Set of policy briefs on regulation and policy instruments

Deliverable 5.8

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D5.8 Set of policy briefs on regulation and policy instruments

Synthetic and accessible 'take away' documents that can be used by policy officers, stakeholders and the public

Summary

D5.8 Set of Policy Briefs on Regulation and Policy Instruments outlines comprehensive guidelines and strategic recommendations to enhance the governance and regulatory frameworks for water-smart systems across Europe. This deliverable builds on the foundational work completed in Task 5.4, which integrates insights from various stakeholders on regulatory and economic aspects, including financial mechanisms, incentives, and tariffs provided by IWW, as well as legal considerations from KWR. Through an analysis of the socio-economic factors and legal barriers identified in Task 5.2 and leveraging the socio-economic metrics developed in WP6, this document provides a set of at least four policy briefs. These briefs aim to foster a supportive environment for the broad application of water-smart solutions, proposing improved policy frameworks at local, national, and EU levels. The timing and thematic focus of these recommendations are aligned with current EU policy processes related to water and the circular economy, identifying optimal windows for the targeted dissemination of these policy briefs. D5.8 serves as a crucial tool for policy officers, stakeholders, and the public, offering synthetic, accessible 'take away' documents that encapsulate contributions from the involved Work Packages.

Milestone number	Work package
D5.8	WP5
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Revision history

The table below provides detailed explanations of the integration of the changes requested as part of the final project review.

Policy Brief	Request for revision	Brief description of the revisions
#2 Accelerating water smartness by successfully implementing the EU Water Reuse Regulation (2020/741)	The policy brief would benefit from a better description of how social acceptance was achieved. As there is a deliverable on the subject, it would be recommended to reflect some of the key messages.	The chapter on challenges and opportunities in the Lisbon Living Lab was further expanded and supplemented with additional key messages from the research and work on D5.7. Best practices from the Lisbon Living Lab were included, such as the CoPs, set-up of the observatory tool. A corresponding recommendation was added, summarizing key recommendations from D5.7 including the importance of transparent governance, clear communication, building trust in institutions, etc.
	The policy brief should better explain why water reuse is essential and critical for the Member States (in the key messages).	The first key message has been expanded to emphasize the crucial role and potential of water reuse in the EU member states.
	The section on challenges and opportunities should be reviewed to better distinguish between what the challenges and opportunities are for the Lisbon LL and what they are	Since this chapter is intended to present the project results on assessed challenges and opportunities in the Lisbon Living Lab (LL), the text has been revised

Policy Brief	Request for revision	Brief description of the revisions
	more generally. As it stands, it is also difficult to make a distinction between the current state of the art, and what is/would be required to enhance water reuse practices.	accordingly to avoid confusion. This includes specifying the title, adding subheadings, and making the language more precise. In doing so, we also clarified the distinction between the current state of the art (e.g., by removing words like "may") and what is needed to improve water reuse practices.
	The section on business models, funding mechanisms, and pricing strategies should be reviewed to make a distinction between the economic and financial tools and the affordability and willingness to pay issues and be more specific on recommendations (also based on D. 4.4)	Some key recommendations from D4.4 have been added (such as private-public partnerships as an opportunity for enhancing CBM) and a reference to the Deliverable promoting the use of the guidelines for creating robust and sustainable CBM have been added. This revised recommendation reflects the principles of Circular Business Models, emphasizing the need for financial innovation, stakeholder collaboration, and the integration of environmental benefits into economic systems. It also highlights the importance of aligning economic incentives with sustainable water use practices, leveraging both public awareness and pricing strategies to drive adoption.
	Typo to be corrected page 13	‘lincensing’ corrected to ‘licensing’
#3 Wastewater and Sludge as Nutrients for Agriculture	The background section should be reviewed to include sub-sections clearly highlighting status, challenges and opportunities.	Sub-sections have been added and the text adapted to clearly show status, opportunities and challenges
	The technologies listed on pages 8 and 12 should be introduced. Why have they been introduced in this section?	Technology referred in Page 8 is deleted, to avoid going into details about the technology which is still under development. A footnote on Technology in Page 12 is added

