

SCALING UP WASTEWATER REUSE: LESSONS FROM REUT'O'SUD LIVING-LABS

ACCROÎTRE LA RÉUTILISATION DES EAUX USÉES : LES ENSEIGNEMENTS TIRÉS DES LIVING-LABS DE REUT'O'SUD

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ABSTRACT

Water scarcity is a growing challenge in Mediterranean regions, driven by climate change, increasing drought frequency, population growth, and urbanisation. In the SUD–Provence–Alpes–Côte d'Azur region, these pressures are intensifying competition among domestic, agricultural, industrial, and environmental water uses, raising major concerns for sustainable water management. In this context, treated wastewater (TWW) reuse has emerged as a promising solution to diversify water resources, secure non-potable uses, and enhance territorial resilience (IPCC, 2023; UNESCO, 2024).

Despite its recognised potential and the support of public policies such as the regional “Or Bleu” strategy, the actual deployment of TWW reuse remains limited. This gap between political ambition, technical feasibility, and operational implementation highlights persistent barriers. The REUT'O'SUD project was developed to address this issue, combining territorial analysis with experimental approaches. Its initial phase identified significant potential for TWW reuse across various uses and locations, but also revealed recurring technical, regulatory, institutional, economic, and social constraints. To overcome these challenges, the project's second phase introduced thematic Living Labs focusing on agricultural, urban, and recreational uses. These collaborative platforms bring together researchers, public authorities, companies, and users to co-design and test solutions in real-life conditions. Their objectives include improving stakeholder cooperation, refining the understanding of barriers, supporting local engagement, and fostering the long-term adoption of solutions.

The first workshops held in 2024, dedicated to agricultural uses, played a key role in building a shared understanding and initiating regional cooperation. Although still at an early stage, the project highlights the relevance of Living Labs in addressing the complexity of TWW reuse. However, challenges remain, including sustaining stakeholder engagement, coordinating diverse interests, and integrating the approach into public policies. Overall, REUT'O'SUD demonstrates significant untapped potential for TWW reuse and contributes to ongoing discussions on adaptive water governance and sustainable resource management.

Keywords: Water scarcity; Treated wastewater reuse; Territorial analysis; Stakeholder cooperation; Sustainable resource management.

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RÉSUMÉ

La pénurie d'eau constitue un défi croissant dans les régions méditerranéennes, sous l'effet du changement climatique, de la fréquence accrue des sécheresses, de la croissance démographique et de l'urbanisation. Dans la région SUD-Provence-Alpes-Côte d'Azur, ces pressions intensifient la concurrence entre les usages domestiques, agricoles, industriels et environnementaux de l'eau, suscitant de vives inquiétudes quant à la gestion durable de l'eau. Dans ce contexte, la réutilisation des eaux usées traitées (EUT) s'est imposée comme une solution prometteuse pour diversifier les ressources en eau, garantir les usages non potables et renforcer la résilience territoriale (GIEC, 2023 ; UNESCO, 2024).

Malgré son potentiel reconnu et le soutien de politiques publiques, telles que la stratégie régionale « Or Bleu », le déploiement effectif de la réutilisation des EUT reste limité. Cet écart entre l'ambition politique, la faisabilité technique et la mise en œuvre opérationnelle met en évidence des obstacles persistants. Le projet REUT'O'SUD a été développé pour répondre à cette problématique, en combinant analyse territoriale et approches expérimentales. Sa phase initiale a permis d'identifier un potentiel significatif de réutilisation des ETP pour divers usages et emplacements, mais a également révélé des contraintes récurrentes d'ordre technique, réglementaire, institutionnel, économique et social. Pour surmonter ces défis, la deuxième phase du projet a mis en place des « Living Labs » thématiques axés sur les usages agricoles, urbains et récréatifs. Ces plateformes collaboratives rassemblent des chercheurs, des pouvoirs publics, des entreprises et des usagers afin de coconcevoir et de tester des solutions en conditions réelles. Leurs objectifs consistent notamment à améliorer la coopération entre les parties prenantes, à affiner la compréhension des obstacles, à soutenir l'engagement local et à favoriser l'adoption à long terme de solutions.

