RSP)



Region-specific portfolio (RSP)
Include three solutions: ICW (Integrated Constructed Wetlands), ICWM (Integrated Constructed Wetlands Monitoring), GB (Green bonds)

Primary targeted SDGs*:

Co-benefits SDGs:

* Targeted SDGs are black bordered.

The interpretation of the profile should focus on **Primary targeted SDGs** with multiple indicator contributions, while co-benefit SDGs typically have limited contributions from specific indicators.

Social domain

Relevant performance categories (indicators):

ICW: Stakeholder Engagement and Participation (Workshop Attendance, Event Attendance)

ICWM: Stakeholder Engagement and Participation (Training Participation, Training Completion), Financial Viability (Investment)

Interpretation:

+++ Workshops and public events focused on ICW solutions educate local communities on sustainable practices, ensuring learning outcomes like flood mitigation and sustainable agriculture are effectively achieved.

+++ Training sessions and citizen science initiatives under ICWM foster inclusive, quality education by building skills, encouraging lifelong learning, and engaging communities in monitoring water quality and biodiversity.

Overall, the ICW and ICWM solutions fosters inclusive, quality education through workshops, training sessions, and citizen science initiatives that build skills, promote lifelong learning, and engage communities in sustainable practices and environmental monitoring.

Economic domain

Relevant performance categories (indicators):

ICW: Readiness and Feasibility – SDG 6, Stakeholder Engagement and Participation – SDG 16 & 17, Flood Vulnerability – SDG 6, Water quality (Reduction in Phosphorus Loading) – SDG 6, Environmental Impact (Climate) – SDG 9, (Water) – SDG 6, Liveability and Comfort -SDG 16, Management and Coordination (Communication Strategy Readiness, Commitment Fulfilment) – SDG 16 & 17, Financial Viability (Investment) – SDG 8 & 9, Risk and Resilience (Landowner Maintenance Willingness) – SDG 17, (Phosphate Credit Calculation Change) – SDF 6 & 8, (Local Authority Permission) – SDG 16 & 17, (Sediment Management) – SDG 9

ICWM: Stakeholder Engagement and Participation – SDG 16 & 17, (Private Investment Attracted) – SDG 9, System Performance – SDG 9, (System Uptime Satisfaction, User Customization Options) – SDG 16, (Integration Capability, Sensor Provider Match) – SDG 17, Data Quality – SDG 9, (Sampling Validation, Sampling Data Matching) – SDG 16, Management and Coordination (Citizen Science Program) – SDG 16, (Stakeholder Coordination) – SDG 16 & 17, (Monitoring Spot Accessibility) – SDG 6 &9, Financial Viability – SDG 8, 9, 12 and 17, Risk and Resilience (Cloud Data Capacity and Storage) – SDG 9

GB: Readiness and Feasibility (Phosphate Credit Implementation Readiness) - SDG6 & 8, (Policy Interventions) – SDG 8, Stakeholder Engagement and Participation – SDG 8, 16 & 17, Governance and Policy – SDG 8 & 17, Monitoring, Evaluation, and Adaptation (Legal Mechanism Effectiveness, Ethical Brokerage Coordination) – SDG 16 & 17, (Credit Revenue Generation) - SDG 6 & 8, (Payment Realization) – SDG 8 & 16, (Landowner Satisfaction) – SDG 8, (Investor Satisfaction) – SDG 12 & 17, (Ethical Broker Satisfaction) – SDG 16 & 17, Management and Coordination -SDG 16 & 17, Financial Viability – SDG 8, 9 & 12, Risk and Resilience – SDG 8, 16 & 17 16

Interpretation:

+++ The implementation of ICW and ICWM significantly improves water quality by reducing phosphorus loads, while fostering community engagement through citizen science and training. Real-time monitoring boosts climate resilience, and collaborative governance enhances local capacity and inclusive decision-making.

+++ The ICW process supports inclusive, responsive governance and nature-based climate action through high stakeholder participation and strong alignment with regulatory frameworks. Riparian buffers and wetlands directly reduce nutrient runoff, while reinforcing local control and sustainable land-use practices.

+++ GB uses supportive regulation like nutrient neutrality to create market incentives for sustainable development. Ethical brokering and cross-sector trust enhance financial transparency and partnerships, while legal offset requirements ensure restoration of ecosystems affected by development.

++ ICW maintains stable landowner engagement despite uncertainties around phosphate credit calculations requiring clearer communication and support; ICWM shows promise by integrating intelligent analysis and renewable energy, though faces issues with data consistency and citizen science validation; and GB has positive ethical broker feedback with emerging solutions, but progress is slowed by high initial costs and the need for standardized offset methodologies.

\+ Five of seventeen targeted nature-based solutions under ICW have been implemented, improving water quality and supporting evidence-based environmental management, though challenges remain in quantifying regional resilience impacts, achieving direct mitigation benefits, and addressing sediment management.

\+ ICWM progress is constrained by limited stakeholder coordination and technical barriers to customization, while GB faces delayed constructed wetlands and slow credit development impacting landowner satisfaction and requiring new frameworks, contracts, and payment design.

Overall, ICW and ICWM contributed to improved water quality (SDG 6) via phosphorus reduction and monitoring, supported innovation (SDG 9) through smart analysis, fostered inclusive governance (SDG 16) via stakeholder engagement, enabled partnerships (SDG 17) through ethical brokering (GB), promoted decent work (SDG 8), and advanced sustainable land-use and resource efficiency (SDG 12) through GB incentives.

Environmental domain

Relevant performance categories (indicators):

ICW: Readiness and Feasibility – SDG 13, Stakeholder Engagement and Participation (Event Attendance) – SDG 13, (Local Landowners Engaging) – SDG 15, Flood Vulnerability – SDG 13, Water quality (Reduction in Phosphorus Loading) – SDG 15, Environmental Impact – SDG 13 & 15, Biodiversity and Habitat – SDG 15, Liveability and Comfort – SDG 13, Risk and Resilience (Landowner Maintenance Willingness) – SDG 15, (Sediment Management) – SDG 13

ICWM: Stakeholder Engagement and Participation (Citizen Science Engagement, CSI Community Resilience), System Performance (Response Efficiency, Tech-enabled Monitoring, Computing Power), Data Quality (Continuous monitoring, Monitoring Data Accuracy, Sensor Coverage Redundancy), Management and Coordination (Citizen Science Program), Financial Viability (Investment)

GB: Readiness and Feasibility (Policy Interventions) – SDG 13, Monitoring, Evaluation, and Adaptation (Legal Mechanism Effectiveness, Landowner Satisfaction) – SDG 15, Risk and Resilience (Conservation Covenant Compliance) – SDG 15

Interpretation:

+++ ICW and ICWM enhance climate resilience by increasing water retention, restoring ecosystems, and enabling real-time monitoring and early warning systems that support adaptive responses to floods, droughts, and pollution.

+++ GB embeds adaptation in policy frameworks (SDG 13) by leveraging nutrient neutrality to drive private investment and establish markets for environmental credits.

++ Although ICW lacks direct GHG mitigation during construction, its land use change enhances carbon sequestration and biodiversity through improved water quality, while GB, despite slow credit development, relies on landowner satisfaction to sustain ecosystem stewardship and wetland conservation.

\+ ICW and ICWM strengthen climate resilience and water quality by creating riparian buffers and enabling early anomaly detection, though challenges in sediment management, outreach, and data consistency remain.

\+ GB secures long-term ecosystem services through legally binding covenants, with partial site coverage indicating progress but also highlighting the need for further land acquisition.

Overall, ICW and ICWM support SDG 13 and SDG 15 by enhancing ecosystem resilience, enabling early warnings, and restoring wetlands for carbon sequestration and biodiversity. GB advances policy-driven adaptation through nutrient neutrality and long-term conservation covenants, despite partial site coverage and slow credit development.

Uncertainties

Uncertainties in interpreting the results include:

- ICW evaluations rely on an individual site, with some missing data on parameters (e.g., pH, dissolved oxygen) and lacking assessments of stakeholder collaboration and maintenance cost efficiency, limiting generalizability and accuracy.

- ICWM faces uncertainties due to missing evaluations on indicators like sensor lifespan, software updates, and economic risks, with several metrics based on assumptions rather than defined baselines.
- GB is in early implementation, with evaluations based on limited pilot data and unconfirmed revenue projections, making broader conclusions about market viability and effectiveness premature.

Improvement and next steps

Actions for the improvement and next steps:

- Data gaps across ICW, ICWM, and GB should be addressed by expanding environmental monitoring, and validating pilot results to ensure accurate assessment and build stakeholder confidence.
- Economic and credit-related uncertainties in ICW and GB should be reduced by improving communication with landowners, finalizing regulatory frameworks, and clarifying financial mechanisms to encourage long-term participation.
- Stakeholder coordination in ICW and ICWM should be strengthened through the establishment of integrated feedback mechanisms, transparent communication structures, and inclusive governance practices.
- Technical and procedural barriers in ICWM and GB should be lowered by simplifying system customization, reducing entry costs, and standardizing methodologies to support scalability and broader adoption.

Overall, data gaps should be closed through improved monitoring and validation. Economic uncertainties and technical barriers must be reduced, while stakeholder coordination and governance practices should be strengthened to enhance scalability, participation, and long-term sustainability of nature-based solutions.

5.0 GALICIA (SPAIN)

5.1 Scoping

Galicia, situated in the North Atlantic region in the northwest of Spain (6.4 - 9.6°W, 41.5 - 44.2°N), is one of the most significant fishing regions in the European Union. Spanning 29,576 km² and encompassing 32.8% of Spain's coastline (1,659 km), the region's economy is heavily influenced by its fisheries and aquaculture sectors (Figure 5.1). The Rías, a series of coastal inlets, play a crucial role in nutrient transport and provide natural protection against seasonal storms, making Galicia an ideal site for mussel aquaculture and bivalve extraction. Notably, Ría de Arousa, the largest bay inlet on the southwest coast, holds 70% of Galicia's mussel rafts and 50% of its clam sales.

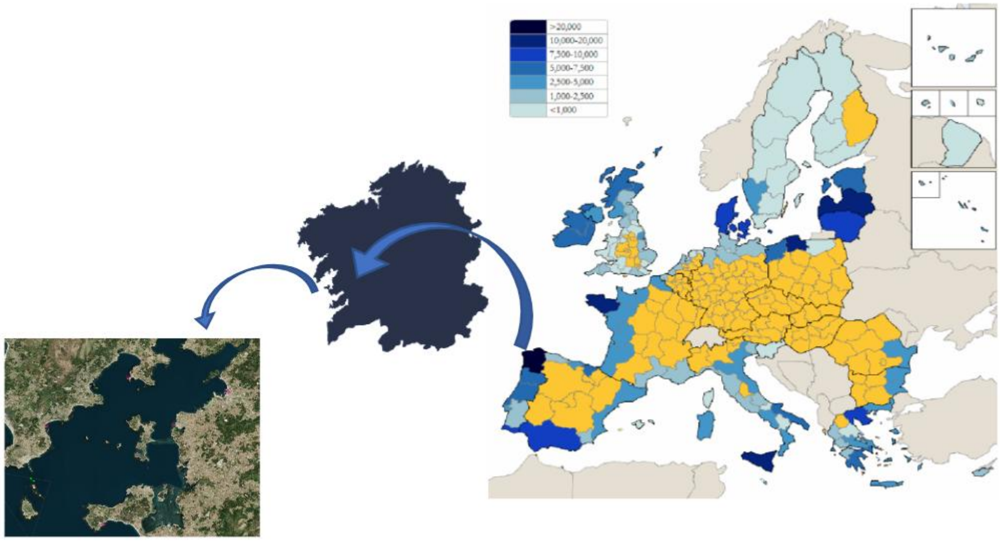


Figure 5.1 Study area – Ria de Arousa – Galicia -Spain

The coastal aquaculture and shellfish harvesting sector in Galicia is a vital economic and social pillar, employing thousands of individuals and supporting the region's maritime culture. However, climate change poses significant challenges that threaten the sustainability and resilience of this industry. Marine aquaculture, particularly mussel farming in the Rías, faces growing risks from extreme weather events, structural damage to mussel rafts, and the increasing occurrence of harmful algal blooms (HABs). Similarly, shellfish harvesting, which sustains over 3,500 self-employed workers - 90% of whom are women - is vulnerable to shifting oceanographic and hydrological conditions that could degrade shellfish banks, reduce productivity, and increase mortality rates. Climate projections indicate an increase in intense winter storms, heavy precipitation, and rising sea levels, exacerbating coastal flooding, infrastructure damage, and habitat loss.

The communities face challenges in understanding their current capacities, requirements, and feasible options for adapting to climate change. The lack of timely and transparent data communication impairs decision-making, project feasibility, and citizen engagement. Digital and technological innovations, along with improved management systems, are critical for enhancing responses to extreme climate events while considering financial constraints. The Galician demonstrator aims to develop a region-specific transformational adaptation process for the clam and mussel sectors, addressing multi-sectoral climate risks. In TransformAr, solutions are implemented in line with specific adaptation objectives, including improving environmental understanding, increasing stakeholder awareness, integrating digital tools, and supporting policymakers (Figure 5.1). These objectives are realized through three key solutions: Mussel Raft Monitoring (MRM), Resilience Index (RI), and Intertidal Monitoring (INTERM). More detailed baseline analysis, additional insights and data can be found in the D5.8 - Intermediary Monitoring Report.

Table 5.1 Specific objectives in relation to solutions demonstrated

Specific objectives	Actionable adaptive solutions (AAS)*		
	MRM	RI	INTERM
• Improve the understanding of the regional oceanographic environment and test tools that will contribute to the effective use of this information.	X		X
• Engage with stakeholders and increase the awareness and the perception of risks to address territorial vulnerabilities linked to CC.	X	X	X
• Facilitate the integration of Internet of Things and Artificial Intelligence to bring digitalization and automation strategies to the shellfish sector.	X		
• Provide policymakers with decision-making support tools to define actions and a roadmap for enhancing resilience.		X	X
• Showcase the efficacy of solutions in bolstering resilience within the mussel and clam sector in Galicia and ascertain their potential for replication.	X	X	X
• Derive a set of recommendations and measures including an appealing document, by using the tools delivered.	X	X	X
* MRM: Mussel Raft Monitoring, RI: Resilience Index, INTERM: Intertidal Monitoring.			

The RI is a mathematical model to support the mussel farming sector in adapting to climate change. Designed as a governance tool within the TransformAr project, RI provides stakeholders and policymakers with a comprehensive assessment framework to identify strategic adaptation priorities and minimize business interruption risks. The model integrates climate data, aquaculture processes, and resilience factors through a hybrid methodology that unfolds in three phases. The first phase involved identifying key experts and collecting critical data on aquaculture operations and climate vulnerabilities. The second phase applied the Delphi methodology, engaging 23 and 20 experts, respectively, in two rounds of consensus-building to prioritize risks and resilience gaps. The final phase defined the mathematical model and calculated RI scores, guiding stakeholders in strengthening adaptive capacities and establishing a strategic roadmap for sustainable mussel farming. The RI evaluation encompasses an overall score and a detailed breakdown across five dimensions: Governance, R+D+I (Research + Development + Innovation), Collaboration, Risk Management, and Operational Environment. Additionally, each dimension is further dissected into four factors, totalling 20 resilience factors. Figure 5.1 shows the results of the synthetic RI. The results emerging from the index will provide specific insights that will allow the formulation of actions and a roadmap for enhancing resilience.

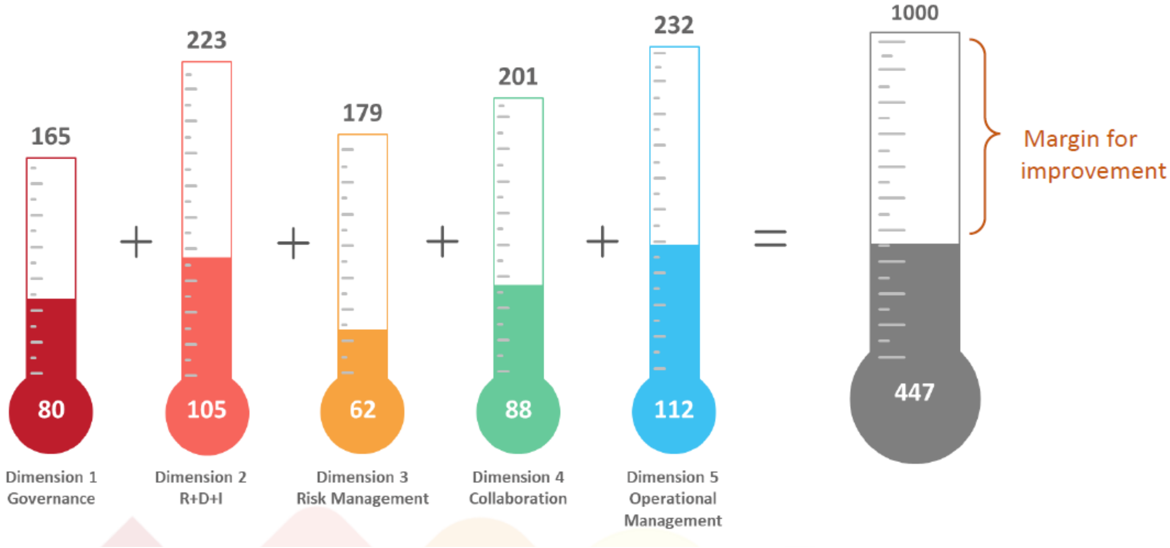


Figure 5.1 Results of the synthetic Resilience Index (RI)

The MRM initiative represents a pioneering step towards the digitalization of mussel aquaculture, integrating real-time environmental and production monitoring to enhance farm management and sustainability. Figure 5.2 explains the logic and the sequence of the data gathered from the moment that the sensor captures them to the visualization on the dashboard.

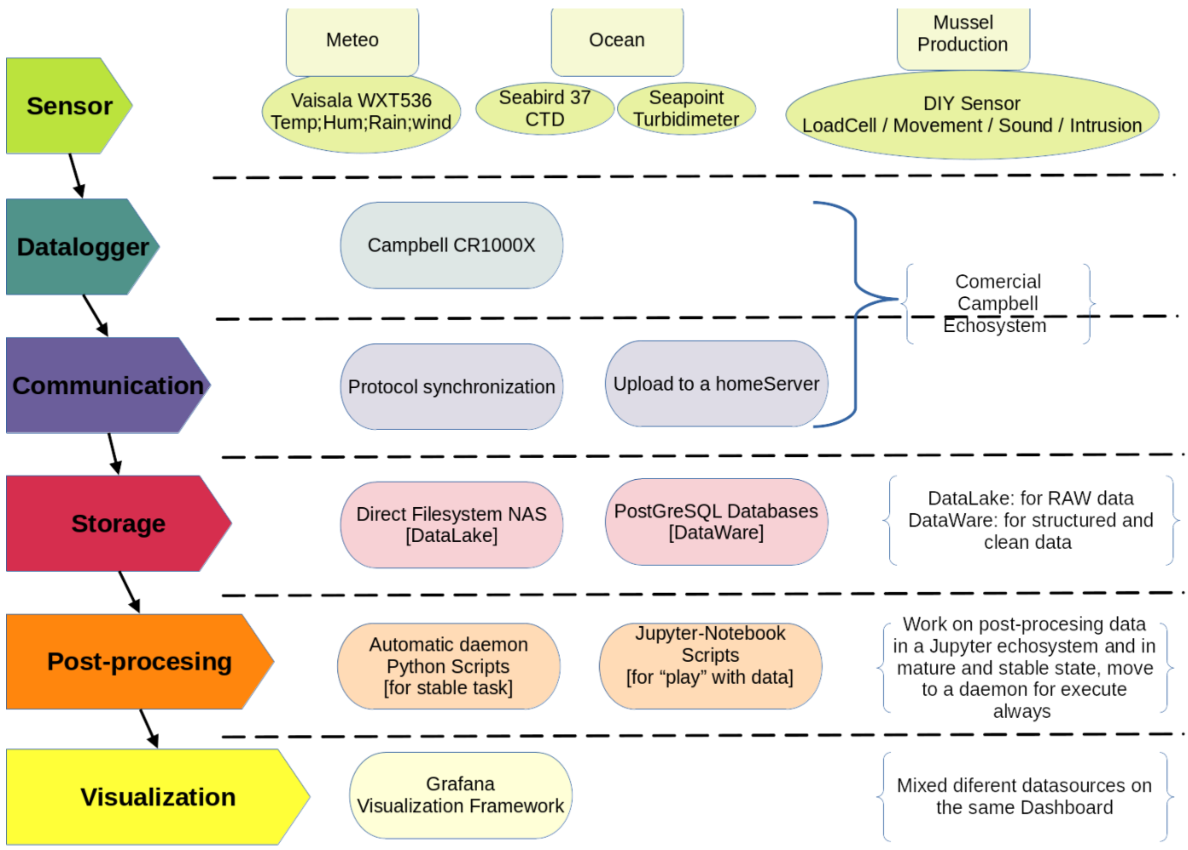


Figure 5.2 MRM flowchart

By equipping active mussel farms with IoT-powered sensors, supported by solar energy, this solution enables continuous data collection on key marine conditions, ensuring informed decision-making for optimal production. The data is remotely accessible via an internet-based platform, allowing mussel farmers to monitor and adapt their operations efficiently. Crucially, stakeholder engagement remains central to the project, with active feedback loops ensuring that the system evolves in alignment with the needs and insights of industry workers, fostering a collaborative and adaptive approach to aquaculture management.

The INTERM solution is a sedimentological monitoring initiative focused on the intertidal sandbanks of Galicia, aiming to enhance understanding of their sediment dynamics, ecosystem stability, and responses to climate change. This knowledge is essential for supporting sustainable shellfish harvesting and informing policymakers on adaptation strategies currently hindered by insufficient data.

The solution directly addresses two critical aspects: 1) Sedimentological context – Understanding the morphological drivers of Galician sandbanks, their seasonal sediment behavior, and their connection to shellfish productivity; 2) Climate change consequences – Assessing how environmental variations impact intertidal sediment composition and ecosystem resilience. With study locations selected in collaboration with local shellfishers and scientists, INTERM follows a threefold mission: 1) Intertidal Monitoring – Systematic data collection on sediment properties and oceanographic parameters; 2) Morphodynamic Modelling – Simulating sediment transport and hydrodynamic changes using DELFT3D, and 3) Knowledge Transfer – Providing insights for improved sandbank monitoring and adaptive management strategies. Figure 5.3 shows the INTERM strategy scheme.

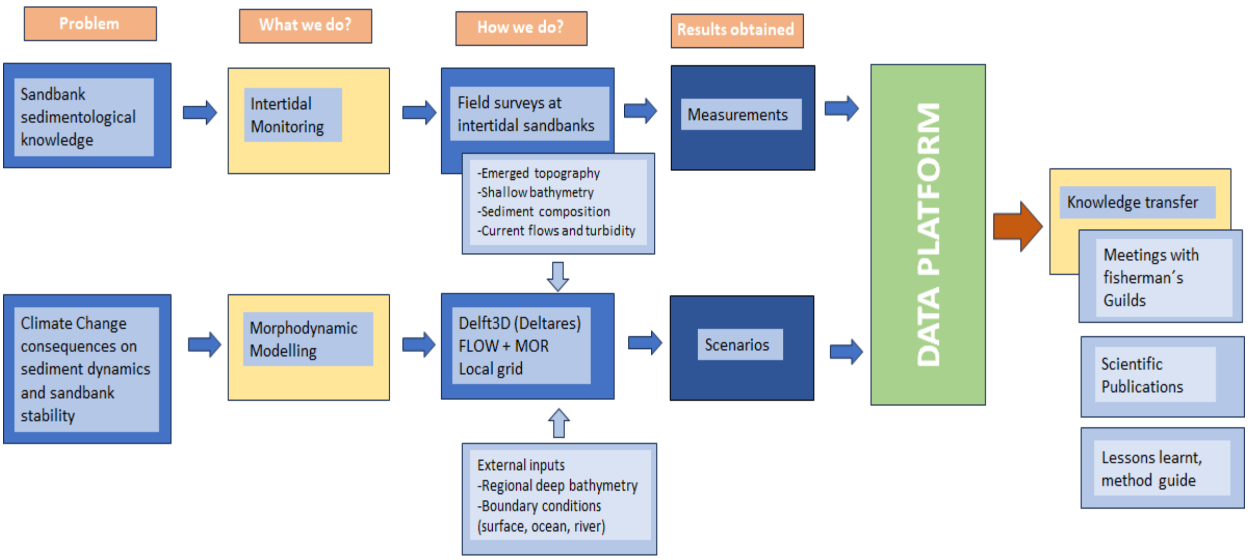


Figure 5.3 INTERM strategy scheme.

5.2 Implementation

The integration of Risk Assessment (RA) and Handprint Thinking (HT) into Life Cycle Thinking (LCT) enhances the evaluation of sustainability solutions by balancing risk mitigation with positive sustainability contributions. RA systematically identifies and mitigates potential threats, ensuring resilience and adaptability, while HT focuses on proactive measures that generate net-positive sustainability effects. Within LCT, this combined approach ensures that environmental, social, and economic impacts are assessed across the entire life cycle of a solution, from development to long-term operation.

Resilience Index (RI)

The performance evaluation of RI is structured into five common categories: Stakeholder Engagement and Participation, Monitoring, Evaluation, and Adaptation, Management and Coordination, Financial Viability, and Risk and Resilience. Table 5.2 outlines the performance categories and corresponding indicators for RI.