Policy Brief	Request for revision	Brief description of the revisions
	There should be similar introductions for the Alicante and Venice LLs.	Modified for Venice to make it similar to Alicante
	The presentation of the barriers for the Venice LL should be homogeneous.	Modified as per the review
	The business barriers for the Venice LL are not fully clear. What are the present barriers? What is the ARERA's MTI4 tariff method? A footnote would be useful.	Added sentences to make it clear. A footnote on ARERA MT14 has been added.
	The recommendations related to the Venice LL are very general. In what way will they address the listed barriers? How can the project partners make them more specific?	The bullet points have been taken out, rewrote it similar to Alicante. The recommendations have been made targeted towards the barriers and recommendations for policy and capacity development added which was missing.
	What is the context of Figure 3?	A reference to the figure has been added in the introduction section
	The review of the two case studies should be better introduced. What is being demonstrated with these two case studies?	In the introduction to the case studies, two sentences have been added summarizing the cases studies on what they demonstrate.
	References to LIFE ENRICH project, Water2Return project, and WalNUT programme should be added.	References added. WalNUT was already referred.
	Some key messages are misleading, i.e., the ones on water reuse and stormwater management should be more targeted towards infrastructure.	These revisions sharpen the focus on the infrastructure-related aspects of water reuse and stormwater management, aligning with the large-scale system development goals in the original policy brief. Two key messages (stakeholder engagement and awareness raising) have been merged, and another message on

Policy Brief	Request for revision	Brief description of the revisions
		"bureaucratic hurdles" have been added.
#4 Fostering circular water infrastructure	Figure 2 should be referred to in the text.	A sentence about the structure of the subirrigation system was added to the text, with a reference to Figure 2.
	The recommendations should be better presented, either as sentences or bullet points (page 13).	Lengthened the two shortest bullet points to "•Provide detailed guidelines for permission processes to reduce bureaucratic hurdles, especially for small pilot plants." and "•Promote public engagement, awareness, and communication to scale innovative circular water management solutions.". Added dots at the end of every bullet point for coherence.
	Typo to be corrected page 8	'blacklines' corrected to 'black lines'

B-WaterSmart

Policy Brief

Unleashing the untapped energy potential of wastewater

Recommendations for achieving the energy neutrality targets of the revised EU Urban Wastewater Treatment Directive

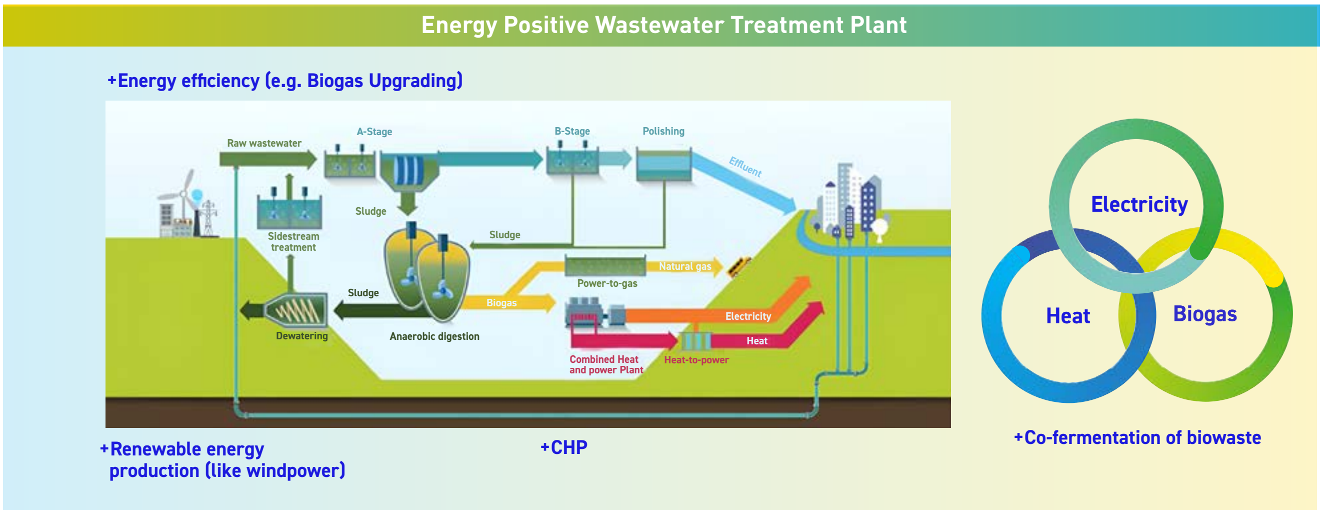
André Müller and Jonathan Schieren
(both from adelphi)

August 2024

Abstract

The revision of the EU's Urban Wastewater Treatment Directive (UWWTD) has recently been adopted by the European Parliament and awaits formal approval by the Council of the European Union before entering into force. The revision entails sweeping changes regarding the way wastewater utilities will have to think about energy. By 2045, all urban wastewater treatment plants (WWTPs) larger than 10.000 population equivalent in EU Member States (MS) must achieve energy neutrality. This will require WWTP operators to both generate their own renewable energy and to make major advances in energy efficiency. The policy will be impactful in the context of the EU's climate mitigation efforts as the wastewater treatment sector is one of the most expensive public industries in terms of energy requirements, accounting for more than 1% of consumption of electricity in Europe. At the same time, wastewater contains roughly five times the energy needed for its own treatment. Through a combination of innovative technologies and management strategies this energy can be harnessed **(see Figure 1)**. This policy brief looks at the challenges and opportunities of realising this ambitious target and provides policy recommendations to stakeholders involved in the implementation process at national and regional levels. It draws on insights from the EU Horizon 2020 project B-WaterSmart (grant agreement No. 869171), which explores different wastewater-to-energy solutions, focusing on Living Labs (LLs) in Spain and Norway[1], [2].