Les premiers ateliers organisés en 2024, consacrés aux utilisations agricoles, ont joué un rôle clé dans l'établissement d'une vision commune et le lancement d'une coopération régionale. Bien qu'il n'en soit encore qu'à ses débuts, le projet souligne la pertinence des « Living Labs » pour appréhender la complexité de la réutilisation des eaux usées traitées. Toutefois, des défis subsistent, notamment le maintien de l'engagement des parties prenantes, la coordination d'intérêts divers et l'intégration de cette approche dans les politiques publiques. Dans l'ensemble, REUT'O'SUD démontre un potentiel inexploité significatif pour la réutilisation des eaux usées et contribue aux débats en cours sur la gouvernance adaptative de l'eau et la gestion durable des ressources.

Mots-clés : Pénurie d'eau; Réutilisation des eaux usées traitées; Analyse territoriale; Coopération entre les parties prenantes; Gestion durable des ressources.

INTRODUCTION

Mediterranean regions are currently facing profound transformations linked to climate change. The gradual decline in available water resources, combined with the increased frequency and intensity of droughts, is placing growing pressure on aquatic environments on the one hand and on access to water for various uses on the other. This deterioration in hydrological conditions is weakening aquatic ecosystems whilst intensifying competition for access to the resource. This trend is leading to increased tensions between agricultural, urban, tourism and environmental uses, making trade-offs increasingly complex (IPCC, 2023; UNESCO, 2024).

The SUD Provence-Alpes-Côte d'Azur region (SUD-PACA region) is a territory particularly representative of these dynamics. It combines several vulnerability factors, including high population density, significant seasonal tourism activity and irrigated agriculture dependent on resources that are sometimes fragile. Added to this is significant spatial and seasonal variability in water resources, exacerbating tensions in certain sub-regions.

In this context, securing the water supply has become a major strategic challenge for local authorities and water managers. This situation has led to growing interest in alternative solutions aimed at diversifying available resources and strengthening the resilience of these regions (OECD, 2024).

Among these solutions, the reuse of treated wastewater (TWW) stands out as a particularly promising option. By making use of a resource that is already available, it reduces the need to draw water from natural sources, ensures water supply for certain uses during periods of scarcity, and aligns with a circular water management approach (Asano et al,1999; Howes et al, 2024; Roche et al, 2026). However, despite this potential, the development of TWW remains limited in France. This situation is largely due to the multifaceted nature of the barriers encountered, which stem from technical, regulatory, institutional, economic and social constraints.

To better understand these barriers, the REUT'O'SUD project was launched with the aim of characterising the conditions for the development of TWW at the regional level. Its first phase was based on an in-depth territorial assessment involving literature reviews, mapping of existing initiatives, a study of over 700 wastewater treatment plants, and interviews with relevant stakeholders (Howes et al, 2024; Lombard-Creisson et al, 2025).

The results highlighted significant potential, particularly for agricultural uses, but also revealed a large number of projects stalled at various stages of their development, often due to administrative, financial or organisational constraints.

These findings led the project partners to conclude that the obstacles to TWW are not solely technical in nature, but are also closely linked to issues of governance, coordination between stakeholders and social acceptability. With this in mind, the search for mechanisms capable of fostering dialogue, collective learning and experimentation under real-world conditions gradually emerged as a key approach.

It is within this framework that the REUT'O'SUD project has focused on establishing Living Labs, designed as spaces for co-creation bringing together a diverse range of stakeholders to address concrete issues related to the reuse of treated wastewater.

LIVING LABS AND THE CHALLENGES OF WATER REUSE

Definition and principles of Living Labs

The concept of the 'Living Lab' emerged in the early 2000s in the field of digital innovation, particularly at the Massachusetts Institute of Technology (MIT), before gradually being applied to other sectors such as energy, transport, urban planning and environmental management (Klein et al, 2020). Over time, Living Labs have become genuine tools for regional innovation, deployed to support complex transitions linked to environmental and societal challenges. (Klein et al, 2020; Schuurman et al, 2016).

Living Labs can be defined as open innovation frameworks based on the active participation of a diverse range of users and stakeholders in co-creation and experimentation processes under real-world conditions (Leminen et al, 2012).

Unlike traditional approaches to innovation, Living Labs seek to integrate user needs, local constraints and interactions between stakeholders from the very earliest stages of project development. Their aim is to enable the various stakeholders involved in a project to participate in the design of solutions, thereby fostering the emergence of more operational approaches that are better suited to on-the-ground needs and more likely to be accepted locally. (Norström et al, 2020).

By incorporating the perspectives of different users from the outset, Living Labs also promote approaches to co-production of knowledge that are suited to the complexity of the issues under study (Norström et al, 2020).

