



NEXOGENESIS

STREAMLINING WATER RELATED POLICIES

Deliverable 5.7

Recommendations, experiences and lessons learned from all case studies

Lead: UU

Date: 25 June 2025



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Abstract

This Deliverable synthesizes the experiences and lessons learned across all case studies in NEXOGENESIS and provides recommendations for future projects on how to engage stakeholders in project co-creation activities and issues on the WEFE nexus.

Keywords

case studies, stakeholder engagement, co-creation, lessons learned, transdisciplinary research, nexus policy issues, stakeholder workshops, WEFE nexus

Abbreviations/Acronyms

| | |
|--------------|---|
| <i>CS(s)</i> | <i>Case study(ies)</i> |
| <i>D</i> | <i>Deliverable</i> |
| <i>KPI</i> | <i>Key Performance Indicator</i> |
| <i>M</i> | <i>Month</i> |
| <i>MS</i> | <i>Milestone</i> |
| <i>NEPAT</i> | <i>Nexus / NEXOGENESIS policy assessment tool</i> |
| <i>NXG</i> | <i>NEXOGENESIS</i> |
| <i>NXGAT</i> | <i>NeXus Governance Assessment Tool</i> |
| <i>SDM</i> | <i>System Dynamics Model</i> |
| <i>SH(s)</i> | <i>Stakeholder(s)</i> |
| <i>SHE</i> | <i>Stakeholder engagement</i> |
| <i>WEFE</i> | <i>Water, energy, food, and ecosystems</i> |
| <i>WP</i> | <i>Work package</i> |
| <i>WS(s)</i> | <i>Workshop(s)</i> |



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Executive Summary

This deliverable synthesises key experiences and lessons learned from the 48-month NEXOGENESIS (NXG) co-creation process in five case studies: Nestos/Mesta (Greece and Bulgaria), Lielupe (Latvia and Lithuania), Jiu (Romania), Adige (Italy) and Inkomati-Usuthu (South Africa). The analytical framework guiding this synthesis is rooted in transdisciplinary research principles, evaluating success through collaborative problem framing, process management, and tangible policy impacts.

Co-creation activities in each case study took place over three phases: *co-exploration* (building awareness and trust), *co-design* (knowledge exchange and tool validation), and *co-development* (collaborative solution-building). Across these phases, stakeholders engaged predominantly through workshops (WSs) and the development, validation and testing of tools like the NExogenesis Policy Assessment Tool (NEPAT) resulting in a set of stakeholder-validated policy packages.

Key findings highlight the importance of early and inclusive stakeholder engagement, particularly in overcoming structural barriers such as sectoral silos and transboundary disparities. Experiences in the *co-exploration phase* emphasised the value of trust-building through local intermediaries and the integration of marginalised voices, which often revealed critical governance gaps. In the *co-design phase*, adaptive engagement methods were essential for maintaining stakeholder interest, while NEPAT emerged as a valuable yet complex tool requiring localised data and capacity-building. Experiences in the *co-development phase* highlighted the need for institutional anchoring to sustain engagement beyond the end of the project, particularly in transboundary contexts where divergent priorities required unbiased facilitation.

Persistent challenges included limited involvement from high-level decision-makers, data gaps, overall stakeholder fatigue, and in some cases the water-centric framing of discussions that inadvertently reinforced silos instead of fostering nexus integration. However, successes were evident in case studies where tools like NEPAT were integrated into existing governance structures or framed around broader policy goals such as climate resilience or job creation. The NEPAT highlighted the synergies and trade-offs in policy implementation, resulting in the facilitation of cross-sectoral discussions on a nexus approach in some case studies.

The report assesses the impact of the co-creation activities and distils the lessons learned into 17 recommendations for future nexus projects, grouped according to the three phases of the NXG process. Overall, the experiences in the NXG case studies suggest that effective co-creation and stakeholder engagement in water, energy, food, ecosystems (WEFE) nexus projects requires a balance of scientific rigour and contextual adaptability. By embedding co-creation within institutional frameworks, aligning tools with stakeholder needs, and prioritising equitable participation, future projects can translate nexus research into more lasting policy and governance impacts. The recommendations offered in this report aim to guide practitioners in overcoming common pitfalls while maximising the potential for transformative, multi-sectoral cooperation in WEFE nexus policy issues.

Introduction

Project Summary

Water, energy, food, and ecosystems (WEFE) are interconnected and comprise a coherent system (nexus), which is characterised by complexity and modulated by climatic and socio-economic drivers. The NEXOGENESIS (NXG) project specifically recognises ecosystems as playing a key role in sustaining the WEF sectors, going beyond traditional WEF approaches by incorporating ecosystems as a fourth pillar of the nexus. In the nexus, economic development (including optimal trade, market, and policy solutions) is hampered by resource constraints and their interconnectedness. In addition, the adoption of a sectoral approach in developing and implementing policies may affect nexus characteristics, which in turn can affect decision-making and policy formulation/implementation. By explicitly incorporating ecosystems into the nexus, NXG enables a more holistic understanding of resource interdependencies to better inform effective policies.

NXG developed a co-creation approach for WEFE nexus governance that integrates a policy coherence assessment methodology, a NeXus Governance Assessment Tool (NXGAT), and the development of governance roadmaps. This approach is embedded within a comprehensive stakeholder (SH) co-creation process, supported by a policy impact assessment tool, to identify SH-validated policy packages and to define actionable pathways for their adoption and implementation as foundational elements of SH agreements.

The policy impact assessment tool exploits reinforcement learning, and supports streamlining policies across all sectors into the WEFE nexus. Originally called the Self-Learning Nexus Assessment Engine (SLNAE) at the outset of NXG, the tool was later renamed and is hereafter referred to as the NEXogenesis Policy Assessment Tool (NEPAT). This is because this new term is more intuitive for non-project/non-expert users of the tool. A WEFE Nexus Footprint accompanies the NEPAT. The footprint is a visualisation that allows SHs to simplistically assess synergies and trade-offs associated with policy implementation.

NXG applied its approach to five case studies (CSs): four European and one in Southern Africa (Figure 1, Table 1). Through the European CSs, strong SH engagement (SHE) and validation of outputs aimed to improve policies and policy-making processes to enhance cooperation and help the EU achieve targets related to the Water Framework Directive, the greener Common Agricultural Policy, Green Deal ambitions, as well as ambitions on water diplomacy. The Inkomati-Usuthu basin was included to widen cooperation beyond Europe, by developing policy-design guidance that can be applied across scales and borders.

The Case Studies

The five CSs explored a variety of nexus policy issues (see Annex 1). Application of coherent approaches throughout the project enabled synthesis and comparison of the experiences and lessons learned in the cases. The use of a similar approach in each CS aimed to foster the exchange of ideas and experiences among them, to allow for broader comparative conclusions and recommendations. The five CSs had diverse spatial, socio-economic and cultural characteristics, and had a history of development challenges. They also featured strong WEFE nexus relations, with the potential for disruption from policy implementation, and allowed for an assessment of how water, energy, food and ecosystems-related policy can be streamlined into

the nexus. The piloting of this coherent co-creation framework in the diversity of cases has demonstrated suitability for its wider out-scaling to other regions globally. Dedicated CS partners offered access to SH consultation at different tiers, ensuring maximum engagement and project impact.

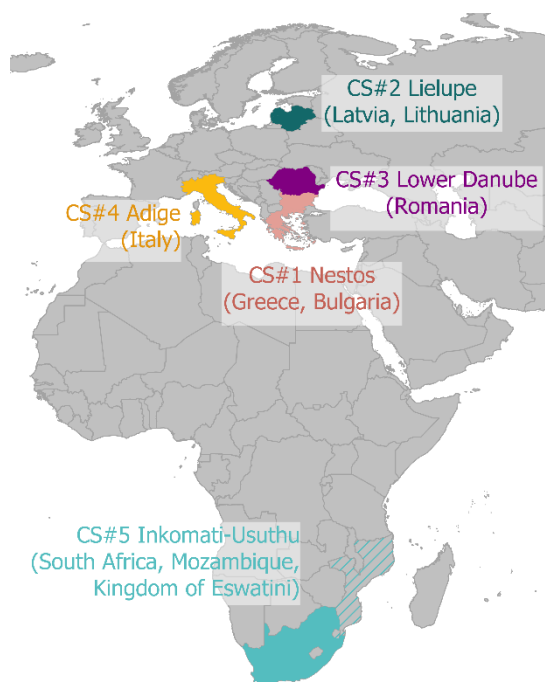


Figure 1: Location of all case studies

| Case Study Name | Countries | Project Category |
|--------------------------|-------------------------------|------------------|
| Nestos/Mesta | Greece (EL) Bulgaria (BG) | frontrunner |
| Lielupe | Lithuania (LT) Latvia (LV) | frontrunner |
| Jiu, Lower Danube | Romania (RO) | follower |
| Adige | Italy (IT) | follower |
| Inkomati-Usuthu | South Africa (RSA) | follower |

Table 1: Overview of the five case studies

Two of the CSs, Nestos and Lielupe, were “frontrunners” (Table 1), which means that they conducted case study activities slightly earlier (ca. 2 months) than the others (so called “followers”). This was to identify potential problems, redundancy or shortcuts in the applied methodology so these could then be adjusted accordingly. The frontrunner CSs had already developed some contacts with SHs and identified local data, due to their involvement in the [SIM4NEXUS project](#), and they also conducted an additional round of SH validation of the policy packages (for more detail, see D1.3 *Policies for the NEPAT* and D1.4 *Governance roadmap and building blocks of a river contract in CSs*). A detailed description of each CS and a list of main nexus challenges is provided in Annex 1. For more detail about all the SHE activities and project results in each CS, see D5.1 *Report on Stakeholder Engagement* and D5.2-5.6 *Implementation Reports for the Case Studies*.

Goals and structure of the report

This deliverable synthesises the results of D5.1-5.6 (and other selected datasets) to summarise key experiences and lessons learned from the NXG CSs regarding co-creation and SH engagement (SHE) in the WEF nexus, as well as the (practical) incorporation of ecosystems into the WEF nexus. The report offers recommendations on co-creation and SHE for future WEF nexus projects.

The report begins with an overview of the co-creation process implemented in the project. The analytical framework used for this deliverable is introduced next and it is explained how the framework is used in synthesising the lessons learned from each phase of the process. Experiences and lessons learned are then presented in line with the framework, and 17

recommendations are developed from the synthesis of the results. Content from other project deliverables is not reproduced in this report, but in-text references are included and these signpost relevant deliverables and other sources that include more detail on specific points.

Methodology to build the report

This report was developed during months 30-46 of the project (February 2024 – June 2025) to summarise all of the experiences and lessons learned within the WP5 SH co-creation activities. The initial outline for this deliverable was developed internally and discussed within WP5. After further elaboration of the outline, the development of MS15 and MS23, discussions at a dedicated session at the annual meeting in September 2024, and the finalisation of D5.2-5.6, a draft of the report structure was sent to CS leads for their inputs. The report was then drafted by WP5 and sent to CSs for review before final submission. A full description of the CS co-ordination process in WP5 throughout the project is provided in Annex 2.

This deliverable specifically synthesises:

- Lessons learned from the report on SHE (D5.1) and the CS implementation reports (D5.2-5.6).
- A cross-case analysis of why and how contextual conditions shape nexus-based approaches in river basin management, conducted by Dr Svetlana Klessova (GAC Group) (Klessova, 2025) with input from CS leaders;
- WP5 discussion sessions at the 2024 NXG General Assembly (using the analytical framework presented in the next section), and at the NXG meetings in Berlin (January 2024) and Athens (January 2025).
- WP5 interviews with CS leaders in 2025. Semi-structured interviews explored how ecosystems are conceptualised, assessed and incorporated in the WEF nexus by the CS teams, challenges that arose in incorporating ecosystems, and lessons learned for future WEF nexus work.

The synthesis therefore draws on many outputs from the project, culminating in a suite of suggested recommendations for co-creation activities and SHE in future projects working with WEF nexus issues.

Overview of the NXG co-creation process

The NXG project followed a 48-month co-creation process over three stages (Figure 2):

- Stage 1 - **Co-exploration** (up to month 18): an information phase, aimed at exploring the context and raising awareness of SHs of the project and nexus issues.
- Stage 2 - **Co-design** (up to month 36): consultation and involvement phases, aimed at knowledge exchange in which SHs were asked for input and feedback into NXG methods (consultation), as well as to discuss certain topics of interest (involvement) and enable understanding of their concerns and aspirations.
- Stage 3 - **Co-development** (up to month 48): collaboration and empowerment phases, aimed at co-development of solutions (transformation pathways) based on co-decision (collaboration) and sometimes empowerment in which SHs 'owned' the decision-making process.