Figure 1: An Energy Positive Wastewater Treatment Plant adapted from: **Loderer and Hananel (2018)**



[1] While Norway is not part of the EU, it collaborates closely with the EU and has aligned many of its policies with EU Directives.

[2] Rani, A., Snyder, S. W., Kim, H., Lei, Z., & Pan, S. Y. (2022).

The EU's untapped energy potential in wastewater

WWTPs are significant energy consumers, contributing substantially to the carbon footprint of municipalities and local governments. Their energy demand often also constitutes a significant portion of the operational expenses of wastewater utilities. Despite wastewater being a substantial source of electricity and heat through biogas production, its energy potential is often overlooked. Recently, an increasing number of utilities have adopted energy-efficient strategies and innovative technologies to maximize this potential. Assessments of pioneering initiatives have shown that utilities can achieve energy self-sufficiency and even become energy providers, thereby diversifying the local energy mix[3].

Implementing the energy neutrality target across EU Member States

Coordinated efforts in the EU Member States, from national to local level, are needed to implement the energy neutrality target outlined in the revised UWWTD. Pathways for utilities to achieve this will depend on contextual factors such as the existing wastewater treatment and sludge management assets, the plant's size and its location. In addition to adopting energy-saving practices, utilities can boost biogas production, particularly by co-digesting organic waste. Technologies such as biogas upgrading and power-to-gas can enhance the use of biogas by providing biomethane for the gas grid. Successfully implementing wastewater-to-energy approaches, specifically when including co-digestion with organic waste, affects policies in the water, wastewater, energy, and solid waste sectors and thus requires a cross-sectoral approach involving a broad range of stakeholders. B-WaterSmart has explored wastewater-to-energy solutions in a number of LLs, which are demonstration sites designed to assess solution feasibility and scalability of different approaches **(see Table 1).**

[3] Mueller (2019) Policies recommendations for improving the legal framework for fostering "wastewater-to-energy" solutions in Europe. Power Point Presentation based on Project Deliverable D.T.2.4.2 (Internal) https://programme2014-20.interreg-central.eu/Content.Node/05-Policy-Recommendations-Andre--Muller-adelphi.pdf.

	Alicante, Spain	Bodø, Norway
Description of the Living Labs	**The Alicante LL investigates technologies that recover and reuse energy and nutrients from wastewater along with salts from brine resulting from the reverse osmosis process. Whilst an array of different technologies is investigated in the project (including the energy potential of microturbines and nutrient recovery), this policy brief focuses on co-digestion to enhance biogas production.**	**The Bodø LL is carrying out a feasibility study to explore different activities aimed at harnessing the energy potential in small wastewater treatment plants. This policy brief examines biogas production through collectively managing sludge disposal and biogas production of multiple small-scale wastewater treatment plants (including systems to improve information for, and collaboration with, stakeholders).**
Barriers & enablers	→ Spain's long history of water scarcity and drought has culminated in extensive expertise in water innovation and an enabling environment that can benefit the uptake of wastewater-to-energy solutions. → Public policies generally support the transition to a circular economy and climate adaptation, but provide limited support for wastewater-to-energy solutions. → The legal and regulatory framework for sludge management and use insufficiently promotes biogas production from wastewater. → While some financial support for biogas exists (e.g. the government provides funding opportunities in the context of the EU recovery funds during the Corona pandemic), funding is generally inadequate to stimulate a large-scale uptake of solutions for improving energy efficiency and selling energy to the grid. → On-site biogas production is constrained through high costs of organic waste transportation and legal requirements for wastewater treatment plant operators to become certified to process organic waste. → Lack of market transparency for and seasonal variations of available organic waste represent a challenge in obtaining a stable supply, hampering co-digestion projects. → Injection of biomethane in the gas grid is limited by high costs for gas purification and pressurization.	→ The combination of accessible funding, widespread knowledge, collaborative governance structures, and public awareness regarding the importance of circularity establishes a conducive environment for energy recovery initiatives. → The current state-of-the-art practices in Norway involve storing sludge in open beds, leading to high methane emissions. This deficiency could be leveraged to drive improved solutions for sludge treatment and biogas production in the future. → The small size of many municipalities and their remoteness in sparsely populated Northern Norway results in low sludge availability and high costs (incl. for transport), which can make biogas production difficult. → Norway's electricity costs, kept low by abundant hydroelectricity, as well as the already high energy efficiency of wastewater plants, deter investments in biogas projects with high initial expenses, particularly for smaller facilities. → Small municipalities struggle to pursue biogas projects independently due to the high administrative and operational requirements. As a result, they often rely on regional waste management facilities for project management. → Municipal regulations for water and waste fees pose hurdles for municipalities to establish viable business models for biogas production. Legal support is required to establish a collaborative agreement between municipalities and regional waste treatment facilities in charge of biogas production.