Several principles generally underpin Living Lab approaches:

- multi-stakeholder participation;
- real-world experimentation;
- co-construction of solutions;
- collective learning;
- open and iterative innovation.

Why set up Living Labs for treated wastewater reuse?

In the field of water management, Living Labs appear to be particularly relevant mechanisms for addressing complex issues characterised by a high degree of interdependence between technical, social, economic, political and environmental dimensions (Howes et al, 2024).

The implementation of TWWR projects requires the involvement of a wide range of stakeholders from different institutional and professional spheres: local authorities, wastewater treatment plant operators, water agencies, government departments, businesses, researchers, associations, citizens and users (Figure 1.).

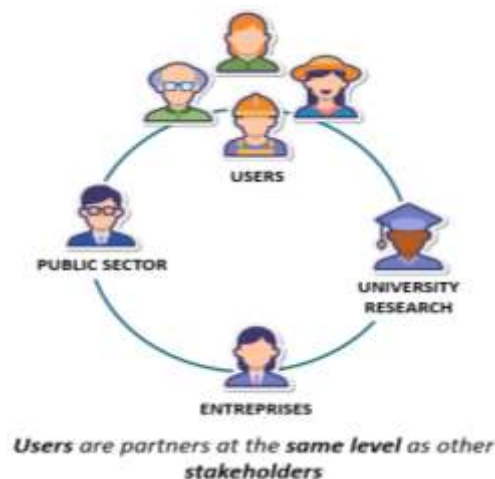


Figure 1. Representation of stakeholders in a Living Lab

This heterogeneity frequently creates institutional barriers and potential conflicts of interest. For example, in the context of a project to reuse water for agricultural irrigation, farmers focus primarily on the availability of water volumes and its agronomic quality, operators on treatment and distribution costs, whilst government departments give priority to health and regulatory requirements. In the absence of forums for dialogue, the lack of coordination between these different professional and institutional spheres often becomes a major obstacle to TWWR projects.

Given this complexity, decisions regarding TWWR involve delicate trade-offs between health, environmental, economic and social issues. They also require strong cooperation between stakeholders who do not always have the same resources, the same knowledge or the same timeframes for action (Smith et al, 2018).

In this context, Living Labs appear to be particularly well-suited tools as they enable the creation of spaces for dialogue that foster the exchange of information, mutual understanding and the gradual development of shared solutions. Collective learning and knowledge-sharing thus help to bridge the gaps in perception between experts, decision-makers and users.

Living Labs also enable the addressing of issues of social acceptability, which are often central to TWWR projects. Perceptions of wastewater remain associated with negative connotations and health concerns that may hinder public acceptance. By directly involving users in experimentation and consultation processes, Living Labs foster a better understanding of technical systems and gradually build trust among stakeholders (Hossain et al, 2019). Furthermore, Living Labs offer the opportunity to test technical and organisational solutions under real-world conditions, enabling the assessment of their operational feasibility prior to potential wider implementation. This local experimentation plays a key role in the gradual adaptation of systems to local realities and in securing public and private investment (Saliba et al, 2018).

LESSONS LEARNED FROM THE TERRITORIAL REUT'O'SUD PROJECT AND CONTRIBUTIONS OF LIVING LABS

Design and structuring of the REUT'O'SUD Living Labs

Based on the territorial assessment carried out as part of the REUT'O'SUD project, the approach gradually shifted towards the creation of several thematic Living Labs dedicated to different uses of TWWR:

- agricultural uses;
- urban multi-uses;
- private and recreational uses.

This structure made it possible to take into account the specific characteristics of each category of use in terms of regulations, stakeholders, technical constraints and social issues. The aim was to encourage the co-creation of problems and solutions rather than imposing predefined models. The Living Labs were designed as spaces for dialogue and experimentation, bringing together:

- researchers;
- local authorities;
- water managers;
- businesses;
- charities;
- citizens and users.

Initial workshops and experimental initiatives

The Living Lab's first workshop, dedicated to agricultural uses, was held in December 2024 at the initiative of the project's founding partners: Région Sud-PACA, Société du Canal de Provence and Aix-Marseille University. The aim of this first meeting was to lay the foundations for the Living Lab by defining its concrete ambitions, its collective vision and the values underpinning the project. The discussions also helped to identify potential stakeholders to join the initiative and to outline an initial strategy for engaging stakeholders over time.