Table 5.2 Performance categories and indicators for resilience index (RI)

Performance categories	Indicator	Sub-indicator
Stakeholder Engagement and Participation	Workshop Attendance	
	Stakeholders Participation	
Monitoring, Evaluation, and Adaptation	Knowledge Outputs	
	Decision Tool Perception Improvement	
	Stakeholder Collaboration Impact	
	Decision-Making Tool Perception	
	Resilience Enhancement Actions and Roadmap	
	Stakeholder Groups Diversity	
	Delphi Consultation Effectiveness	
Management and Coordination	Institutional Coordination	
	Communication Strategy Readiness	
	Expertise Identification	
	Stakeholder Experts Identification	
Financial Viability	Investment	Design and Data Resources
		Investment cost efficiency
Risk and Resilience	Partner Dependency	

For Stakeholder Engagement and Participation, RA identifies barriers to stakeholder participation, and HT promotes inclusive capacity-building initiatives, ensuring stakeholders are well-equipped to engage in resilience-building efforts. LCT ensures that the engagement strategies remain sustainable throughout the project lifecycle. Workshop Attendance and Stakeholders Participation indicators track engagement, ensuring that participation strategies evolve to foster adaptive governance within the mussel aquaculture sector. In Monitoring, Evaluation, and Adaptation, RA assesses risks related to the effectiveness of knowledge dissemination, the reliability of decision-making tools, and the long-term impact of stakeholder collaboration. HT emphasizes active knowledge-sharing mechanisms to ensure knowledge outputs are effectively transferred and perception of decision-making tools is improved. For example, Stakeholder Collaboration Impact evaluates changes in stakeholder behavior and decision-making practices, reinforcing the importance of inclusive governance models. In Management and Coordination, RA identifies inefficiencies in institutional coordination, while HT fosters integrated governance models that enhance cross-sector collaboration. LCT ensures that coordination strategies remain adaptive over time. For Financial Viability, RA identifies risks related to investment allocation and efficiency, ensuring that financial resources are deployed effectively. HT promotes cost-efficient investment models that enhance the long-term sustainability of adaptation solutions. In Risk and Resilience, RA identifies external dependencies that may impact the sustainability of adaptation solutions, while HT strengthens local capacity-building efforts. LCT ensures that resilience measures remain robust throughout the entire solution lifecycle.

Mussel Raft Monitoring (MRM)

The performance evaluation of MRM is structured into two tailored categories – System Performance and Data Quality, along with four common categories: Monitoring, Evaluation, and Adaptation, Management and Coordination, Financial Viability and Risk and Resilience. Table 5.3 outlines the performance categories and corresponding indicators for MRM.

Table 5.3 Performance categories and indicators for Mussel Raft Monitoring (MRM)

Performance categories	**Indicator**	**Sub-indicator**
System Performance	System Uptime	System Uptime
		System Uptime Satisfaction
	System Scalability	
	Integration Capability	
	System Installation Satisfaction	
	User Customization Options	
	Response Efficiency	
	Sensor Lifespan Satisfaction	
	Tech-enabled Monitoring	Use of Energy
		Use of AI and ML
	Computing Power	
	Sensor Maintenance Frequency	
	Iterations for System Improvemnts	
	Software Update Frequency	
Data Quality	Continuous Monitoring	
	Data Accuracy	Data Accuracy
		Data Accuracy Satisfaction
	Sampling Validation	
	Sensor Coverage Redundancy	
Monitoring, Evaluation, and Adaptation	Local Conditions Corroboration	
	Environmental Data Access	
	COTS Sensor Adoption	
	Public Replication Interest	
	Company Replication Interest	
	Producer Replication Interest	
	Stakeholder Use of Data	
	Data Satisfaction	
Management and Coordination	Traditional Knowledge Integration	
	Stakeholder Coordination	
Financial Viability	Investment	Investment cost
		Investment cost efficiency
	Maintenance	Maintenance cost
		Maintenance cost efficiency
	Business Model Economic Risk	
Risk and Resilience	Cloud Data Capacity and Storage	
	Partner Dependency	
	Energy Supply Reliability	
	Environmental Challenges	

In System Performance, RA identifies vulnerabilities and ensures mitigation for reliability and efficiency. System Uptime and System Uptime Satisfaction reduce downtime risks, while Integration Capability enables seamless data exchange. HT ensures robust design, user satisfaction, and energy efficiency, with

User Customization Options enhancing personalization, Use of Energy supporting sustainability, and Sensor Provider Match ensuring quality sensors. LCT extends longevity through System Scalability, Sensor Lifespan Satisfaction, Iterations for System Improvements, and Software Update Frequency, ensuring adaptability. For Data Quality, RA detects risks in continuous monitoring, ensuring early failure detection. HT enhances resilience with redundancy and robust sensor designs. LCT ensures long-term sustainability while balancing cost. Continuous Monitoring prevents data gaps, while Accuracy and Satisfaction ensure reliability. Sampling Validation and Provider Match strengthen verification, and Sensor Redundancy prevents data loss. In Monitoring, Evaluation, and Adaptation, RA identifies vulnerabilities in environmental data and sensor deployment. HT drives adaptive strategies, and LCT ensures long-term scalability. Local Conditions Corroboration improves assessments, while Environmental Data Access aids decision-making. Replication Interest fosters scalability. In Management and Coordination, RA identifies gaps in knowledge integration and collaboration. HT fosters participatory governance, and LCT ensures adaptability. Traditional Knowledge Integration incorporates local insights into sensor design and operations. Stakeholder Coordination optimizes collaboration between scientists, conservationists, and producers. For Financial Viability, RA assesses financial risks in investment, maintenance, and business models. HT emphasizes cost-effective, sustainable strategies, while LCT ensures long-term efficiency. Investment optimizes financial resources, Maintenance supports sustainability, and Business Model Risk balances cost, risk, and flexibility. In Risk and Resilience, RA identifies vulnerabilities in data storage, partnerships, energy supply, and environmental risks. HT promotes autonomy, sustainability, and efficiency. LCT ensures long-term adaptability. Cloud Storage secures data, Partner Dependency assesses reliance, Energy Supply optimizes autonomy, and Environmental Challenges address sensor durability.

Intertidal Monitoring (INTERM)

The performance evaluation of INTERM is structured into one tailored category – Data Quality, along with four common categories: Monitoring, Evaluation, and Adaptation, Management and Coordination, Financial Viability, and Risk and Resilience. Table 5.4 outlines the performance categories and corresponding indicators for INTERM.

In Monitoring, Evaluation, and Adaptation, RA helps identify vulnerabilities in data collection and environmental monitoring, HT emphasizes proactive adaptation strategies, and LCT ensures that monitoring frameworks remain robust and scalable over time. Topography Area & Submerged Bathymetry Area focus on mapping accuracy and survey methods, Spatial Resolution & Sandbank Monitoring Completion address data consistency and representativeness, Current Flow and Turbidity ensure hydrodynamic data reliability and monitoring efficiency, and Sampling Requirements evaluate workforce constraints, logistical feasibility, and scalable methodologies. For Data Quality, RA identifies risks related to sampling errors and contamination, HT promotes best practices to enhance data reliability, and LCT ensures continuous improvement in validation techniques. Within this category, Sampling Validation focuses on ensuring the robustness of manual sampling processes, expert involvement, and contamination mitigation strategies. In Management and Coordination, RA identifies risks in project implementation and stakeholder engagement, HT strengthens cooperation and knowledge sharing, and LCT ensures adaptability and long-term framework sustainability. Strategy Scheme Readiness evaluates the preparedness of monitoring frameworks, while Stakeholder Involvement and Collaboration focuses on engagement between researchers, industry professionals, and local communities. For Financial Viability, RA identifies financial and operational risks, HT emphasizes innovative cost-effective approaches, and LCT ensures sustainable resource allocation. Investment & Investment Cost Efficiency focus on optimizing financial resources, while Business Model Economic Risk evaluates different economic models to ensure financial resilience. In Risk and Resilience, RA identifies vulnerabilities in data infrastructure and external dependencies, HT promotes sustainable data solutions and local capacity-building, and LCT ensures future-proof system scalability. Cloud Data Capacity and

Storage focuses on secure and scalable data management, while Partner Dependency evaluates the reliance on external entities and the development of independent operational capabilities.

Table 5.4 Performance categories and indicators for Intertidal Monitoring (INTERM)

Performance categories	Indicator	Sub-indicator
Monitoring, Evaluation, and Adaptation	Topography Area	Topography Area
		Topography Area Satisfaction
	Submerged Bathymetry Area	
	Spatial Resolution	Spatial Resolution
		Spatial Resolution Satisfaction
	Current Flow and Turbidity	
	Sandbank Monitoring Completion	
	Sampling Requirements	Sampling requeriments
		Sampling requeriments Satisfaction
Data Quality	Sampling Validation	
Management and Coordination	Strategy Scheme Readiness	
	Stakeholder Involvement and Collaboration	
Financial Viability	Investment	Investment cost
		Morphodynamic Modelling
		Investment cost efficiency
	Business Model Economic Risk	
Risk and Resilience	Cloud Data Capacity and Storage	
	Partner Dependency	

In addition, Stakeholder Engagement and Participant across three solutions were collected, which targets project's overall objectives in improving environmental understanding and increasing stakeholder awareness, such as Population that Enhance Resilience, Inclusion of Disadvantaged Groups (Fishermen and Women).

Table 5.5 Performance categories and indicators for all solutions

Performance categories	Indicator	Sub-indicator
Stakeholder Engagement and Participation*	Shellfish Sector Publications/Outputs	
	Transfer Events/Meetings	
	Risks and Adaptation Awareness Increase	
	Population that Enhance Resilience	
	Farmers/Fishermen Engaged	
	Actors Involved in the Adaptive Process	
	Inclusion of Disadvantaged Groups	Fishermen
		Women
	Share of Population that is Vulnerable (5%)	
	Policymakers Involved	

*This data spans across three solutions and will be included in the analysis of the Region-Specific Portfolio (RSP).

After the indicators were selected, they were assigned to the relevant SDGs by matching each indicator's measured outcome to the appropriate sub-targets, following methodology described in Section 2.2.3. For example:

- Workshop Attendance, reflecting stakeholders' willingness to actively engage in capacity-building activities, training, and knowledge-sharing sessions, contributes to sub-goal 16.7, which aims to "ensure responsive, inclusive, participatory, and representative decision-making at all levels." By encouraging participation in learning opportunities, it helps stakeholders take part in decision-making, making governance more inclusive and representative.

- Traditional Knowledge Integration assesses the extent to which traditional knowledge from local mussel farmers is integrated into the design and requirements of digital sensors. It is connected to sub-goal 16.7, as traditional farmers' active involvement in shaping monitoring requirements and data usage directly supports participatory decision-making, aligning with SDG 16.7's objectives
- Institutional Coordination evaluates the extent to which local institutions coordinate their actions to address adaptation needs effectively. This indicator contributes to sub-goal 16.6, which aims to "develop effective, accountable, and transparent institutions at all levels." By encouraging better coordination among institutions, it improves efficiency and ensures adaptation strategies are implemented transparently and effectively, supporting accountable governance.

Together, these indicators are all linked to SDG 16 – Peace, Justice, and Strong Institutions, as they support inclusive participation, knowledge sharing, and strong coordination, helping to improve governance and decision-making for effective adaptation. At the same time, Workshop Attendance aligns with SDG 4.7, which focuses on ensuring that all learners acquire the knowledge and skills needed to promote sustainable development. High participation in workshops shows that the solution effectively educates stakeholders on mussel farming resilience strategies. Institutional Coordination aligns with SDG 17.14, which focuses on enhancing policy coherence for sustainability. Strong collaboration ensures that adaptation efforts are well-organized, resources are used efficiently, and institutions work together effectively. Traditional Knowledge Integration connects to SDG 9.5, which encourages scientific research and innovation, as incorporating experienced farmers' knowledge into digital sensor design helps create better aquaculture solutions that align with real-world needs.

5.3 Data process

The data process involves several stages starting with data gathering, followed by assigning scores for qualitative indicators, while scores for quantitative indicators are calculated and normalized. After that, the scores are assigned to relevant SDG sub-goals, and the corresponding SDGs are then used for assessment. Next, the indicator scores are combined to generate aggregate scores for SDGs. The goal is to ensure that the collected data is consistently evaluated, standardized, and presented in a way that aligns with sustainability goals.

The project employs a systematic data gathering process, Integrating Iterative participatory Interviews with supporting sources, such as monitoring reports, field studies, and institutional documentation. This multi-source approach ensures a comprehensive and evidence-based assessment of adaptation solutions, enhancing both qualitative and quantitative evaluations.

Multiple sources are cross-checked, covering key deliverables such as:

- Stakeholders Matrix and IE Baseline Profiles (D1.2)
- Six Region-Specific Portfolios of Solutions (D3.8)
- Compendium of Pathways and Action Plans (D3.9)
- Learning Stories on Governance Schemes (D4.2)
- Learning Stories on Digital and Technological Solution (D4.4)
- Intermediary Monitoring Report (D5.8)
- Resilience Index (RI) for the mussel aquaculture operations in Galicia: Briefing on the development process of the RI solution and results
- Mussel Raft Monitoring (MRM) in Ría de Arousa (Galicia): Briefing on the development process of the MRM solution and results

- Intertidal Monitoring (INTERM) in Ría de Arousa (Galicia). Briefing on the development process of the solution and results

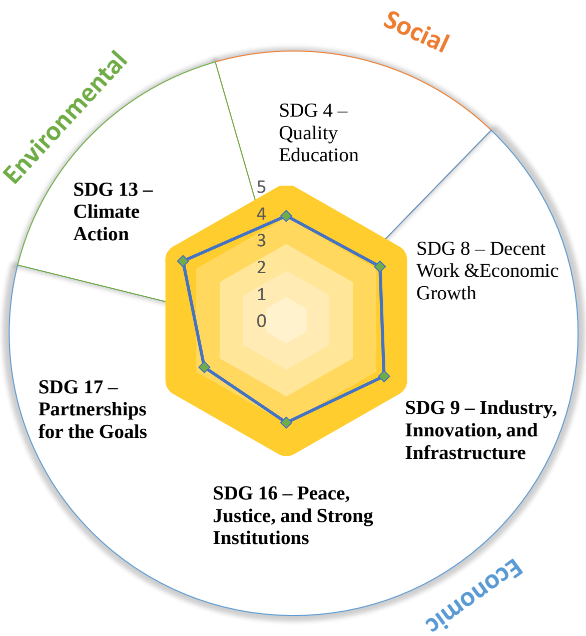
Institutional documentation plays an important role in supporting data collection and validating adaptation solutions, such as cost records related to investment, maintenance, and operation, as well as stakeholder engagement tracking records to monitor participation and impact. Additionally, it encompasses action plans and supporting literature that contribute to estimation. Field data and experimental results, combined with modeling analysis, offer critical insights by assessing environmental changes and ecosystem resilience while evaluating long-term sustainability and adaptive capacity. By integrating these elements, the project ensures a data-driven, evidence-based approach that strengthens the effectiveness and scalability of adaptation strategies.

Qualitative indicator data is processed using the general approach outlined in Section 2.2.3. All indicators are assigned scores ranging from 0 to 5, which are then allocated to the relevant SDG sub-goals identified for each indicator. The final contribution to each SDG is aggregated using the weighted sum method, with an assumption of equal weights for all indicators. However, this weighting can be adjusted based on project goals, stakeholder input, or specific contextual needs.

5.4 Assessment

The sustainability profiles of each solution and region-specific portfolio (RSP) are presented here. They align with SDG goals, as well as the sustainability domains of social, economic, and environmental aspects. The assessment begins with an evaluation of each solution, followed by the RSP, addressing three key aspects: results and their interpretation, uncertainties, and areas for improvement and next steps.

5.4.1 Sustainability profile of Resilience Index (RI)



Primary targeted SDGs*:

Co-benefit SDGs:

* Targeted SDGs are black bordered.

RI (Resilience Index)

The interpretation of the profile should focus on **Primary targeted SDGs** with multiple indicator contributions, while co-benefit SDGs typically have limited contributions from specific indicators.

Social domain

Relevant performance categories (indicators):

Stakeholder Engagement and Participation

Interpretation:

++ Engagement of stakeholder groups (Delphi methodology) encompassing administration, academia, productive sector, environmental organizations and society to identify the vulnerabilities, risks and resilience factors within the mussel aquaculture production, empowering participants with the knowledge for sustainable decision-making.

Economic domain

Relevant performance categories (indicators):

Stakeholder Engagement and Participation -SDG 9 & 16, Monitoring, Evaluation, and Adaptation – SDG 9, (Stakeholder Collaboration Impact) – SDG 17, (Resilience Enhancement Actions and Roadmap) -SDG 16, Management and Coordination – SDG 9, 16 & 17, Financial Viability -SDG 8 & 9, Risk and Resilience – SDG 9 &16

Interpretation:

+++ The RI fosters technological advancements and research by refining decision-making tools on climate adaptation governance while strengthening the improvement of aquaculture infrastructure, data reliability, and scientific rigor to enhance resilience and sectoral sustainability.

++ Informed decision making based on the insights of the resilience index allows for efficient investments aimed at real improvement of aquaculture, increasing resource efficiency and cost savings. This allows strengthening production processes and infrastructures to support economic resilience and sustainable employment opportunities in the mussel sector.

\+ Institutional coordination is moderate, with sporadic collaboration and aligned policies in specific areas, but occasionally remains inconsistent and reactive, relying on external stakeholders for support in solution development.

Overall, RI fosters technological innovation (SDG 9), enhancing resource efficiency and economic resilience in aquaculture (SDG 8), promoting institutional robustness despite inconsistent coordination (SDG 16), and encouraging multi-stakeholder collaboration for sustainable adaptation (SDG 17).

Environmental domain

Relevant performance categories (indicators):

Stakeholder Engagement and Participation, Monitoring, Evaluation, and Adaptation, Management and Coordination (Communication Strategy Readiness), Financial Viability

Interpretation:

+++ Climate actions are implemented by raising awareness through climate adaptation findings, prioritising resilience actions to strengthen adaptive capacity, integrating diverse stakeholder perspectives for inclusive adaptation strategies, and enhancing climate mitigation approaches through Delphi-based consensus-building.

++ Outputs aimed at enhancing awareness of the need for a decision-making assistance tool for climate change adaptation are still in development and will be further communicated, discussed, and refined.

Uncertainties

Several main issues should be considered when interpreting the results:

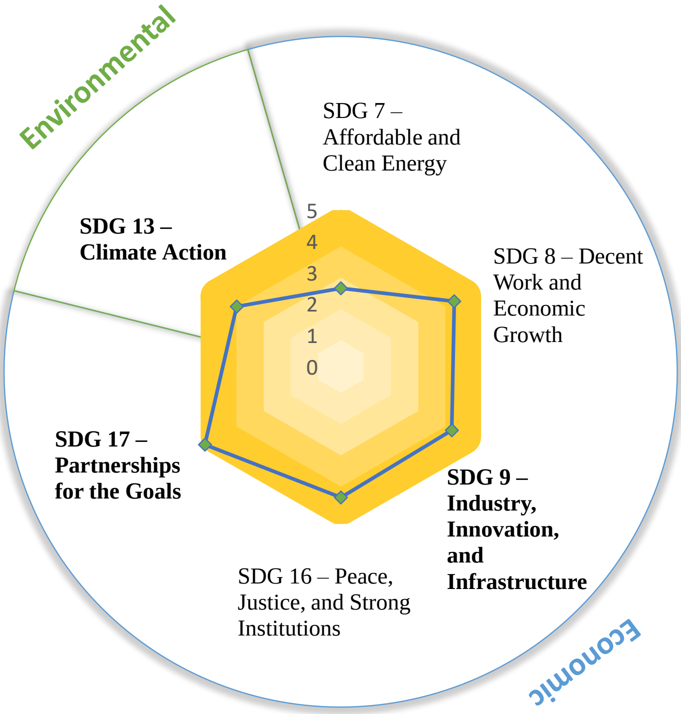
- Some targets are based on estimation, e.g., stakeholders' participation, more of an expected maximum than a target, as the Delphi method is suitable for a maximum of 30 participants, plus the 10 agents validating technical data, making a maximum of 40 agents.
- New correlations on improved perception of the need for a decision-making assistance tool for climate change adaptation are still under development.

Improvement and next steps

Actions for the improvement and next steps:

- Refinement and continuous improvement of the RI methodology updating the RI with new data, evolving climate scenarios, and sectoral changes to maintain its relevance.
- Application of the RI methodology to other aquaculture industries and related industries where resilience to climate change is a priority to assess its applicability and refine sector-specific factors.
- Strengthen partnerships with aquaculture producers, research institutions, and work with policymakers to ensure continue development and usability of the RI and incorporate RI findings into governance strategies and regulatory frameworks.

5.4.2 Sustainability profile of Mussel raft monitoring (MRM)



MRM (Mussel Raft Monitoring)

* Targeted SDGs are black bordered.

The interpretation of the profile should focus on **Primary targeted SDGs** with multiple indicator contributions, while co-benefit SDGs typically have limited contributions from specific indicators.

Economic domain

Relevant performance categories (indicators):

System Performance – SDG 9, (System Uptime, User Customization Options) – SDG 16, (Tech-enabled Monitoring) – SDG 7, (Sensor Maintenance Frequency, Iterations for system improvements) – SDG 8, Data Quality – SDG 9, (Data Accuracy) – SDG 16, Monitoring, Evaluation, and Adaptation – SDG 9, (Environmental Data Access, Data Satisfaction) – SDG 16, (Public Replication Interest, Company Replication Interest, Producer Replication Interest) – SDG 17, Management and Coordination – SDG 9, 16 & 17, Financial Viability – SDG 8 & 9, Risk and Resilience – SDG 9, (Partner Dependency) – SDG 16

Interpretation:

+++ The system is highly scalable, seamlessly integrating with external databases and analytics tools for technological flexibility and expansion, while its reliable solar-powered energy supply and planned sensor maintenance ensure durability; sensors perform reliably in challenging marine environments with protection measures in place, though extreme weather events may require additional checks.

+++ High satisfaction with system installation while strong stakeholder coordination and the integration of traditional knowledge ensure effective collaboration and alignment of digital tools with aquaculture expertise.

+++ Easy access to environmental data enhances transparency and stakeholder decision-making, while adaptive COTS sensors drive strong replication interest from public agencies, private companies, and mussel producers; additionally, a flexible business model minimize economic risks, offering either a subscription model (Sensors-as-a-Service) or a hybrid/performance-based model, depending on client needs.

++ The MRM system achieved 73% uptime reliability over 18 months, with an estimated 80% uptime due to data errors that could potentially reach 90% by addressing identified issues. Meanwhile, user customization options show room for improvements, particularly in solar panel positioning and equipment brand selection, to enhance adaptability and efficiency.

++ Data validated through manual sampling protocols and comparisons with scientific monitoring stations fosters trust and transparency; however, challenges in data accuracy suggest the need for better correlation analysis and the integration of additional data sources to improve interpretation of the vast amount of gathered data.

++ System alerts efficiently notify engineers within 10 minutes, but on-site intervention for repairs takes longer, while external stakeholders are required for complex tasks and system optimization.

+ Some sensors, such as load cells and temperature sensors, underperformed and required replacements, while the high cost and maintenance demands of water and air temperature and atmospheric pressure sensors limit duplication feasibility, increasing the risk of data collection gaps; formulas will be integrated to enhance system iteration processes and optimize software update frequency for continuous improvements.

Overall, the MRM solution promotes technological innovation (SDG 9) through scalable integration with robust sensor infrastructure and analytics tools. Stakeholder coordination and knowledge-sharing (SDG 17) enhance collaboration and sector-wide adoption. Transparency and reliable data validation (SDG 16) foster trust in decision-making. Solar-powered energy supply (SDG 7) ensures sustainability, while a flexible business model (SDG 8) minimizes economic risks and supports aquaculture growth. Addressing sensor limitations, alerts response, and data accuracy challenges will further enhance efficiency and resilience, improving uptime and operational sustainability.

Environmental domain

Relevant performance categories (indicators):

System Performance Data Quality, Monitoring, Evaluation, and Adaptation (Local Conditions Corroboration, Stakeholder Use of Data), Risk and Resilience (Environmental Challenges)

Interpretation:

+++ System scalability ensures future expansion aligns with climate adaptation in aquaculture, integrating resilience measures, leveraging data analysis for predicting environmental stressors, and enabling uninterrupted monitoring to anticipate climate-driven risks in mussel farms.

++ Real-time data enables farmers to adapt swiftly to environmental changes and climate impacts, with system alerts notifying engineers within 10 minutes, though repairs take longer; ongoing analysis assesses how local conditions align with established correlations in mussel farming raft environmental impacts, helping refine adaptation strategies to enhance system resilience.

\+ Challenges in data accuracy highlight the need for improved correlation analysis and additional data sources to enhance interpretation, as accurate environmental data is crucial for climate readiness, early warning, and adaptation in mussel farming; limited sensor redundancy due to costs and maintenance demands increase the risk of data gaps, affecting consistent detection of environmental changes.

Overall, system scalability enhances climate adaptation by integrating real-time monitoring for swift adaptation and strengthening early warning systems. Improving data accuracy and expanding monitoring capabilities ensure reliable environmental assessments, reinforcing mussel farming's ability to mitigate risks and adapt effectively to climate-driven challenges.

Uncertainties

Several issues should be considered when interpreting the results:

- System uptime is estimated with potential for improvement, yet uncertainty remains regarding satisfaction; data accuracy varies, for example, with atmospheric pressure, Meteo measurements at 80%, while cell load measurements is 50%.
- Stakeholder use of data focuses on the number of organisations, as we could anticipate their possible use, such as administration incorporating it into future programs or considering it in the national integrated plan for energy and climate.
- Response efficiency in addressing system alerts depends on timely detection, engineer availability, travel time to the raft, weather conditions, and resource constraints, ensuring necessary repairs are conducted promptly while balancing operational demands and environmental factors.