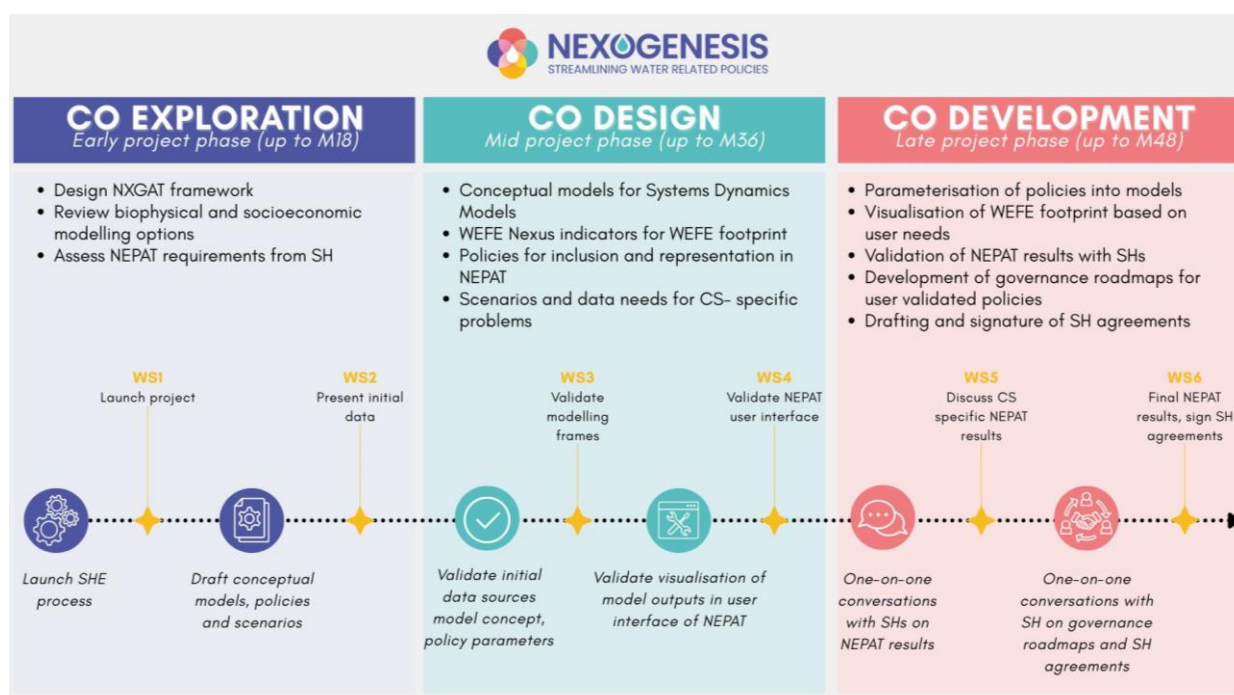


Figure 2: Overview of the NXG co-creation process

Within the three stages - co-exploration, co-design and co-development - there are five strategic SHE steps (Figure 3). The established SHE principles underlying the three stages of the co-creation process, and more details about the five SHE steps, are included in D5.1 *Report on Stakeholder Engagement*.



Figure 3: Five steps of the stakeholder engagement strategy

Workshops (WSs) were conducted with SHs in each case study, spread evenly throughout the duration of the project (Figure 2). The overall aim of the WSs was to co-create knowledge within the project. While the aim and content of each WS was in general pre-defined at the beginning of the project, a co-creative, consortium-wide approach enabled the integration of the specific needs from technical partners and the CSs into each WS. Bilateral sessions were also held with key SHs, to discuss selected issues further and gain specific knowledge that was not able to be shared during the WSs.

D5.1 *Report on Stakeholder Engagement* provides full details of the SHE plan development tailored to each of the five CSs and the various implementation stages of the project, as well as workshop aims, content and implementation. D5.2-5-6 *Implementation Reports for the Case Studies* provide detailed descriptions of the co-creation activities conducted in each CS and reflections on the successes and challenges related to implementation.

Analytical framework

The co-creation process in NXG is transdisciplinary, involving actors from outside academia in co-creating outputs of the research process. This is crucial “to integrate the best available knowledge, reconcile values and preferences, as well as create ownership for problems and solution options” (Lang et al. 2012, p.25). Evaluating the lessons learned from co-creation processes in transdisciplinary projects is an important exercise, with success generally judged in relation to the facilitation of dialogue and the learning processes that occur between science and society (Jahn and Keil, 2015). It is a challenge to secure sustained levels of high quality SHE across large-scale, transdisciplinary projects, and leveraging impact from engagement is also difficult (Huzzard, 2020). An analytical framework is therefore used to guide the synthesis in a way that complements the three phases of the NXG co-creation process (Table 2). The framework is underpinned by existing scientific

research on evaluating the success of transdisciplinary co-creation processes and comprises guiding themes from the academic literature. These themes were used to explore lessons learned in *D5.2-5.6 Case Study Implementation Reports* and in the WP5 discussion at the NXG General Assembly meeting in 2024.

Table 2: Analytical framework used to guide the synthesis of experiences and lessons learned across the case studies (adapted from Lang et al. 2012 and Huzzard 2020).

| Phase | NXG activities | Guiding themes for the synthesis |
|--|--|---|
| <p>CO EXPLORATION <i>Early project phase (up to M18)</i></p> <p>Pre-conditions <i>Collaborative framing and building a collaborative research team</i></p> | <p><i>SH identification and analysis</i></p> <p><i>NeXus Governance Assessment Tool (NXGAT)</i></p> <p><i>Policy coherence assessment</i></p> <p><i>Analysis of WEFE interlinkages – conceptual maps as the basis for System Dynamics Modelling</i></p> <p><i>Scenario building and data collection</i></p> <p><i>Overall co-creation approach across the project team</i></p> | <p>Including all relevant expertise, experience, and other relevant “stakes” needed to tackle the issues in a way that provides solution options and contributes to the related scientific body of knowledge.</p> <p>Reaching a common understanding of the problem to be addressed. Partners accepting a joint definition of the problem.</p> <p>Formulating and agreeing on a common research object or guiding question(s), and common success criteria.</p> <p>A methodological framework that adequately accounts for both the collaboration among the scientific fields and with the project partners with technical expertise.</p> |
| <p>CO DESIGN <i>Mid project phase (up to M36)</i></p> <p>Process <i>Co-producing solution-oriented transferable knowledge through collaborative research</i></p> | <p><i>NEPAT development and validation – exploring policy package options, validating policy packages (via facilitated SH dialogue)</i></p> <p><i>SHE process/ co-production</i></p> <p><i>Scenario building and data collection</i></p> | <p>Clear definition of the tasks and roles of the actors from science and practice involved in the research process.</p> <p>Use or development of methods suitable to generate solution options for the problem addressed.</p> <p>Adoption of procedures/processes for managing conflict as and when it arises.</p> <p>Adequate attention paid to the (material and intellectual) capabilities that are required for effective and sustained participation in the project over time.</p> |
| <p>CO DEVELOPMENT <i>Late project phase (up to M48)</i></p> <p>Outcomes/impact <i>(Re-)integrating and applying the produced knowledge in scientific and societal practice</i></p> | <p>Relevant to scientific practice:</p> <ul style="list-style-type: none"> <i>-Methodological innovations (NEPAT)</i> <i>-SHE/co-creation approach in WEFE Nexus Projects</i> <i>-Capacities of research teams to enable policy impact/capacities of policy-makers to take up scientific evidence for policy</i> <p>Useful for societal practice:</p> <ul style="list-style-type: none"> <i>-SH agreements and governance roadmap (changes in policies)</i> <i>-Actions fostering adoption of NEPAT</i> | <p>Project results implemented to resolve or mitigate the problem addressed.</p> <p>Integration of results into the existing scientific body of knowledge for transfer and scaling-up efforts.</p> <p>The research team provides practice partners and scientists with products, publications, services, etc. in an appropriate form and language.</p> <p>Achievement of the goals, with any additional (unanticipated) positive effects being accomplished.</p> |



Experiences and lessons learned

This section highlights key experiences and lessons learned from the co-creation activities carried out in the CSs, focusing on three phases: co-exploration, co-design, and co-development. The findings use illustrative examples from the CSs and show the importance of structured yet adaptable processes, inclusive participation, trust-building, and aligning technical tools with SH needs. Challenges such as transboundary cooperation, data limitations, and sustaining engagement are discussed, along with strategies to address them.

Co-exploration phase

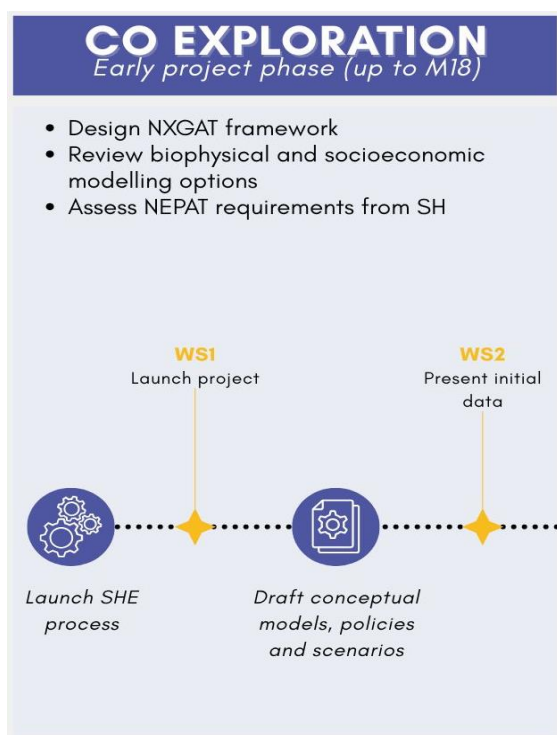


Figure 4: Overview of the co-exploration phase

The early stages of SHE are critical for trust-building and developing shared understandings (Figure 4). Across the CSs, several key lessons emerged regarding the identification, recruitment, and initial collaboration with SHs.

The experiences in the CSs suggest that a well-defined process was instrumental in ensuring clarity, inclusivity, and alignment among diverse SHs. For example, experiences in the Nestos/Mesta case demonstrated how the five-step SHE approach (Figure 3) facilitated systematic identification of actors, their interests, and potential conflicts. Similarly, in Lielupe, the process of updating SH registers to include transboundary representatives from Latvia and Lithuania improved sectoral coverage and dialogue. These structured processes¹ not only ensured representation but also highlighted synergies and disparities early on, enabling proactive management of SH dynamics.

A critical challenge across the cases was the inclusion of marginalised SHs such as local environmental groups or small-scale farmers. These SHs generally have high interest but low power. In Nestos/Mesta, the power-interest assessments that were carried out explicitly flagged these groups, leading to targeted efforts to engage them, such as forming local coalitions to amplify their voices. The work in Adige further highlighted this issue, as environmental associations, who had generally been excluded from water governance discussions, then gained a platform through participating in the project workshops. Empowering such SHs early on has proved vital for equitable participation and long-term commitment, as these marginalised actors often provided insights into localised pressures and governance gaps that might otherwise have been overlooked in the project.

¹ For a detailed description of these processes, see *D5.1 Report on Stakeholder Engagement*.

Trust-building emerged as a cornerstone of successful SH recruitment and retention, often hinging on pre-existing relationships and local intermediaries. In the co-exploration phase in Nestos/Mesta, the involvement of local municipalities (Municipality of Nestos, Greece, and Municipality of Gotse-Delchev, Bulgaria) as project partners leveraged existing trust networks, while in Inkomati-Usuthu and Jiu the pre-existing connections of the CS leads with the Catchment Management Agency facilitated engagement across sectors. Interactive face-to-face engagement was acknowledged by SHs in Lielupe as an efficient and dynamic involvement approach to engage in prioritization and validation activities. Although the advantage of face-to-face settings provided more effective engagement, in the Inkomati-Usuthu catchment this resulted in reduced attendance, as SHs were not always able to travel to the workshops due to the large size of the catchment. However, virtual engagement, though logistically convenient, was less effective than in-person interactions for fostering rapport, as noted in Adige and Inkomati-Usuthu. This emphasises the need for hybrid approaches that balance accessibility with the relational advantages of face-to-face interactions.

The development and validation of the conceptual models in the early stages of the project were pivotal in establishing a shared understanding of nexus complexities. In Jiu, the initial workshops focused on intersectoral linkages, helping SHs to recognise and understand cross-sectoral influences and impact such as positive and negative effects of energy and agricultural activities on water quality. Adige used the conceptual models developed in the project (WP3) to visualise the effect of hydropower on downstream users, which helped to bridge gaps between technical experts and local SHs. However, technical complexity sometimes hindered engagement, as seen in Inkomati-Usuthu; in this case, simplifying data visualisation improved understanding amongst the SHs. Overall, engaging SHs in the development and validation of the conceptual models not only aligned them on recognising mutual challenges but also laid the groundwork for co-designing the policy packages, and ensuring local relevance and ownership. Based on the conceptual model for Lielupe, for example, prioritisation of critical nexus interlinkages by SHs supported the selection of WEFEE interventions of importance for further analysis and modelling.