Table 1: Barriers and enablers for implementing B-WaterSmart approaches and technologies in the Spanish and Norwegian Living Labs

Towards an enabling environment for the implementation of wastewater-to-energy solutions

The extent to which wastewater-to-energy solutions are adopted differs significantly among EU MS, but in general implementation is at an early stage. Creating an enabling environment for wastewater-to-energy solutions is a complex endeavour that can take decades. The required framework conditions including supportive policies and regulations, institutions and finances are only in their infancy, if present at all **(see Figure 2).**

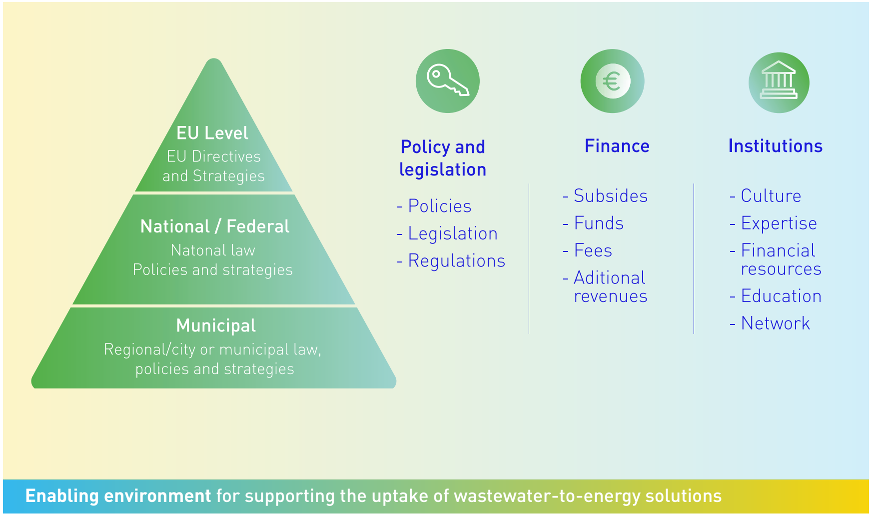


Figure 2: Key dimensions and enabling factors for supporting the uptake of wastewater-to-energy solutions (Mueller, 2019)

Policy and regulations

In most EU MS, **regulations struggle to incentivise wastewater-to-energy** solutions. One common problem is that utilities are legally prohibited, or at least constrained, from venturing outside their core business of treating solid waste and wastewater. This is the case in Spain and Norway. Moreover, there are rarely any incentives to produce and sell energy to the grid or regulatory pressure to save energy. Other, more environmentally harmful forms of biogas, such as biofuels from feedstock, receive more policy support than wastewater-to-energy solutions. Furthermore, specific regulations that promote technologies or management solutions, for example permission to blend organic waste and sludge for co-digestion, are often still missing. While far from being sufficient, some governments have taken initial steps to promote wastewater-to-energy solutions, and awareness of the need to make use of the energy in wastewater is growing.

Finance

Introducing wastewater-to-energy systems involves **significant upfront expense, especially when it involves co-digestion.** Operators usually depend on subsidies to cover such costs. However, such subsidies are not common in most EU MS. Operators must therefore recover costs through energy savings, improved self-supply or selling excess energy to the grid. One significant challenge is that revenues from cost savings or energy sales can only be used for limited purposes, often excluding reinvestment in energy-related measures. This can make the adoption of wastewater-to-energy solutions economically unviable and unattractive. In Spain, for example, many wastewater sector contracts stipulate that cost savings from energy efficiency measures reduce the plant's future operational budget, with no bonuses awarded. In Norway, electricity prices are lower than in most of Europe, thanks to the abundance of clean hydroelectric power. This disincentivises investments in costly wastewater-to-energy solutions, especially for smaller plants. In Northern Norway, the size of settlements and their remoteness make biogas use from wastewater unviable due to long transportation distances and the limited volumes of sludge produced.