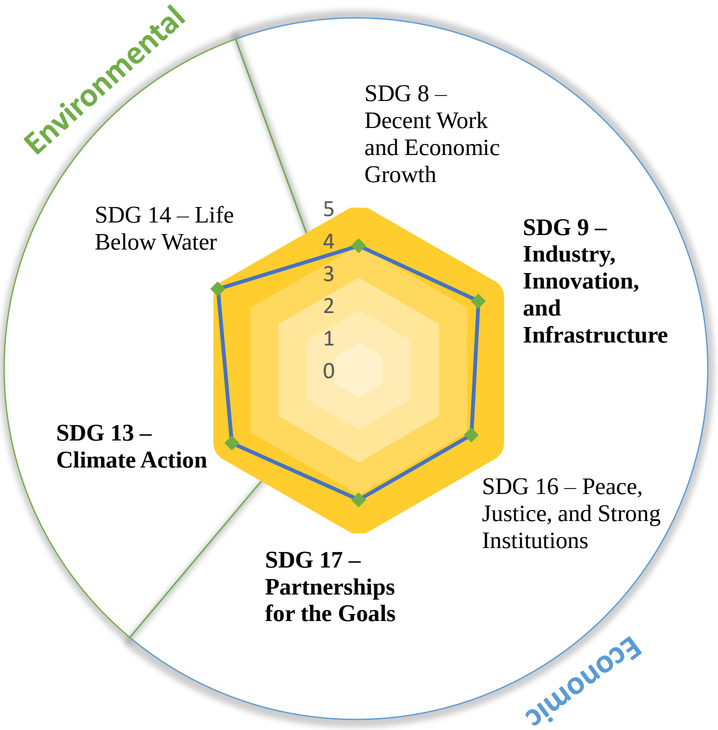
Improvement and next steps

Actions for the improvement and next steps:

- Increase system uptime and data accuracy by addressing identified data errors to improve uptime from 80% to 90% and implementing better correlation analysis with additional data sources for more reliable environmental assessments and monitoring.
- Leverage AI to optimize data calibration, automate anomaly detection, and identify patterns that enhance predictive capabilities for improved system reliability.
- Enhance response efficiency by streamlining on-site intervention processes, minimizing repair time, and developing a strategy that considers engineer availability, travel logistics, and environmental constraints.
- Optimize sensor performance and cost-effectiveness by replacing underperforming load cells and temperature sensors while exploring cost-efficient alternatives for water, air temperature, and atmospheric pressure sensors to improve redundancy and minimize expenses.
- Refine software and system adaptability by integrating formulas to optimize iteration processes, enhancing update frequency, and continuously improving sensor calibration, alert efficiency, and overall system performance.
- Improve usability and customization, for example, adjusting solar panel positioning for better energy efficiency and optimizing equipment selection (specific brands for load cells), to enhance system reliability.

Overall, next steps focus on improving system uptime, data accuracy, and response efficiency by addressing data errors, enhancing correlation analysis, and leveraging AI for better predictive capabilities. Sensor performance and cost-effectiveness will be optimized by replacing underperforming components. Software updates and usability improvements, such as solar panel positioning and equipment selection, will enhance system adaptability and reliability.

5.4.3 Sustainability profile of Intertidal monitoring (INTERM)



INTERM (Intertidal Monitoring)

Primary targeted SDGs*:

Co-benefit SDGs:

* Targeted SDGs are black bordered.

The interpretation of the profile should focus on **Primary targeted SDGs** with multiple indicator contributions, while co-benefit SDGs typically have limited contributions from specific indicators.

Economic domain

Relevant performance categories (indicators):

Monitoring, Evaluation, and Adaptation (Topography Area, Submerged Bathymetry Area, Spatial Resolution) – SDG 9, (Sampling Requirements) – SDG 8 & 9, Data Quality – SDG 9, Management and Coordination (Strategy Scheme Readiness) – SDG 9, (Stakeholder Involvement and Collaboration) – SDG 16 & 17, Financial Viability – SDG 8 & 9, Risk and Resilience – SDG 9 & 16

Interpretation:

+++ Submerged bathymetry measurements and current flow and turbidity surveys exceed targets, providing crucial data for marine habitat monitoring and for simulating the responses of sediment transport and hydrodynamics under altered climate scenarios in shellfish harvesting environments.

+++ Emerged topography, measured through ground surveys, ensures sufficient land exposure for its intended use. Seasonal sediment sampling ensures quality baseline data of sandbanks substrate to evaluate future sediment changes improving the decision-making process.

- +++ High-resolution data and innovative solution in intertidal monitoring enhance digital infrastructure, driving technological innovation, scientific research, and resilient environmental modeling for improved coastal resilience.
- ++ Equitable stakeholder engagement enhances collaboration among researchers, engineers, policymakers, and local communities, fostering knowledge-sharing and strong partnerships; improving data quality and reliability supports sustainable infrastructure development, while creating skilled labor opportunities and driving job growth in scientific data collection and coastal monitoring.

Overall, the initiative enhances digital infrastructure, drives technological innovation, and strengthens resilient environmental modeling (SDG 9). It fosters stakeholder collaboration and knowledge-sharing through partnerships (SDG 17), creates skilled labour opportunities in scientific data collection and coastal monitoring (SDG 8), and reinforces equitable stakeholder engagement (SDG 16), ensuring transparent decision-making and sustainable infrastructure development.

Environmental domain

Relevant performance categories (indicators):

Monitoring, Evaluation, and Adaptation (Topography Area, Spatial Resolution) – SDG 13, (Submerged Bathymetry Area, Current Flow and Turbidity) – SDG 14, (Sandbank Monitoring Completion) – SDG 13 & 14, Management and Coordination (Strategy Scheme Readiness) – SDG 13, Financial Viability (Investment) – SDG 13

Interpretation:

- +++ Climate awareness has been strengthened through widespread data usage, facilitating better early warnings and adaptation measures. Coastal resilience strategies have been reinforced by tracking topographic shifts, and by studying sediment distribution and coastal hydrodynamics.
- +++ Marine habitat preservation and pollution detection has been strengthened through detailed monitoring of sediment distribution and sediment quality. Knowledge of sediment transport dynamics has been improved by tracking currents and turbidity surveys, contributing to the protection of marine ecosystems.

Overall, climate adaptation has been supported through improved early warnings and coastal resilience strategies (SDG 13), while marine ecosystem protection has been enhanced by monitoring intertidal topography, sediment distribution, and pollution control (SDG 14).

Uncertainties

Several issues should be considered when interpreting the results:

- The calibration of the morphodynamical model needs to be improved for some areas of the Ría de Arousa
- Targeted spatial resolution was not defined, and sampling requirements were based on qualitative satisfaction assessment, with five persons per km^2 per day performing the task without a clear benchmark.

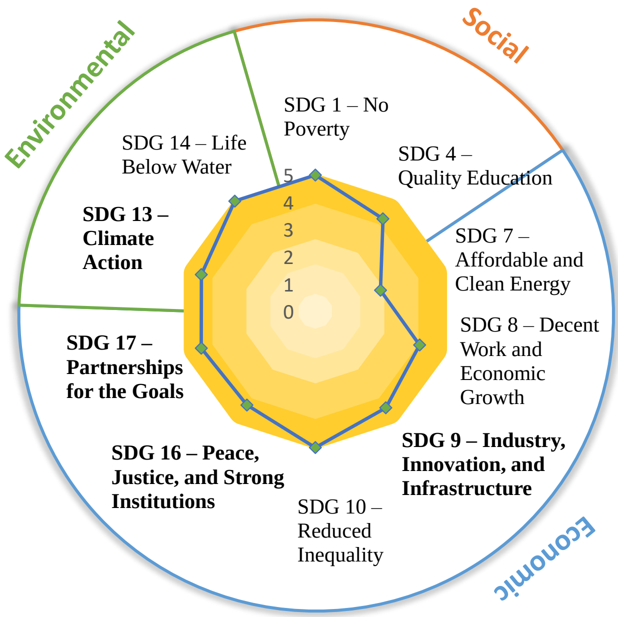
Improvement and next steps

Actions for the improvement and next steps:

- Increase time-scale sediment sampling at locations where biological samples are collected by shellfishers' guilds to improve data correlation and ecosystem understanding.
- While spatial resolution has improved, minor refinements in sampling distribution should be made to further enhance characterization and ensure comprehensive coverage.
- Identify minor process improvements to streamline sampling operations, ensuring efficiency while maintaining adequate personnel availability.
- Enhance interactions between researchers and shellfish harvesters by fostering more structured communication and collaboration in data interpretation and application.
- Maintain and expand the local team's strong data analysis skills while ensuring external support is available only for advanced technical issues or strategic system upgrades.
- Conduct experiments in a controlled environment to establish the influence of substrate characteristics on shellfish species

Overall, next steps could include expand sediment sampling for better data correlation, refine spatial distribution for enhanced characterization, and streamline sampling efficiency. Strengthening stakeholder collaboration and maintaining local data analysis capabilities while minimizing external support would further improve monitoring effectiveness.

5.4.4 Sustainability profile of Region-specific portfolio (RSP)



Region-specific portfolio (RSP)
Include three solutions: RI (Resilience Index), MRM (Mussel raft monitoring), INTERM (Intertidal monitoring)

Primary targeted SDGs*:

Co-benefit SDGs:

* Targeted SDGs are black bordered.

The interpretation of the profile should focus on **Primary targeted SDGs** with multiple indicator contributions, while co-benefit SDGs typically have limited contributions from specific indicators.

Social domain

Relevant performance categories (indicators):

RI: Stakeholder Engagement and Participation – SDG 4

Stakeholder Engagement and Participation (Risks and Adaptation Awareness Increase) – SDG 4, (Population that Enhance Resilience, Share of population that is vulnerable (5%)) - SDG 1

Interpretation:

+++ Stakeholder engagement through the Delphi methodology (RI), involving administration, academia, the productive sector, environmental organizations, and society to assess vulnerabilities, risks, and resilience factors in mussel aquaculture, combined with training and outreach events, enhances climate adaptation knowledge, fosters sustainability in the shellfish sector, and empowers participants with expertise for sustainable decision-making.

+++ Training and outreach events enhance resilience in low-income and marginalized groups, reducing their vulnerability to environmental and economic shocks in the aquaculture sector. Targeted resilience measures protect vulnerable communities from climate and financial stressors, promoting long-term economic stability and sustainable livelihoods.

Overall, vulnerable groups are targeted to reduce climate and economic risks (SDG 1) through training and outreach, while RI fosters sustainable decision-making and strengthens climate adaptation knowledge in the aquaculture sector (SDG 4).

Economic domain

Relevant performance categories (indicators):

RI: Stakeholder Engagement and Participation -SDG 9 & 16, Monitoring, Evaluation, and Adaptation – SDG 9, (Stakeholder Collaboration Impact) – SDG 17, (Resilience Enhancement Actions and Roadmap) -SDG 16, Management and Coordination – SDG 9, 16 & 17, Financial Viability -SDG 8 & 9, Risk and Resilience – SDG 9 &16

MRM: System Performance – SDG 9, (System Uptime, User Customization Options) – SDG 16, (Tech-enabled Monitoring) – SDG 7, (Sensor Maintenance Frequency, Iterations for system improvements) – SDG 8, Data Quality – SDG 9, (Data Accuracy) – SDG 16, Monitoring, Evaluation, and Adaptation – SDG 9, (Environmental Data Access, Data Satisfaction) – SDG 16, (Public Replication Interest, Company Replication Interest, Producer Replication Interest) – SDG 17, Management and Coordination – SDG 9, 16 & 17, Financial Viability – SDG 8 & 9, Risk and Resilience – SDG 9, (Partner Dependency) – SDG 16

INTERM: Monitoring, Evaluation, and Adaptation (Topography Area, Submerged Bathymetry Area, Spatial Resolution) – SDG 9, (Sampling Requirements) – SDG 8 & 9, Data Quality – SDG 9, Management and Coordination (Strategy Scheme Readiness) – SDG 9, (Stakeholder Involvement and Collaboration) – SDG 16 & 17, Financial Viability – SDG 8 & 9, Risk and Resilience – SDG 9 & 16

Stakeholder Engagement and Participation (Transfer Events/Meetings, Farmers/Fishermen Engaged, Actors Involved in the Adaptive Process, Inclusion of Disadvantaged Groups, Policymakers Involved) – SDG 6, 17, (Share of Population that is Vulnerable (5%)) – SDG 10

Interpretation:

+++ Including farmers/fishermen in decision-making enhances social inclusion in adaptation strategies, while recognizing vulnerability rates ensures that marginalized and at-risk populations are adequately considered in climate adaptation efforts.

++ The solutions drive technological advancements in climate adaptation, aquaculture infrastructure, and environmental monitoring. The RI refines research methodologies, while the MRM and INTERM solutions integrate advanced digital tools and enhance scientific rigor and data reliability. Institutional coordination (RI) and dependence on external stakeholders (RI, MRM, INTERM) for solution development can be improved for long-term sustainability.

++ Transparent data access, stakeholder-driven decision-making, and the integration of traditional knowledge enhance aquaculture management, ensuring informed and inclusive practices. The MRM system improves data quality through validation from manual sampling and monitoring stations, while the INTERM solution fosters open data sharing. Nonetheless, further improvements in data accuracy are needed.

++ Skilled labour opportunities in scientific data collection and coastal monitoring can be expanded through the INTERM and RI solutions, which support workforce development, while the MRM system provides flexible business models to reduce economic risks. However, high costs and maintenance demands for certain sensors limit feasibility, increasing the risk of data collection gaps and long-term financial burdens.

\+ Tech-enabled monitoring (MRM) utilizes solar-powered sensors to ensure energy efficiency, though optimizing solar panel positioning and equipment brand selection could enhance renewable energy reliability. Integrating AI could further support data processing, analysis, and predictive capabilities for improved monitoring accuracy and efficiency.

Overall, the RI, MRM, and INTERM solutions drive technological advancements (SDG 9) in climate adaptation, aquaculture, and environmental monitoring. Transparent data access and stakeholder-driven decision-making (SDG 16) enhance aquaculture management, though institutional coordination (RI) and external reliance (SDG 17) need improvement. MRM monitoring improves renewable energy efficiency (SDG 7), while INTERM expands skilled labor opportunities (SDG 8). Inclusive adaptation strategies promote social equity (SDG 10), but high sensor costs challenge duplication feasibility (risk of data gaps). AI integration could enhance data analysis and predictive capabilities.

Environmental domain

Relevant performance categories (indicators):

RI: Stakeholder Engagement and Participation, Monitoring, Evaluation, and Adaptation, Management and Coordination (Communication Strategy Readiness), Financial Viability

MRM: System Performance Data Quality, Monitoring, Evaluation, and Adaptation (Local Conditions Corroboration, Stakeholder Use of Data), Risk and Resilience (Environmental Challenges)

INTERM: Monitoring, Evaluation, and Adaptation (Topography Area, Spatial Resolution) – SDG 13, (Submerged Bathymetry Area, Current Flow and Turbidity) – SDG 14, (Sandbank Monitoring Completion) – SDG 13 & 14, Management and Coordination (Strategy Scheme Readiness) – SDG 13, Financial Viability (Investment) – SDG 13

Stakeholder Engagement and Participation (Risks and Adaptation Awareness Increase, Population that Enhance Resilience) – SDG 13, (Shellfish Sector

Publications/Outputs, Farmers/Fishermen Engaged, Inclusion of Disadvantaged Groups) – SDG 14

Interpretation:

+++ The INTERM enhances marine habitat preservation and sediment transport monitoring by tracking topographic shifts, underwater topography, and hydrodynamic conditions, thereby reinforcing coastal resilience and ecosystem protection.

++ The RI, MRM, and INTERM solutions collectively enhance climate adaptation strategies, resilience measures, and early warning systems, with RI fostering climate awareness by defining resilience actions and integrating diverse stakeholder perspectives, fostering inclusive and data-driven adaptation strategies, while MRM strengthens aquaculture adaptation through real-time monitoring and system alerts, despite challenges in on-site repair, data accuracy, and sensor redundancy.

Overall, the INTERM contributes to preserve marine habitats and monitoring sediment transport, strengthening coastal resilience (SDG 14). RI, MRM, and INTERM enhance climate adaptation and resilience while fostering inclusive, data-driven strategies for sustainable aquaculture and environmental protection (SDG 13).

Uncertainties

Several main issues should be considered when interpreting the results:

- Target definition issues: RI and INTERM both have some indicators rely on estimated or qualitative benchmarks rather than clear, predefined targets.
- Data accuracy & reliability: MRM and INTERM both highlight some challenges in measurement precision, with MRM facing sensor variability and INTERM's manual sampling subject to potential human error risks.
- Operational dependencies: MRM’s response efficiency and INTERM’s sampling process both depend on external logistical factors, such as personnel availability and environmental conditions.
- Stakeholder Engagement: RI coordination is inconsistent and reactive, requiring external support, while INTERM benefits from close collaboration between researchers and shellfish harvesters but still requires external assistance for advanced technical issues. MRM's success relies on frequent stakeholder meetings and telephone contact, which are crucial for its development and transfer.

Overall, RI and INTERM face some target definition uncertainties, relying on qualitative benchmarks. MRM experiences sensor data accuracy variability, while INTERM’s manual sampling carries risk of human error. Operational dependencies impact MRM and INTERM due to logistical constraints. Stakeholder engagement varies, with RI needing external support, INTERM requiring enhanced interaction, and MRM depending on frequent contacts.

Improvement and next steps

Actions for the improvement and next steps:

- Enhancing data accuracy & system performance: RI will deliver more correlation outputs to enhance awareness of climate adaptation tools, MRM aims to improve system uptime from 80% to 90% by addressing data errors and integrating additional data sources, while INTERM will increase sediment sampling at biological sampling locations to strengthen data correlation and ecosystem understanding.
- Optimizing monitoring & measurement techniques: MRM will enhance sensor performance and cost-effectiveness by replacing underperforming components and exploring alternatives, while INTERM will refine spatial distribution to improve characterization and ensure comprehensive coverage.
- Improving response efficiency & operational processes: MRM will streamline on-site intervention by optimizing repair response times based on engineer availability, travel logistics, and environmental constraints, while INTERM will enhance sampling operations through minor efficiency improvements while ensuring sufficient personnel availability.
- Strengthening stakeholder engagement & decision-making: RI will engage and empower practitioners and policymakers to integrate the Resilience Index into mussel aquaculture adaptation, MRM will expand stakeholder data utilization for decision-making in regional programs, and INTERM will enhance collaboration between researchers and shellfish harvesters through structured communication and data interpretation.
- Improving system adaptability & customization: MRM will optimize software updates, refine system adaptability, enhance sensor alert efficiency, improve usability through solar panel positioning and equipment selection, and AI could be implemented for data calibration and anomaly detection, while INTERM will strengthen local data analysis skills, limiting external support to advanced technical challenges and system upgrades.

Overall, actions for next steps will focus on enhancing data accuracy and system performance, improving monitoring techniques, and optimizing response efficiency. Stakeholder engagement will be strengthened for better decision-making, while system adaptability and customization will be refined. Integrating AI and improving local data analysis capabilities are recommended to enhance sustainable aquaculture adaptation.

6.0 ORISTANO (ITALY)

6.1 Scoping

The coastal area of Oristano, located in Sardinia, Italy, is a dynamic and ecologically rich environment characterized by a complex system of rivers, lagoons, and salt marshes (Figure 6.1). These wetlands, spanning approximately 7,700 hectares, represent over 60% of Sardinia's wetlands and are safeguarded under the Ramsar Convention and the Natura 2000 network. The Gulf of Oristano demonstrates a unique integration of human settlements with the surrounding coastal wetlands, where urbanization remains low-density, with most communities concentrated inland. Along the coast, fishing cooperatives, agricultural activities, and small tourist villages contribute to the region's economic fabric.

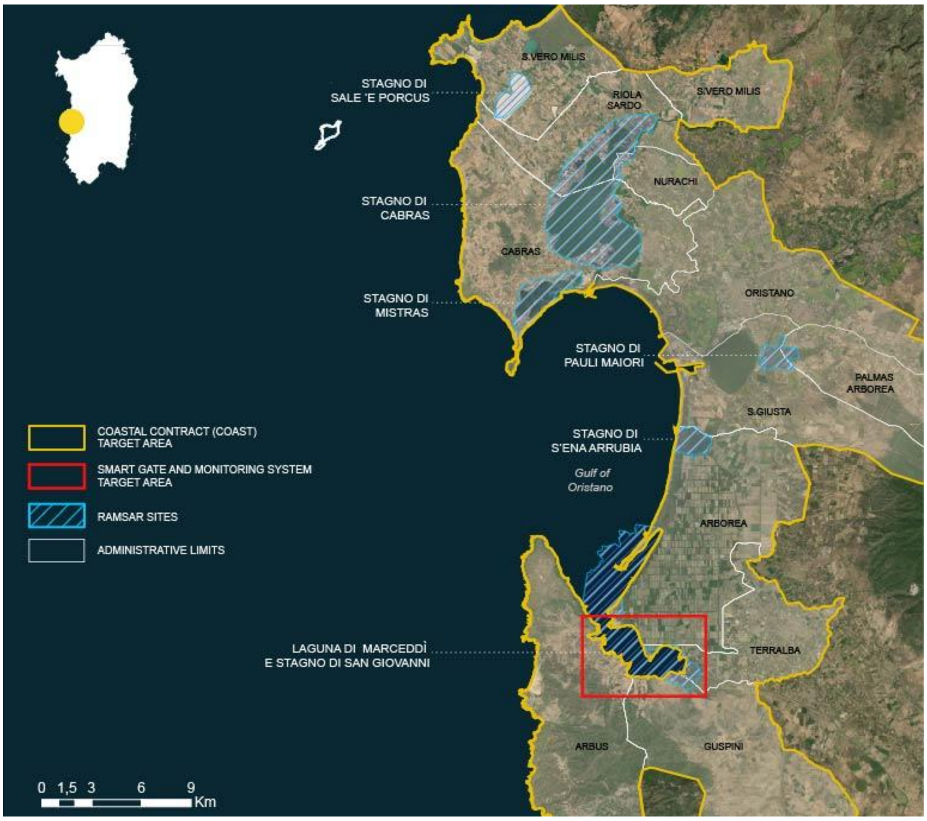


Figure 6.1 General map of the Gulf of Oristano

The coastal region of Oristano faces significant challenges due to climate change, exacerbating risks such as rising sea levels, increased temperatures, and extreme weather events. Prolonged droughts lead to competition for water resources, heightening conflicts between agricultural, industrial, and urban sectors. Heavy rainfall and storms cause inland and coastal flooding, endangering infrastructure, human lives, and ecosystems. The aquaculture sector is particularly vulnerable to disruptions in salinity and water quality, threatening fish stocks and livelihoods. Biodiversity loss, habitat degradation, and invasive species further impact fisheries and nature conservation efforts. These challenges demand urgent adaptation strategies to protect the region's economy and ecosystems.

In TransformAr, Oristano is actively working on two transformative solutions — the Coastal Contract (COAST) and the Nature-Based Solutions (NBS) initiative — aimed at addressing climate change and environmental challenges (Figure 6.2). To enhance the understanding of this report – focused on the sustainability profiles of the solutions – objectives and review of the two solutions are included. This ensures that readers grasp the contextual background and strategic approach. More detailed baseline analysis, additional insights and data can be found in the D5.8 – Intermediary Monitoring Report.

Specific objectives of the solutions are to:

- inform key stakeholders on the potential role of healthy coastal wetlands in mitigating climate change impacts.
- raise awareness on the efficacy of COAST and LWO to support wetland managers and planners into decision-making processes and developing successful adaptation actions.
- improve the scientific knowledge on the status of Marceddì and San Giovanni wetlands for planning opportune mitigation actions in case of critical conditions of the lagoon.
- test a technological and replicable model to increase the water quality and the hydro-geological dynamics and reduce the loss of habitats and species.
- limit areas damaged by both coastal and inland floods, resulting in reduced economic losses and cultural heritage damage.
- create synergies between regional and local administrators for an integrated and coordinated wetland water management.

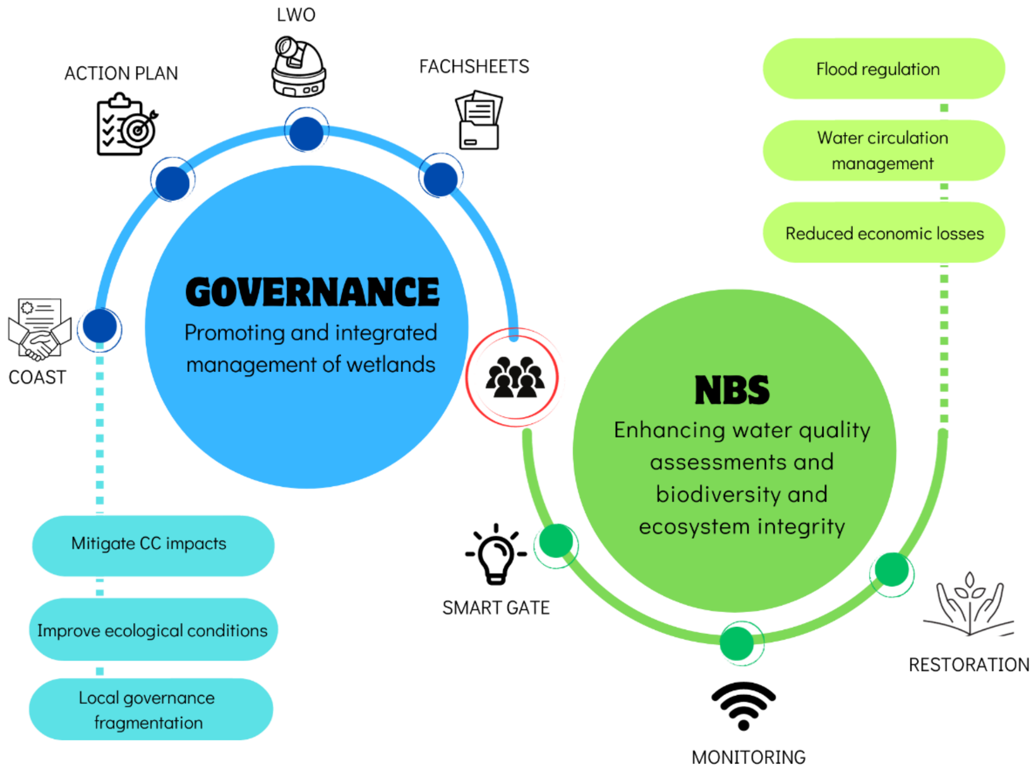


Figure 6.2 The Coastal Contract and Smart Gate (Nature-Based Solutions initiative)

The COAST initiative is a governance tool designed for the integrated management of wetlands, addressing governance fragmentation and mitigating environmental and human-induced impacts. It aims to improve ecological conditions while emphasizing community engagement through participatory meetings that enhance public awareness and knowledge. Beyond fostering local involvement, COAST extends its impact by disseminating factsheets to support regional replicability and long-term sustainability. A key component of the initiative is the Local Wetland Observatory (LWO), which monitors wetland conditions, tracks trends, and shares scientific insights to aid in decision-making and promote conservation efforts.