Transboundary engagement required intentional facilitation to address divergent priorities and administrative asymmetries. In Nestos/Mesta, Greek SHs prioritised fair allocation of water resources among several uses, i.e., irrigation, electricity production and ecological flow, while Bulgarians focused on waste management. In this case, the joint discussions in the co-exploration phase revealed shared interests like water quality and effective management of agricultural water (e.g., limitation of water losses), forming a basis for future collaboration. Language barriers and differing paces of government action posed challenges in Lielupe, but were mitigated through bilingual materials and unbiased facilitation. These efforts highlighted the importance of creating neutral spaces for dialogue and aligning incentives to foster cross-border cooperation.

Engaging high-level decision-makers remained a persistent challenge throughout the process, as national authorities often viewed participation as low priority. For Nestos/Mesta and Adige, involving 'champions' like provincial leaders (e.g. municipal/regional authorities) from very early on in the process (or even at the proposal stage) helped to advocate for the process. It was also important in these cases to demonstrate concrete policy impacts, such as linking NXG tools developed in Jiu to the implementation of the Sustainable Development

Goal ambitions at the national level in Romania. These experiences suggest that framing engagement around tangible outcomes, aligning the work with ongoing policy processes, and leveraging influential intermediaries can enhance buy-in from policymakers from the outset.

Overall, SHE in the co-exploration phase of NXG was not only about recruitment but about establishing a collaborative foundation for the subsequent stages. The successes experienced by the CSs appeared to rely on structured yet adaptable processes, inclusive empowerment of marginalised voices, trust-building through local intermediaries, and the integration of conceptual models, policy packages and governance assessments to help to bridge technical and local knowledge from early in the process. The transboundary cases (Nestos/Mesta and Lielupe) demanded additional facilitation to harmonise priorities between the SHs, and high-level engagement required clear links to policy processes and outcomes. Combined, the experiences from the CSs indicate the importance of structured and inclusive SHE in the early phases of WEF nexus governance initiatives.

Additionally, relevant lessons were learned from the experiences of conceptualising ecosystems during the SHE process. CS teams rarely explicitly defined ecosystems in the co-exploration phase, assuming the concept to be pre-existing background knowledge. The exception was Lielupe, where the CS team started the process by adopting a clear definition of ecosystems, i.e., terrestrial (land) and aquatic (water) bodies. The interviews conducted by WP5 in 2025 revealed a variety of ways in which ecosystems were conceptualised in NXG, which highlights the ambiguous nature of the concept and that it may not be as uniquely understood as expected. This implicit approach to conceptualising ecosystems within the nexus also meant that definitions were often developed in parallel with the process of incorporating them into the practical tools (SDM/NEPAT/NXGAT), which was guided by the available data and led to data-driven definitions of ecosystems.

Key lessons learned in the co-exploration phase:

- The SHE plans provided a clear framework that ensured clarity, inclusivity, and early conflict identification among SHs.
- Targeted efforts to include low-power, high-interest groups improved equity and uncovered localised insights.
- Pre-existing connections and in-person interactions were more effective for building rapport than virtual engagement.
- Co-developing models fostered shared understanding of nexus complexities and local ownership.
- Framing engagement around concrete policy impacts and involving champions early boosted decision-makers' participation.
- Defining ecosystems before starting its incorporation into the nexus would increase understanding of the concept and coherence in its incorporation.

Co-design phase

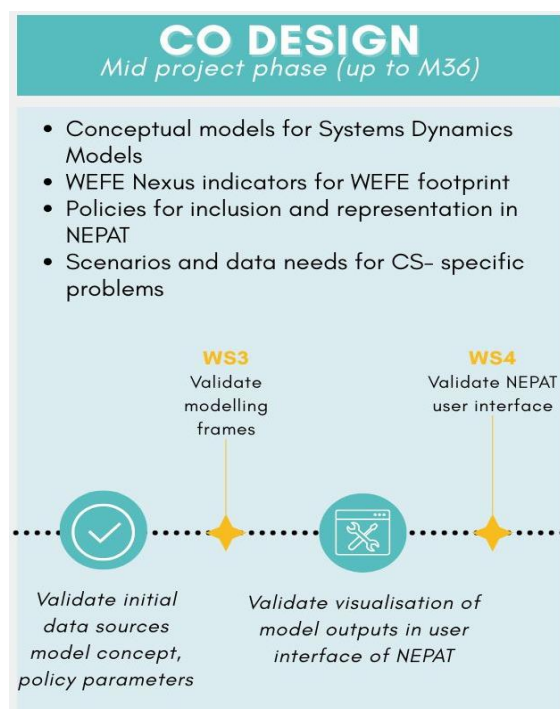


Figure 5: Overview of the co-design phase

The middle phase of SHE focused on validation and co-design, and provided critical insights into effective collaboration, conflict resolution, and tool usability (Figure 5). Across the CSs, the iterative validation of the SDM and the analyses produced by NEPAT revealed both successes and challenges in aligning scientific outputs with SH needs. Key lessons emerged on sustaining participation, the clear definition of roles, and managing conflicts that occurred.

Flexibility and continuous feedback were key for adapting the SHE as the process progressed. The surveys answered by SHs at the workshops revealed their preferences for brief presentations and open discussions, while interim updates such as newsletters in Jiu or bilateral check-ins in Adige helped sustain SH interest in the project between workshops. Adaptive methods, like Inkomati-Usuthu’s focus groups for detailed policy discussions, also

ensured relevance for local contexts. These iterative improvements highlighted the need for responsive mechanisms that evolve with SH needs.

A clear division of the roles between the project partners with technical expertise and SHs was also an essential aspect of the NXG process. In Nestos/Mesta, for example, hydrologists and modellers led the technical development while local SHs validated assumptions, ensuring policy relevance. However, misalignments sometimes arose when model outputs conflicted with local observations. This was the experience in Adige, where SHs questioned basin-scale results that lacked provincial-scale granularity. The Inkomati-Usuthu CS also encountered this challenge, having to remove a policy from analysis in the NEPAT after it became clear that their interpretation differed from that of SHs. It was clear from the engagement with SHs that although the policy was critical within the catchment, the impacts of the policy are still unknown and require further study. This underlined the need for continuous feedback loops in the engagement process, rather than one-off validation sessions, as well as involving SH in policy research from the beginning, rather than solely conducting desk research. The NEPAT tool served as a bridge between the technical partners and the SHs, with hands-on testing enabling SHs to explore policy packages and refine usability of the tool (see additional lessons related to NEPAT below).

Data-driven discussions were also important in the mitigation of transboundary and sectoral conflicts that arose during the process. In Nestos/Mesta, for example, NEPAT visualisations helped the Greek and Bulgarian SHs assess trade-offs objectively (e.g., dam operations versus ecological flow). Similarly, in Adige, presentations and questionnaires during the project workshops allowed discussions to take place around the upstream-downstream dynamics, though resource constraints limited long-term conflict resolution around these

issues. Both examples also highlighted the value of unbiased facilitation and transparent data to help mitigating disputes during the process.

Finally, maintaining SH interest at this stage of the process required addressing technical and logistical barriers. In Inkomati-Usuthu, for example, NEPAT demonstrations compensated for limited internet access among some of the SHs, while the training modules used in Jiu appeared to improve SDM literacy. In general, the co-ownership approach appeared to help sustain SHE, whereby SHs shaped the quantification of policy packages.

Specific experiences with NEPAT

For the CSs, the NEPAT has demonstrated its value in assessing policy impacts across water, energy, food and ecosystems. Its greatest strength, together with the WEF Footprint, appears to lie in transforming abstract nexus concepts into tangible, quantitative insights for diverse audiences. Nonetheless, some key issues emerged during its application. Data limitations presented a significant challenge, as seen in Nestos/Mesta, Inkomati-Usuthu and Adige, where the lack of localised or granular data restricted the effectiveness of the tool. High-quality, scalable data collection and adaptable modelling are, thus, crucial for future improvements to the tool. During workshops, SHs also emphasised the need for quantifiable evidence, with examples from Nestos/Mesta and Jiu showing how NEPAT visualisations and numeric outputs helped policymakers understand complex trade-offs and justify decisions. However, usability barriers, such as the need for hands-on training and simplified interfaces, show the importance of capacity-building for long-term adoption of the tool.

Measuring and modelling ecosystems presented another data-related challenge. The Nestos/Mesta model had capacity within the CS partner team to model ecological flow, which is a critical ecosystem component measuring water flow and the ability of fish to migrate. Similarly, Lielupe succeeded in including indicators related to water quality into the NEPAT model, as a result of successful cooperation between project consortium partners (CS lead and modelling team from IHE) with available time to focus on this task. Other CSs expressed a wish to measure these components in the model, but data and time constraints prevented this in practice. These differences highlighted both the possibilities for improvements of the models where the necessary input data exists, and the value of investing time in the co-design stage on attempts to incorporate ecosystems-related components into the model from various data sources.

Another challenge was the mismatch between the tool's scale and practical policy needs in the CSs. In Adige, for example, basin-level results were irrelevant for provincial planning, while it was difficult to ensure that the tool's output met modelling expectations in Inkomati-Usuthu due to the complexity of the tool and the intricate nature of the underlying SDM. This resulted in delays and limited engagement with the tool during workshops. In the future, aligning outputs with jurisdictional scales and enabling dynamic policy inputs could enhance the tool's relevance. Nonetheless, NEPAT had value in Inkomati-Usuthu in showing trade-offs and synergies, which facilitated additional dialogue between different sectors. In Lielupe, NEPAT showed potential beyond policy making as an educational tool that helped SHs and students to grasp the interconnected nature of sectoral impacts. However, the tool's static data and complex model setup posed limitations for real-time decision-making, which again emphasises the need to be able to update the tool continually. The risk of NEPAT becoming

obsolete can be mitigated by its continued promotion for integration into broader planning and policy processes, and its enhancement with modules to facilitate its updating.

Key lessons learned in the co-design phase:

General

- Defining clear roles for the technical partners and the SHs improved collaboration and helped to keep the process productive.
- Adapting methods, like using newsletters, focus groups and bilateral meetings, helped to maintain SH interest between workshops.
- Addressing technical barriers, such as by providing offline options for training on the tools, ensured that SHs could stay involved.

Specific to NEPAT

- Quantifiable outputs enhanced decision-making, with SHs benefiting from clear visualisations and numeric results that illustrated complex trade-offs.
- Data availability limited effectiveness because insufficient or non-granular data reduced the ability of the tool to quantify and assess policy impacts accurately.
- Usability of the tool depended on training and design - SHs required training and intuitive interfaces for effective long-term use.
- Scalability of the tool affected its relevance for SHs - results needed to fit what local SHs (especially planners) require on the ground.
- Allocating sufficient time and considering alternative data sources is needed to accurately measure and model multiple ecosystem components.

Co-development phase

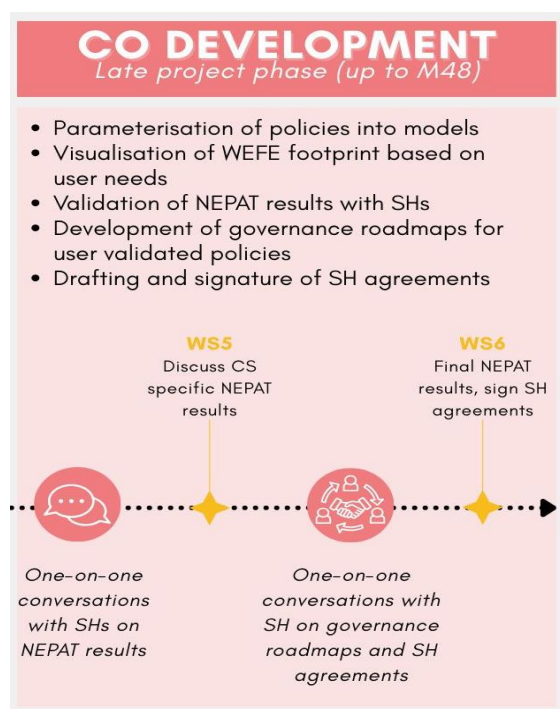


Figure 6: Overview of the co-development phase

The co-development phase of the process provided further critical insights into effective collaboration, SHs reactions to the NXG tools, and the challenges of sustaining engagement (Figure 6). The process of finalising results, testing the NEPAT, and negotiating SH agreements revealed several key lessons.