Workshop No. 2, held in January 2025, was primarily devoted to defining the Living Lab's framework through discussions on governance, the definition of the roles of the various stakeholders, and the drafting of an initial operating charter. The discussions provided an opportunity to examine the arrangements for the collective organisation of the initiative, the coordination mechanisms between the founding organisations, and the conditions for the gradual integration of additional institutional and technical partners. The discussions also highlighted the need to clarify the division of responsibilities and to establish a sustainable management structure for the Living Lab in order to ensure the long-term involvement of stakeholders.

Workshop No. 3, held in February 2025, marked an important milestone in building a shared vision for the project, with the integration of new stakeholders into the collaborative process. On this occasion, four new entities joined the Living Lab's founding circle: a National Park, a community of municipalities, a metropolitan area and an urban community, in regions where TWWR projects had already been identified as existing, under development or at the planning stage.

The main aim of this meeting was to familiarise all participants with the Living Labs methodology, so that everyone could share a common knowledge base and foster a climate of trust conducive to co-creation. In this context, an initial collective discussion was held on the expectations and contributions of each stakeholder within the Living Lab. Once everyone's needs and contributions had been clarified within the REUT'O'SUD project, the participants worked on reformulating the Living Lab's vision to better highlight the diversity of the profiles involved, the replicability of TWWR projects and the continuous improvement of existing schemes. The discussions also helped to identify the various stakeholders to be involved in the Living Lab, as well as the most appropriate timelines for their integration.

The discussions also highlighted a strong need to pool feedback, share technical and regulatory expertise, and network the stakeholders involved in TWWR.

Workshop No. 4, held in May 2025 in Maussane-les-Alpilles, built on this momentum by adopting an approach more focused on the operational challenges encountered in the field. The day alternated between technical visits to experimental sites, presentations of TWWR projects led by participants, and collaborative workshops dedicated to identifying barriers to the development of TWWR.

Discussions revealed that perceptions of TWWR varied significantly depending on the stakeholders and regions involved. Some participants viewed TWWR as a strategic solution to secure access to water resources in the context of climate change and growing pressures on water use. Others expressed greater reservations regarding investment costs, regulatory constraints, technical difficulties, or the social acceptability of the projects.

The workshops also highlighted the importance of trust-building dynamics for the success of TWWR projects. The creation of neutral spaces for dialogue, fostering exchanges between local authorities, researchers, water managers, government departments and agricultural stakeholders, was identified as a key lever for reducing misunderstandings and facilitating the co-development of projects.

Although the experiments are still at an exploratory stage, these initial workshops have helped to establish a framework for regional cooperation around agricultural TWWR. They have also enabled the testing of different approaches to running the Living Lab, the clarification of stakeholders' needs, and the identification of several avenues for further work within the REUT'O'SUD project.

The main barriers to the development of treated wastewater reuse

The work carried out during the first REUT'O'SUD workshops identified several categories of barriers limiting the development of TWWR at the regional level. Technical barriers primarily concern the control of treated water quality and the reliability of the facilities. Participants highlighted, in particular, the difficulties associated with monitoring physico-chemical parameters and other analyses, potential malfunctions at the effluent outlet of the treatment plant, and the lack of technical support available to assist project leaders.

Regulatory barriers constitute another major difficulty. Despite recent changes to the French regulatory framework, administrative procedures are still perceived as lengthy, complex and sometimes difficult to interpret. Institutional and organisational barriers mainly concern the multitude of stakeholders involved and the fragmentation of responsibilities. The workshops highlighted the need for a clear governance framework as well as better coordination between local authorities, wastewater treatment plant operators, chambers of agriculture, government departments, researchers and end-users. Economic barriers relate mainly to the investment costs required to establish infrastructure for the treatment,

storage and distribution of reused water. Participants also raised the difficulties associated with defining suitable and sustainable business models.

Finally, social and cultural barriers remain particularly significant. Negative perceptions associated with treated wastewater, health concerns and certain cultural reservations can limit the acceptability of projects, even when technical safeguards are deemed satisfactory.

INITIAL FINDINGS AND CHALLENGES ENCOUNTERED

The initial work carried out as part of the REUT'O'SUD project has yielded several lessons regarding the conditions for deploying TWWR and the potential role of Living Labs in supporting territorial transitions related to water management.