An **SG** and a monitoring system are part of Nature-Based Solutions (NBS) focused on the restoration of the wetland system. The NBS improves water quality management and circulation in the lagoon, supporting long-term environmental assessments. By enhancing flood regulation capacity, it reduces economic losses, particularly for the fishing sector, while protecting cultural heritage. The solution fosters collaboration among public organizations, strengthening social synergies. Additionally, the SG system introduces advanced, efficient, and precise water flow management. This technological innovation ensures reliability and serves as a replicable prototype for other lagoons facing similar challenges, offering a scalable approach to sustainable water resource management and climate adaptation.

6.2 Implementation

Risk Assessment (RA), Handprint Thinking (HT), and Life Cycle Thinking (LCT) are integrated to provide a comprehensive sustainability assessment for solutions like COAST and Smart Gate (SG). LCT ensures the analysis of environmental, social, and economic impacts throughout the solution's life cycle, while RA focuses on identifying and mitigating potential negative impacts. HT complements this by emphasizing the positive sustainability contributions of the solution. Together, these approaches enable a holistic evaluation of COAST and SG, balancing the minimization of risks with the enhancement of sustainability benefits, and supporting the identification of key performance categories and indicators necessary for assessing effectiveness across multiple domains.

Coastal Contract (COAST)

The performance evaluation of COAST is structured into one tailored category – Governance and Collaboration, along with five common categories: Stakeholder Engagement and Participation, Monitoring, Evaluation, and Adaptation, Management and Coordination, Financial Viability, and Risk and Resilience. Table 6.1 outlines the performance categories and corresponding indicators for COAST.

Table 6.1 Performance categories and indicators for Coastal Contract (COAST)

Performance categories	Indicator	Sub-indicator
Stakeholder Engagement and Participation	Meeting and workshop	Meeting and workshop attendance
		Meeting Engagement Satisfaction
Governance and Collaboration	Action Plan Clarity	
Monitoring, Evaluation, and Adaptation	Resilience Awareness	
	Replicability Reachout	
	Public Authorities Engagement	
	Observatory Reporting	
	Private Sector Engagement	
	Contract Action Achievement	Contract Action Achievement
		Contract Action Achievement Satisfaction
	Financial Coverage Progress	
Management and Coordination	Stakeholder Coordination	
	Commitment Fulfillment	
Financial Viability	Investment	Setup Cost
		Setup Efficiency
Risk and Resilience	Political and Policy Stability	

In Stakeholder Engagement and Participation, RA mitigates risks such as lack of commitment, while HT fosters an inclusive, participatory culture. Meeting and Workshop Attendance tracks stakeholder involvement, ensuring continuous participation, while Meeting Engagement Satisfaction measures the quality of discussions and contributions. This ensures informed decision-making and project ownership, which is critical for COAST's long-term acceptance and success. For Governance and Collaboration, RA identifies inefficiencies in decision-making, while HT ensures a proactive, transparent approach. Action Plan Clarity assesses whether roles, resources, and timelines are clearly defined, reducing misinterpretations and fostering accountability. A structured governance framework ensures cooperation between diverse stakeholders, enhancing COAST's effectiveness. In Monitoring, Evaluation, and Adaptation, RA identifies potential weaknesses in data collection and evaluation, while HT enhances learning and knowledge-sharing. Resilience Awareness measures stakeholders' understanding of climate adaptation, while Replicability Reachout tracks the dissemination of COAST-related knowledge, promoting scalability. Public Authorities Engagement ensures COAST's integration into governance frameworks, reinforcing policy support. Management and Coordination benefits from RA's risk anticipation and HT's proactive collaboration strategies. Stakeholder Coordination aligns diverse interests, ensuring balanced decision-making, while Commitment Fulfillment evaluates institutional accountability. For Financial Viability, RA prevents cost overruns, while HT promotes cost-efficient resource allocation. Setup Cost assesses the financial investment in COAST's establishment, while Setup Efficiency ensures proportional long-term benefits. In Risk and Resilience, RA identifies external threats such as political instability, while HT strengthens adaptive strategies. Political and Policy Stability monitors governmental changes, ensuring COAST remains resilient and sustainable in varying contexts.

Smart Gate (SG)

The performance evaluation of **SG** is structured into three tailored categories – Water Quality, System Performance, and Data Quality, along with five common categories: Stakeholder Engagement and Participation, Monitoring, Evaluation, and Adaptation, Management and Coordination, Financial Viability, and Risk and Resilience. Table 6.2 outlines the performance categories and corresponding indicators for **SG**. Due to the ongoing project, some data are still being collected, i.e., research collaboration, water quality, Hydraulic Variations Response, Fishing Sector Revenue Enhancement, Maintenance and Operational Cost. However, water quality is estimated as a general indicator, with testing still required to validate the results.

In Stakeholder Engagement and Participation, RA minimizes risks associated with stakeholder disengagement. Meeting Engagement Satisfaction measure stakeholder commitment, ensuring the quality of engagement. Research Collaboration with universities enhances knowledge transfer, strengthening resilience in wetland management. For Water Quality, RA focuses on preventing ecological degradation, while HT promotes proactive conservation. pH Levels, Conductivity, Redox Potential, Dissolved Oxygen Levels, Temperature, Turbidity, and Salinity are monitored to ensure water quality. In System Performance, RA addresses operational inefficiencies, while HT ensures long-term functionality. System Reliability, Hydraulic Variations Response, and Aperture/Closure Control Accuracy optimize water flow management. System Scalability and Integration Capability enhance adaptability, ensuring seamless interoperability with external technologies. HT leverages innovation in energy use for sustainable management. Computing Power, and Sensor Maintenance Frequency enhance monitoring effectiveness. RA and HT balance risk mitigation and impact maximization to assess Monitoring, Evaluation, and Adaptation. NBS Surface Area Coverage enhances biodiversity and resilience, while Reduction of Economic Losses quantifies avoided damages. In Data Quality, RA safeguards against inaccuracies, while HT enhances precision in environmental monitoring. Continuous Monitoring in data collection supports water management strategies. Sensor Coverage Redundancy prevents data loss, ensuring reliable real-time insights into water system dynamics. For Management and Coordination, RA mitigates governance inefficiencies, while HT promotes inter-agency collaboration. Internal Communication Effectiveness, Commitment Fulfillment, and System Integration Responsibility optimize project execution. Strong institutional coordination ensures sustainable long-term operations. In Financial Viability, RA reduces investment risks, while HT maximizes resource efficiency. Investment Cost Efficiency, Maintenance Cost

Efficiency, and Operational Cost Efficiency ensure economic feasibility. SG's ability to prevent economic losses justifies continued financial commitment to adaptive solutions. For Risk and Resilience, RA prepares for disruptions, while HT strengthens recovery mechanisms. Installation Disruptions and Energy Supply Reliability measure SG's robustness against climate-related threats. Proactive risk management strategies ensure operational stability, enhancing long-term sustainability.

Table 6.2 Performance categories and indicators for Smart Gate (SG)

Performance categories	Indicator	Sub-indicator
Stakeholder Engagement and Participation	Meeting Attendance	Meeting Attendance
		Meeting Engagement Satisfaction
	Research Collaboration	
Water Quality	Water Quality	
	Water Quality Satisfaction	
System Performance	System Reliability	
	Hydraulic Variations Response	
	System Uptime Satisfaction	
	System Scalability	
	Integration Capability	
	Data Network Coverage	
	Tech-enabled Monitoring	Use of Energy
	Computing Power	
	Sensor Maintenance Frequency	
Monitoring, Evaluation, and Adaptation	NBS Surface Area Coverage	
	Reduction of Economic Losses	
Data Quality	Fishing Sector Revenue Enhancement	
	Continuous Monitoring	
	Data Collection and Analysis	
	Data Accuracy	
	Sensor Coverage Redundancy	
Management and Coordination	Internal Communication and Collaboration	
	Institutional Coordination	
	Commitment Fulfillment	
	System Integration Responsibility	
Financial Viability	Investment	Investment cost
		Investment cost efficiency
	Maintenance	Maintenance cost
		Maintenance cost efficiency
	Operational	Operational cost
		Operational cost efficiency
Risk and Resilience	Installation Disruptions	
	Energy Supply Reliability	

* Indicator/Sub-indicator in gray color indicates that data are not available yet.

After the indicators were selected, they were assigned to the relevant SDGs by matching each indicator's measured outcome to the appropriate sub-targets, following methodology described in Section 2.2.3.For example, the indicator "System Reliability," which evaluates the system's ability to maintain stable lagoon conditions and mitigate disruptions that could impact the ecosystem, is assigned to sub-goal 9.1, which aims to “develop quality, reliable, sustainable, and resilient infrastructure…”. In addition to 'System Reliability,' sub-goal 9.1 is relevant for other indicators that enhance system performance, including:

- Sensor Coverage Redundancy, which assesses how sensor redundancy helps prevent data gaps due to sensor failures.
- System Scalability, which focuses on the system’s ability to adapt to higher/lower demand or changing configurations.
- Data Collection and Analysis, which evaluates how effectively collected data is analyzed to enhance stakeholders’ understanding of water quality and support informed decision-making.

Taken together, these indicators align with SDG 9 – Industry, Innovation, and Infrastructure. Beyond SDG 9, some indicators also align with other SDGs. For instance, “System Reliability” contributes to SDG 13 – Climate Action through sub-goal 13.1, “Strengthen resilience and adaptive capacity to climate-related hazards…”. Similarly, “Data Collection and Analysis” supports SDG 16 through sub-goal 16.7, “Ensure responsive, inclusive, participatory, and representative decision-making at all levels” by providing stakeholders with actionable insights into water quality parameters, enabling informed and inclusive decision-making.

6.3 Data process

Data process involves several stages starting with data gathering, followed by assigning scores for qualitative indicators, while scores for quantitative indicators are calculated and normalized. After that, the scores are assigned to relevant SDG sub-goals, and the corresponding SDGs are then used for assessment. Next, the indicator scores are combined to generate aggregate scores for SDGs. The goal is to ensure that the collected data is consistently evaluated, standardized, and presented in a way that aligns with sustainability goals.

The project employs a systematic data gathering process, integrating iterative participatory interviews with supporting sources, such as monitoring reports, field studies, and institutional documentation. This multi-source approach ensures a comprehensive and evidence-based assessment of adaptation solutions, enhancing both qualitative and quantitative evaluations. By synthesizing diverse data sources and refining indicator processing methods, this methodology strengthens the robustness of evaluations and advances effective climate resilience strategies, ensuring that adaptation solutions are well-validated, context-specific, and responsive to stakeholder needs.

Multiple sources are cross-checked, covering key deliverables such as:

- Stakeholders Matrix and IE Baseline Profiles (D1.2)
- Six Region-Specific Portfolios of Solutions (D3.8)
- Compendium of Pathways and Action Plans (D3.9)
- Intermediary Monitoring Report (D5.8)
- Learning Stories on Governance Schemes (D4.2)
- Learning Stories on Nature-Based Solutions and Book of Nature-Based Solutions (D4.3)

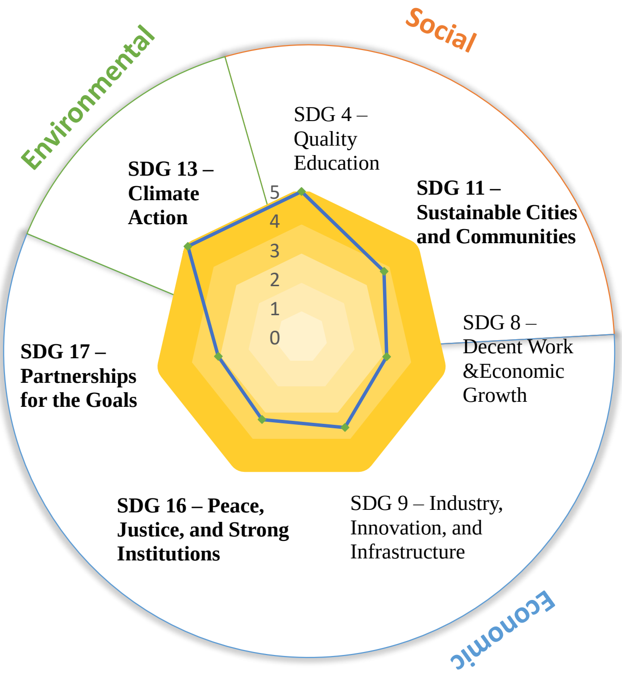
Institutional documentation plays an important role in supporting data collection and validating adaptation solutions, such as cost records related to investment, maintenance, and operation, as well as stakeholder engagement tracking records to monitor participation and impact. Additionally, it encompasses action plans and supporting literature that contribute to estimation. Field data and experimental results, combined with modeling analysis, offer critical insights by assessing environmental changes and ecosystem resilience while evaluating long-term sustainability and adaptive capacity. By integrating these elements, the project ensures a data-driven, evidence-based approach that strengthens the effectiveness and scalability of adaptation strategies.

Qualitative indicator data is processed using the general approach outlined in Section 2.2.3. All indicators are assigned scores ranging from 0 to 5, which are then allocated to the relevant SDG sub-goals identified for each indicator. The final contribution to each SDG is aggregated using the weighted sum method, with an assumption of equal weights for all indicators. However, this weighting can be adjusted based on project goals, stakeholder input, or specific contextual needs.

6.4 Assessment

The sustainability profiles of each solution and region-specific portfolio (RSP) are presented here. They align with SDG goals, as well as the sustainability domains of social, economic, and environmental aspects. The assessment begins with an evaluation of each solution, followed by the RSP, addressing three key aspects: results and their interpretation, uncertainties, and actions for improvement and next steps.

6.4.1 Sustainability profile of Coastal contracts (COAST)



COAST (Coastal Contract)

Primary targeted SDGs*:

Co-benefit SDGs:

* Targeted SDGs are black bordered.

The interpretation of the profile should focus on **Primary targeted SDGs** with multiple indicator contributions, while co-benefit SDGs typically have limited contributions from specific indicators.

Social domain

Relevant performance categories (indicators):

Stakeholder Engagement and Participation – SDG 11; Monitoring, Evaluation, and Adaptation (Resilience Awareness and Replicability Reachout) – SDG 4 & 11, (Public Authorities Engagement, Private Sector Engagement, Contract Action Achievement) – SDG 11

Interpretation:

- +++ By increasing knowledge and awareness among key stakeholders at various levels, the initiative empowers communities to actively support sustainable coastal development and promotes the integration of sustainable coastal management practices into local and regional strategies.
- ++ Moderate engagement from public authorities helps anchor coastal and wetland management in local policies, fostering sustainable regional planning.
- + Implementing contract actions to enhance the integration of sustainable coastal management practices into local and regional planning is still ongoing, with further developments anticipated.
- + Limited private stakeholder engagement can hinder efforts to reduce environmental impacts.

Overall, the initiative supports SDG 11 and SDG 4 by promoting knowledge-sharing to empower communities in sustainable coastal management. Strengthening public governance can enhance policy integration for resilience (SDG 11). Ongoing contract actions require progress and cross-sector collaboration, while limited private engagement highlights the need for stronger public-private partnerships to enhance long-term sustainability.

Economic domain

Relevant performance categories (indicators):

Stakeholder Engagement and Participation – SDG 16, Governance and Collaboration- SDG 9 & 16, Monitoring, Evaluation, and Adaptation (Public Authorities Engagement) – 17, (Observatory Reporting) – SDG 9 & 16, (Private Sector Engagement) – SDG 8 & 17, Management and Coordination and Risk and Resilience – SDG 16 & 17, Financial Viability – SDG 8 & 9

Interpretation:

- +++ The setup investment is estimated to be effective and resource-efficient for sustainable coastal governance, with a clear Action Plan establishing reliable infrastructure for wetland restoration and monitoring.
- +++ High attendance and positive feedback from meetings indicate inclusive participation, reinforcing just and effective institutions, while clear plans and adherence to responsibilities enhance institutional accountability and ensure efficient resource utilization.
- ++ Public authority engagement, commitment fulfilment, and stakeholder coordination can be strengthened to enhance multi-sector collaboration, foster partnerships, and underscore the importance of collaborative efforts for sustainable wetland management.
- + Moderate political stability is challenged by occasional policy shifts and re-prioritizations that impact resource allocation, necessitating adaptive planning for continuity, while strengthening multi-stakeholder collaboration can enhance policy consistency and resource mobilization, fostering long-term sustainable governance and partnerships.

+ Enhancing private sector engagement is crucial for creating new economic opportunities, driving resource mobilization and innovation, and ensuring wetland conservation.

Overall, resource-efficient investment and a clear Action Plan establish reliable infrastructure for wetland restoration and monitoring (SDG 16, 9). Inclusive participation and institutional accountability reinforce transparent and effective governance (SDG 16). Public authority engagement and policy stability need reinforcement to ensure consistent resource allocation (SDG 17). Private sector engagement requires stronger incentives for economic opportunities, innovation, and sustainable growth in coastal regions (SDG8).

Environmental domain

Relevant performance categories (indicators):

Monitoring, Evaluation, and Adaptation (Resilience Awareness)

Interpretation:

+++ Increased awareness of climate-related hazards helps stakeholders adapt and mitigate negative impacts on wetlands and coastal zones.

By disseminating accessible and applicable knowledge, it strengthens adaptive capacity, ensuring informed decision-making and proactive responses to climate challenges.

Uncertainties

Several factors should be considered when interpreting the results:

- Replicability Reachout: The targeted number of people and managers reached through the factsheet to disseminate COAST at the regional level is based on estimation, with completion expected by March 2025.
- Observatory Reporting: The number of reports and factsheets produced and shared by the Local Wetland Observatory (LWO) is also projected, with final reporting anticipated by the same timeline.
- Contract Action Achievement: This is currently monitored through an ongoing process; however, the primary goal of this initiative is to disseminate the governance tool, thereby expanding stakeholder engagement across different sectors.

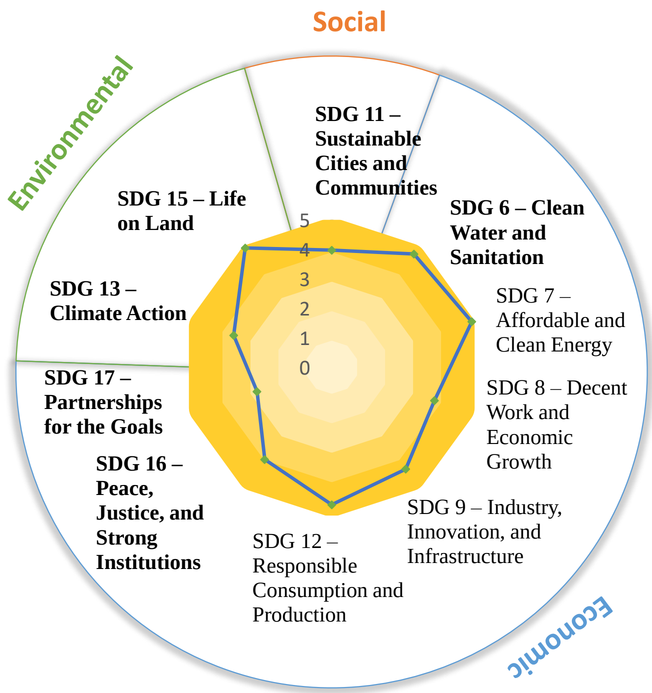
Improvement and next steps

Improvement and next steps include:

- Finalizing the targeted outreach efforts to ensure the COAST factsheet reaches the intended audience, while the Local Wetland Observatory (LWO) continues compiling and sharing reports and factsheets.
- For the Action Plan Clarity, the technical coordinator is still working to ensure the same level of detail in defining tasks, timelines, responsibilities, and resources.
- Monitoring of Contract Action will be finalized by gathering pending feedback from involved bodies to ensure a comprehensive assessment of the implemented actions.
- Identifying additional solutions through the adaptation pathway work for potential inclusion in the updated Action Plan, followed by submission to the coordination group (signatories) for approval.

The next steps will focus on finalizing outreach efforts for the COAST factsheet and continuing LWO reporting, while the technical coordinator refines the Action Plan with clear tasks and responsibilities. Monitoring of Contract Actions will be completed through pending feedback, and new solutions identified through adaptation pathways will be submitted for approval by the coordination group.

6.4.2 Sustainability profile of Smart Gate (SG)



SG (Smart Gate)

Primary targeted SDGs*:

Co-benefit SDGs:

* Targeted SDGs are black bordered.

The interpretation of the profile should focus on **Primary targeted SDGs** with multiple indicator contributions, while co-benefit SDGs typically have limited contributions from specific indicators.

Social domain

Relevant performance categories (indicators):

Stakeholder Engagement and Participation, Monitoring, Evaluation, and Adaptation (Reduction of Economic Losses), Data Quality (Continuous Monitoring, Sensor Coverage Redundancy), Risk and Resilience (Installation Disruptions)

Interpretation:

- +++ Real-time flow information and sensor coverage redundancy enhance flood risk warnings and detection, enabling timely interventions that reduce disaster risks and support safer, more resilient coastal environments.
- ++ Regular participation helps incorporate local voices and knowledge into regional planning around water resources, ensuring solutions align with community needs for sustainable development.
- \+ Moderate evidence of economic loss reduction indicates adaptation measures are partially effective but require enhancements for greater financial protection.
- \+ The installation faces risks of disruptions and schedule delays, as flooding is somewhat predictable, but varying intensity requires occasional adjustments.

Overall, real-time flow monitoring and sensor redundancy improve flood risk detection, enabling timely interventions for resilient coastal environments. Community participation ensures water resource planning aligns with local needs for sustainable development. While economic loss reduction is estimated as moderate, installation challenges happen, requiring adaptive scheduling due to variable flood intensity and disruptions.

Economic domain

Relevant performance categories (indicators):

Stakeholder Engagement and Participation – SDG 16, Water Quality – SDG 6 & 8, System Performance – SDG 9, (System Uptime Satisfaction, Integration Capability, Computing Power) – SDG 16, (Tech-enabled Monitoring) – SDG 7 & 12, (Sensor Maintenance Frequency) – SDG 8, Monitoring, Evaluation, and Adaptation – SDG 6 & 8, Data Quality – SDG 6, 9, 12, 16, Management and Coordination – SDG 16 & 17, Financial Viability – SDG 8, 9, 12, Risk and Resilience (Energy Supply Reliability) – SDG 7 & 9

Interpretation:

+++ The integration capability of the monitoring system ensures reliable water infrastructure for effective lagoon management, while efficient computing and redundant sensors enhance system reliability and data accuracy.

+++ Continuous monitoring and real-time data enhance reliable forecasting of water availability and flow dynamics, while accurate data analysis supports effective water resource management, ensuring the sustainable use and preservation of lagoon ecosystems.

+++ The monitoring system is fully powered by solar energy and assessed as highly reliable, with adequate energy storage to maintain continuous operation, even during extended low-sunlight periods.

+ Institutional coordination is moderate but inconsistent, tending to be reactive rather than proactive, with commitments made irregularly, requiring follow-ups to ensure timely delivery.

+ System integration presents challenges for the coordinator, involving the integration of design, engineering, software/IT systems, and construction, which impacts the project by causing delays and inefficiencies.

+ External factors such as the pandemic, geopolitical instability, and weather events have significantly increased costs, leading to budget concerns and the need for additional funding.

Overall, the monitoring system's integration capability supports SDG 9 by ensuring reliable water management, while real-time data insights enhance sustainable resource use, contributing to SDG 6. Solar-powered system aligns with SDG 7, ensuring access to affordable, reliable, and sustainable energy. However, institutional coordination is inconsistent (SDG 16), requiring follow-ups for resource allocation. System integration challenges cause delays and inefficiencies (SDG 17). Rising costs from external factors create budget constraints (SDG 8 and SDG 12) by increasing the need for sustainable funding.

Environmental domain

Relevant performance categories (indicators):

System Performance (System Reliability) – SDG 13, Monitoring, Evaluation, and Adaptation (NBS Surface Area Coverage) – SDG 15, Risk and Resilience (Installation Disruptions) – SDF 13

Interpretation:

+++ The system meets the targeted coverage of surface area designated for Nature-Based Solutions (NBS).

++ The system is estimated reliable, but minor inconsistencies might occur during extreme flood events, requiring occasional adjustments to maintain ecological balance.

+ The installation of the system carries a moderate to high risk, as unpredictable flooding necessitates regular schedule adjustments and resource reallocation to mitigate impacts.

The system supports SDG 13 (Climate Action) by integrating Nature-Based Solutions (NBS) to mitigate flooding impacts and enhance ecosystem resilience. It aligns with

SDG 15 (Life on Land) by protecting wetlands, though unpredictable flooding risks require adaptive management and resource reallocation.

Uncertainties

Several issues should be considered when interpreting the results:

- As the system was recently installed, its performance metrics—including System Reliability, System Uptime, Data Network Coverage, and Energy Supply Reliability—are based on estimations, rated between 4 and 5, with validation still required.
- The water quality parameters will be merged into a single indicator that considers water quality improvement (considering Legislative Decree 152/2006 et seq. as a regulatory reference). The result here is based on estimation.
- Commitment Fulfilment currently stands at 3/5, with two more meetings planned, and the final outcome will depend on validation through successful coordination and stakeholder engagement.

Overall, the system's performance metrics (reliability, uptime, data coverage, and energy supply) are based on estimations (rated 4-5) and require validation. Water quality parameters will be merged into a single indicator, with results still estimated. Commitment Fulfilment depends on stakeholder engagement and coordination, with two meetings planned.