For transboundary cooperation, one important lesson related to fostering shared solutions. The transboundary cases (Nestos/Mesta and Lielupe) found that joint workshops helped to align priorities despite differences in national administrative processes and sectoral focus. For instance, in Nestos/Mesta, SHs from Greece prioritised ecological flow and irrigation needs, while Bulgarian counterparts focused on solid waste management. The structured dialogue facilitated through NXG workshops enabled mutual understanding and identified common goals, particularly in managing shared water resources. In the Nestos/Mesta CS, SHs

openly shared their opinions and preferences on future priorities and validated the policy packages proposed by NEPAT, which were included in the final agreements during the sixth workshop. These packages focused on common actions aimed at improving the overall management of the river basin. Through structured dialogue, SHs had the chance to share experiences and visions, exchange views and agree on the implementation of specific policies at transboundary level.

In the Lielupe CS, SHs from Latvia and Lithuania engaged in a structured dialogue to validate the policy packages developed within NEPAT and the activities outlined in the governance roadmap aimed at achieving water quality goals in the Lielupe River Basin. This process took place during national focus groups and the sixth SH workshop. Additionally, SHs shared experiences from ongoing initiatives, fostering networking and transboundary cooperation. The workshops provided a platform for open discussions and idea generation on joint activities between Latvia and Lithuania. Common topics addressed included innovative water management solutions, economic assessments of new measures, the existing legal framework, and strategies for improving water quality, such as environmental data exchange, collaborative projects, site visits, SH meetings, and the use of online tools. In this CS, commitment to continued collaboration was reaffirmed through the signing of the Letter of Intent for Cross-sectoral and Cross-boundary Collaboration in the Lielupe River Basin District. The case study lead, BEF, has assumed a coordinating role and serves as the main point of contact for future activities.

Local institutional partnerships were also essential in maintaining SH trust and engagement. In Nestos/Mesta, the active involvement of municipalities as NXG consortium members

strengthened credibility, as SHs were more willing to engage with familiar local authorities. Similarly, in Adige, collaboration with the Province of Trento increased policy relevance, demonstrating how institutional buy-in can enhance the legitimacy of project outcomes. However, long-term engagement remained challenging, with SHs often struggling to commit beyond workshops due to competing priorities or scepticism about influencing higher decision-making levels. Marginalised groups, such as environmental associations in Adige, who at the outset valued the NXG process as a platform for engagement, doubted their ability to drive change.

The NEPAT was a central component of the SHE in this phase, with its quantitative approach to policy assessment being widely appreciated. SHs in Nestos/Mesta found the tool valuable for evaluating trade-offs and validating locally proposed policies, while Lielupe's participants were motivated by its ability to demonstrate transboundary benefits, such as improved water quality through coordinated efforts. However, its complexity also posed barriers. For example, non-technical users in Adige and Inkomati-Usuthu described NEPAT as a 'black box', which signals a need for simplified outputs like the WEFE footprint and tailored training sessions to improve usability. SHs' motivation to use NEPAT also increased when they saw their policy inputs integrated into the NEPAT tool, as observed in Nestos/Mesta and Jiu, where it strengthened the interest for using it in educational processes.

From the CS perspective, implementing the WEFE Footprint also proved challenging due to several basin-specific realities. Although CSs and WP leads agreed that a single set of pillars, sub-pillars and indicators had to be applied uniformly across all five CSs, many of the candidate metrics were only reported at national scale, making them unsuitable for river-basin models and forcing modellers to identify basin-level indicators. During joint reviews with the SDM teams, indicators were dropped whenever several CSs lacked adequate data, or an acceptable proxy. These constraints limited the indicators that would ultimately inform the WEFE Footprint².

Data limitations constrained full sectoral integration in some cases. As already noted above, Inkomati-Usuthu faced gaps in mining and energy data at a basin level, while Adige relied on basin-scale analysis with limitations to uptake results at the finer provincial levels. Also, most of the CSs struggled with availability of data pertaining to ecosystems (see next section for more detail). Despite these challenges, SHs recognised the tool's potential for future refinement in the co-development phase and after the project, provided data accessibility improves.

Overall, the later stages of engagement appear to have successfully solidified SH participation in WEFE nexus issues and validated tools, but sustaining impact will require addressing administrative barriers, ensuring tool usability, and securing institutional pathways for uptake of the policy packages. The NXG experience underscores that while co-creation fosters trust and relevance, long-term success depends on embedding participatory processes within governance frameworks beyond the project lifecycle.

² For more information about the WEFE Footprint, see [D3.7 Final report on the WEFE Nexus Index methodology and visualization](#).

Key lessons learned in the co-development phase:

- Local partnerships boost trust, but long-term engagement is hard without the involvement of regional, national and often the European levels (for CSs in Europe).
- The value of NEPAT is enhanced by easy-to-grasp outputs for non-experts.
- Experiences in this phase confirm that lasting impact within governance systems should be strategically considered throughout the life of a project, from design to adaptive management.
- Common understanding and broadly accepted solutions create a basis for coordinated actions and improve cooperation at the local scale.
- The creation of local coalitions at transboundary level has the potential to support the holistic management of the river and the available resources.
- Knowledge exchange and co-development of solutions and policies support awareness on water-diplomacy issues.
- Language barriers are a limiting factor in the case of transboundary river basins.
- Governance roadmaps facilitate both policy adoption and implementation by clearly outlining the necessary steps and actions for each SH involved.

Reflections on key challenges

The co-creation activities across the five CSs faced persistent challenges in achieving true cross-sectoral collaboration, particularly due to water-centric and project-centric barriers. The energy sector was notably absent or minimally engaged in some cases, highlighting a structural limitation in the project's framing in this regard: it was difficult to engage this sector without a clear value proposition that linked energy interests to water or ecosystem management. In Nestos/Mesta, energy SHs only provided data retroactively, while in Adige national energy companies remained disengaged. Even in Lielupe, SHs representing hydropower plants, which are critical to the nexus, did not participate. However, the energy sector was represented by SH affiliated to wind and solar applications related to the land-use exploitation consequences. In Jiu, however, the energy sector participated more due to extensive outreach by the CS team, and in Inkomati-Usuthu, SHs from the national energy provider showed interest throughout the project, although other representatives from the energy sector were absent. The mining sector was also hard to engage in the Inkomati-Usuthu case.

A deeper issue was the temporal and project-focused nature of SHE, which limited long-term SH ownership. Many participants viewed the initiative as a research exercise rather than a platform for actionable change, particularly when workshops were framed around 'project deliverables' rather than sectoral priorities. This disconnect was evident in Inkomati-Usuthu, for example, where SHs were concerned about water management, but saw NEPAT as an academic tool rather than a decision-making aid. This, coupled with a number of research projects within the catchment that are completed but then sit on the shelf, with no actions/achievements flowing from the project, resulted in SHs questioning the sustainability of outcomes beyond the project's lifespan. Similarly, in Adige and Lielupe, SHs questioned the sustainability of outcomes after the project, reducing their motivation to invest time in co-

creation processes. In Jiu, this challenge was overcome by linking project objectives with active policies and policy targets to which SHs could easily relate to during dialogues.

The water-centric framing of discussions often inadvertently reinforced silos rather than promoting nexus integration. In most cases, non-water sectors perceived workshops as irrelevant to their core interests, leading to lopsided participation dominated by water and ecosystems SHs. For example, in Nestos/Mesta, energy and ecosystem SHs struggled to see their roles in flood management debates. In Jiu, however, reframing active discussions driven by the EU Water Framework Directive around broader sustainable development goals such as climate resilience and regional economic growth successfully attracted and kept diverse SHs around the table. This approach shifted the focus from sectoral conflicts (e.g., water vs. energy) to shared objectives, suggesting that a nexus lens works best when embedded in higher-level policies and wider policy agendas.

Specific challenges when integrating ecosystems into the WEF nexus

CS teams rarely formally agreed on a definition of ecosystems during the co-exploration phase, often treating the concept as pre-existing background knowledge. However, interviews conducted by WP5 in 2025 revealed a range of interpretations of what ecosystems mean within the NXG framework. This diversity highlights both the conceptual ambiguity of ecosystems and the fact that the term may not be as universally understood as initially assumed. For instance, while some CSs made a distinction between terrestrial and aquatic ecosystems (e.g., Lielupe), others approached ecosystems through the lens of ecosystem services, or framed them in terms of biodiversity protection.

Moreover, nearly all interviewees acknowledged the inherent ambiguity of the ecosystem concept and the difficulties associated with its inclusion. Part of this challenge stems from the interconnectedness of ecosystems and their overlap with other WEF nexus components, particularly water and food (via land and water use). This interdependence made it difficult for CSs to assign elements to a single sector and continues to complicate efforts to describe ecosystems as a distinct category.

The transition from qualitative conceptual maps to quantitative SDMs/NEPAT posed further difficulties, especially in relation to ecosystems. Given its broad scope, the concept requires the measurement of multiple aspects, yet only a few could be effectively modelled due to data limitations. This is unfortunate, as it suggests that even deliberate attempts to integrate ecosystems tend to result in a constrained and partial representation. In many cases, these limitations prompted a shift toward a more data-driven definition of ecosystems.

Frequently measured components included land use (such as forests and protected areas) and dealt with the land use consequences from agriculture (nitrogen pollution levels), and quantitative water availability (which overlaps with the water sector). At the same time, many respondents expressed a strong interest in including ecological flow and water quality, both of which are more difficult to capture with current data. These findings point to a clear need for greater investment in measuring key ecosystem variables to enhance the quality and relevance of models intended to support policy-making.

Impact assessment

NXG aims to support a shift in governance frameworks towards holistic WEF E Nexus management, through the evidence-based and co-created policy scenarios. At the CS level, the following impacts were anticipated within the duration of the project (see [D6.11 Policy Impact Strategy](#) for more detail).

- a. Facilitate collaboration among conflicting SHs at the transboundary scale;
- b. Willingness of SHs to use learning tools;
- c. Validation of trade-offs and win-win solutions within the WEF E nexus;
- d. Validation of upstream water policy plans affecting water flow/quality, ecosystem sustainability and energy production capacity downstream;
- e. Enhanced knowledge and understanding of WEF E nexus behaviour, including trade-offs to avoid.

D6.11 also includes a specific impact (Impact 2) relating to ‘mainstreamed use of “ecosystems” in nexus thinking and associated policymaking’.

While each CS in NXG reflects unique regional challenges and SH dynamics, common themes have emerged in the SH engagement process in relation to trust-building, capacity building, cross-sectoral collaboration, and the integration of the WEF E nexus approach into governance frameworks.

One of the most prominent impacts across the CSs is the strengthening of trust between SHs and project partners. In Nestos/Mesta, for example, participatory planning - which is generally uncommon in Greece and Bulgaria - has led to unexpected cooperation between Greek and Bulgarian SHs, who identified shared challenges such as water loss reduction and renewable energy generation. Similarly, in Lielupe, Nestos/Mesta and Jiu, SHs have become increasingly engaged as they saw their inputs reflected in project outputs like the conceptual model, policy packages, adjustment of data sets for SDM and NEPAT. This trust was often tied to the emphasis in NXG on scientific evidence and transparency, particularly through the NEPAT. Experiences across the CSs suggested that SHs were especially responsive to data-driven discussions, though maintaining engagement outside formal workshops remained a challenge.

Capacity constraints have emerged as a recurring barrier, particularly in Lielupe, Jiu and Inkomati-Usuthu. Municipalities in Lielupe attributed this to insufficient personnel and uneven resource distribution, while SHs in Jiu noted their limited influence over high-level policy changes despite increased awareness of WEF E interactions. SH in Inkomati-Usuthu have highlighted a lack of the necessary skills and training within municipalities to ensure effective policy implementation within the basin. However, the NXG project has facilitated capacity-building by introducing tools like NEPAT and fostering knowledge-sharing platforms. For instance, in Jiu the sustainable development authority expressed interest in incorporating NXG methodologies in the activities of policy working groups in each of the WEF E Ministries, and SHs from the academic sector have tested the methods in education processes, thus signalling potential long-term institutional impact.

Increased cross-sectoral collaboration was another key impact of the project, with SHs in multiple cases recognising the value of integrated resource management. This was

demonstrated strongly in Inkomati-Usuthu, where workshops have enabled SHs to engage in inter-sectoral discussions fostering opportunities for inter-sectoral partnerships to be established, and the NEPAT tool has helped identify synergies and trade-offs in policy implementation. Nestos/Mesta has similarly noted a growing willingness among SHs to form local coalitions advocating for nexus-based approaches (see Box 1). Such transboundary and multi-sector cooperation has faced structural roadblocks in Lielupe, where collaboration between Latvian and Lithuanian municipalities has remained project-dependent rather than institutionalised.

Box 1: Engagement and collaboration in Nestos/Mesta

The growing willingness among SHs to advocate for nexus-based approaches was expressed through:

- the broad participation of both Greek and Bulgarian stakeholders in two international workshops organised in March 2023 (third SH workshop) and in May 2025 (sixth SH Workshop);
- the participation of the mayor of Nestos Municipality (Greece) and the mayor of Gotse Delchev Municipality (Bulgaria) in the project workshops;
- the signing of the final agreements focusing on the continuation of the co-creation processes beyond the completion of NXG;
- the SH endorsement of the governance roadmaps, and the mobilization of financial mechanisms supporting the implementation of the policies included in roadmaps
- promotion of policies in local communities and their further development within the framework of other projects.