Institutions

Water utilities adopt a cautious approach to innovation for two main reasons. They act as protectors of public health, and they oversee significant asset bases with long operational lifespans. Especially small municipalities and utilities lack the time, financial resources and expertise to engage with and implement innovations. Guidelines, such as the Spanish biogas roadmap published in 2022, can offer support to utilities to overcome implementation hurdles. Implementing and operating these technologies, however, poses an even bigger challenge. In the Bodø example, small municipalities tend to find it easier to deliver sludge through a regional waste management facility, and subsequently do not participate in biogas projects, due to the significant operational and maintenance burdens they entail. Co-digestion involves additional hurdles for utilities. In Spain, promoting co-digestion could benefit from the establishment of smart organic waste marketplaces, providing essential data on waste properties, reliable supply, and delivery services. Currently, gaining access to regular quantities of organic waste represents a significant barrier.

Opportunities & Policy Recommendations

Increase the support for wastewater-to-energy solutions in national and sub-national legislation and policy

For example, by integrating targets for energy recovery from wastewater into national energy strategies and climate plans. Policies and legislation should recognize the enhanced environmental performance of bioenergy produced from solid waste and wastewater compared to forms using unsustainable feedstocks.

Harmonise policies and regulations by integrating cross-sectoral interlinkages and conflicts between the energy, water and solid waste systems innate to wastewater-to-energy solutions

For example by dissolving the regulatory issue that organic waste from food cannot be combined with sludge to produce biogas through co-digestion. Policies should encourage collaboration between the energy, water, and waste management sectors. This can be achieved by forming inter-agency working groups that streamline regulations, ensuring that the policies of one sector do not hinder those in another.

Provide financial incentives such as subsidies, tax breaks, or feed-in tariffs to reduce the initial investment burden and make biogas projects more financially viable

High upfront costs currently dissuade operators from pursuing biogas production, co-digestion and biogas upgrading. As highlighted for Spain, potential options include performance-based contracting or performance bonuses tied to high energy efficiency in the wastewater sector. Additionally, it is crucial to ensure that co-digestion projects in existing WWTPs are eligible for government financing schemes to promote biogas generation.

Enable utilities to take advantage of multiple revenue streams from wastewater treatment to improve their business case, considering varying local contexts

This will help utilities to become independent of subsidies in the long-term with a focus on developing a profitable way of managing co-digestate. To this end, it is important to simplify the regulatory process for biogas projects, including streamlined permitting and support for connecting biogas facilities to the gas grid. This can reduce administrative barriers and accelerate project development. Importantly, WWTPs need to be enabled to make profits from producing and selling energy from wastewater, for example by implementing long-term budget fixes (over five years).

Foster a waste regime that drives up the production of, and easy access to, organic waste and consequently stimulates co-digestion in WWTPs as an economically attractive disposal pathway

Potential measures are supporting smart local-to-regional marketplaces to efficiently match supply and demand for waste streams at national or regional level or simplifying the certification process for utilities to purchase and process organic waste for co-digestion.

Increase multi-sectoral information transfer, education and targeted support

For example by offering advice and guidelines on how wastewater operators and municipalities can find legal and regulatory workarounds to generate profits from biogas, such as the inter-municipal and regional strategies for biogas production outlined for the Norwegian case. The government could also support strategic alliances for wastewater treatment, as exists in Spain. Also useful are guidelines for utilities and municipalities (e.g. on lessons learnt and best practices for implementing wastewater-to-energy projects).

References

Rani, A., Snyder, S. W., Kim, H., Lei, Z., & Pan, S. Y. (2022). **Pathways to a net-zero-carbon water sector through energy-extracting wastewater technologies.** NPJ Clean Water, 5(1), 49.

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Mueller (2019) **Policies recommendations for improving the legal framework for fostering "wastewater-to-energy" solutions in Europe.** Power Point Presentation based on Project Deliverable D.T.2.4.2 (Internal) https://programme2014-20.interreg-central.eu/Content.Node/05-Policy-Recommendations-Andre--Muller-adelphi.pdf.

Imprint

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See the download section of the B-Water Smart website b-watersmart.eu for further reading.

Policy Brief | Unleashing the untapped energy potential of wastewater - August 2024

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Policy Brief

Accelerating water smartness by successfully implementing the EU Water Reuse Regulation (2020/741)

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August 2024

Abstract

Water is fundamentally connected to essential areas like health, agriculture, and energy, acting as a vital resource that supports life, sustains ecosystems, and drives economic development. However, freshwater resources worldwide are increasingly under pressure. To safeguard these resources, enhance resilience, and ensure an adequate and high-quality water supply for all stakeholders, a transition to water-smart societies and economies is imperative. In response to the growing pressure on freshwater resources across the EU, the European Commission adopted the **EU Regulation on Minimum Requirements for Water Reuse**. This regulation, which has been in effect in Member States since June 2023, aims to foster the safe use of treated wastewater for agricultural irrigation across the European Union.