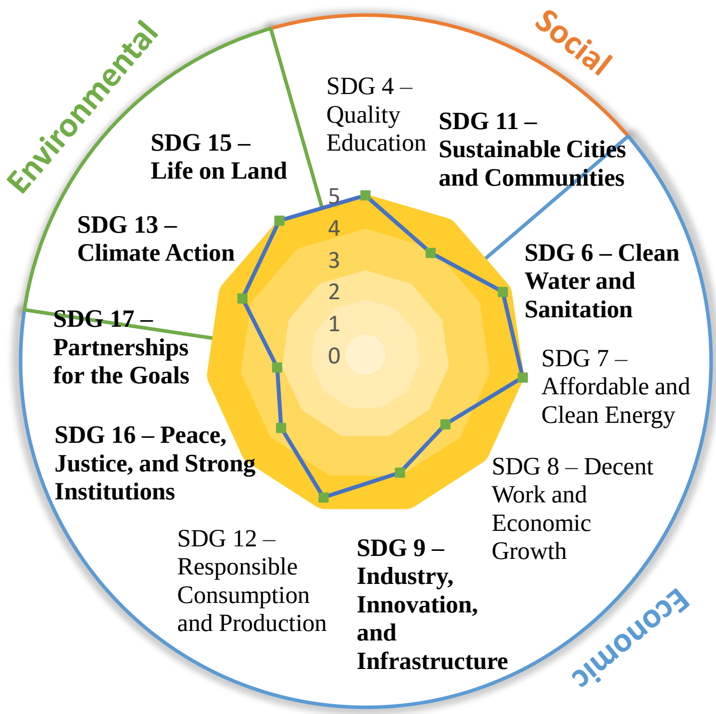
Improvement and next steps

Several ongoing activities for the improvement and next steps:

- Collaboration with universities and research institutes will be pursued to enhance knowledge on the effectiveness and benefits of the monitoring system, support scientific research, and drive system improvements.
- Meetings are planned to enhance Commitment Fulfilment, aiming to increase the current rating from 3 to 4 by the end of the project.
- Testing and validation are required to assess system performance, water quality improvements and energy supply reliability, addressing uncertainties in long-term operational stability.

In summary, collaboration with universities and research institutes will be pursued to enhance knowledge of the monitoring system. Planned meetings aim to increase Commitment Fulfilment. Ongoing testing and validation are being conducted to address the uncertainties related to long-term operational stability.

6.4.3 Sustainability profile of Region-specific portfolio (RSP)



Region-specific portfolio (RSP)
Include two solutions: COAST (Coastal Contract) and SG (Smart Gate)

Primary targeted SDGs*:

Co-benefit SDGs:

* Targeted SDGs are black bordered.

The interpretation of the profile should focus on **Primary targeted SDGs** with multiple indicator contributions, while co-benefit SDGs typically have limited contributions from specific indicators.

Social domain

Relevant performance categories (indicators):

COAST: Stakeholder Engagement and Participation – SDG 11; Monitoring, Evaluation, and Adaptation (Resilience Awareness and Replicability Reachout) – SDG 4 & 11, (Public Authorities Engagement, Private Sector Engagement, Contract Action Achievement) – SDG 11

SG: Stakeholder Engagement and Participation, Monitoring, Evaluation, and Adaptation (Reduction of Economic Losses), Data Quality (Continuous Monitoring, Sensor Coverage Redundancy), Risk and Resilience (Installation Disruptions)

Interpretation:

+++ Increasing stakeholder knowledge enhances coastal resilience and sustainable planning (COAST), while regular participation in SG initiatives ensures local voices shape water resource management, making solutions more inclusive and community-driven.

++ Moderate public authority engagement in COAST supports policy integration for wetland and coastal management, while SG participation ensures shared knowledge and stakeholder engagement, with both contract actions in COAST and real-time data from SG requiring further integration to enhance long-term sustainability.

\+ Minimal private sector participation in COAST hinders efforts to develop resilient and sustainable coastal communities, while moderate evidence of economic loss reduction in SG suggests that adaptation measures are partially effective but require further enhancements for greater financial protection and resilience.

\+ SG installation faces delays and disruptions due to unpredictable flooding, requiring regular adjustments to schedules and resource allocation.

Overall, the strongest contributions to SDG 11 & SDG 4 come from stakeholder knowledge-sharing and participatory planning, which improve coastal resilience and sustainability. Moderate public engagement supports regional policy integration, but system installation risks require regular adjustments to schedules and resource allocation and limited private sector involvement poses challenges to long-term success.

Economic domain

Relevant performance categories (indicators):

COAST: Flood Vulnerability (Reduced Runoff) - SDG 6, Water Quality (Reducation in Nutrients and Metals) – SDG 6 & 12, and life cycle Environmental Impact (water, human) – SDG 6, 12, Management and Co-ordination – SDG 16 &17, Financial Viability - SDG 9 and SDG 17

SG: Stakeholder Engagement and Participation – SDG 16, Water Quality – SDG 6 & 8, System Performance – SDG 9, (System Uptime Satisfaction, Integration Capability, Computing Power) – SDG 16, (Tech-enabled Monitoring) – SDG 7 & 12, (Sensor Maintenance Frequency) – SDG 8, Monitoring, Evaluation, and Adaptation – SDG 6 & 8, Data Quality – SDG 6, 9, 12, 16, Management and Coordination – SDG 16 & 17, Financial Viability – SDG 8, 9, 12, Risk and Resilience (Energy Supply Reliability) – SDG 7 & 9

Interpretation:

+++ The setup investment is effective and resource-efficient, ensuring reliable infrastructure for sustainable coastal governance (COAST), while the SG monitoring system integrates advanced technology, real-time data insights, redundancy, supporting sustainable management.

++ Institutional challenges: COAST requires stronger public authority engagement and multi-sector collaboration for wetland management, while SG encounters inconsistent coordination, needing follow-ups to ensure commitment fulfilment and timely resource allocation.

\+ Collaboration challenges: COAST shows strong institutional participation but limited private sector engagement, restricting economic opportunities and resource mobilization, while coordinator struggles with system integration (SG), cause delays and hinder effective coordination.

+ Financial challenges: COAST requires adaptive planning to address political re-prioritization affecting resource allocation, while SG struggles with budget concerns and funding gaps due to external factors like the pandemic and geopolitical instability.

Overall, the COAST investment ensures resource-efficient infrastructure (SDG 9) for sustainable coastal governance, while the SG monitoring system enables effective monitoring and data-driven management (SDG 6, 9). Institutional challenges require stronger public engagement (SDG 16) and multi-sector collaboration (SDG 17). Limited private participation hinders economic opportunities (SDG 8, 12). Financial instability necessitates adaptive planning amid geopolitical and pandemic-related uncertainties (SDG 7).

Environmental domain

Relevant performance categories (indicators):

COAST: Monitoring, Evaluation, and Adaptation (Resilience Awareness)

SG: System Performance (System Reliability) – SDG 13, Monitoring, Evaluation, and Adaptation (NBS Surface Area Coverage) – SDG 15, Risk and Resilience (Installation Disruptions) – SDF 13

Interpretation:

+++ Increased awareness of climate-related hazards through COAST helps stakeholders adapt and protect coastal and wetland ecosystems, while the SG system effectively covers designated NBS areas, directly enhancing climate resilience and ecosystem protection.

+ The SG system is reliable, but minor inconsistencies may occur during extreme flood events, requiring adjustments to maintain ecological balance.

+ The installation process carries moderate to high risk as unpredictable flooding requires frequent schedule adjustments and resource reallocation.

Overall, COAST enhances climate hazard awareness (SDG 13), while SG integrates nature-based solutions (NBS) to protect wetlands (SDG 15). System reliability is high, but extreme floods cause minor inconsistencies. Adaptive planning is needed to address moderate-to-high installation risks from unpredictable flooding, ensuring long-term resilience.

Uncertainties

Several main issues should be considered when interpreting the results:

- Both COAST's Replicability Reachout and Observatory Reporting and SG's system performance metrics (System Reliability, Uptime, Data Network Coverage, and Energy Supply Reliability, rated 4-5) are based on estimates, with final validation pending — COAST by March 2025 and SG requiring further assessment.
- Both COAST and SG solutions require ongoing monitoring and stakeholder engagement, with COAST focusing on expanding stakeholder involvement without a fixed completion metric, while SG aims to improve Commitment Fulfilment through planned meetings.
- Water quality parameters will be merged into a single indicator based on Legislative Decree 152/2006 et seq., but results remain estimates at this stage.

Overall, both COAST and SG solutions rely on some estimated data, requiring further assessment and validation. Ongoing monitoring and stakeholder engagement are crucial, with COAST focusing on expanding involvement and SG working to improve Commitment Fulfilment. Water quality parameters remain estimates, awaiting further validation for accuracy and compliance.

Improvement and next steps

Actions for the improvement and next steps:

- COAST continues to have LWO compiling and sharing reports shared to improve wetland management, while SG pursues collaboration with universities and research institutes to advance research.
- The COAST technical coordinator is refining the Action Plan to ensure clarity in tasks, timelines, and responsibilities, while SG meetings are planned to enhance Commitment Fulfillment.
- COAST focuses on finalizing Contract Action monitoring through pending feedback collection, while SG prioritizes testing and validation to evaluate system performance, water quality improvements, and energy supply reliability, addressing uncertainties in long-term operational stability.
- COAST incorporates additional solutions into the updated Action Plan for approval, while SG utilizes testing results to drive system refinements for enhanced performance and reliability.

Overall, both COAST and SG solutions prioritize scientific collaboration, stakeholder engagement, governance refinement, and performance validation. COAST focuses on outreach, planning clarity, and contract monitoring, while SG emphasizes system testing, commitment fulfilment, and energy reliability. Ongoing research, adaptation, and stakeholder coordination remain critical for both solutions to achieve long-term sustainability and operational stability.

7.0 GUADELOUPE (FRANCE)

7.1 Scoping

Guadeloupe (16-15° N, 61-35° W), an overseas French department and region, is an archipelago located in the Caribbean. It consists of five inhabited islands - Basse-Terre, Grande-Terre, Marie-Galante, La Désirade, and Les Saintes, approximately 6,800 km away from mainland France (Figure 7.1). Covering an area of approximately 1,628 km^2 with a population of around 378,561 residents (2024).

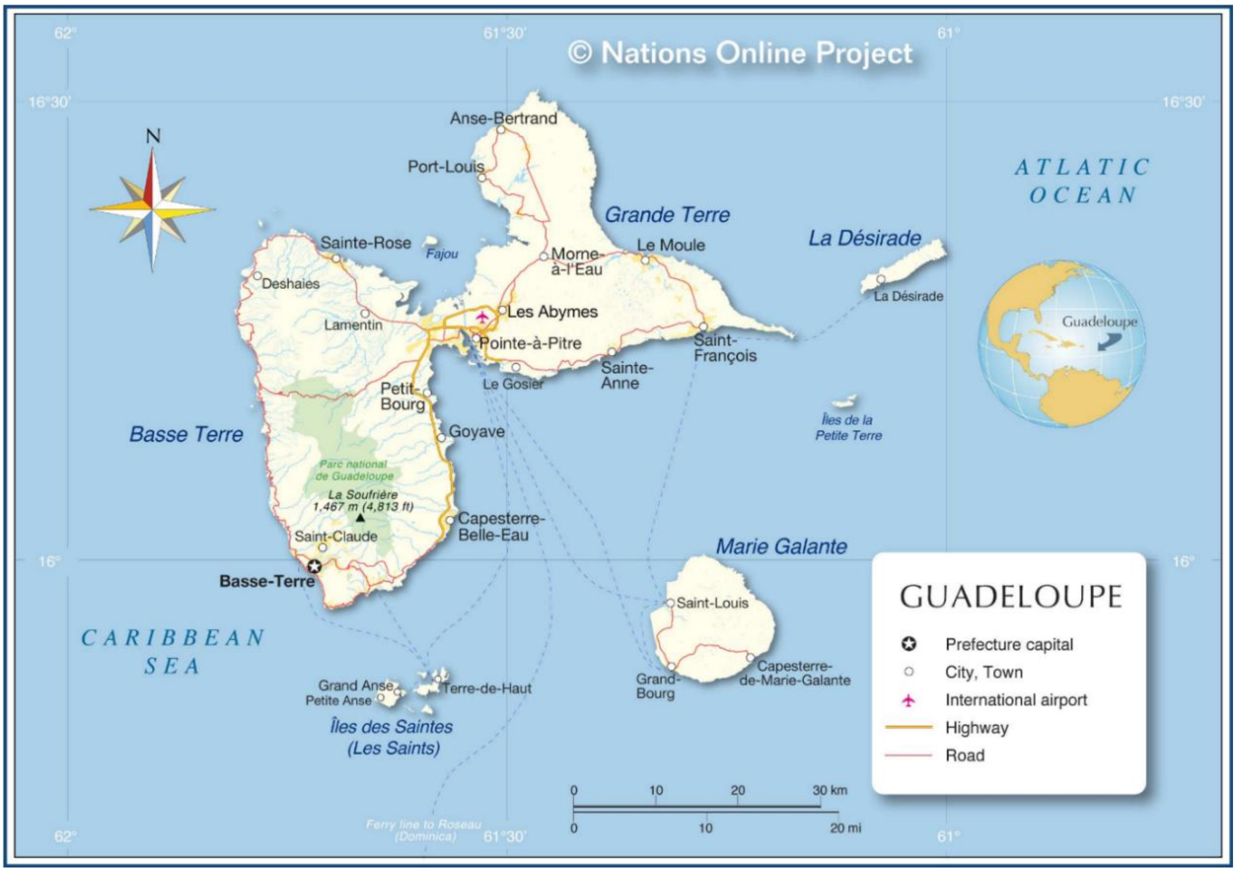


Figure 7.1 Map of Guadeloupe Archipelago (Source: Nationsonline.org, 2024)

Guadeloupe faces a high exposure to climate change-related disasters due to its geographical position and biophysical characteristics. The region is vulnerable to hurricanes, floods, droughts, coastal erosion, forest fires, earthquakes, and volcanic eruptions. Climate change has increased temperatures, the frequency of droughts and floods, and the intensity of hurricanes, which further stress key economic sectors such as agriculture and tourism. These environmental threats have secondary effects, including land salinization, sargassum seaweed invasion, and water scarcity, making adaptation measures crucial.

For TransformAr, the key community systems (KCS) (representing the territory's key economic sectors that are vulnerable from a climate perspective) that were retained are tourism and agriculture. Two solutions are identified: awareness-raising, and behavioral change through nudging (NUDG) and a local adaptation acceleration fund (AF). To enhance the understanding of this report - focused on the sustainability profiles of the solutions - a review of the solutions is included here. More detailed baseline analysis, additional insights and data can be found in other deliverables (list in 7.2 Implementation).

There are three objectives for NUDG (Figure 7.2):

- create awareness about the water-related issues in Guadeloupe. The awareness creation is mainly targeted towards tourists, but it will also help with the awareness of the hotel staff, even though they are more aware of the problems and the consequences.
- make the tourists more aware of their water consumption. This step is vital in the nudging experiment as they won't change their behavior if they are not aware of it.
- nudge the tourists to use less water. The main focus of this nudging experiment is the water consumption in the shower (closely linked to the previous one).

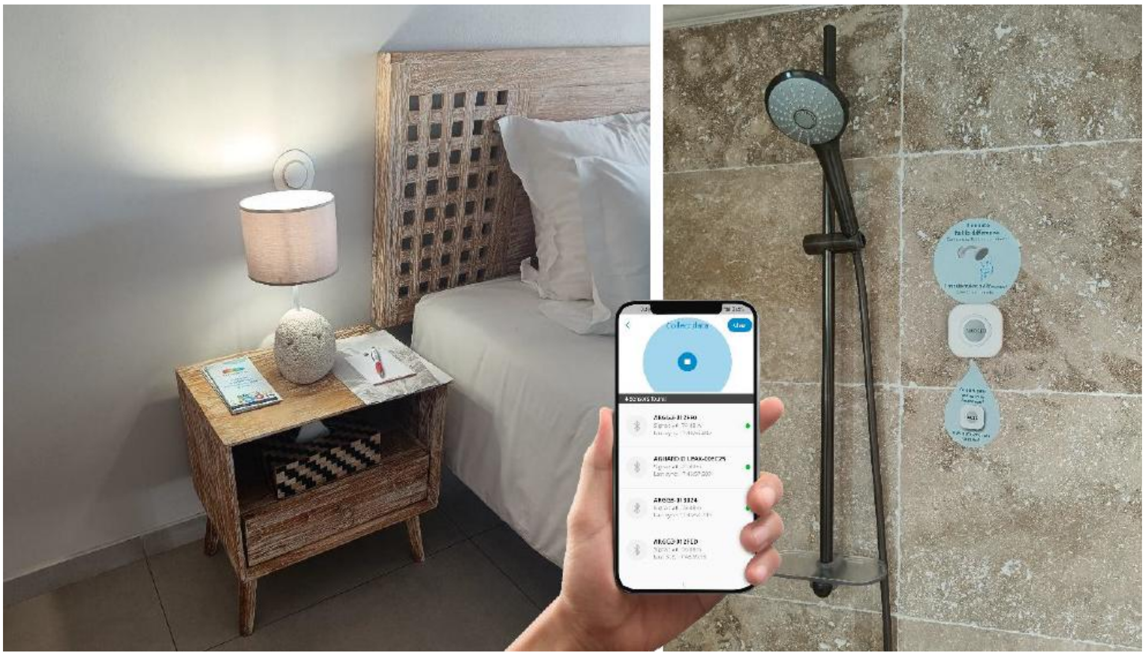


Figure 7.2 A nudging experiment (NUDG) targeting tourists to consume less water by using flyers, stickers and shower sensors

The AF aims to prioritize adaptation financing in a region urgently requiring tailored solutions, setting a precedent for more targeted and inclusive climate action within both French and European frameworks. This initiative marks a groundbreaking step, introducing the most advanced adaptation-focused financial mechanism in France. The experiment of setting up an AF is organized in two phases: 1) Feasibility study for the financial mechanism and 2) Testing of the financial mechanism. Creation of a Technical and Financial Committee is critical in the 2nd step, which is gathering 15 technical and 7 financial partners, mostly from the public sector (Figure 7.3).

Figure 7.3 Adaptation (AF) with 15 technical and 7 financial partners

7.2 Implementation

Risk Assessment (RA) and Handprint Thinking (HT), integrated within Life Cycle Thinking (LCT), provide a structured framework for evaluating the solutions of Nudging (NUDG) and the Adaptation Fund (AF). RA identifies and mitigates risks related to implementation, governance, and financial viability, while HT emphasizes long-term benefits such as stakeholder engagement, behavioral change, and financial resilience. LCT ensures a holistic evaluation, incorporating feasibility, monitoring, and impact assessment. This synergy enhances NUDG’s effectiveness in driving sustainable behavior and strengthens AF’s role in supporting climate adaptation, ensuring adaptive, scalable, and impactful solutions for long-term sustainability and resilience.

Nudging (NUDG)

Nudging is a behavioral science concept that aims to subtly guide people's decisions without restricting their choices. In the context of water conservation, a nudging experiment was conducted in Guadeloupe to encourage hotel guests to reduce their water usage. The initiative included an informational brochure in hotel rooms to raise awareness about water scarcity issues and practical conservation tips. Stickers placed in bathrooms served as visual reminders of these messages. The most impactful element was the Aguardio Shower Sensor, which displayed real-time shower duration, prompting guests to shorten their showers. This sensor also collected data on water usage, allowing for analysis of behavioral changes. Guest feedback was gathered through surveys, providing insights into the effectiveness of these interventions. Despite logistical challenges in engaging hotel managers, the experiment demonstrated that nudging can effectively influence sustainable behaviors in tourism.

The performance evaluation of NUDG is structured into one tailored category - Readiness and Feasibility - along with five common categories: Stakeholder Engagement and Participation, Monitoring, Evaluation, and Adaptation, Management and Coordination, Financial Viability, and Risk and Resilience. Table 7.2 outlines the performance categories and corresponding indicators for NUDG.

Table 7.1 Performance categories and indicators for Nudging (NUDG)

Performance categories	Indicator	Sub-indicator
Readiness and Feasibility	Sectoral Readiness	
	Stakeholder Adoption Readiness	
	Solution Development Readiness	
Stakeholder Engagement and Participation	Meeting Engagement Satisfaction	
	Workshop Attendance	
	Event Attendance	Event Attendance
		Event Attendance Satisfaction
	Feedback Submission Satisfaction	
Monitoring, Evaluation, and Adaptation	Manual Language Diversity	
	Pilot-to-Full Adjustments	
	Solution Implementation Completeness	
	Material Reception	
	Valid Functionality	
	Data Availability and Usability	
	Data Accuracy	
	Deployment Reliability Balance	
	Implementation Effectiveness Satisfaction	
	Commitment Fulfillment	
	Maintenance Frequency	
	Coverage Area	
	Behavioral Change	Shower Duration Improvement
		Change in Shower Breaks
		Behavioral Change Satisfaction
	Water Consumption	Change in Water Consumption
		Water Consumption Satisfaction
	Energy Use	Change in Energy Use
		Energy Use Satisfaction
	Sensor Prodiver Match	
Management and Coordination	Timely Support Response	
	Check-Ins Frequency	
Financial Viability	Investment	Design and Data Resources
		Nudging kits
		Investment cost efficiency
	Cost Savings	Cost Savings
		Cost Savings Satisfaction
	Business Model Economic Risk	
Risk and Resilience	Partner Dependency	
	Data Hosting and Accessibility	
	Post-Project Solution Viability	

In Readiness and Feasibility, indicators such as Sectoral Readiness, Stakeholder Adoption Readiness, and Solution Development Readiness ensure preparedness. RA addresses regulatory gaps, financial constraints, and institutional limitations, while HT fosters adaptive capacity through training programs and engagement strategies. LCT ensures that the tourism sector can integrate and sustain the solution. For Stakeholder Engagement and Participation, through Meeting Engagement Satisfaction, Workshop Attendance, Event Attendance, and Feedback Submission Satisfaction, this category identifies participation effectiveness. RA highlights risks such as low engagement and communication barriers, while HT leverages workshops and feedback mechanisms to enhance adoption. LCT ensures that stakeholder-driven insights refine interventions for better outcomes. In Monitoring, Evaluation, and Adaptation, indicators like Pilot-to-Full Adjustments, Solution Implementation Completeness, and Data Accuracy measure NUDG's effectiveness. RA identifies risks like inconsistent data collection and incomplete implementation, while HT promotes continuous improvements and learning cycles. LCT ensures iterative adaptation to maximize efficiency and impact. Behavioral Change and Water and Energy Consumption are evaluated, where RA identifies barriers such as user resistance and inefficiencies, HT enhances awareness campaigns and conservation strategies, and LCT ensures sustained behavioral shifts and optimized resource efficiency while maintaining user satisfaction. In Management and Coordination, Timely Support Response and Check-Ins Frequency measure operational effectiveness. RA addresses risks such as delayed responses and technical failures, while HT fosters proactive engagement and streamlined support mechanisms. LCT ensures that coordination efforts align with risk mitigation and efficiency improvements. For Financial Viability, Indicators like Investment Cost Efficiency, Cost Savings assess economic feasibility. In Risk and Resilience, RA identifies risks related to reliance on external partners or data accessibility limitations, while HT encourages local capacity-building and sustainable ownership. LCT ensures that NUDG remains viable beyond the project's duration, reinforcing long-term resilience and scalability.

Adaptation Fund (AF)

The AF is a collaborative financing mechanism designed to support climate resilience projects addressing hurricanes, floods, high temperatures, droughts, and coastal erosion. Its governance in Guadeloupe combines two approaches: ADEME Guadeloupe coordinates a common budget line from some investors, while others fund projects independently. The AF supports projects in four categories: Governance, improving policies and coordination; Nature-Based Solutions, leveraging ecosystems for resilience; Technology, utilizing innovation for adaptation; and Behavior Change, promoting sustainable practices. This hybrid governance model ensures flexibility and efficiency, aligning stakeholders' interests while strengthening local adaptation strategies to climate change.

The performance evaluation of AF is structured into one tailored category - Governance and Policy - along with five common categories: Stakeholder Engagement and Participation, Monitoring, Evaluation, and Adaptation, Management and Coordination, Financial Viability, and Risk and Resilience. Table 7.2 outlines the performance categories and corresponding indicators for AF.

Table 7.2 Performance categories and indicators for Adaptation Fund (AF)

Performance categories	Indicator	Sub-indicator
Stakeholder Engagement and Participation	Event Attendance	Event Participation
		Event Attendance Satisfaction
	Public Organization Conversion	
	Private Organization Conversion	
	Private Sector Engagement	
Governance and Policy	Governance Structure Flexibility	
	Governance Structure Satisfaction	
Management and Coordination	Institutional Coordination	
	Commitment Fulfillment	
	Investor Training Sufficiency	
Monitoring, Evaluation, and Adaptation	Application Engagement	Application Engagement in Tourism
		Application Engagement in Agriculatural
	Project Approval	
	Project Initiation Duration	
	Applications Satisfaction on Call	
	Fund Application Support	
	Fund Distribution Method	
	Public-Private Project Alignment	
Financial Viability	Fund Setup Efficiency	
	Funding Adjustment	
Risk and Resilience	Fund Financing Viability	
	Partner Dependency	

For Stakeholder Engagement and Participation, AF's success is largely dependent on stakeholder's engagement from both public and private sectors. Event attendance satisfaction highlights whether engagements effectively promote climate adaptation strategies. The conversion rates of public and private organizations into active participants, along with private sector engagement, reflect AF's ability to mobilize investments for adaptation efforts. RA identifies risks such as low participation rates, while HT focuses on fostering long-term stakeholder collaboration through increased outreach. In Governance and Policy, the Governance Structure Flexibility and Satisfaction assess the adaptability of policies supporting AF implementation. RA highlights risks associated with rigid policies and inefficiencies, whereas HT ensures that governance frameworks evolve to encourage stakeholder collaboration and effective decision-making. In Management and Coordination, institutional efficiency is measured through Institutional Coordination, Commitment Fulfillment, and Investor Training Sufficiency. RA addresses potential coordination challenges, ensuring that commitments are met. HT enhances cooperation by promoting capacity-building efforts, ensuring effective project implementation and investment returns. For Monitoring, Evaluation, and Adaptation, AF's effectiveness is evaluated through Application Engagement in tourism and agriculture, Project Approval Rates, Application Satisfaction, and Fund Distribution Methods. RA highlights bottlenecks in fund allocation and project approval delays, while HT ensures transparent and equitable distribution, maximizing the benefits of adaptation projects. In Financial Viability, Fund Setup Efficiency and Funding Adjustments are key indicators of AF's financial sustainability. RA helps identify risks such as inefficient resource allocation, while HT ensures that funding mechanisms remain adaptable to changing economic conditions. For Risk and Resilience, the long-term sustainability of AF is measured by Fund Financing Viability and Partner Dependency. RA assesses potential risks related to unstable financial sources or excessive reliance on specific partners, while HT fosters diversified partnerships and resilient funding strategies to support sustained adaptation efforts.