Two agreements were signed during the sixth SH workshop. The Bulgarian agreement was signed by the mayor of Gotse Delchev Municipality and the mayor of Nestos Municipality. The Greek agreement was signed by the mayor of Nestos Municipality, the mayor of Gotse Delchev Municipality, the representative of Civil Protection (Greece) and the president of the Nestos Farmers' Association (Greece).

Policy impact varied across cases, reflecting differences in governance structures and SH influence. In Nestos/Mesta, while local SH-supported policies like modernising irrigation systems, implementation depends on national-level decisions, limiting local agency. The experiences in Adige have underscored the challenge of translating basin-level insights into provincial policymaking, despite some SHs championing the nexus approach. Conversely, there were concrete commitments in Inkomati-Usuthu, such as integrating NXG outputs into catchment management forums, which create potential for sustained impact in that case.

The project's tools, particularly NEPAT and the governance roadmaps, have proved instrumental in bridging science and policy. SHs in Inkomati-Usuthu used the decision-support system to identify viable policy scenarios, while those in Jiu saw NEPAT as a means to streamline national policy evaluations. SHs in Nestos/Mesta, Lielupe and Inkomati-Usuthu validated policy packages included in the NEPAT, which were further elaborated in the context of governance roadmaps. However, data limitations, as noted in Adige, for example, sometimes hindered tool reliability, emphasising the need for improved monitoring and data updating and sharing mechanisms.

Despite these challenges, NXG has succeeded in raising awareness and fostering dialogue on WEF nexus governance. In Nestos/Mesta and Lielupe, the SHE process has empowered SHs to advocate for integrated solutions, even in regions where such approaches were previously untested. In Adige and Jiu, the importance of aligning project tools with SH needs has been demonstrated, which may be done through technical modelling or policy evaluation frameworks.

Overall, the NXG co-creation activities appear to have maximised impact by adapting to the local contexts of the CSs, while promoting shared principles of co-creation, scientific rigor, and cross-sectoral integration. While institutional and capacity barriers persist, the CSs collectively illustrate how sustained engagement, tailored tools, and SH empowerment can advance WEF nexus thinking in diverse governance settings. The lessons learned in this report underscore the importance of flexible, context-sensitive approaches to ensure that research outcomes can be translated into tangible policy and practice improvements.

Recommendations

The lessons learned during the NXG co-creation process inform 17 evidence-based recommendations for future WEFE Nexus projects. These are grouped according to the three phases of the process (co-exploration, co-design, co-development) and the guiding themes in the analytical framework (Table 2).

Collectively, the recommendations aim to address the recurrent structural, operational and motivational challenges experienced in the CSs. By offering actionable pathways, they are intended to enhance co-creation and policy impact in future WEFE nexus projects. The thematic grouping also allows projects to prioritise relevant recommendations based on their specific context and stage in the co-creation process.

Co-exploration phase

The guiding themes of the co-exploration phase in the analytical framework relate to (1) including all relevant expertise and stakes; (2) reaching a common understanding of the problem; (3) agreeing on a common research question and success criteria; and (4) a methodological framework for collaboration. This phase in NXG was particularly successful in establishing trust and shared understanding among SHs (theme 2) through structured processes and inclusive engagement. However, challenges in attracting high-level policymakers and broadening sectoral participation (theme 1) highlighted some areas for future refinement. On this basis, three recommendations are made for the co-exploration phase:

CO EXPLORATION

Early project phase (up to M18)

RECOMMENDATION 1 → Define ecosystems before integration to ensure clarity of the concept and local relevance

RECOMMENDATION 2 → Expand nexus framing beyond water-centric discussions to attract underrepresented sectors

RECOMMENDATION 3 → Engage high-level policymakers early by linking nexus goals to their priorities

RECOMMENDATION 1 → Define ecosystems before integration to ensure clarity of the concept and local relevance

NXG demonstrated that ecosystems were often assumed to be universally understood by CSs, rather than defined explicitly. Determining an understanding of ecosystems at the outset, before developing conceptual maps or data models (SDMs/NEPAT), would help to reduce complexity by shaping a shared interpretation of the term. This includes selecting relevant ecosystem categories, considering ecosystem services, ecosystem health (biodiversity), and/or land use, and could involve reflecting on interlinkages with other sectors. Based on WP5 interviews with CS teams, it is recommended to begin with a general definition and framework for ecosystems, which can then be narrowed to the specific local

context. This is something SHs could be invited to assist with to ensure both conceptual clarity and local relevance. Ecosystems could be positioned at the centre of the nexus, surrounded by the other WEF sectors. This would encourage SHs to reflect on bidirectional influences, an approach believed to foster more effective incentives for change³.

RECOMMENDATION 2 → Expand nexus framing beyond water-centric discussions to attract underrepresented sectors

The absence of the energy sector from the NXG engagement process in some CSs underscored the limitations of water-dominated framings in NXG. In Nestos/Mesta, energy SHs only engaged when discussions shifted to the economic value of hydropower and the exploitation of the hydrological model developed and covering the entire transboundary river basin. The success in Jiu in attracting diverse participants was a result of framing nexus goals as part of sustainable development more broadly: in this case, water management was aligned with job creation, energy security, and EU Green Deal compliance. Future projects should identify and emphasise sector-specific entry points: energy SHs may engage around grid resilience or renewable revenue streams, farmers around soil health or subsidy access, and industry around ESG compliance or operational efficiencies. The Adige case also showed that embedding nexus tools within sectoral planning processes such as provincial energy audits could normalise integrated thinking better than standalone 'nexus' workshops.

RECOMMENDATION 3 → Engage high-level policymakers early by linking nexus goals to their priorities

Engaging decision-makers was a persistent challenge in NXG, with CSs' experiences showing how securing participation from national, regional and local decision-makers required demonstrating the direct relevance of nexus projects to their mandates. For example, in Nestos/Mesta, energy-sector SHs only engaged retroactively and through personal, face-to-face bilateral meetings when data gaps became apparent, while in Adige, provincial leaders joined workshops only after preliminary results aligned with their water management goals. There was success in Jiu through making an explicit connection between the tools and Romania's '*Just Transition*' funding initiative, which resonated with policymakers' economic priorities. It is therefore recommended that future projects conduct a pre-engagement scoping study to identify the incentive for SHs. These might include regulatory compliance, funding access, or climate adaptation and energy security pressures (e.g., the role of hydropower in drought resilience). The planned nexus activities could then be framed as solutions to these priorities, rather than purely environmental or water-centric framings.

³ Over time, ideas on how to incorporate ecosystems into the Nexus have evolved. At the start of NXG, the standard approach was to include ecosystems as a separate, fourth system. However, multiple perspectives have since emerged. Lucca et al. (2025) outline three distinct approaches for incorporating ecosystems into the WEF nexus, based on a literature review: as a fourth system, as a foundational element underpinning each of the other systems, or by situating the Nexus within a broader socio-ecological system. They ultimately recommend a hybrid approach, combining elements of all three to capture the full complexity of ecosystem interactions within the nexus framework. This paper can serve as one potential resource when deciding on the integrating of ecosystems in future nexus work.

Co-design phase

The guiding themes in this phase of the analytical framework relate to (1) having a clear definition of tasks and roles; (2) methods suitable for generating solutions; (3) conflict management procedures; and (4) capabilities for sustained participation. Experiences during the co-design phase of NXG highlighted the importance of adaptive engagement methods, unbiased facilitation, and SH-driven tool development. Challenges included data limitations and sustaining participation, particularly among non-technical SHs. Building on the lessons learned, eleven recommendations are made for the co-design phase:

CO DESIGN Mid project phase (up to M36)

Structuring engagement for effective collaboration

RECOMMENDATION 4 → Embed projects within existing governance structures to avoid parallel systems

RECOMMENDATION 5 → Create feedback loops between local and national stakeholders to address governance tensions or imbalances

RECOMMENDATION 6 → Use unbiased, experienced and trusted facilitators to bridge sectoral and transboundary divides

RECOMMENDATION 7 → Establish sector-specific 'champions' to drive engagement within their domains

Adapting methods for inclusive participation

RECOMMENDATION 8 → Develop tiered engagement strategies to accommodate varying stakeholder capacities

RECOMMENDATION 9 → Design flexible engagement formats to sustain participation

RECOMMENDATION 10 → Invest in measuring aspects of ecological flow and water quality to improve models and policy-making

Co-designing usable and relevant tools

RECOMMENDATION 11 → Adapt tools like NEPAT to local contexts through co-design, simplification and flexible updates

RECOMMENDATION 12 → Address data gaps proactively by collaborating with local agencies

RECOMMENDATION 13 → Balance technical rigour with accessible communication and visualisation to engage non-experts

RECOMMENDATION 14 → Consider integrating gender and equity analyses explicitly into nexus assessments

Structuring engagement for effective collaboration

RECOMMENDATION 4 → Embed projects within existing governance structures to avoid parallel systems

Embedding NXG activities within routine governance processes was a success in some of the NXG CSs, as this reduced SH fatigue and leveraged institutional memory. For example, Jiu's syncing with the existing strategies of the river basin authority and Lielupe's alignment with NGO-led platforms ensured continuity. The Nestos/Mesta case also demonstrated that creating entirely new transboundary coalitions required excessive time and resources. Future efforts could instead integrate with pre-existing cross-border agreements or regional development agencies. This approach would also mitigate the risk of dismissal from SHs of "just another research project," a perception that undermined SH engagement to some extent in Inkomati-Usuthu and Adige. However, projects should evaluate which processes, initiatives and institutions add credibility, relevance or legitimacy required to advance their efforts – and not simply dovetail with other efforts simply to reduce duplication.

RECOMMENDATION 5 → Create feedback loops between local and national stakeholders to address governance tensions or imbalances

A common frustration in the NXG CSs was the inability of local SHs to influence national policies. In Jiu, this challenge was partially addressed by using the river basin authority and its role in the river basin committee as an intermediary, though more structured mechanisms are needed. Future projects should therefore attempt to institutionalise upward feedback channels, such as mandated local input to national policy processes or joint working groups with representation from the regional level. The Inkomati-Usuthu experience demonstrated that when local catchment management forums lacked formal links to mineral/energy ministries, and critical conflicts remained unresolved (e.g., mining *versus* water allocation).

RECOMMENDATION 6 → Use unbiased, experienced and trusted facilitators to bridge sectoral and transboundary divides

The NXG CSs consistently highlighted that trust-building across sectors and borders depends on facilitators who are perceived as impartial, locally credible and deeply knowledgeable about local contexts. In Jiu, for example, a facilitator with 30 years of regional experience successfully mediated between agriculture and energy SHs by leveraging pre-existing relationships and understanding unspoken political dynamics. Interestingly, in the case of Inkomati-Usuthu, their pragmatic reliance on external SHs without strong local ties (though they had deep knowledge of the local context) led to difficulties in institutionalising SH engagement beyond the project lifespan. Transboundary cases like Nestos/Mesta further emphasised the need for unbiased facilitation - Greek and Bulgarian SHs only embraced shared solutions when discussions were moderated by a university team that was perceived to be independent of political stakes. Future projects should therefore allocate dedicated resources to recruiting or training impartial facilitators with both technical credibility (e.g., nexus expertise) and contextual legitimacy (e.g., familiarity with regional governance structures), ensuring they remain engaged beyond single workshops to sustain dialogue.

RECOMMENDATION 7 → Establish sector-specific 'champions' to drive engagement within their domains

The NXG CSs experienced persistent difficulties in engaging SHs from certain sectors who often perceived nexus projects as irrelevant to their core interests. This was particularly the case for the energy sector. In Jiu, it became apparent that when local energy experts became active advocates for the process and translated nexus benefits into sector-specific language (e.g., a positive impact of energy sector actions for water quality), participation improved significantly. Future projects should thus try to identify and empower technical-level champions within reluctant sectors, and provide them with targeted training and incentives. These might include leadership recognition and access to sectorally relevant data outputs, for example. The experience in Inkomati-Usuthu demonstrated that without such intermediaries, even well-designed tools like NEPAT may fail to access siloed sectors like mining.

Adapting methods for inclusive participation

RECOMMENDATION 8 → Develop tiered engagement strategies to accommodate varying stakeholder capacities

The ability of SHs to engage in the NXG process varied markedly within and between the CSs. There was a wide range of capabilities, from data-literate policymakers to resource-constrained small farmers. Because of this, future projects should systematically assess and segment SHs by both influence and capacity, then design engagement activities accordingly. The experience in Adige highlighted the risks of a one-size-fits-all approach when farmers disengaged from overly technical workshops. Lielupe applied differentiated engagement approaches - technical working groups, and visual conceptual models. In Jiu, different SH tiers were engaged from the outset of the project, with active participation and capacity building among technical experts, enabling them to effectively communicate messages to higher decision-making levels.