This policy brief highlights challenges and enablers for the national implementation of water reuse in Portugal, examining both the national legal framework and selected success practices for water reuse. It offers recommendations to address these challenges and promote enablers, targeting EU Member States to assist in their national implementation and the EU Commission to continue fostering and reinforcing an enabling environment for water reuse. These recommendations are informed by insights gathered from the Living Labs of the Horizon 2020 project B-WaterSmart (located in Lisbon, Portugal; Alicante, Spain; East Frisia, Germany; Flanders, Belgium; Venice, Italy; and Bodø, Norway) and from the WATER-MINING project. One of the Living Labs is specifically highlighted in this policy brief, detailing the associated success practices, enablers, and challenges. B-WaterSmart and WATER-MINING have developed innovative technological and data application solutions to enhance circularity in the water cycle.

Key messages

Essential role of water reuse: Water reuse is a crucial solution to tackle water scarcity by providing a secure and reliable water source, while enhancing EU climate change adaptation capacity and alleviating pressure on freshwater resources across the EU. Yet it remains underutilized, with only 2.4% of treated water being reused. Successful examples from Mediterranean countries highlight its potential, and recent droughts expanding to Northern Europe underscore the growing need for broader adoption of water reuse practices across the continent. The EU Water Reuse Regulation (2020/741) promotes the safe use of treated wastewater, primarily for agricultural irrigation making its sound implementation across EU Member States important to address growing water scarcity, stabilize food supplies, protect ecosystems, and reduce reliance on overexploited freshwater resources.

Challenges in implementation: National implementation of the EU regulation faces several challenges, including complex approval processes, and regulatory and financial barriers. Overcoming these challenges is essential for effective water reuse practices.

Successes and innovations from the Horizon 2020 project B-WaterSmart: The Lisbon Living Lab of B-WaterSmart demonstrates successful water reuse practices and the tools developed to facilitate them, such as unrestricted irrigation of urban parks (tools for smart water allocation, risk assessment and risk management) and direct potable reuse for beer production (protocol for reclamation and monitoring).

Policy recommendations at EU level

→ Extend the scope of the EU Water Reuse Regulation to urban, industrial, and environmental uses;

→ Develop a strategic agenda on water reuse, mandating the integration of water reuse into EU water resources management strategies, providing guidelines for prioritizing the use of fresh and reclaimed water and on how to account for indirect water reuse, and promoting research on direct potable reuse;

→ Foster public engagement, raise awareness, and enhance communication on reclaimed water safety.

Policy recommendations at Member States level

→ Facilitate efficient permitting by promoting the use of appropriate tools for risk assessment and risk management (e.g., from B-WaterSmart);.

→ Develop robust business models, funding mechanisms, and pricing strategies.

Background

The rising necessity of water reuse in the EU

A key measure in alleviating pressure on freshwater resources is recycling and reusing water for various beneficial uses. However, water reuse in the EU remains significantly below its potential. In the entire EU, only 2.4 % of the total treated water is reused, with significant differences among Member States[1]. Positive examples include Cyprus, where reclaimed water has been used in the cement industry and for agricultural irrigation for many years. Similarly, Spain and France utilize reclaimed water for various purposes such as agricultural irrigation, urban uses, and golf course irrigation, while Portugal also uses it for golf course irrigation[2]. While most of these examples are predominantly found in the Mediterranean regions, where water scarcity has long been a concern, recent droughts and increasing water demand in Northern Europe have highlighted the need for alternative water management practices continent-wide.

Policy context - EU Water Reuse Regulation (2020/741)

The need for a systematic approach to water reuse in Europe was underlined by the European Green Deal, which brought forward a new EU Circular Economy Action Plan (CEAP) in 2020. This plan includes the review and implementation of various directives related to water, wastewater, and nutrients to facilitate enhanced water reuse and efficiency. Notably, the **EU Regulation on Minimum Requirements for Water Reuse** establishes binding requirements for water quality, monitoring, risk assessment, and public information concerning the use of reclaimed water for agricultural irrigation. The implementation of these binding legal measures varies among EU Member States. For instance, some countries impose additional water quality parameters (e.g., France, Italy and Greece)[3] or expand the scope beyond agricultural irrigation (e.g., Portugal). The regulation also allows Member States to opt out of water reuse, subject to justification to the Commission.