After the indicators were selected, they were assigned to the relevant SDGs by matching each indicator's measured outcome to the appropriate sub-targets, following the methodology described in Section 2.2.3.

For example, indicators

- "Commitment Fulfillment" measures institutional accountability by evaluating the gap between commitments and actual contributions. It is connected to sub-goal 16.6, which aims to develop effective, accountable and transparent institutions.
- "Data Hosting and Accessibility" reflects the control and accessibility of sensor-generated data, comparing local management to external hosting. It is connected to sub-goal 16.10 by ensuring stakeholders have unrestricted access to data, which is essential for informed decision-making.
- "Event participation" measures stakeholder participation in events by comparing expected versus actual attendance. It is connected to sub-goal 16.7, as it reflects an inclusive decision-making process.

Together, these indicators are all linked to SDG 16 – Peace, Justice, and Strong Institutions. At the same time, "Commitment Fulfillment" also contributes to SDG 17 – Partnerships for the Goals, specifically sub-goal 17.17, which promotes and encourages effective partnerships at all levels. "Data Hosting and Accessibility" further aligns with SDG 17 – Partnerships for the Goals, under sub-goal 17.18, which focuses on enhancing data availability to support sustainable development. "Event Participation" also contributes to SDG 13 – Climate Action, through sub-goal 13.3, which aims to "improve education, awareness, and human and institutional capacity on climate change mitigation, adaptation, impact reduction, and early warning." High stakeholder engagement in climate adaptation events plays a crucial role in enhancing awareness, and ensuring inclusive participation in climate-related decisions.

7.3 Data process

The data process involves several stages, beginning with data gathering, followed by assigning scores to qualitative indicators, whereas scores for quantitative indicators are calculated and normalized. After that, the scores are assigned to the relevant SDGs through their corresponding sub-goals. Next, the indicator scores are combined to generate aggregate SDG scores using the weighted sum method, following the general approach outlined in Section 2.2.3, under the assumption that all indicators have equal weight. However, this weighting can be adjusted based on project goals, stakeholder input, or specific contextual needs. The goal is to ensure that the collected data is consistently evaluated, standardized, and presented in a way that aligns with sustainability goals.

The project employs a systematic data gathering process, integrating iterative participatory interviews with supporting sources, such as monitoring reports, field studies, and institutional documentation. This multi-source approach ensures a comprehensive and evidence-based assessment of adaptation solutions, enhancing both qualitative and quantitative evaluations. By synthesizing diverse data sources and refining indicator processing methods, this methodology strengthens the robustness of evaluations and advances effective climate resilience strategies, ensuring that adaptation solutions are well-validated, context-specific, and responsive to stakeholder needs.

Multiple sources are cross-checked, covering key deliverables such as:

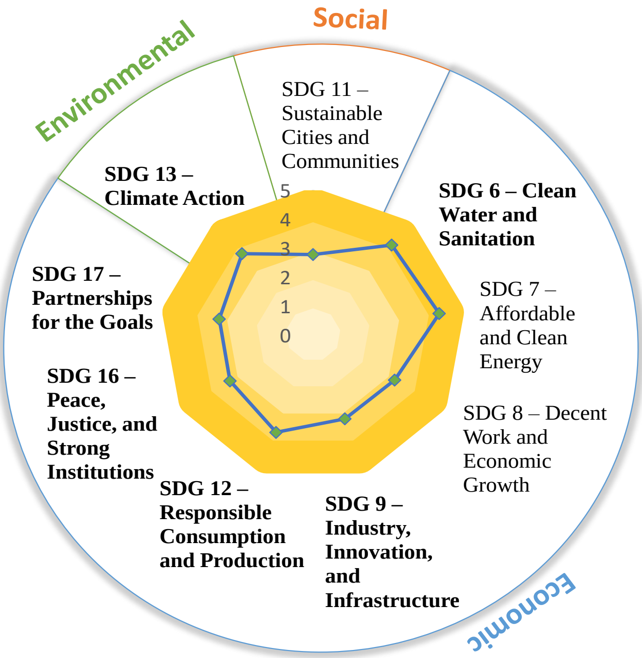
- Stakeholders Matrix and IE Baseline Profiles (D1.2)
- Six Region-Specific Portfolios of Solutions (D3.8)
- Compendium of Pathways and Action Plans (D3.9)
- Learning Stories on Awareness-raising and Behavioral Change Solutions (D4.1)
- Learning Stories on Insurance and Financial Solutions (D4.5)
- Final Report: Nudging Experiment in Guadeloupe (WP4)

Institutional documentation plays an important role in supporting data collection and validating adaptation solutions, such as cost records related to investment, maintenance, and operation, as well as stakeholder engagement tracking records to monitor participation and impact. Additionally, it encompasses action plans that contribute to estimation. Field data and experimental results, combined with modeling analysis, offer critical insights by assessing environmental changes and ecosystem resilience while evaluating long-term sustainability and adaptive capacity. By integrating these elements, the project ensures a data-driven, evidence-based approach that strengthens the effectiveness and scalability of adaptation strategies.

7.4 Assessment

The sustainability profiles of each solution and region-specific portfolio (RSP) are presented here. They align with SDG goals, as well as the sustainability domains of social, economic, and environmental aspects. The assessment begins with an evaluation of each solution, followed by the RSP, addressing three key aspects: results and their interpretation, uncertainties, and actions for improvement and next steps.

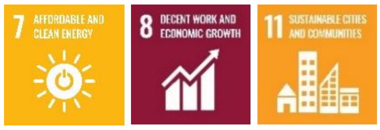
7.4.1 Sustainability profile of Nudging (NUDG)



NUDG (Nudging)

Primary targeted SDGs*:

Co-benefit SDGs:



* Targeted SDGs are black bordered.

The interpretation of the profile should focus on **Primary targeted SDGs** with multiple indicator contributions, while co-benefit SDGs typically have limited contributions from specific indicators.

Social domain

Relevant performance categories (indicators):

Stakeholder Engagement and Participation (Workshop Attendance), Monitoring, Evaluation, and Adaptation (Coverage Area), Management and Coordination (Timely Support Response)

Interpretation:

++ Enhancing stakeholder engagement in capacity-building strengthens urban resilience, promotes environmental awareness and inclusive planning.

++ Moderate coverage of the participated accommodations across the island promotes inclusive and sustainable community and can be enhanced to ensure equitable access to resilient services.

\+ The efficiency and effectiveness of support services in responding to and resolving incidents face challenges due to distance, time differences, and language barriers, which can be improved to enhance emergency response and promote sustainable community management.

Overall, stakeholder engagement strengthens community resilience and inclusive planning, while expanding accommodation coverage ensures equitable access to resilient communities. Improving support services is essential to overcoming barriers, enhancing emergency response, and promoting sustainable community management.

Economic domain

Relevant performance categories (indicators):

Readiness and Feasibility – SDG 9, 12, 16, 17, Stakeholder Engagement and Participation – SDG 16, Monitoring, Evaluation, and Adaptation (Data Accuracy, Behavioural Change, Water Consumption) – SDG 6 & 12, (Pilot-to-Full Adjustments, Commitment Fulfilment) – SDG 17, (Valid Functionality, Data Availability and Usability) – SDG 9 & 16, (Material Reception, Implementation Effectiveness Satisfaction) – SDG 16, (Deployment Reliability Balance) – SDG 8, (Energy Use) – SDG 7 & 16, Sensor Provider Match) – SDG 12 & 16, Management and Coordination – SDG 16 & 17, Financial Viability – SDG 8, Risk and Resilience – SDG 9, 16 & 17

Interpretation:

++ The tourism sector was chosen to pilot the solution due to its geographical concentration and high value density, with the solution developed from scratch to drive innovation in tourism operations.

++ Tracking water consumption and reducing shower time, promoting sustainable resource use, while nudging materials proves to encourage behavioural changes in water use, foster responsible consumption and minimize environmental impact.

\+ The selection of easy-to-install sensors enhances accessible technology in sustainable water management, but data transmission, connectivity issues, and stakeholder engagement require stronger partnerships and commitment, with challenges such as staffing shortages and privacy concerns.

\+ The primary interest was to determine whether guests could be effectively nudged to reduce water consumption rather than focus on cost savings, and while limited feedback was received, it was not strongly expected either.

\+ The solution's implementation relies on external partners, and the absence of discussions with hotel managers on post-project viability underscores the need for stronger stakeholder engagement and long-term commitment to ensure sustainable adoption and continuity.

Overall, the solution promotes resource efficiency (SDG 12) and fosters innovation in tourism operations (SDGs 8, 9) by piloting a solution in a high-value sector. Tracking water consumption and reducing shower use (SDGs 6, 7) encourage responsible resource management, while nudging materials foster behavioral changes (SDG 12). Easy-to-install sensors improve accessibility (SDG 9), but data transmission and stakeholder engagement require stronger partnerships (SDG 17). Commitment fulfillment challenges (SDG 16) emphasize the need for inclusive governance and long-term stakeholder involvement for sustainability.

Environmental domain

Relevant performance categories (indicators):

Readiness and Feasibility (Sectoral Readiness, Stakeholder Adoption Readiness), Monitoring, Evaluation, and Adaptation (Water Consumption)

Interpretation:

++ Reducing water consumption through behavioral changes enhances awareness and capacity-building for climate adaptation, fostering sustainable resource management and strengthening resilience against climate-related challenges.

\+ The partners prioritized sustainability over financial gains, focusing on raising awareness of water issues and promoting a sustainable image by fostering climate-conscious behavior and responsible resource management.

\+ The sector's mixed readiness and stakeholder adoption (e.g., challenges in staffing shortages and privacy concerns) can be improved through enhanced engagement, capacity-building, and governance reforms, ensuring more effective implementation of sustainable solution.

Overall, reducing water consumption through behavioral changes fosters climate awareness, adaptation, and sustainable resource use. Prioritizing sustainability over financial gains promotes climate-conscious behavior and responsible management. Strengthening stakeholder engagement and capacity-building ensures effective implementation of sustainable solutions.

Uncertainties

Several main issues should be considered when interpreting the results:

- While cooperation was strong once stakeholders joined meetings, initial participation was difficult, indicating barriers in engagement strategies.
- The completeness of solution implementation lacked full certainty, as installation verification - including the informational brochure, stickers, and sensors (guest feedback) - relied on limited visual checks and sensor data.
- Stakeholder cooperation varied, with larger accommodations receiving multiple nudging kits, but with poor communication and low engagement, which reduced implementation effectiveness, while smaller accommodations synchronized data more effectively but received fewer kits, limiting the overall impact.
- Water savings were estimated, variations in shower types and lack of baseline targets reduced measurement accuracy. Energy savings were calculated based on water consumption estimates, introducing further variability in outcomes.

- Limited cooperation and inconsistent participation created uncertainty in evaluating the intervention's effectiveness, making it challenging to assess its long-term impact.

Overall, there are uncertainties in stakeholder engagement, implementation verification, and data estimation. Initial participation was low, and installation completeness lacked full certainty due to limited verification methods. Stakeholder cooperation varied, with larger accommodations less engaged, affecting implementation success. Water and energy savings estimations lacked accuracy due to shower type variations and missing baseline targets, making it difficult to assess the nudging strategy's effectiveness.

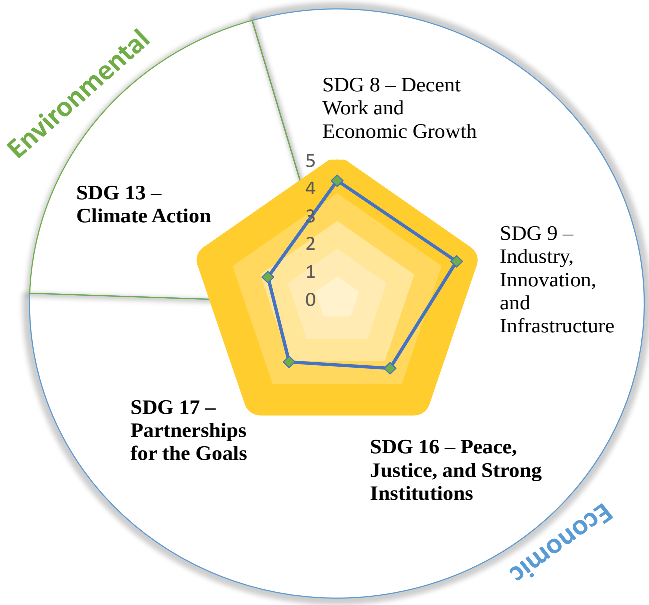
Improvement and next steps

Actions for the improvement and next steps:

- Implement continuous monitoring to track long-term behavioural changes, document best practices, share insights, and promote the adoption of sustainable initiatives across the tourism sector and beyond.
- Develop advanced nudging strategies using personalized feedback systems, interactive technologies, and data-driven insights to improve engagement and effectiveness.
- Leveraging local teams to conduct workshops and training sessions for hotel staff will enhance capacity, improve engagement, and ensure timely management and coordination, while partnering with policymakers to integrate nudging strategies into sustainable tourism policies.
- Expand outreach to hotels not yet focused on sustainability, highlighting water conservation benefits and providing practical solutions to drive greater behavioural impact.

Overall, actions for improvement and next steps include implementing continuous monitoring to track long-term behavioural changes and expanding nudging techniques across the tourism sector and beyond. Enhancing personalized, data-driven nudging strategies will improve engagement, while strengthening training, policy integration, and outreach to non-sustainable hotels will foster broader participation.

7.4.2 Sustainability profile of Adaptation Fund (AF)



AF (Adaptation Fund)

Primary targeted SDGs*:

Co-benefit SDGs:

* Targeted SDGs are black bordered.

The interpretation of the profile should focus on **Primary targeted SDGs** with multiple indicator contributions, while co-benefit SDGs typically have limited contributions from specific indicators.

Economic domain

Relevant performance categories (indicators):

Stakeholder Engagement and Participation – SDG 16 & 17, Governance and Policy – SDG 16, Management and Coordination (Institutional Coordination, Commitment Fulfillment) – SDG 16 & 17, Investor Training Sufficiency – SDG 8, Monitoring, Evaluation, and Adaptation – SDG 16, (Project Approval, Fund Distribution Method) – SDG 17, (Public-Private Project Alignment) – SDG 8, 16 & 17, Financial Viability – SDG 8, 9, 16, Risk and Resilience – SDG 9 & 16

Interpretation:

+++ Fund applicants report high satisfaction with the fund application process, citing clarity, fairness, efficiency, and timely communication. Investor training effectively engages participants, ensuring confidence in projects. The fund setup was cost-efficient, minimizing overhead while maximizing resources for sustainable investments.

++ Events attract strong attendance and engagement, but passive participation persists, while public institutions fulfil commitments, reinforcing trust; however, engaging private sector funders remains challenging due to financial, regulatory, and structural barriers.

++ The governance structure is flexible, adapting to investors' needs, with a hybrid approach integrating different options (based on feasibility study).

++ The fund distribution method effectively reaches most applicants, but gaps in accessibility remain, while securing additional funding beyond the initial

budget poses risks, requiring efforts to convince investors to meet new financial requirements.
+ The fund engages both tourism and agriculture, with stronger participation from agriculture, but slow project initiation highlights inefficiencies in transitioning from validation to resource allocation, while weak institutional coordination leads to fragmented actions, hindering effective adaptation to evolving needs.

Overall, the fund application process ensures transparency and efficiency (SDG 16), fostering trust, while investor training fosters responsible investment in resilient projects (SDG 8). Public-private partnerships face funding barriers (SDG 17). Governance flexibility aids adaptation, but weak coordination hinders responsiveness. Agriculture engagement is strong, yet slow project initiation impacts sustainable innovation and resource allocation (SDG 9).

Environmental domain

Relevant performance categories (indicators):

Stakeholder Engagement and Participation, Monitoring, Evaluation, and Adaptation (Application Engagement, Project Approval, Public-Private Project Alignment)

Interpretation:

+ Participation in climate adaptation events fosters knowledge sharing and awareness, but passive involvement and private sector hesitation hinder financial and strategic support for effective climate adaptation initiatives.
+ Public institutions demonstrate commitment to climate adaptation, reinforcing trust, but private sector participation remains limited, while stronger collaboration is needed to maximize climate adaptation.

Overall, participation in climate adaptation events enhances knowledge sharing, but passive involvement and private sector hesitation limit support. Public institutions show commitment, yet stronger public-private collaboration is needed to maximize climate adaptation efforts and ensure inclusive, long-term resilience.

Uncertainties

Several main issues should be considered when interpreting the results:

- Some targets, such as event attendance, are based on estimations.
- A prolonged project initiation period due to investor commitment processes, coupled with exceeding the initial budget cap, necessitates strategic negotiation and persuasion for effective implementation.

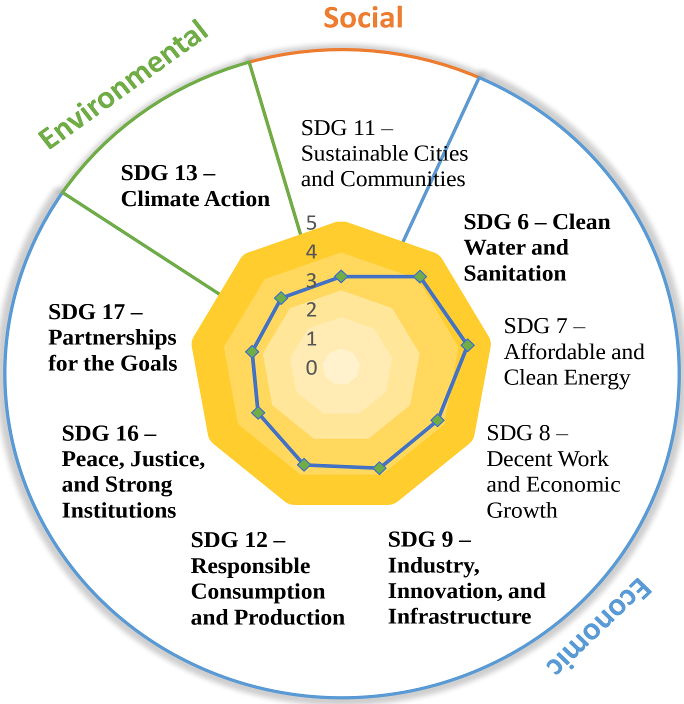
Improvement and next steps

Actions for the improvement and next steps:

- Accelerating funding deployment to increase access to local climate adaptation funds, streamlining application and approval processes to minimize delays, and developing flexible financing mechanisms to support diverse project needs.
- Strengthening stakeholder engagement to involve local stakeholders from the early design phase to implementation, defining clear governance structures and eligibility criteria through participatory processes, and fostering long-term commitment by demonstrating project impact.
- Optimizing co-financing strategies enhances project bankability by aligning financial models with private sector interests, simplifying procedures, sharing risks, and fostering public-private collaboration.

To improve effectiveness, actions should focus on accelerating funding deployment by streamlining processes and developing flexible financing mechanisms. Strengthening stakeholder engagement through participatory governance ensures long-term commitment, while optimizing co-financing strategies enhances project bankability, aligns financial models with private sector interests, and fosters collaboration.

7.4.3 Sustainability profile of Region-specific portfolio (RSP)



Region-specific portfolio (RSP)
Include two solutions: NUDG (Nudging) and AF (Adaptation Fund)

Primary targeted SDGs*:

Co-benefit SDGs:

* Targeted SDGs are black bordered.

The interpretation of the profile should focus on **Primary targeted SDGs** with multiple indicator contributions, while co-benefit SDGs typically have limited contributions from specific indicators.

Social domain

Relevant performance categories (indicators):

NUDG: Stakeholder Engagement and Participation (Workshop Attendance), Monitoring, Evaluation, and Adaptation (Coverage Area), Management and Coordination (Timely Support Response)

Interpretation:

+++ NUDG utilizes behavioural change interventions to enhance stakeholder engagement in environmental awareness, capacity-building, and resilience-building efforts, thereby fostering inclusive planning.

++ Moderate coverage of participating accommodations across the island in NUDG enhances accessibility and resilience, but further efforts are needed to ensure more equitable access to resilient services.

+ The efficiency and effectiveness of support services in responding to and resolving incidents within NUDG should be strengthened to optimize emergency response mechanisms and promote more sustainable community management.

Overall, NUDG leverages behavioural change interventions to enhance stakeholder engagement in environmental awareness, capacity-building, and resilience efforts. It strengthens accessibility to resilient service and optimizes emergency response mechanisms for sustainable and inclusive community management.

Economic domain

Relevant performance categories (indicators):

NUDG: Readiness and Feasibility – SDG 9, 12, 16, 17, Stakeholder Engagement and Participation – SDG 16, Monitoring, Evaluation, and Adaptation (Data Accuracy, Behavioural Change, Water Consumption) – SDG 6 & 12, (Pilot-to-Full Adjustments, Commitment Fulfilment) – SDG 17, (Valid Functionality, Data Availability and Usability) – SDG 9 & 16, (Material Reception, Implementation Effectiveness Satisfaction) – SDG 16, (Deployment Reliability Balance) – SDG 8, (Energy Use) – SDG 7 & 16, Sensor Provider Match) – SDG 12 & 16, Management and Coordination – SDG 16 & 17, Financial Viability – SDG 8, Risk and Resilience – SDG 9, 16 & 17

AF: Stakeholder Engagement and Participation – SDG 16 & 17, Governance and Policy – SDG 16, Management and Coordination (Institutional Coordination, Commitment Fulfillment) – SDG 16 & 17, Investor Training Sufficiency – SDG 8, Monitoring, Evaluation, and Adaptation – SDG 16, (Project Approval, Fund Distribution Method) – SDG 17, (Public-Private Project Alignment) – SDG 8, 16 & 17, Financial Viability – SDG 8, 9, 16, Risk and Resilience – SDG 9 & 16

Interpretation:

- +++ NUDG encourages sustainable water use and energy efficiency through behavioral nudging, while AF supports sustainable investments, enhancing water infrastructure in agriculture and tourism, and funding climate action projects.
- ++ NUDG drives innovation in sustainable tourism with easy-to-install sensors. AF boosts investment in tourism and agriculture, financing sustainable projects and fostering job creation and economic resilience.
- + Both solutions struggle with stakeholder engagement and commitment. NUDG faces challenges in sensor installation and synchronization, requiring stronger hotel manager involvement. AF sees effective public sector engagement, but private sector participation remains low due to financial and regulatory barriers.
- + Both NUDG and AF face technology and infrastructure challenges, with NUDG with sensor data transmission for impact assessment, while AF's fund distribution is effective but weak institutional coordination, delaying project implementation.

Over, NUDG promotes sustainable water use (SDG 6), energy efficiency (SDG 7, 12) through behavioural nudging, while AF funds sustainable projects (SDG 9, 17) in tourism and agriculture. Both solutions support economic growth (SDG 8) and innovation (SDG9) but face stakeholder engagement (SDG 16) challenges. NUDG requires stronger partnerships (SDG 17) for sensor adoption, while AF struggles with private investment (SDG 9, 16) and coordination.

Environmental domain

Relevant performance categories (indicators):

NUDG: Readiness and Feasibility (Sectoral Readiness, Stakeholder Adoption Readiness), Monitoring, Evaluation, and Adaptation (Water Consumption)

AF: Stakeholder Engagement and Participation, Monitoring, Evaluation, and Adaptation (Application Engagement, Project Approval, Public-Private Project Alignment)

Interpretation:

++ NUDG fosters water conservation through behavioural changes, while AF encourages investment on sustainable development, reinforcing responsible resource use and sustainability practices.

\+ Both NUDG and AF face challenges in stakeholder participation. Strengthening engagement through targeted capacity-building and governance improvements can drive more effective climate resilience-building efforts.

\+ Increasing collaboration and financial commitment from private entities (AF) would enhance the scalability and impact of climate resilience initiatives.

Uncertainties

Several main issues should be considered when interpreting the results:

- Stakeholder engagement challenges: NUDG struggles with inconsistent cooperation from accommodations, while AF experienced long project initiation period due to investor commitment barriers, highlighting shared difficulties in performance evaluation.
- Implementation and data verification challenges: NUDG experienced incomplete kit synchronization and AF relied on estimated attendance figures, leading to uncertainties in measuring success and assessing actual impact.
- Financial and resource constraints, NUDG had challenges in inefficiencies in kit distribution and accommodation engagement leading to incomplete or inconsistent data collection, while AF encountered budget cap challenges requiring strategic negotiation for successful project execution limiting comprehensive data tracking and verification.
- Measurement and evaluation uncertainties, NUDG was lack of baseline targets for water and energy savings, reducing accuracy, while AF relied on

estimated attendance and participation figures, introducing variability and limiting precise impact assessment.

Overall, both NUDG and AF faced stakeholder engagement difficulties, implementation challenges, financial constraints, and evaluation uncertainties. NUDG struggled with inconsistent cooperation, incomplete data synchronization, and resource inefficiencies, while AF experienced investor commitment delays, budget cap challenges, and reliance on estimations, limiting precise impact assessment.

Improvement and next steps

Actions for the improvement and next steps:

- Enhance Cross-Sector Collaboration – Establish partnerships between NUDG and AF initiatives to align funding mechanisms with behavioral change interventions, extending nudging techniques to other areas like energy efficiency and waste reduction, ensuring financial support for sustainability-focused projects.
- Develop Integrated Monitoring & Impact Assessment Systems – Create standardized data collection frameworks that track the effectiveness of nudging strategies and climate adaptation projects, optimizing decision-making and scalability.
- Expand Stakeholder Training & Policy Integration – Strengthen engagement by providing targeted training for hotel managers, policymakers, and local actors, ensuring behavioral interventions are embedded in long-term sustainability policies.
- Optimize Funding & Accessibility – Improve financial accessibility by streamlining application processes for climate adaptation funds while integrating nudging techniques, such as incentives and behavioral prompts, to encourage wider adoption of sustainable practices.

Overall, enhancing cross-sector collaboration, integrating monitoring systems, expanding stakeholder training, and optimizing funding accessibility will strengthen the impact of NUDG and AF initiatives. Aligning behavioral change with financial support and policy integration ensures scalable, data-driven, and inclusive sustainability and climate adaptation efforts.