RECOMMENDATION 9 → Design flexible engagement formats to sustain participation

SH attrition due to competing priorities, fatigue, or logistical barriers was a cross-cutting challenge in NXG. Hybrid (online/in-person) workshops in Inkomati-Usuthu accommodated officials with limited travel budgets, while Jiu's targeted follow-ups (e.g., through newsletters and bilateral calls) kept SHs informed between formal meetings and workshops. However, rigid schedules sometimes backfired and caused disengagement. Future projects should therefore adopt adaptive scheduling, such as shorter but more frequent check-ins, and offer multiple participation levels (e.g., core group for co-design, broader consultations for feedback). The Lielupe and Jiu CSs also demonstrated that informal settings like shared meals or field visits could rebuild momentum when formal workshops stalled. Critically, virtual engagement must be complemented by face-to-face options for SHs with limited connectivity, as seen in the NEPAT demos in Inkomati-Usuthu.

Co-designing usable and relevant tools

RECOMMENDATION 10 → Invest in measuring aspects of ecological flow and water quality to improve models and policy-making

All NXG CSs expressed the desire to measure ecological flow and water quality, components they consider vital to ecosystem health. These aspects both influence and are influenced by all other sectors, making their inclusion in modelling tools crucial for generating an accurate picture to support policy-making. Each of these aspects was successfully modelled by at least one CS, highlighting the value of collaboration across CSs to share knowledge and jointly address common challenges. In cases where data limitations persist, CSs also recommend exploring alternative data sources, such as qualitative data, to enrich the modelling process and capture key ecosystem components.

RECOMMENDATION 11 → Adapt tools like NEPAT to local contexts through co-design, simplification and flexible updates

While SHs across the CSs valued the ability of the NEPAT to quantify policy trade-offs, the effectiveness of the tool hinged on customisation to local needs. In Adige, for example, basin-scale model outputs were ignored by provincial policymakers who required finer-grained data, whereas in Jiu, SHs actively used the tool because it incorporated their co-designed scenarios (e.g., irrigation policies tied to energy costs). Simplified visuals in the WEF footprint and the training modules improved accessibility where SHs had some difficulties understanding the tool. It is suggested that future tool development should integrate SH feedback iteratively. This could be done by prototyping dashboards in local languages or aligning data scales with jurisdictional boundaries. Additionally, embedding tools within existing decision-making workflows, such as river basin committee meetings in Jiu, were found to enhance long-term adoption beyond project timelines. Tools should also support flexible updates and iterative feedback loops.

RECOMMENDATION 12 → Address data gaps proactively by collaborating with local agencies

The use of NEPAT was frequently constrained by missing or mismatched data, particularly for underrepresented sectors such as energy and mining, and those SHs working on issues related to ecosystems. In Inkomati-Usuthu, the absence of localised mining impact data forced SHs to rely on generic assumptions, while Adige's provincial authorities dismissed basin-wide models due to discrepancies with their own datasets. Proactive partnerships with data holders, such as national statistical offices, utilities, or industry associations, could have pre-empted these issues. Where possible, future projects should initiate joint data-collection initiatives with local agencies early in the process, to ensure access to granular, sector-specific data, and align metrics with SH needs (e.g., municipal water-use records for city planners, crop-yield correlations for farmers). In transboundary contexts like Nestos/Mesta, harmonising data standards across borders is essential. In this case, the project's retroactive data requests from Bulgarian energy SHs delayed analyses and eroded trust.

RECOMMENDATION 13 → Balance technical rigour with accessible communication and visualisation to engage non-experts

While scientific robustness gave credibility to the tools developed during the project, overly technical presentations of these tools alienated key NXG SHs. In Adige, for example, agricultural producers disengaged when workshops focused on the details of hydrological modelling, whereas Lielupe's use of visual conceptual maps and sticky-note exercises made nexus linkages more tangible for diverse participants. Jiu successfully bridged this divide by pairing quantitative policy packages with narratives about local livelihoods, such as how energy-efficient irrigation could reduce farmer debt. Future engagement should employ tiered communication strategies: e.g., high-level summaries for policymakers, interactive demos for practitioners, and hands-on training for technical staff. Tools must also accommodate varying literacy levels.

RECOMMENDATION 14 → Consider integrating gender and equity analyses explicitly into nexus assessments

While implicit in some CSs (e.g., marginalisation of smallholder farmers in Nestos/Mesta), systematic attention was not paid to gender and social equity in NXG. Discussions in the Inkomati-Usuthu catchment about water allocation, for example, suggest that the activities in this CS would have benefited from gender-disaggregated data on water use, given women's dominant role in small-scale farming and their role within family structures. Future projects could therefore examine any possible gender and equity disparities in the nexus assessment process.

Co-development phase

The guiding themes in the analytical framework relate to (1) implementing project results to resolve the problem; (2) integrating results into scientific and societal practice; (3) providing appropriate outputs for SH; and (4) achieving goals and unanticipated positive effects.

The experiences in the NXG CSs in the co-development phase emphasised the importance of institutionalising outcomes and leveraging unexpected events or crises for sustained impact. Challenges mainly related to post-project disengagement and sustaining cross-sector involvement. Three recommendations are therefore made for the co-development phase:

CO DEVELOPMENT
Late project phase (up to M48)

RECOMMENDATION 15 → Leverage crises as windows of opportunity for nexus collaboration but plan for post-crisis sustainability

RECOMMENDATION 16 → Leverage private sector partnerships to sustain tools and platforms after the project

RECOMMENDATION 17 → Secure long-term funding or institutional anchoring to prevent post-project disengagement

RECOMMENDATION 15 → Leverage crises as windows of opportunity for nexus collaboration but plan for post-crisis sustainability

During the NXG process, acute challenges like droughts or floods tended to unify SHs temporarily. For example, Greek and Bulgarian SHs in Nestos/Mesta found common ground during water scarcity debates, while Lielupe's nutrient pollution as a key issue has spurred Latvian-Lithuanian dialogue. However, these gains often disappeared once the urgency subsided, revealing a potential window of opportunity provided by institutionalising crisis-driven cooperation. Future projects should consider capitalising on crisis moments to establish permanent governance structures, such as cross-sectoral task forces or shared funding pools for resilience measures. This was exemplified in Jiu, where post-workshop actions have been linked to Romania's climate adaptation budget, ensuring drought responses became systemic rather than reactive.

RECOMMENDATION 16 → Leverage private sector partnerships to sustain tools and platforms after the project

Most NXG CSs relied on public funding, leading to concerns about tools and platforms becoming obsolete after the project ends (e.g., where these are based on static data that is not updated). Future projects should explore co-investment models with private actors who would benefit from nexus tools and therefore secure long-term tool maintenance (e.g., NEPAT updates). This may include agricultural insurers supporting climate-resilient irrigation modules in NEPAT, or energy companies funding transboundary data platforms like those needed in Nestos/Mesta. Public-private partnerships could also maintain engagement infrastructure (e.g., by paying the salaries of local facilitators) and address post-project abandonment of the tools and platforms. However, projects should have the legal expertise onboard (or budget for legal services) to skilfully manage discussions and partnerships around issues around open data, ownership, intellectual property rights, etc.

RECOMMENDATION 17 → Secure long-term funding or institutional anchoring to prevent post-project disengagement

The temporal nature of project-based funding repeatedly undermined the sustainability of the NXG processes and tools. In Adige, for example, the departure of a single provincial champion at the end of their project-based employment halted progress, while SHs in Inkomati-Usuthu were concerned that NEPAT would become obsolete without updates. In contrast, nexus tools in Jiu aim to be integrated into Romania's Sustainable Development Strategy as well as the planned updates of the River Basin Management Plans at national scale, to ensure post-project relevance. Similarly, in Lielupe, embedding project outcomes into the ongoing advocacy work of an NGO ensures continuation. Where possible, future initiatives should therefore seek to align with institutional budgets (e.g., earmarking nexus issues in municipal plans) or secure multi-phase funding from inception. Experiences in the Nestos/Mesta case also suggested that formalising transboundary commitments such as joint monitoring agreements could ensure cooperation beyond *ad hoc* workshops. Without such anchoring, even successful SH engagement risks being dismissed as an academic exercise and duplicating rather than advancing existing efforts, which was a recurring critique

in Inkomati-Usuthu and Adige. It is also worth exploring options to cluster with related nexus projects in a specific area, to harmonise efforts, avoid duplication, share resources, reduce SH fatigue and achieve collective impact. Lielupe, for example, employed this strategy by dedicating time during workshops for other initiatives to briefly present their work and participate in networking sessions. This stimulated discussions on collaboration, revealed previously unknown funding opportunities, and ultimately helped secure a SH agreement.

Conclusion

The experiences and lessons learned from the co-creation process in the NXG project highlight both the potential and the challenges of co-creation in advancing WEF nexus governance. By fostering structured dialogue, NXG built trust among stakeholders, particularly in transboundary settings where divergent priorities often complicate cooperation. Tools such as NEPAT proved valuable in translating complex interdependencies into actionable insights, enabling SHs to assess policy trade-offs and identify synergies. However, the project also revealed persistent barriers, including data gaps, uneven sectoral engagement, and the difficulty of maintaining momentum after initial workshops.

Looking ahead, the lessons from NXG suggest that long-term success hinges on institutionalising participatory processes within existing governance frameworks. Without formal anchoring in policy cycles or funding mechanisms, even well-designed tools risk becoming obsolete. Future WEF nexus initiatives should prioritise adaptive engagement methods that accommodate diverse SH capacities, from technical experts to local communities. Additionally, aligning nexus discussions with broader policy agendas, such as climate resilience or sustainable development, can help attract sectors that were underrepresented in the NXG workshops.

Ultimately, the NXG project demonstrates that meaningful progress in WEF nexus governance requires more than innovative tools; it demands sustained commitment to collaboration, equitable participation, and institutional support. By applying the suggested recommendations during each phase of the co-creation process, future efforts could transform nexus research even further into lasting, cross-sectoral solutions that address the interconnected challenges WEF nexus governance.

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Annexes

Annex 1 - Case study summaries

This annex includes a brief description of each CS, the main challenges faced, and the expected outcomes for that CS.

CS1 Nestos/Mesta river



Nestos/Mesta is a transboundary river situated in the Balkan area. It springs from the Rila Mountains in Bulgaria and discharges in the Thracian Sea, Northern Greece. Its basin covers an area of 5,479 km² (approximately 2,000 km² in Greek territory), and its length is about 243 km. The greater part of Nestos/Mesta river basin is (semi-)mountainous; the only exception is the delta area (estuaries).

The river forms a significant ecosystem throughout its course and its delta is a unique ecosystem protected by the Ramsar Convention. It is also considered as a first priority site under EU Natura 2000. In the early 1990s, two dams were constructed mainly for electricity production purposes, in the Greek part of the river, Thissavros and Platanovrisi (170 m and 95 m height, respectively), by the Greek Public Power Corporation S.A. at a distance of 30 km and 45 km respectively from the Greek-Bulgarian border. The dams, besides energy production, cover the irrigation needs of the highly cultivated areas downstream and regulate the ecological flow throughout the year. Moreover, an irrigation dam was constructed near Toxotes village, which distributes part of the flow to the irrigation network of the delta plain.

Small towns and villages are located within the Nestos/Mesta river basin and the main activities supporting local income are agriculture and livestock. Aquaculture and mussel farming activities are also taking place within the Nestos Delta region. High value crops (e.g., kiwi) are intensively cultivated and thus, seasonal water resources management is a major issue that needs to be resolved to overcome the conflicting water uses between electricity production and irrigation needs. Water is also needed to maintain the sensitive and protected Nestos Delta ecosystem. Finally, it should be mentioned that the region is an important transit hub as the airport of Kavala and the port of Keramoti serve nationally and internationally significant tourist flows, especially during the summer.