[1] EC 2023.
[2] Lazarova et al. 2013.
[3] McLennan 2024.

The Water Reuse Regulation (EU) 2020/741 sets out

- → Harmonised minimum water quality requirements for the safe reuse of treated urban wastewaters in agricultural irrigation: requirements increase progressively based on the degree of human contact with the water (does not address other applications, Member States may use reclaimed water for other uses, provided its compliance with other relevant EU laws).
- → Harmonised minimum monitoring requirements for facility operators, depending on water quality classes.
- → The draft of a risk management plan to assess and address potential additional health risks and possible environmental risks along the entire water reuse system. In case of modifications to the number of control parameters, they have to be explained in the risk.
- → Permitting requirements for production or supply of reclaimed water by national authorities.
- → Provisions on transparency, whereby Member States provide key information on every water reuse project and develop awareness-raising campaigns.

The implementation of successful and safe water reuse across all member states requires practical guidelines and good practice examples to demonstrate their safety and build social trust.

Insights from B-WaterSmart

The Lisbon Living Lab of the EU Horizon 2020 project B-WaterSmart offers valuable insights for improved implementation of the EU water reuse regulation at member state level.

Success practices, enablers, and challenges identified in the B-WaterSmart Living Lab in Lisbon

In Lisbon, Portugal, economic growth, population increase, and the need to expand green areas and increase irrigation—driven by climate change—are intensifying the demand for freshwater. Coupled with more frequent and severe droughts, this has placed significant pressure on freshwater resources. Consequently, water reuse is gaining attention as an effective measure to alleviate this pressure, while contributing to climate change adaptation. As a Southern European country with a long history of water scarcity, Portugal developed advanced national legislation well before the EU regulation came into force in 2023. Initial water reuse efforts began in the Algarve region, particularly on golf courses, while Lisbon initiated its first pilots in the late 2000s[4]. Since then, the city has been consolidating and extending its reuse practices, including pioneering the use of reclaimed water for public park irrigation[5].

Legal enablers

Portugal preceded the European legislation by introducing legislation that regulates the production of water for non-potable reuse, integrating developments and best practices at European level as well as by the International Organization for Standardization (ISO). The Portuguese legislation (Decree Laws 119/2019, 16/2021, 11/2023) governs the production of reclaimed water from urban, domestic, and industrial wastewater, as well as surplus water from agricultural irrigation. Allowed applications in the legislation include agricultural irrigation, industrial uses, and urban uses such as irrigation, toilet flushing, street cleaning, vehicle washing, firefighting, cooling water make-up and recreational uses (landscaping). This comprehensive approach surpasses the EU Water Reuse Regulation, setting a benchmark for both the production and use of reclaimed water.

Additionally, Portugal's Strategic Plan for Water Supply, Wastewater, and Stormwater Management (PENSAARP 2030) offers a thorough and comprehensive strategy for water management. It addresses "non-potable uses" across urban, agricultural, forestry, industrial, and landscape applications, whereas the EU regulation is limited to agricultural uses.

[4] Franco 2009.
[5] Viegas et al. 2015, 2020; Begonha 2022; Cordeiro et al. 2023.

Technical enablers and success practices

In Lisbon and its surrounding areas, several examples of water reuse for urban non-potable uses exist. These include a pilot for direct water reuse in the cooling systems of a large commercial building and the irrigation of the urban park Parque das Nações.

Figure 1. Second licensed water reuse for the irrigation of a big urban park (unrestricted urban irrigation)

The B-WaterSmart Living Lab in Lisbon (2020-2024) has successfully demonstrated the potential for non-potable water reuse through a new pilot near Parque Tejo. This project involves creating 38-hectare green park on a decommissioned landfill, irrigated with reclaimed water to promote lawn growth **(Figure 1)**. This park offers citizens a scenic space along the Tagus River, suitable for hosting large events. It was inaugurated during the biggest 2023 World Youth Day ceremony attended by over 1 million pilgrims during the Pope's visit to Lisbon in August 2023, and also hosted the Rock in Rio 2024 music festival.