8.0 EGALEO (GREECE)

8.1 Scoping

The municipality of Egaleo (MOE), Greece (37.9924° N, 23.6781° E), is located in the western part of the urban planning complex of the Attica region, approximately 4 km from Athens. Positioned along both sides of the historic Iera Odos (Sacred Way), Egaleo belongs to the wider Mediterranean biogeographical region, with a population of around 120,000. The borders of Egaleo can be seen in Figure 8.1 below.

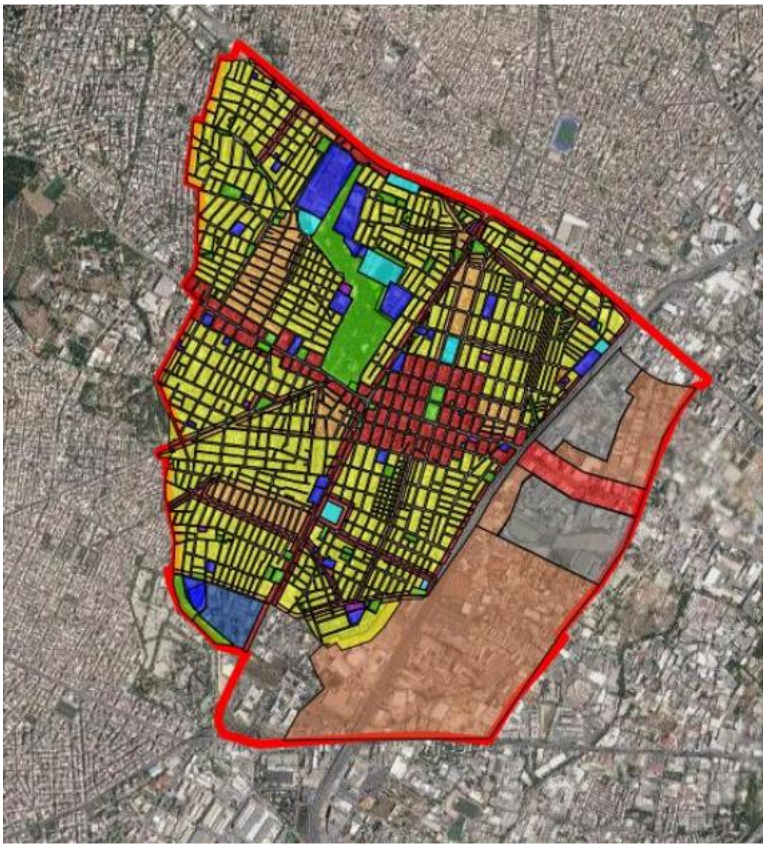


Figure 8.1 Egaleo borders

Egaleo faces multiple environmental and socio-economic challenges, exacerbated by climate change. The city is highly vulnerable to heatwaves, extreme precipitations, thunderstorms, and flooding events, with rising temperatures expected to intensify these risks. Wildfires in Baroutadiko Grove, driven by extreme summer heat and dry vegetation, remain a critical threat. Urban flash floods, worsened by insufficient flood risk management and the proximity to the Kifissos River, have historically caused severe damage. Socioeconomic vulnerabilities, including high unemployment, slow population growth, and at-risk groups, further increase the city's susceptibility. Additionally, inefficient urban planning, heavy traffic, and industrial pollution contribute to environmental degradation and climate-related risks.

Three key community systems (KCS) where the Egaleo will be implementing solutions to adapt the impacts of climate change include health, infrastructures, and urban planning. Solutions include smart climate stations (SCS) at key municipal buildings to acquire a view of the microclimatic conditions. A citizen's app (CAE) will allow inhabitants to participate in the debate around Climate Change (CC), the changes of the microclimate and potential solutions. Awareness-raising modules (AWAR) will be designed, especially for young people and school pupils to promote climate awareness. In addition, a climate innovation hub (CIH) will be installed to promote green and climate friendly entrepreneurship. A demand analysis for social services and infrastructures (DSI) will be conducted. Figure 8.2 illustrates the coupling of the solutions and the flow of information from data sources to communication channels.

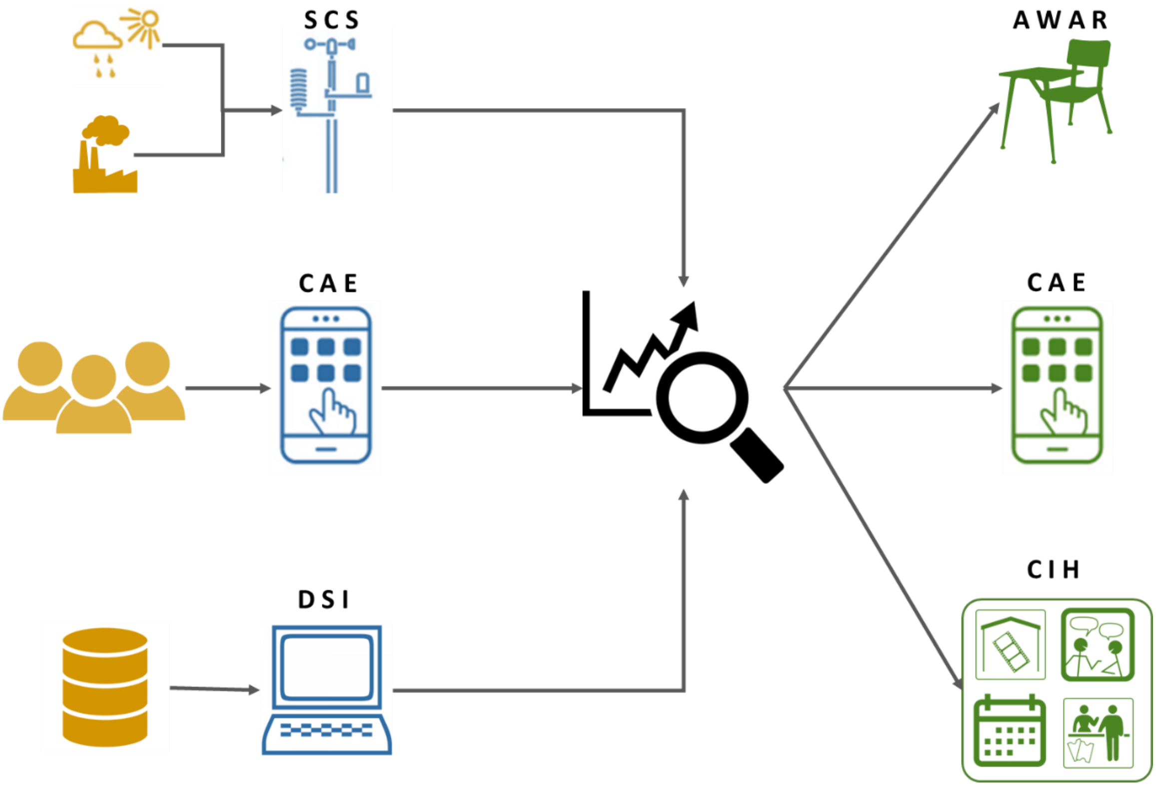


Figure 8.2 Illustration of Egaleo solutions working complementary to each other

8.2 Implementation

The AWAR, CAE, CIH, SCS, and DSI solutions are evaluated through a structured approach that integrates Risk Assessment (RA), Handprint Thinking (HT), and Life Cycle Thinking (LCT). RA identifies potential risks, HT measures positive sustainability impacts, and LCT ensures long-term viability. These methods complement each other to provide a comprehensive assessment across multiple indicators. By combining risk analysis, sustainability benefits, and life cycle considerations, this approach supports informed decision-making and promotes resilience. The structured evaluation ensures consistency in assessing each solution's performance, sustainability, and long-term impact across different contexts.

Awareness-raising (AWAR)

The performance evaluation of AWAR is structured into four common categories: Stakeholder Engagement and Participation, Monitoring, Evaluation, and Adaptation, Management and Coordination and Risk and Resilience. Table 8.1 outlines the performance categories and corresponding indicators for AWAR.

RA, HT, and LCT are systematically applied within Stakeholder Engagement and Participation to evaluate stakeholder commitment, participation quality, and long-term engagement strategies. RA identifies risks related to low participation rates, lack of engagement, and ineffective communication strategies. HT promotes proactive engagement approaches that enhance stakeholder involvement, while LCT ensures that participation strategies are scalable and adaptable over time. In Monitoring, Evaluation, and

Adaptation, RA identifies risks related to commitment fulfillment and material design complexity, HT supports effective youth engagement methods, and LCT ensures that awareness initiatives remain sustainable and impactful. For Management and Coordination, RA identifies risks related to poor coordination among stakeholders and insufficient teacher engagement, HT fosters cooperative engagement strategies, and LCT ensures long-term sustainability in program implementation. Within this category, Stakeholder Coordination, Teacher Engagement, and Investment Cost Efficiency assess coordination effectiveness, teacher involvement, and financial resource optimization. RA, HT, and LCT are systematically applied within Risk and Resilience to evaluate external dependencies, data accessibility, and behavioral impact. RA identifies risks associated with reliance on external partners and data availability challenges, HT enhances strategies for sustained engagement, and LCT ensures that climate awareness efforts lead to tangible behavioral change.

Table 8.1 Performance categories and indicators for Awareness-raising and behavioral change modules (AWAR)

Performance categories	**Indicator**	**Sub-indicator**
Stakeholder Engagement and Participation	Meeting	Meeting Attendance
		Meeting Engagement Satisfaction
	Workshop	Workshop Attendance
		Workshop Participation Satisfaction
	Event	Event Attendance
		Event Attendance Satisfaction
	Training	Training Participation
		Training Participation Satisfaction
Monitoring, Evaluation, and Adaptation	Educational Material Design	
	Awareness-raising Modules	
	Innovation in Youth Engagement	
	Implementation Effectiveness Satisfaction	
Management and Coordination	Stakeholder Coordination	
	Teacher Engagement	
Financial Viability	Investment	
	Investment cost efficiency	
Risk and Resilience	Partner Dependency	
	Sustained Engagement	
	Data Accessibility	
	Awareness-Behavior Gap	

Smart Climate Stations (SCS)

The performance evaluation of SCS is structured into two tailored categories – System Performance and Data Quality, along with four common categories: Monitoring, Evaluation, and Adaptation, Management and Coordination, Financial Viability, and Risk and Resilience. Table 8.2 outlines the performance categories and corresponding indicators for SCS.

In System Performance, RA identifies risks related to system uptime, integration challenges, and installation conditions. HT promotes technological advancements and user-friendly customization options, while LCT ensures long-term operational efficiency and adaptability. For Monitoring, Evaluation, and Adaptation, RA identifies challenges in site selection, data gaps, and emissions variability, HT enhances methodologies for risk assessment and environmental monitoring, and LCT ensures long-term data accessibility and usability. In Data Quality, RA identifies risks related to data inconsistencies and vulnerabilities due to environmental conditions, HT emphasizes methodologies that improve monitoring reliability, and LCT ensures long-term usability and redundancy. For Management and Coordination, RA identifies risks related to bureaucratic inefficiencies and stakeholder misalignment, HT fosters cooperative engagement, and LCT ensures that coordination efforts remain sustainable and adaptable. In Financial Viability, RA identifies financial risks related to investment feasibility and operational expenses, HT emphasizes responsible financial planning, and LCT ensures optimal long-term economic performance. For Risk and Resilience, RA identifies risks associated with reliance on external providers and funding availability, HT fosters local capacity-building and resilience planning, and LCT ensures resource sustainability and long-term infrastructure maintenance.

Table 8.2 Performance categories and indicators for Smart climate stations (SCS)

Performance categories	Indicator	Sub-indicator
System Performance	System Uptime	System Uptime
		System Uptime Satisfaction
	System Scalability	
	Integration Capability	
	Installation Requirements	
	User Customization Options	
	Response Efficiency	Response Efficiency
		Response Efficiency Satisfaction
	Sensor Lifespan	Sensor Lifespan
		Sensor Lifespan Satisfaction
	Tech-enabled Monitoring	Use of AI and machine learning (ML)
		Use of Energy
	Sensor Provider Match	
	Computing Power	
	Cloud Data Capacity and Storage	
	Sensor Maintenance Frequency	
	Software Update Frequency	
Monitoring, Evaluation, and Adaptation	Site Selection	
	Coverage Area	
Data Quality	Continuous monitoring	
	Data Accuracy	Data Accuracy
		Data Accuracy Satisfaction
	Weather Vulnerability	
	Sensor Coverage Redundancy	
Management and Coordination	Cross-departmental Coordination	
	Stakeholder Coordination	
Financial Viability	Investment	Investment cost
		Investment cost efficiency
	Maintenance	Maintenance cost
		Maintenance cost efficiency
	Operational	Operational cost
		Operational cost efficiency
	Business Model Economic Risk	Business Model Economic Risk
Risk and Resilience	Partner Dependency	
	Resource Allocation	

Citizen App (CAE)

The performance evaluation of CAE is structured into four common categories: Stakeholder Engagement and Participation, Management and Coordination, Financial Viability, and Risk and Resilience. Table 8.3 outlines the performance categories and corresponding indicators for CAE.

Table 8.3 Performance categories and indicators for Citizen app (CAE)

Performance categories	Indicator	Sub-indicator
Stakeholder Engagement and Participation	Survey	Survey Participation
		Survey Effectiveness Satisfaction
	Meeting	Meeting Attendance
		Meeting Engagement Satisfaction
	Usability Satisfaction	
	App Utilization	App Utilization Rate
		App Utilization Satisfaction
	Coverage Area	
	Integration Capability	
Management and Coordination	Timely Support Response	
	Collaborative Engagement	
	Engagement strategy	
Financial Viability	Investment	Investment cost
		Investment cost efficiency
	Maintenance	Maintenance cost
		Maintenance cost efficiency
	Operational	Operational cost
		Operational cost efficiency
Risk and Resilience	Partner Dependency	
	Local Control and Ownership	
	Data Hosting and Accessibility	

In Stakeholder Engagement and Participation, RA identifies risks related to low participation rates, lack of engagement, and feedback inefficiencies. HT promotes inclusive engagement strategies that encourage active stakeholder involvement, while LCT ensures that participation mechanisms remain scalable and adaptable. For Monitoring, Evaluation, and Adaptation, RA identifies risks related to data reliability, accessibility challenges, and implementation gaps. HT ensures that engagement strategies enhance user awareness and interaction with climate-related risks, while LCT supports long-term usability and inclusivity of the solution. In Management and Coordination, RA identifies risks related to inefficient coordination, lack of responsiveness, and ineffective engagement strategies. HT promotes cooperative engagement models and capacity-building efforts, while LCT ensures that stakeholder interactions remain sustainable and adaptive. For Financial Viability, RA identifies risks related to investment feasibility, maintenance costs, and operational efficiency. HT emphasizes responsible resource utilization and cost-effective solutions, while LCT ensures long-term financial viability and optimal resource allocation. In Risk and Resilience, RA identifies risks related to partner reliance, data security, and accessibility challenges. HT fosters local ownership and control of critical solutions, while LCT ensures that data infrastructure remains scalable and resilient over time.

Climate Innovation Hub (CIH)

The performance evaluation of CIH is structured into four common categories: Stakeholder Engagement and Participation, Monitoring, Evaluation, and Adaptation, Management and Coordination and Risk and Resilience. Table 8.4 outlines the performance categories and corresponding indicators for CIH.

Table 8.4 Performance categories and indicators for Climate innovation hub (CIH)

Performance categories	Indicator	Sub-indicator
Stakeholder Engagement and Participation	Workshop	Workshop Attendance
		Workshop Participation Satisfaction
	Event	Event Attendance
		Event Attendance Satisfaction
	Training	Training Participation
		Training Participation Satisfaction
	Feedback	Feedback Submission
		Feedback Submission Satisfaction
Monitoring, Evaluation, and Adaptation	Behavioral Change Satisfaction	
Management and Coordination	Stakeholder Collaboration	
Risk and Resilience	Political and Administrative Support	
	Resource and Skill Adequacy	
	Local Needs and Values	

In <u>Stakeholder Engagement and Participation</u>, RA identifies risks related to low participation rates, lack of engagement, and feedback inefficiencies. HT promotes inclusive engagement strategies that encourage active stakeholder involvement, while LCT ensures that participation mechanisms remain scalable and adaptable. For <u>Monitoring, Evaluation, and Adaptation</u>, Behavioral Change Satisfaction assesses stakeholder satisfaction with shifts in environmental awareness, sustainable practices, and climate-resilient behaviors influenced by the CIH initiatives. For <u>Management and Coordination</u>, RA identifies risks related to misalignment among public, private, and civil society organizations, HT fosters cooperative collaboration, and LCT ensures that stakeholder coordination efforts remain sustainable. In <u>Risk and Resilience</u>, RA identifies risks associated with political stability and administrative support, HT promotes strategic alignment with local needs, and LCT ensures that resources and skill availability are sufficient for sustainable operation.

<u>Demand analysis for social services/infrastructures (DSI)</u>

The performance evaluation of DSI is structured into three common categories: <u>Monitoring, Evaluation, and Adaptation</u>, <u>Financial Viability</u>, and <u>Risk and Resilience</u>. Table 8.5 outlines the performance categories and corresponding indicators for DSI.

Table 8.5 Performance categories and indicators for Demand analysis for social services/infrastructures (DSI)

Performance categories	Indicator
Monitoring, Evaluation, and Adaptation	Mortality rate
	Health impacts of air pollution
	Integration Efficiency
	Data Reliability
	Potential in Decision-Making
Financial Viability	Analysis Resources
	Investment Cost Efficiency
Risk and Resilience	Partner Dependency
	Unpredictable Climate Impacts
	Engagement and Cooperation
	Organizational Perception

In <u>Monitoring, Evaluation, and Adaptation</u>, RA identifies vulnerabilities related to exposure to extreme weather, mortality rates, and public health indicators, HT emphasizes strategies for improving environmental health and resilience, and LCT ensures that monitoring frameworks support long-term well-being. For Financial Viability, RA identifies risks related to inadequate funding and resource constraints, HT promotes responsible allocation strategies, and LCT ensures that financial investments are sustainable and optimized for long-term impact. In Risk and Resilience, RA identifies risks related to reliance on external partners and unpredictable climate impacts, HT fosters proactive engagement with citizens and stakeholders, and LCT ensures that resilience-building strategies are adaptable and sustainable.

After the indicators were selected, they were assigned to the relevant SDGs by matching each indicator's measured outcome to the appropriate sub-targets, following the methodology described in Section 2.2.3.

For example, indicators

- Coverage Area measures how comprehensively the SCS network monitors climate variables across the target region. It contributes to SDG 9.1 It contributes to sub-goal 9.1, which aims to "develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all.". By providing broad, representative data coverage, it supports the development of resilient, data-informed infrastructure and ensures equitable service provision.
- Investment Cost Efficiency measures how effectively resources are allocated to minimize waste and maximize impact, aligning with SDG 9.4 ("Upgrade infrastructure and retrofit industries to make them sustainable and resource-efficient…"). Optimizing expenditures on eco-friendly sensor technologies supports responsible infrastructure development and long-term resilience.
- Integration Efficiency examines how well the DSI is integrated with SCS and CAE, contributing to SDG 9.1 through a resilient data framework that ensures timely, accurate information flow for effective climate-related services.

Together, these indicators contribute to SDG 9 by supporting the development of sustainable, resilient, and data-informed infrastructure through broad climate monitoring coverage, efficient resource use, and seamless integration of digital systems. At the same time, "Coverage Area" also contributes to SDG 13 (sub-goal 13.3) by enabling real-time climate data for accurate early warnings and targeted adaptation. Meanwhile, "Investment Cost Efficiency" supports SDG 8 (sub-goal 8.4) by promoting financial efficiency that directs more resources into high-impact improvements. Finally, "Integration Efficiency" strengthens SDG 16 (sub-goal 16.6) by ensuring a coherent, reliable data flow for transparent and accountable governance.

8.3 Data process

The data process involves several stages starting with data gathering, followed by assigning scores for qualitative indicators, while scores for quantitative indicators are calculated and normalized. After that, the scores are assigned to relevant SDG sub-goals, and the corresponding SDGs are then used for assessment. Next, the indicator scores are combined to generate aggregate scores for SDGs. The goal is to ensure that the collected data is consistently evaluated, standardized, and presented in a way that aligns with sustainability goals.

The project employs a systematic data gathering process, integrating iterative participatory interviews with supporting sources, such as monitoring reports, field studies, and institutional documentation. This multi-source approach ensures a comprehensive and evidence-based assessment of adaptation solutions, enhancing both qualitative and quantitative evaluations. By synthesizing diverse data sources and refining indicator processing methods, this methodology strengthens the robustness of evaluations and advances effective climate resilience strategies, ensuring that adaptation solutions are well-validated, context-specific, and responsive to stakeholder needs.

Multiple sources are cross-checked, covering key deliverables such as:

- Stakeholders Matrix and IE Baseline Profiles (D1.2)
- Six Region-Specific Portfolios of Solutions (D3.8)
- Compendium of Pathways and Action Plans (D3.9)
- Intermediary Monitoring Report (D5.8)
- Learning Stories on Awareness-raising and Behavioral Change Solutions (D4.1)
- Learning Stories on Digital and Technological Solution (D4.4)

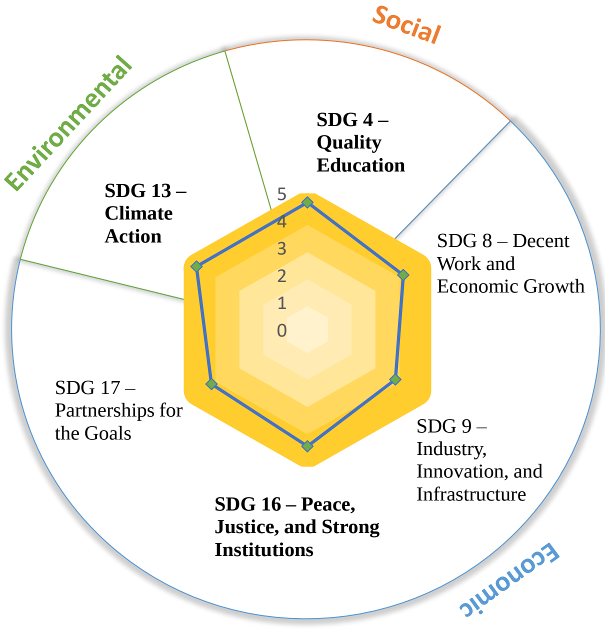
Institutional documentation plays an important role in supporting data collection and validating adaptation solutions, such as cost records related to investment, maintenance, and operation, as well as stakeholder engagement tracking records to monitor participation and impact. Additionally, it encompasses action plans and supporting literature that contribute to estimation. Field data and experimental results, combined with modeling analysis, offer critical insights by assessing environmental changes and ecosystem resilience while evaluating long-term sustainability and adaptive capacity. By integrating these elements, the project ensures a data-driven, evidence-based approach that strengthens the effectiveness and scalability of adaptation strategies.

After all relevant information for quantitative indicators have been collected, it was normalized to ensure comparability both among the quantitative indicators themselves and with the qualitative indicators. Normalization is carried out using the general approach in the SRM described in Section 2.2.3. All indicators are assigned scores ranging from 0 to 5, which are then allocated to the relevant SDG (Sustainable Development Goal) sub-goals identified for each indicator. The final contribution to each SDG is aggregated using the weighted sum method, with an assumption of equal weights for all indicators. However, this weighting can be adjusted based on project goals, stakeholder input, or specific contextual needs.

8.4 Assessment

The sustainability profiles of each solution and region-specific portfolio (RSP) are presented here. They align with SDG goals, as well as the sustainability domains of social, economic, and environmental aspects. The assessment begins with an evaluation of each solution, followed by the RSP, addressing three key aspects: results and their interpretation, uncertainties, and actions for improvement and next steps.

8.4.1 Sustainability profile of Awareness-raising (AWAR)



AWAR (Awareness-raising)

Primary targeted SDGs*:

Co-benefits SDGs:

* Targeted SDGs are black bordered.

The interpretation of the profile should focus on **Primary targeted SDGs** with multiple indicator contributions, while co-benefit SDGs typically have limited contributions from specific indicators.

Social domain

Relevant performance categories (indicators):

Stakeholder Engagement and Participation, Monitoring, Evaluation, and Adaptation, Management and Coordination (Teacher Engagement), Risk and Resilience (Sustained Engagement, Awareness-Behaviour Gap)

Interpretation:

+++ High attendance and facilitator satisfaction indicate strong youth engagement, commitment to climate learning, and effective climate literacy development through capacity-building activities and age-appropriate materials.

+++ Engaged teachers and sustained youth participation ensure consistent climate awareness, embedding sustainability into lessons, and promoting lasting pro-environment habits for future generations.

+++ Variety in modules and novel engagement strategies enhance the youth climate curriculum, encouraging deeper learning, creative solutions, and fostering long-term sustainability competencies.

Overall, high attendance and facilitator satisfaction reflect strong youth engagement and commitment to climate learning, while sustained participation and diverse modules enhance climate literacy, embedding sustainability into education and promoting lasting competencies.

Economic domain

Relevant performance categories (indicators):

Stakeholder Engagement and Participation – SDG 16, Management and Coordination (Stakeholder Coordination) – SDG 16 & 17, Financial Viability – SDG 8 & 9, Risk and Resilience (Partner Dependency, Data Accessibility) – SDG 9 & 16

Interpretation:

+++ Satisfaction with engagement quality and effective facilitation reflects transparent, accountable processes, ensuring well-run events and strengthening institutional capacity for inclusive climate education and governance.

+++ Coordinating municipalities and schools fosters collaboration and synergies, strengthening partnerships for climate education, ensuring broad, collective input, and enabling the integration of diverse stakeholders for sustainable impact.

+++ Strong attendance and stakeholder interest in climate education planning signal support for innovative climate education solutions, fostering the development of robust infrastructure for youth climate literacy and sustainable educational systems.

++ The program relies on external partners for specialized content while maintaining internal development capacity, and reducing this reliance will foster a self-sustaining AWAR infrastructure with local capacity to independently design and deliver climate modules, making the investment generally cost-efficient.

Overall, the program ensures transparency and strengthens institutional capacity for inclusive climate education (SDG 16). It fosters innovation in climate education infrastructure (SDG 9), promotes cost-efficient, self-sustaining climate education solutions (SDG 8), and advances strong partnerships and collaboration (SDG 17).