The workshops confirmed the multidimensional nature of the barriers to the development of TWWR. The difficulties encountered are not solely technical in nature but are part of highly interconnected regulatory, institutional, economic, social and environmental issues. The work carried out also highlighted the central importance of territorial governance in the success of TWWR projects. In this context, Living Labs have proven to be particularly effective mechanisms for strengthening capacity for dialogue, coordination and collective learning among stakeholders. The REUT'O'SUD workshops have created spaces for discussion that encourage the exchange of views, the sharing of experiences and the gradual co-construction of a shared vision for agricultural TWWR.

However, the operational implementation of Living Labs also raises several significant challenges. The sustained mobilisation of stakeholders is a key challenge. Maintaining collective commitment over the long term requires significant facilitation, mediation and coordination efforts. Facilitating the Living Labs also requires substantial human and financial resources. Participatory approaches rely on specific facilitation skills. Tensions may also arise between the experimental ambitions of the project and the operational constraints faced by local stakeholders. Certain experiments remain difficult to implement due to administrative delays, regulatory requirements or economic uncertainties affecting TWWR projects. Finally, the question of ensuring the sustainability of Living Labs beyond the project's duration remains a key challenge. Discussions during the workshops highlighted the need to consolidate governance mechanisms, establish sustainable networks of stakeholders and secure the funding required to continue collaborative initiatives.

Potential levers for action through Living Labs

Despite these various obstacles, Living Labs nevertheless appear to be levers for action in support of TWWR development. Firstly, they foster cooperation between stakeholders by creating spaces for dialogue, consultation and collective learning. This cooperation enables a better understanding of the constraints, expectations and rationales for action specific to each category of stakeholder, whether local authorities, wastewater treatment plant operators, farmers, researchers or government departments. The workshops thus demonstrated that sharing experiences and comparing perspectives help to reduce certain misunderstandings and gradually build a shared culture around TWWR in the SUD-PACA region. Field visits and discussions regarding existing experimental projects in the region have particularly highlighted the value of an approach based on experimentation and feedback. By promoting transparency in discussions and the dissemination of knowledge, Living Labs can help to reduce certain fears associated with treated wastewater, strengthen trust between stakeholders and enhance the social acceptability of projects by directly involving the relevant actors in the processes of reflection and co-creation.

Finally, Living Labs can foster the emergence of governance models that are more integrated and better suited to the complexity of TWWR projects. The work undertaken on governance, the REUT'O'SUD charter and the structuring of a regional network shows that these mechanisms can play an important role in organising regional cooperation and coordinating the stakeholders involved in treated wastewater reuse projects.

CONCLUSION

The REUT'O'SUD project highlights the existence of significant, yet largely untapped, potential for the development of treated wastewater reuse in the Sud–Provence–Alpes–Côte d'Azur region. The analyses carried out show that the development of TWWR does not depend solely on the availability of

effective technical solutions. It also relies on the ability of local authorities to establish appropriate governance frameworks capable of coordinating a wide range of stakeholders and taking into account the social, economic, regulatory and institutional dimensions of projects.

In this context, Living Labs emerge as particularly relevant tools for territorial innovation to support transitions linked to the sustainable management of water resources. Their value lies in their ability to foster dialogue between stakeholders, collective learning, the sharing of knowledge and experimentation under real-world conditions. The first REUT'O'SUD workshops helped to initiate regional cooperation dynamics, gradually build a network of regional stakeholders, and identify several priority issues concerning the technical, economic, regulatory and organisational aspects of TWWR for agricultural use. However, this work has also revealed the many difficulties associated with the operational implementation of Living Labs. The sustained engagement of stakeholders, significant needs for facilitation and territorial engineering, administrative constraints, and funding challenges all pose significant hurdles to the long-term viability of these collaborative initiatives.

The continuation of the project should help to strengthen the network of TWWR stakeholders, develop regional experiments and assess more precisely the effects of Living Labs on the effective deployment of TWWR at regional level. Beyond the results achieved in each of the pilot areas, the aim is to make Living Labs genuine spaces for knowledge generation and collective innovation, the lessons from which can be capitalised on, adapted and replicated in other regional contexts. The discussions held, the governance methods tested, the technical and organisational solutions trialled, and the feedback from these initiatives will form a common knowledge base for the benefit of the entire regional territory. This capacity for transfer and replication is a key factor in accelerating the development of the TWWR in the Sud–Provence–Alpes–Côte d'Azur region and strengthening the resilience of local areas in the face of growing pressures on water resources.

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