WEFE nexus components

| Water sector | Energy sector | Food sector | Ecosystems |
|--|--|--|--|
| <p>Flood Management and Water Diplomacy:</p> <p>Key priorities include flood risk assessment through models that will support the design of relevant infrastructures, and policies addressing water pollution from agricultural runoff and plastic waste.</p> <p>Water Use Conflicts:</p> <p>Competing demands from irrigation, hydro-power, and ecological flow preservation, particularly critical during summer. Maintaining ecological flow is essential for ecosystem health.</p> <p>Water saving by the agricultural sector (reduction of water losses) and efficient use of irrigation water.</p> | <p>Hydropower and Conflicts:</p> <p>Electricity production from two dams (Thissavros and Platanovrisi) regulates downstream water flow but limits water availability for irrigation.</p> <p>Renewable Potential:</p> <p>Rich geothermal resources and opportunities for cultivating energy crops and expanding photovoltaics on low-productivity land.</p> | <p>Climate Impact on Agriculture:</p> <p>Increased irrigation needs due to climate change affect high-value crops like kiwis, grapes, and asparagus. Diverse agricultural and livestock production supports the local food supply chain.</p> <p>Aquaculture:</p> <p>Significant activity includes fish and mussel farming.</p> <p>Cultivation of dynamic crops:</p> <p>Cultivation of crops with export capabilities based also on RIS3 strategy.</p> | <p>Ecological Significance:</p> <p>The Nestos/Mesta river basin is a critical ecosystem in the Southern Balkans, protected under the Ramsar Convention and the EU NATURA 2000 network.</p> <p>Threats:</p> <p>Fluctuating ecological flow, coastal erosion, climate change impacts on flora and fauna, flood risks, and drought.</p> <p>Reforestation activities are suggested, supporting CO2 sequestration and ecosystem viability.</p> <p>Tourism:</p> <p>Natural beauty attracts summer visitors, highlighting the ecosystem's economic and environmental importance.</p> |

Dominant nexus issues

- Ecologically-significant **delta**
- **Hydropower** activities
- Flood risk
- Coastal erosion
- Water **diplomacy** issues – up-/downstream countries
- Water quality – surface and groundwater pollution
- **Water uses** (irrigation, power production, ecological flow) – management of conflicts



- Climate change **impacts on aquatic ecosystem** (food production, threats on flora and fauna, water deficit, etc.)
- Cultivation of water-demanding crops - Increased needs for irrigation water

The main nexus issues addressed during the project include water use, energy production, ecosystem health and food production. The Nestos river basin is among the low-income regions in Greece. The prevalent economic sectors supporting local income are agriculture and livestock, and there is limited industrial activity which is more pronounced in the Bulgarian part. Within the basin, intensive agricultural activities are taking place and water-demanding crops are cultivated. This entails high demand for irrigation water, particularly during the Mediterranean summer, which, in turn, creates conflicts between the energy and water sectors as to the fair allocation of the available water resources. Livestock activities also demand significant volumes of water. Over-pumping groundwater has emerged as a problem, threatening water balance of the groundwater aquifer and resulting in impacts on wetland ecosystems. Thus, water use conflicts and sustainable management of the available surface and ground-water resources constitute important issues that should be taken into consideration.

Expected outcomes

The aims of SHE are⁴:

- To generate system knowledge:
 - Deepen into existing problems
 - Explore possible conflicts and synergies among SHs
 - Identify pressures in all sectors (water availability/quality, ecosystem, climate, extreme events, energy generation, agricultural/food production etc.)
 - Provide data for model development
 - Inform the research team about plans/projects that are in progress
- To generate target knowledge:
 - See which are their future expectations/perspectives
 - Set future goals
 - Co-creation of possible solutions/responses to current/future challenges
- To generate transformation knowledge:
 - Design suggestions and a river contract proposal (final agreement)
 - To build a trustful relationship among project partners and local SHs
 - Design pathways/policies through which the study system will achieve future goals and 'pass' from the current to the desirable future state

⁴ In NEXOGENESIS, we structured the co-created knowledge in three types (ProClim 1997):

- System knowledge: knowledge about the current state of the real-world situation and its context
- Target knowledge: knowledge about the desired target state
- Transformation knowledge: knowledge about the pathways from the current to the target state

CS-Leads were asked to write these aims along the co-creation of the three different types of knowledge, based on their perspectives and contextual insights on the CS's situation. Meetings were held with them to identify the system, target, and transformation knowledge that should be created to fulfil the project's goals as well as to tackle the problem(s) that they perceive relate to the project.

- To establish a group of key SH that will exploit the outcomes of the project and disseminate relevant results (policies, solutions) to higher levels of administration (e.g. decision-makers at national level).

CS2 Lielupe river



The Lielupe CS is in the lowland part of north-eastern Europe and covers the territory of the transboundary Lielupe river basin - ca. 17,788 km² shared almost equally between Latvia and Lithuania. Around 12% of the Latvian population and around 11% of the Lithuanian population live in this territory. The land area of the basin is predominantly used for agriculture but also

includes large areas of forests and urban areas, as well as wetlands and floodplain meadows with protected areas and nature parks. The topography, climate and high soil fertility make suitable conditions for agricultural activities significantly contributing to the economy of the region. Other economic activities in the Lielupe CS relate to trade and transport services, as well as the processing industry and public services.

In Latvia, the third Lielupe River Basin Management Plan and Flood Risk Management Plan 2022 – 2027 has been elaborated by the Latvian Environment, Geology and Meteorology Centre, under the supervision of the Ministry of Environmental Protection and Regional Development (MEPRD). Involvement of the main SHs, for example municipalities (local governments) and non-governmental organisations, in the planning process is achieved by means of River Basin District Consultative Boards.

After completion of the administrative territorial reform in 2021, the Lielupe river basin comprises 12 municipalities in the Latvian territory: Tukums, Saldus, Dobele, Jelgava, Bauska, Mārupe, Ogre, Aizkraukle, Jēkabpils, Augšdaugava, Ķekava, Olaine, and two state cities: Jelgava, Jūrmala.

In Lithuania, the third Lielupe River Basin Management Plan 2022-2027 is being developed by the Lithuanian Environmental Agency. The Lielupe river basin includes 11 district municipalities in Lithuania: Biržai, Joniškis, Pasvalys, Akmenė, Pakruojis, Šiauliai, Rokiškis, Kupiškis, Panevėžys, Radviliškis, Anykščiai and two city municipalities: Panevėžys and Šiauliai.

WEFE nexus components

| Water sector | Energy sector | Food sector | Ecosystems |
|--|--|--|---|
| <p>Characteristics:</p> <p>The Lielupe River, with a dense network of slow-flowing rivers, shallow lakes, and ponds, is heavily modified by human activities like river straightening, dams and other obstacles.</p> <p>Hydrology:</p> <p>Influenced by seasonal floods (spring, summer, autumn) and shallow water periods in summer and winter.</p> <p>Water Quality Issues:</p> <p>High nitrogen and phosphorus levels due to agricultural pollution and hydro-morphological changes.</p> <p>Transboundary pollution from Lithuania worsens water quality in Latvia and the Baltic Sea.</p> <p>Nature-based solutions considered to reduce pollution with nutrients</p> | <p>Energy Mix:</p> <p>Combines renewable sources (wood biofuel, small-scale HPPs) and imported natural gas.</p> <p>Renewable Potential:</p> <p>Underutilized biomass from agriculture, forestry, and food industries. Increasing focus on wind and solar energy.</p> <p>Challenges:</p> <p>Ecological impacts of HPPs on river flow and fish migration.</p> | <p>Agricultural Dominance:</p> <p>62% of the land is agricultural, producing cereals, potatoes, fodder crops, and supporting dairy farming.</p> <p>Land use:</p> <p>Arable land vs meadows and land use practices affect all WEFE sectors</p> <p>Food Industry:</p> <p>Significant economic contributor, producing dairy products, canned fish, grains, meat, confectionery, and beverages.</p> | <p>Diverse Landscapes:</p> <p>Includes agricultural, agro-forested, forest, wetland, and urbanized landscapes.</p> <p>Habitat Loss:</p> <p>Conversion of natural grasslands into cropland has reduced meadows and pastures.</p> <p>Protected Areas:</p> <p>Home to national parks and nature reserves, highlighting the region's ecological importance</p> |

Dominant nexus issues

- Water quality - **nutrient load** from diffuse and point sources
- Intensive agriculture – application of **fertilisers**
- Pressure on terrestrial ecosystems - **homogenisation** of land and monocultures
- Renewable energy production - additional pressure on other nexus sectors
- Exploitation of natural resources - intensive use of **wood biomass**
- Pressure on aquatic ecosystems - fluctuations in hydrological regime
- **Water diplomacy issues** (i.e., transnational aspects):

- Significant amounts of pollution from Lithuania are transported across the border to Latvia and by adding to the local pollution, deteriorate river water quality and result in excessive loads into the Baltic Sea.

Expected outcomes

The aims of SHE are:

- System knowledge:
 - Characterise social, economic, ecological, and institutional contexts associated with regional development planning.
 - Improve understanding of the water quality issues (the status quo and targets).
 - Gain understanding of the river basin management plans between both countries.
- Target knowledge:
 - Determine what set of solutions balances different sectors by their design and scale of applicability.
 - Knowledge on potential conflicts between the agricultural and ecological sectors.
 - Determine innovative systems for sustainable production.
- Transformation knowledge:
 - Gain understanding on how to improve communication between SHs as well as the requirements of an appropriate platform to do so.
 - Determine suitable pathways to design and implement formal agreements for the case of a transboundary river basin.
 - Design and implement suitable ways for a coordinated management between the countries.

CS3 Jiu river



The Jiu river flows from the Carpathian Mountains southwards through several counties before it discharges into the Danube at Zaval, near the border with Bulgaria. The Jiu river basin is one of Romania's 11 catchments and one of six that border the Danube, in Romania.

Its hydrographic area includes Jiu river and the Danube tributaries from the south-west Oltenia region. It has 286 registered watercourses, with a total length of 4,954 km and an average density of 0.30 km/km². The Jiu river basin covers 16,759 km², with a length of 260 km and a width of 60 km in the upper part and 20

km in the lower part. The population of the Jiu river basin contains 1,461,661 inhabitants, 56% living in the urban area.

The basin is mainly characterised by arable land (48%), forest (30%) and pastures (9%). In the north the main activities in the basin are related to the coal mining industry for lignite-based electricity and heat generation. The areas in the south and south-west are characterized by agricultural activities that depend on water supplies for irrigation and hydropower production.

Anthropogenic interventions (e.g., dams) along the Danube have stimulated erosion and negatively affected the riverbed, while floods and drought events continue to impact the region. The Lower Danube wetland ecosystem also includes several EU Natura 2000 sites.

WEFE nexus components

| Water sector | Energy sector | Food sector | Ecosystems |
|---|---|---|--|
| <p>Priorities:</p> <p>Ensure water availability for population also considering the expanding of public water supply and sanitation networks.</p> <p>Ensure the needed flows to secure hydropower production, at Iron Gates plants on the Danube.</p> <p>Ensure the water availability for irrigation</p> <p>Challenges:</p> <p>Competing water demands between hydropower and agriculture.</p> <p>Impacts of past lignite mining and old agricultural practices on water quality and quantity.</p> <p>Vulnerability to extreme climate events (droughts and floods).</p> | <p>Current Use:</p> <p>Hydropower in the south and legacy lignite-based energy in the north.</p> <p>NECP providing for an integrated strategic approach for climate resilience at national level also including actions with local impact</p> <p>Just Transition Mechanism activated in the North of the basin:</p> <p>Shift to renewable energy sources (solar, gas) and sustainable local resource use (quartz, limestone, clay) to support carbon neutrality and economic diversification.</p> | <p>Agriculture Role:</p> <p>Occupies 53% of land for vegetable farming, horticulture, aquaculture, and husbandry.</p> <p>Challenges:</p> <p>Historic intensive agriculture impact on groundwater quality.</p> <p>Strong impact of climate change (droughts, floods)</p> <p>Strategic frame:</p> <p>The Romanian National Strategic Plan for CAP (2023–2027) acknowledges providing incentives for efficient resource management, and biodiversity conservation.</p> | <p>Ecosystem preservation, particularly in Natura 2000 sites prioritized by the River basin Management Plan</p> <p>Restoration Goals:</p> <p>Wetland restoration along the Danube using nature-based solutions, addressing the 80% loss of wetlands in the past century.</p> <p>Protected Areas:</p> <p>Includes 27 water-related sites with conservation plans targeting habitats and species dependent on water ecosystems.</p> |

Dominant nexus issues

- **Water availability** (quantity) competing interests: population, hydropower, agriculture



- **Transition to a carbon neutral economy:** reducing mining activities while diversifying economic activities (including RES)
- **Agriculture sector adaptation to climate change:** efficient management of natural resources (water, soil, air) and conservation of biodiversity and landscapes
- **Wetland ecosystem restoration** along the Danube (nature-based solutions with economic co-benefits)

Expected outcomes

The aims of SHE are:

- **System knowledge:**
 - Current state of the social, economic, institutional, and ecological contexts that are relevant for a WEFE Nexus approach.
 - Increase understanding of the institutional and organisational structure, functions, and information flows.
 - Explore aspects related to the clean energy transition that are relevant to address for the WEFE Nexus in the region.
 - Understand existing conflicting actions and strategies regarding WEFE Nexus.
- **Target knowledge:**
 - Determine the appropriate level of public awareness of water as a depleting resource.
 - Determine expectations and requirements for an assessment and planning instrument including interface for communication and reporting instrument.
 - Build towards a common language to facilitate SH understanding of WEFE Nexus paving the reduction of the potential conflicts.
- **Transformation knowledge:**
 - Determine pathways to enhance awareness on water resource and its management.
 - Gain understanding on how to break silos based on an integrated view of the reality in the local context.
 - Tailor the design of the NXG platform to support communication and reporting of the status of water resources among SHs.
 - Build capacity and identify/select relevant indicators for monitoring WEFE Nexus in connection with strategic objectives for water management and sustainable development.