Environmental domain

Relevant performance categories (indicators):

Stakeholder Engagement and Participation (Event, Training), Monitoring, Evaluation, and Adaptation, Management and Coordination (Teacher Engagement), Risk and Resilience (Sustained Engagement, Awareness-Behaviour Gap)

Interpretation:

+++ Strong attendance and active engagement in capacity-building activities demonstrate a commitment to improving climate literacy among youth, enhancing climate resilience and knowledge on climate action.

+++ The development of accurate, age-appropriate materials and expanded module variety equips students with relevant climate knowledge, increasing climate awareness and empowering the younger generation with the tools to address climate challenges.

+++ High training attendance and sustained participation indicate strong youth commitment to climate learning, reinforcing long-term climate literacy and cultivating a foundation for lifelong pro-environmental habits and mitigating climate change impacts.

Overall, the initiative enhances climate resilience through capacity-building, fosters climate literacy via engaging, age-appropriate education, and promotes long-term commitment to sustainability.

Uncertainties

Uncertainties in interpreting the results include:

- The assessment is based on qualitative evaluation, without quantitative data due to the absence of targets, such as in Stakeholder Engagement and Participation.
- Some indicators are not included due to a lack of data, i.e., Awareness-raising Modules and investment costs.

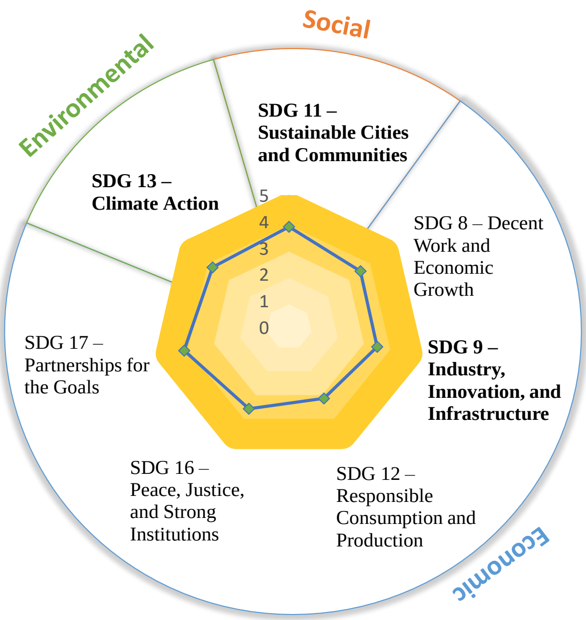
Improvement and next steps

Actions for the improvement and next steps:

- Focus on building local capacity to develop awareness-raising modules and climate education content, gradually decreasing reliance on external collaborators to foster a more self-sustaining and resilient program.
- Implement strategies to maintain active participation and sustain engagement over time, such as regular follow-ups, community-driven initiatives, and feedback mechanisms to ensure lasting impact and foster behavioral change.
- Improve data accessibility and reliability from Smart Climate Stations, ensuring seamless integration into educational programs to enhance learning outcomes and better inform decision-making.

Overall, actions will be taken to reduce dependency on external partners by building local capacity for awareness-raising module development. Long-term engagement will be enhanced through follow-ups and community initiatives. Data accessibility risks will be addressed by improving reliability and integration of Smart Climate Station data into educational programs.

8.4.2 Sustainability profile of Smart climate stations (SCS)



SCS (Smart Climate Stations)

Primary targeted SDGs*:

Co-benefits SDGs:

* Targeted SDGs are black bordered.

The interpretation of the profile should focus on **Primary targeted SDGs** with multiple indicator contributions, while co-benefit SDGs typically have limited contributions from specific indicators.

Social domain

Relevant performance categories (indicators):

System Performance (Response Efficiency), Data Quality (Continuous monitoring, Sensor Coverage Redundancy), Risk and Resilience (Resource Allocation)

Interpretation:

+++ The monitoring system enhances urban resilience through efficient response mechanisms, ensuring rapid action in the event of emergencies or environmental issues. Continuous monitoring and redundant sensor coverage improve data quality, enabling informed decision-making for sustainable urban management.

\+ The resource allocation for maintaining and upgrading the infrastructure is inadequate, with limited evidence of post-project funding and support, raising concerns about the long-term functionality and operational reliability of the system.

Overall, the system supports urban resilience, ensuring rapid response to emergencies and enabling informed decision-making for sustainable urban management, however, resource allocation remains insufficient for long-term reliability.

Economic domain

Relevant performance categories (indicators):

System Performance – SDG 9, (System Uptime, User Customization Options, Response Efficiency) – SDG 16, (Integration Capability) – SDG 17, Data Quality – SDG 9, (Data Accuracy) – SDG 16, Management and Coordination – SDG 16 & 17, Financial Viability – SDG 8, 9, and 12, Risk and Resilience – SDG 9 & 16

Interpretation:

+++ The system is designed to enhance scalability, response efficiency, and continuous monitoring, driving infrastructure innovation and supporting economic growth through effective resource management.

+++ Cross-departmental and stakeholder coordination is supported by the system, promoting transparent governance and institutional capacity, fostering partnerships for sustainable climate solutions.

++ Moderate satisfaction with data accuracy is reported, with occasional inaccuracies from sensor malfunctions or environmental factors, while customizing the monitoring system to meet user needs is challenging and requires technical expertise; some operational areas could be optimized to reduce costs.

+ The insufficient computational power for processing data leads to delays, errors, and operational inefficiencies, with minimal intelligent data analysis and no clear integration of sustainable energy solutions.

+ Partner dependency limits the local team's autonomy, as they rely on external stakeholders for critical data analysis and system functions, while inadequate resource allocation raises concerns about the system's long-term functionality and operational reliability.

Overall, the system supports infrastructure innovation and economic growth through scalable, efficient resource management (SDG 9). Transparent governance and institutional capacity (SDG 16) fosters partnerships for sustainable climate solutions (SDG 17). Optimized operational efficiency and cost reduction promotes SDG 12.

Environmental domain

Relevant performance categories (indicators):

System Performance (System Uptime, System Scalability, Response Efficiency, Tech-enabled Monitoring, Computing Power), Monitoring, Evaluation, and Adaptation, Data Quality

Interpretation:

+++ Continuous monitoring and system scalability are ensured, enabling real-time data collection and adaptation to climate change impacts, ultimately contributing to improved climate resilience.

+++ Response efficiency and sensor coverage redundancy are incorporated, enhancing the reliability of the system and enabling swift responses to climate-related threats, ensuring comprehensive data accessibility for effective climate action and informed decision-making.

++ The satisfaction with the accuracy and reliability of real-time data is moderate, with occasional inaccuracies due to sensor malfunctions or environmental factors, although data is generally reliable and requires periodic validation.

+ The computational power for processing data is insufficient, with systems struggling to handle data volume or complexity, resulting in delays, errors, and operational inefficiencies, along with no indication of intelligent data analysis and minimal evidence of sustainable energy integration.

Overall, the system enables real-time data collection, enhancing climate resilience through continuous monitoring and system scalability. Response efficiency, sensor redundancy, and data accessibility support climate action; however, challenges in computational power and data accuracy remain, affecting overall operational efficiency and the reliability of decision-making for climate adaptation.

Uncertainties

Uncertainties in interpreting the results include:

- The assessment is based on qualitative evaluation, without quantitative data due to the absence of targets.
- Some indicators are not included in the assessment due to a lack of data evaluation, such as sensor provider match, sensor maintenance frequency, and software update frequency.

Improvement and next steps

Actions for the improvement and next steps:

- Allocate sufficient resources for system maintenance and upgrades, and enhance computational power to ensure reliable, efficient data processing and reduced operational delays.
- Incorporate smart data analytics and sustainable energy sources to boost system performance and environmental resilience.
- Reduce dependency on external partners by building local technical capacity, streamlining system functions, and ensuring knowledge transfer.

Overall, data systems should be upgraded with better resource allocation and computational power. Intelligent analytics and sustainable energy integration are recommended. Local capacity must be strengthened to reduce partner dependency and ensure long-term functionality, efficiency, and autonomous system operation.

8.4.3 Sustainability profile of Region-specific portfolio (RSP)

Region-specific portfolio (RSP)
Include five solutions: AWAR (Awareness-raising), SCS (Smart Climate Stations),CAE (Citizen App), CIH (Climate Innovation Hub), DSI (Demand analysis for social services/infrastructures)

Primary targeted SDGs*:

Co-benefits SDGs:

* Targeted SDGs are black bordered.

The interpretation of the profile should focus on **Primary targeted SDGs** with multiple indicator contributions, while co-benefit SDGs typically have limited contributions from specific indicators.

Social domain

Relevant performance categories (indicators):

AWAR: Stakeholder Engagement and Participation, Monitoring, Evaluation, and Adaptation, Management and Coordination (Teacher Engagement), Risk and Resilience (Sustained Engagement, Awareness-Behaviour Gap) – SDG 4

CSC: System Performance (Response Efficiency), Data Quality (Continuous monitoring, Sensor Coverage Redundancy), Risk and Resilience (Resource Allocation) – SDG 11

CAE: Stakeholder Engagement and Participation (Survey, App Utilization), Management and Coordination (Engagement strategy) – SDG 4

CIH: Stakeholder Engagement and Participation – SDG 4, Monitoring, Evaluation, and Adaptation

DSI: Monitoring, Evaluation, and Adaptation (Health impacts of air pollution) – SDG 11, Risk and Resilience (Unpredictable Climate Impacts) – SDG 11

Interpretation:

+++ AWAR, CIH, and CAE fosters climate literacy, youth engagement, and stakeholder participation through training, surveys, and creative learning strategies. These initiatives embed sustainability values, promote behavioral change, and build long-term competencies for informed climate action.

+++ SCS and DSI enhance urban resilience and adaptive capacity. Real-time monitoring and predictive analysis enable rapid emergency response and ensure uninterrupted social services during extreme climate events, supporting sustainable urban management.

++ CAE shows moderate usage and stakeholder engagement, with some benefits recognized, but limited daily integration and inconsistent retention indicate that the current strategy is partially effective and requires refinement to enhance scalability and long-term impact.

\+ The resource allocation for SCS is insufficient, with limited evidence of post-project funding or support, raising concerns about the system's long-term functionality and operational reliability.

Overall, AWAR, CIH, and CAE promote climate literacy and sustainable behaviour through inclusive education (SDG 4). SCS and DSI enhance urban resilience, though long-term impact depends on improved resource allocation and stronger stakeholder engagement strategies (SDG 11).

Economic domain

Relevant performance categories (indicators):

System Performance – SDG 9, (System Uptime, User Customization Options, Response Efficiency) – SDG 16, (Integration Capability) – SDG 17, Data Quality – SDG 9, (Data Accuracy) – SDG 16, Management and Coordination – SDG 16 & 17, Financial Viability – SDG 8, 9, and 12, Risk and Resilience – SDG 9 & 16

Interpretation:

+++ CIH and AWAR promote inclusive, accountable climate education through well-facilitated training, stakeholder collaboration, and institutional support, while fostering skills and resource adequacy that support long-term capacity building and responsible practices.

+++ CAE and DSI promote data accessibility and encourage responsive governance; CAE's survey feedback and support responsiveness reflect transparency, while DSI emphasizes organizational perception and data reliability for informed decision-making.

+++ SCS and CAE support scalable, real-time systems that enhance monitoring, coordination, and institutional capacity; cross-departmental collaboration and infrastructure innovation support sustainable development and transparent partnerships.

+++ SCS and DSI promote efficient resource use, economic resilience, and adaptive infrastructure through effective environmental monitoring and data-driven service planning, ensuring sustainability and operational efficiency under climate pressures.

++ CAE and DSI demonstrate moderate performance, with CAE requiring improved coordination to enhance engagement and retention, while DSI faces data flow inconsistencies and mixed perceptions that limit confident implementation, highlighting the need for better system integration and stakeholder trust.

++ AWAR and SCS show generally cost-efficient outcomes, though AWAR's reliance on external content partners and SCS's technical customization challenges suggest the importance of building internal capacity and optimizing operations to improve sustainability and system usability.

\+ SCS faces operational inefficiencies due to insufficient computational power, limited intelligent data analysis, and lack of sustainable energy integration, while partner dependency and inadequate resource allocation constrain local autonomy and raise concerns about long-term functionality and system reliability.

Overall, CIH and AWAR support SDGs 8, 9, 12, 16 by fostering skills, accountable education, and institutional capacity. CAE enhances transparency and digital engagement (SDG 16, 17). DSI enables informed decisions and adaptive planning (SDG 9, 12). SCS promotes real-time monitoring and infrastructure innovation, though constrained by technical and resource limitations (SDG 9).

Environmental domain

Relevant performance categories (indicators):

AWAR: Stakeholder Engagement and Participation (Event, Training), Monitoring, Evaluation, and Adaptation, Management and Coordination (Teacher Engagement), Risk and Resilience (Sustained Engagement, Awareness-Behaviour Gap)

CSC: System Performance (System Uptime, System Scalability, Response Efficiency, Tech-enabled Monitoring, Computing Power), Monitoring, Evaluation, and Adaptation, Data Quality

CAE: Stakeholder Engagement and Participation (App Utilization)

CIH: Stakeholder Engagement and Participation (Event and Training), Monitoring, Evaluation, and Adaptation

DSI: Monitoring, Evaluation, and Adaptation (Mortality Rate), – SDG 11, Monitoring, Evaluation, and Adaptation (Potential in Decision-Making), Risk and Resilience (Unpredictable Climate Impacts, Organizational Perception)

Interpretation:

+++ CIH, AWAR, CAE, and DSI build climate literacy, foster behavioral change, and encourage stakeholder engagement, particularly among youth and communities, which strengthens awareness, adaptive capacity, and long-term resilience to climate impacts.

+++ SCS and DSI support SDG 13 through real-time environmental monitoring and accurate forecasting, enabling timely, informed responses to climate-related events and ensuring service continuity, while reinforcing institutional recognition and action toward climate change adaptation.

++ SCS, CAE, and DSI show moderate effectiveness, with generally reliable but occasionally inaccurate data (SCS), partial user engagement and limited integration into daily routines (CAE), and cautious implementation driven by mixed organizational confidence despite mostly reliable data (DSI).

\+ SCS faces insufficient computational capacity, leading to delays and errors without intelligent analysis or sustainable energy integration, while DSI shows no observed change in Mortality Rate based on current analysis.

Overall, CIH and AWAR strengthen the building of climate literacy and behavioral change. CAE promotes engagement but needs deeper integration. DSI aids adaptive planning with climate forecasts. SCS enables real-time response, though limited by computational capacity and lack of intelligent analysis.

Uncertainties

Uncertainties in interpreting the results include:

- AWAR, SCS, and CAE face data limitations, with assessments based largely on qualitative evaluation and some indicators, such as stakeholder engagement, system integration, and investment or maintenance costs - excluded due to lack of available data and defined targets.
- CIH and DSI show uncertainties stemming from the absence of project-specific targets or benchmark values, making it difficult to quantify their performance or impact despite operational continuity (CIH) and generally reliable data (DSI).

Improvement and next steps

Actions for the improvement and next steps:

- Enhance Engagement and Usability (CAE, AWAR): Refine engagement strategies through targeted outreach, improved app usability, and regular follow-ups to boost daily integration, user retention, and sustained participation in climate education programs.

- Strengthen Data Infrastructure and Reliability (SCS, DSI): Allocate resources to improve system maintenance, computational power, and sensor validation while enhancing data reliability and integration into decision-making and educational tools.
- Build Local Capacity and Reduce External Dependency (AWAR, SCS): Invest in local skill development and technical training to decrease reliance on external partners for content creation and system operation, supporting long-term autonomy and resilience.
- Increase Institutional Confidence and Impact Visibility (DSI): Promote transparent reporting and internal capacity building to strengthen organizational trust in system outputs and encourage confident, data-driven planning and responses.

Overall, next steps include refining engagement strategies (CAE, AWAR), improving data reliability and processing capacity (SCS, DSI), building local capacity to reduce external dependency (AWAR, SCS), and enhancing institutional confidence through transparent reporting and strengthened internal capabilities (DSI) to ensure long-term impact and resilience.

9.0 CONCLUSIONS AND NEXT STEPS

9.1 Conclusions

This report presents integrated sustainability profiles for validated solutions across six TransformAr demonstrators. These profiles assess each solution's environmental, economic, and social performance using the SRM, which integrates life cycle thinking (LCT) and handprint thinking (HT). The methodology was applied through a four-phase framework -Scoping, Implementation, Data Process, and Assessment, which allows comparison across demonstrators and aligns with SDGs. Both qualitative and quantitative indicators were used to assess benefits and risks. The report reflects TransformAr's aim to support transformational adaptation through diverse solutions, including behavioural change and awareness-raising, governance schemes, NBS, technological and digital solutions, and financial and economic schemes. The sustainability profiles offer valuable insights to support evidence-based decision-making and the integration of sustainability metrics into adaptation strategies at local, regional, and EU levels. By systematically assessing the performance of implemented solutions, the report functions both as a monitoring tool and a reference for guiding replication and upscaling efforts. These profiles are included to enhance transparency, support strategic planning, and promote the transferability of successful approaches across diverse contexts.

Sustainability scores for each demonstrator's RSP are presented in Table 9.1 (see the scores on solution level in ANNEX). The scoring considered primarily targeted and co-benefit SDGs across social, economic, and environmental domains. The RSP scores reflect each demonstrator's progress in integrating adaptive solutions.

Table 9.1 Scores for RSP for each demonstrator

Sustainability	Sustainable Development Goals (SDGs)	Lappeenranta	Westcountry Region	Galicia	Oristano	Guadeloupe	Egaleo
Social	1. No Poverty			5,00			
	2. Zero Hunger						
	3. Good Health and Well-being	3,33					
	4. Quality Education		4,52	4,19	5,00		4,26
	5. Gender Equality						
	11. Sustainable Cities & Communities	3,04			3,80	3,11	3,57
Economic	6. Clean Water and Sanitation	3,21	3,58		4,75	4,06	
	7. Affordable and Clean Energy			2,50	5,00	4,25	
	8. Decent Work & Economic Growth	3,79	2,67	4,00	3,33	3,69	3,55
	9. Industry, Innovation, &Infrastructure	3,68	2,29	4,38	3,85	3,71	3,62
	10. Reduced Inequality			5,00			
	12. Responsible Consumption & Production	3,27	2,38		4,67	3,59	4,00
	16. Peace, Justice, and Strong Institutions	4,05	3,60	4,25	3,50	3,17	3,87
	17. Partnerships for the Goals	3,99	3,77	4,38	2,80	2,99	3,92
Environmental	13. Climate Action	2,65	3,58	4,37	4,25	3,09	3,92
	14. Life Below Water			5,00			
	15. Life on Land	3,00	3,50		5,00		

These scores illustrate varied strengths shaped by local contexts, solution types, and implementation maturity across the six regions. Throughout the demonstrators, some key insights have emerged:

Social Domain

TransformAr demonstrators significantly advanced social sustainability, with clear contributions to SDG 3, 4 and SDG 11. Galicia demonstrated a strong social impact through its initiative, which effectively engaged disadvantaged groups in climate-resilient practices, promoting inclusivity and community-driven adaptation. Cooperation is key, as shown by the need for RI to identify and engage external stakeholders in solution development. Guadeloupe's behavioural change initiatives (NUDG) engage hotels managers and tourists in climate adaptation efforts, although challenges in efficiency and effectiveness of support services arose due to distance, time differences, and language barriers. Egaleo used educational programs (AWAR) to raise awareness among youth communities, empowering them with climate knowledge and tools for action.

Economic Domain

Economic resilience was boosted across demonstrators through innovation and sustainable financing. Galicia's MRM and RI tools enhanced aquaculture's ability to withstand climate shocks, improving sector productivity. Oristano's COAST reinforced multi-level governance and stakeholder collaboration, crucial for long-term financial and policy support. However, its SG faced budget challenges and delays due to external factors such as the pandemic, geopolitical instability, and weather events. Westcountry's use of GB also exemplified financial innovation to support nature-based infrastructure, but its setup faced major delays due to the need for new contracts, frameworks, and payment rate design.

Environmental Domain

The environmental benefits were evident across all demonstrators. Lappeenranta, Westcountry, and Oristano emphasized nature-based solutions (NBS) like constructed wetlands, urban green infrastructure, and coastal restoration. However, some challenges may affect their effectiveness; for instance, Lappeenranta's SWMM with a two-hour data submission delay to the cloud/data platform hinders real-time responsiveness. Galicia and Guadeloupe deployed digital monitoring solutions to better understand and manage environmental change, laying the groundwork for proactive risk management. These efforts showcase a holistic approach to climate adaptation, integrating data, nature, and people to build sustainable, resilient systems.

9.2 Uncertainties

The sustainability assessment across the six TransformAr demonstrators revealed both valuable insights and methodological limitations rooted in data quality and contextual variability. A key source of uncertainty stemmed from incomplete or inconsistent baseline and target data, especially for financial indicators. In several cases, the absence of quantified targets or standard benchmarks complicated the evaluation of progress, and the availability of pre-implementation data varied significantly between demonstrators. As a result, qualitative assessments played a greater role than initially planned.

To address these data limitations, the analysis incorporated assumptions to ensure a more holistic understanding of cumulative impacts. While this approach enhanced the comparability of results, it also introduced additional complexity in attributing scores to individual solutions. Moreover, some indicators had overlapping relevance across domains (e.g., public engagement affecting both social and governance scores), requiring careful interpretation to avoid over- or underweighting contributions.

In conclusion, while uncertainties persist - especially regarding long-term impact and replicability – the profiles provided a valuable structure for synthesizing diverse adaptation efforts. Future iterations of the method should prioritize data standardization, expand monitoring capacity, and strengthen stakeholder input to improve robustness and comparability.

9.3 Next steps

To build on these insights and enhance the long-term impact of the project, the following next steps will be undertaken:

Refinement of Sustainability Metrics

- Further development of sustainability indicators will focus on enhancing measurement accuracy, improving data standardization, and incorporating emerging climate risks.
- A weighted scoring system will be introduced to better reflect the relative importance of each indicator, improving the precision and contextual relevance of the sustainability profiles.
- Special attention will be given to LCA to quantify both positive and negative impacts of adaptation solutions.
- So far, the connection between indicators and SDG goals has been established by comparing each indicator to relevant targets. To improve consistency and comparability across solutions, a systematic method should be developed to standardize this assignment process.

SRM Adaptation for Varied Environments

- Insights from this report serve to validate the SRM methodology, integrating both strengths and areas needing refinement across different demonstrators.
- Lessons learned will guide the evolution of the SRM into a more scalable and adaptable framework, capable of supporting sustainability assessment across varied adaptation pathways, to be formalized in Deliverable D5.9.

Integration into Decision-Making

- The SRM framework will be further refined and transferred to TSP to assess the resilience capacity of each solution in relation to the specific needs of cities, communities, and regions.
- Results from the six demonstrators will be compiled into a guide for ex-post assessment of the solution reports (D5.7, M48) to guide best practices.

As TransformAr moves forward, these steps will solidify the legacy of the project by ensuring that tested solutions become integral components of European climate adaptation strategies. The SRM methodology will continue evolving, providing a robust and scalable framework that supports evidence-based decision-making, fosters collaboration, and enhances climate resilience across diverse operational environments.

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ANNEX: Scores for validated solutions in each demonstrator

Sustainability	Sustainable Development Goals (SDGs)	Lappeenranta				Westcountry Region			Galicia			Oristano		Guadeloupe		Egaleo	
		URB	SWMM	CAF	CEI	ICW	ICWM	GB	RI	MRM	INTERM	COAST	SG	NUDG	AF	AWAR	SCS
Social	1. No Poverty																
	2. Zero Hunger																
	3. Good Health and Well-being	3,33															
	4. Quality Education					4,38	4,67		3,89			5,00				4,67	
	5. Gender Equality																
	11. Sustainable Cities & Communities	3,17	2,30	3,65								3,63	3,97	3,11			3,80
Economic	6. Clean Water and Sanitation	3,42	3,00			3,74	4,00	3,00					4,75	4,06			
	7. Affordable and Clean Energy									2,50			5,00	4,25			
	8. Decent Work & Economic Growth	3,33	3,50	4,33	4,00	3,50	1,67	2,84	4,00	4,20	3,83	3,00	3,67	3,13	4,30	4,00	3,40
	9. Industry, Innovation, &Infrastructure	3,33	3,27	4,10	4,00	1,67	3,84	1,38	4,18	4,10	4,25	3,44	4,27	3,09	4,30	3,67	3,36
	10. Reduced Inequality																
	12. Responsible Consumption & Production	3,75	2,05	4,00			2,50	2,25					4,67	3,59			3,00
	16. Peace, Justice, and Strong Institutions	5,00	2,66	4,16	4,40	3,91	3,56	3,33	3,81	4,20	4,00	3,13	3,87	3,24	3,10	4,29	3,44
	17. Partnerships for the Goals	4,50	3,00	4,00	4,50	3,79	4,20	3,31	3,50	5,00	4,00	2,94	2,67	3,16	2,80	4,00	4,00
Environmental	13. Climate Action	3,33	2,63	2,00		2,39	4,34	4,00	4,41	3,83	4,50	5,00	3,50	3,67	2,50	4,63	3,64
	14. Life Below Water										5,00						
	15. Life on Land	3,00				4,00		3,00					5,00				

Climate change impacts are here and now. The impacts on people, prosperity and planet are already pervasive but unevenly distributed, as stated in the new EU Blueprint strategy (European Commission-EC, 2019). To reduce climate-related risks, the EC and the IPCC agree that transformational adaptation is essential. The TranformAr project aims to develop and demonstrate products and services to launch and accelerate large-scale and disruptive adaptive process for transformational adaptation in vulnerable regions and communities across Europe.

The 6 TransformAr lighthouse demonstrators face a common challenge: water-related risks and impacts of climate change. Based on existing successful initiatives, the project will develop, test and demonstrate solutions and pathways, integrated in Innovation Packages, in 6 territories.

Transformational pathways, including an integrated risk assessment approach are co-developed by means of 9 Transformational Adaptive Blocks. A set of 22 tested actionable adaptive solutions are tested and demonstrated, ranging from nature-based solutions, innovative technologies, financing, insurance and governance models, awareness and behavioral change solutions.

TransformAr

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