CS4 Adige river

The Adige River flows in the southern-eastern Alps starting from the Italian-Swiss-Austrian border at the elevation of 1586m a.s.l., and ending in the Adriatic Sea after 409 km (Figure 2). The Adige River flows through the territories of the Province of Bolzano (62% of the overall river basin surface), the province of Trento (29%) and the Veneto region in the



provinces of Verona, Belluno, Padova, Rovigo and Venice (9%). With a size of about 12,100 km² is the third largest Italian river basin and the second longest river.

The case study area covers 369 municipalities with a total of about 1,600,000 inhabitants. Specifically, 28.33% of the total population live in the Province of Bolzano, 21.43% live in the Province of Trento, 34.71 % in the Province of Verona, 3.80% in the Province of Vicenza, 1.03% in the Province of Belluno, 1.03% in the Province of Padova, 5.64% in the Province of Rovigo, 4.13% in the Province of Venezia and 0.11% in Switzerland.

Winter and summer tourism play an important role with the total population often increasing by five to six times in many parts of the upper basin, with consequences for the management of water, energy and waste. Several hydropower dams and plants are located in the upstream part of the basin and produce renewable energy which often exceeds energy demand. The mountain landscapes are characterized by intensive cultivation of apple orchards, which provide more than 15% of European apple production. The downstream part of the basin is characterized by intensive anthropogenic land use, with vineyards and cereals as the main irrigated cultivations.

The Adige River Basin is characterized by different cultural, linguistic (i.e., south Tyrolean, Ladin and Italian), economic and legislative autonomy levels which challenge the management of common resources from upstream to downstream. During extreme conditions, such as droughts and floods, disputes and tensions arise in relation to water management and governance.

WEFE nexus components

| Water sector | Energy sector | Food sector | Ecosystems |
|--|---|---|--|
| <p>Historically abundant due to high rainfall, snowmelt, and glacier melt.</p> <p>Increasing water disputes arise from complex multi-sector usage and governance challenges, worsened by:</p> <p>(i) Climate change impacts on rainfall, snowfall, and seasonal water availability.</p> <p>(ii) Growing anthropogenic demand (e.g., tourism-related water needs for snowmaking and accommodation).</p> <p>(iii) Lack of trust and cooperation among provinces.</p> <p>Impacts on artificial lakes and downstream water availability highlight the need for improved governance.</p> | <p>Hydropower:</p> <p>Dominates energy production with 61 plants and 28 dams, supplying more energy than local demand.</p> <p>Reservoirs buffer water supply but are vulnerable to drought conditions, raising concerns about quantity and quality.</p> <p>Renewables:</p> <p>Supplemented by photovoltaic (415.3 MW), biogas (95.7 MW), and wind (0.4 MW).</p> | <p>Agricultural Production:</p> <p>Upper basin: Intensive apple orchards (15% of European apple production) and vineyards for high-quality wine.</p> <p>Downstream: Irrigated cereals, maize, and intensive livestock farming, which increase water consumption and nutrient runoff (nitrogen and phosphorus).</p> | <p>Ecosystems</p> <p>Heterogeneous Landscapes:</p> <p>Includes mountainous forests, glaciers, flatlands, and wetlands.</p> <p>Mountainous regions dominate (80% of the area), with significant woodland and biodiversity.</p> <p>Threats:</p> <p>Transition from traditional to intensive agriculture affects landscape quality, biodiversity, and water resources.</p> |

Dominant nexus issues

- Hydropower production – influences the amount and timing of **flow** for downstream users
- Tourism – affects the total **water demand**, especially for snow production and domestic consumption.
- Lack of guarantee of minimum ecological flow – intensive water uses (above) and water scarcity
- **Saltwater intrusion** from the delta – threatens river ecosystems



- Climate change – induced shifts in the **river flow regime** affect seasonal water availability

Expected outcomes

The aims of SHE are:

- To improve system knowledge:
 - Explore the current state of the Nexus by improving modelling approaches related to water supply and demand, with a special focus on water scarcity and its implications on the other Nexus sectors.
 - Increase understanding of the current institutional and political context that characterise the area, to identify existing and potential conflicts.
- To generate target knowledge:
 - Determine the drivers of cooperation between SHs to share data and foster a coordinated management of water resources.
- To generate transformation knowledge:
 - Enhancing SH awareness on water resources, their management and uses among different sectors.
 - Co-develop, validate, and promote the use of the NEPAT and WEF Footprint tools that the projects will develop to plan for future environmental and socio-economic conditions.
 - Determine drivers for a cross-catchment dialogue that fosters a coordinated design and implementation of existing and future river contracts between upstream and downstream areas of the river basin

CS5 Inkomati-Usuthu Water Management Area



The Inkomati-Usuthu Water Management Area (IUWMA) is situated on the eastern boundary of South Africa. The catchments of the Inkomati and Usuthu Rivers are transboundary and classified as strategic water source areas. The Inkomati sub-catchment is divided into the following sub-areas, Upper and Lower Inkomati, Sabie-Sand and the Crocodile, while the Usuthu is treated as one area. Vital attributes of this area include agriculture, industry, mining, eco-tourism, forestry, and nature conservation. Irrigation-based agriculture and forestry provide approximately 60% of the jobs in the WMA and subsequently utilise the majority of the water in the WMA;

31% and 21% for irrigation and forestry, respectively” (IUCMA APP 2020/21).

Based on the spatial data associated with the 2011 Census, together with the 2021 Mid-year population estimates, the population in the Inkomati-Usuthu WMA was estimated to be 2.3 million in 2021, consisting of an urban, semi-urban and rural population. In 2012, it was

estimated that the Gross Geographic Product (GGP) of the IUWMA was approximately R9 billion per annum and made up about 0.3% of South Africa’s Gross Domestic Product (GDP). The manufacturing and mining sectors were the most significant contributors.

Water resource management in the IUWMA is administered by the Inkomati-Usuthu Catchment Management Agency (IUCMA) in terms of Section 78 of the National Water Act (NWA) 36 of 1998.

WEFE nexus components

| Water sector | Energy sector | Food sector | Ecosystems |
|---|---|--|---|
| <p>Rainfall varies significantly across the Inkomati-Usuthu Water Management Area (IUWMA): 400–1200 mm annually in the Inkomati sub-catchment ; 550–850 mm annually in the Usuthu sub-catchment.</p> <p>Rivers in the IUWMA (e.g., Komati, Crocodile, Sabie) flow through Eswatini, South Africa, Mozambique, and into the Indian Ocean.</p> <p>Water resources are over-allocated and face significant quality challenges due to:</p> <p>Industrial/mining activities and pollution.</p> <p>Sewage contamination from aging infrastructure and untreated discharges.</p> <p>Mining effluent and stormwater runoff.</p> | <p>No coal-fired power stations or large-scale renewable energy systems exist within the IUWMA.</p> <p>Water is exported to support Eskom, classified as a Strategic Water User.</p> <p>Used for cooling, steam generation, ashing, and air emission control at coal-fired power plants.</p> <p>Bulk water licence permits use of 360.3 million m³ annually for 11 power stations.</p> <p>Water supply schemes include key dams (e.g., Vygeboom, Nooitgedacht, Morgenstond, Heyshope).</p> <p>Solar and wind energy potential maps exist for the area but are underutilized.</p> | <p>Irrigated agriculture is widespread, with significant production of export crops:</p> <p>Citrus, macadamia nuts, soya, and sugar.</p> <p>Increasing land conversions:</p> <p>From agriculture to domestic use, mining, and forestry.</p> <p>Subsistence farming remains common.</p> | <p>Rivers such as the Sabie-Sand and Crocodile flow through Kruger National Park and into Mozambique.</p> <p>Kruger National Park is part of the Great Limpopo Transfrontier Park, connecting ecosystems in Mozambique and Zimbabwe.</p> <p>Ecosystem services are vital, with mapping efforts highlighting significant conservation areas.</p> |

Dominant nexus issues

- Equitable access to WEFE resources - **disparities** in socio-economic standards
- Rapid development of upstream **mining** – impacts on downstream water quality
- **Overallocation** of water – limits development
- **Mismanagement** of water infrastructure including bulk supply and water treatment facilities
- **Algal blooms** more widespread – water quality deterioration
- Land conversion – to grow **crops for export**
- Unreliable baseload **energy supply** from the national provider - affects all sectors of the economy
- Climate change – heat, precipitation and biodiversity impacts

Expected outcomes

The aims of SHE are:

- System knowledge:
 - Gain knowledge about the social, economic, institutional, and ecological contexts of the area, with special emphasis on spatial scales of social and economic data (available at a provincial scale).
 - Gain general, qualitative knowledge, e.g., at a national level, of the neighbouring countries (Mozambique and Eswatini) that share part of the river basin to complement the information of the South African portion of the basin (focus of this cases study).
 - Gain knowledge on the existing WEFE interactions taking place within the catchment.
- Target knowledge:
 - Determine drivers for sustainable development in the area, e.g., economic growth, jobs, socio-economic equality.
 - Gain knowledge on the required infrastructural improvements.
 - Determine criteria that characterise a balance between tourism activities and nature conservation.
 - Determine drivers that could assist in promoting WEFE nexus interactions between relevant SHs in the catchment.
- Transformation knowledge:
 - Determine requirements to invest in infrastructure.
 - Gain knowledge on the transition to renewable energy, including the re-skilling of workers and transfer of jobs.
 - Identify and understand relevant components for nature conservation and their relation to the WEFE Nexus.
 - Identify and understand main aspects that support the alignment of policies or the design and implementation of aligned policies.

Annex 2 - Work Package 5 and its role

WP5 supported the implementation of the NXG approach in the five CSs through: a) the development of a roadmap that guided the work of CSs in NXG; b) the management of internal communication between CSs and WPs; c) the development and implementation of a SHE strategy; d) the continuous coordination and monitoring of all CSs activities.

Special emphasis was placed on the provision of guidelines and training to support SHE processes in the five CSs, as SHs provide valuable inputs to the WPs (WP1-4). The WP5 guidance led to better integration of the project results coming from the different WPs. This work helped to maximise the impact of the project (WP6).

The work of WP5 is complementary to T1.3 in WP1. T1.3 ensured the coordination of WP1, 2, 3, 4 and in particular the timely and effective flow of information between the technical WPs (2, 3, 4) and the policy and governance work package (WP1), based on the input received from SHs from CSs. As such, WP5 work connected all the other WPs in the project. An overview of the links between WP5 and other WPs is presented in Figures 7 and 8 in MS2 - *Roadmap for Case Study Work/Activities in NEXOGENESIS*.

Throughout WP5 (months 1-48), five (5) tasks, seven (7) deliverables and six (6) related milestones were set with specific dates and timelines. A timeline of these WP5 activities can be found in MS2 - *Roadmap for Case Study Work/Activities in NEXOGENESIS*, Figure 9. They all required close collaboration of the WP5 team with each CS leadership team and coordination with other WPs. CS leaders played a critical role in co-developing the guiding documents (e.g., the CS roadmap) by expressing their needs, their preferred mode of communication, their ability to contribute with local knowledge, and by validating the developed guidelines, documents, and roadmap.

The first milestone of WP5 (MS2 – *Roadmap for Case Study Work/Activities in NEXOGENESIS*) concerned the development of a roadmap for CS work with the aim of guiding CSs in NXG and more particularly their contribution to each WP. It constituted a timeline for all relevant activities described in relation to the work and needs of all relevant WPs (WP1-4).

The second milestone of WP5 (MS5 – *Internal Communication Strategy*) was a practical resource that fostered the communication between CS leaders and WP leaders, but also supported the exchange of relevant information/experience among the leaders of different CSs, as explained below.

The third milestone of WP5 (MS6 – *Stakeholder Register*) presented the SH identification process to generate the SH register for each CS. This document reported on the steps and considerations given to CS leaders for the identification of the respective relevant SHs. It also provided preliminary results for each CS, including the categorisation of different SH groups according to their engagement interest and function.

The fourth milestone (MS8 – *CS Monitoring Plan*) included activities to enable WP5 to monitor the CSs' work and potential amendment actions (if needed, in the case of delayed work). Its aim was to facilitate the progress of the CS activities, thereby ensuring a successful implementation of the project work in each CS.

The fifth and sixth milestones (MS15 and MS23 - *Intermediate and second reports on case study implementation and co-creation activities*) provided detailed internal monitoring of case study activities during the project. These milestones underpin Deliverables 5.2-5.6, which are the implementation reports for the CSs.