In this context, the Lisbon Living Lab developed a smart water allocation toolset designed to optimize water supply and demand, while managing water volume, cost, energy, nutrients and risk. This suite of four digital tools includes

- → The Water-Energy-Phosphorus balance planning tool[6] **(Figure 2)**
- → The Risk Assessment tool for Urban Water Reuse[7]
- → The Water Quality Modelling tool for reclaimed water distribution networks[8]
- → The Environment for Decision Support and Selection of Alternative Courses of Action[9]

[6] Water-energy-phosphorous balance planning module: mp.uwmh.eu/d/Product/55
[7] Risk Assessment for urban water reuse module: mp.uwmh.eu/d/Product/67
[8] Reclaimed water quality model in the distribution network: mp.uwmh.eu/d/Product/51
[9] Environment for decision support and alternative course selection: mp.uwmh.eu/d/Product/66/

Figure 2. Water-energy-phosphorus balance planning module developed by Baseform and LNEC in B-WaterSmart

These tools aim to enhance water and related energy and phosphorus efficiency, promote water-smart allocation (fit-for-purpose quality), support circular economy practices, and ensure safe non-potable urban water reuse.

Beyond non-potable applications, the potential of water reuse extends to producing food-grade water. Based on pilot demonstration results, the Lisbon Living Lab has developed a protocol for producing craft beer-grade water from treated wastewater that complies with EU and Portuguese drinking water standards, e.g. 32 out of the 54 pharmaceutical compounds analysed below the limit of quantification (LOQ) and the remaining below 0.1 or 0.3 ug/L; 10 PFAS below LOQ and 10 PFAS below 0.3, 1 or 2 ng/L, far below the drinking water quality standard of 100 ng/L for PFAS-total; the ozonation by-product NDMA below the international guidelines. This process involves ultrafiltration, ozone treatment, activated carbon filtration, and reverse osmosis **(Figure 3)**. With this pilot, Lisbon demonstrated the safety of reclaimed water to pave the way for future potable water reuse.

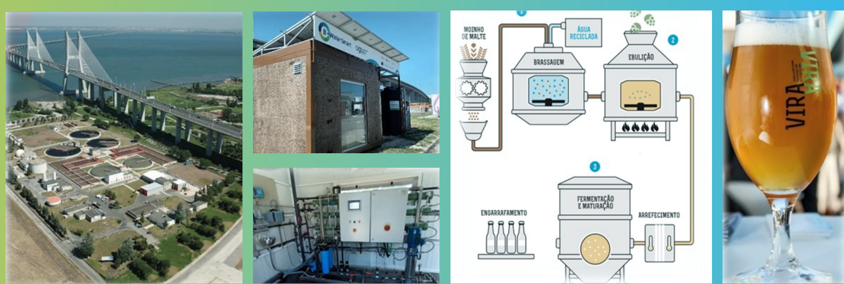

Figure 3. Lisbon Living Lab pilot (Águas do Tejo Atlântico, S.A. and LNEC) providing safe and clean water for beer production

Challenges and opportunities

Although Portugal's national strategy and legislation are generally supportive of water reuse, the Lisbon LL has encountered several local challenges that hinder the widespread adoption of reclaimed water. A major constraint is the national legislation prohibiting licensed users of reclaimed water from transferring it to third parties, either through sale or free distribution, due to risk management concerns. The creation and regulation/licensing of a reclaimed water supply service could overcome this bottleneck through a producer-distributer-user(s) model, each party with an adequate risk management. Multiple users likely offer a steadier consumption with the inherent technical and financial advantages resulting from a decreased variation in demand throughout the year and among years, by a wider and more diverse number of interested parties.

Where water reuse is to replace drinking water consumption, as currently in the Lisbon LL for non-potable uses, the financial viability of water reuse is not an issue (with reasonable return on investment) provided the investment capacity exists. However, when it is to replace freshwater abstraction, as in many regions in Portugal, the EU's cost-recovery principle coupled with Portugal's user-pays-principle undermine the cost-effectiveness of reclaimed water compared to almost free freshwater abstraction, which is only subject to minimal water abstraction charges regulated under Decree-Law No. 97/2008. In this case, as found in stakeholder interviews and discussions within the CoPs, the willingness to pay for reclaimed water remains a significant concern. The cost of new infrastructure and potential tariff increases could hinder expansion unless future business models ensure a fair distribution of costs and benefits among all users.

Despite these challenges, there are several opportunities for advancing water reuse in Lisbon. Social acceptance of water-smart solutions has been a central focus of the B-WaterSmart approach, with the Lisbon LL evaluating public perceptions through interviews, surveys, and engagement with Communities of Practice (CoPs). Recent surveys demonstrate a wide acceptance of reclaimed water in Portugal for non-potable uses, provided there is trust in water authorities, transparent information, and sound risk management[10].

Enhancing public awareness about water scarcity was therefore vital in Lisbon. Broader stakeholder involvement across the value chain improved shared problem ownership and investment opportunities. The CoPs served as platforms to promote regional best practices. In Lisbon, the CoP has engaged municipalities and water utilities, as possible replicators of water-smart solutions. These regional networks allowed to reflect on the diverse circumstances of the municipalities involved, at the environmental, social and economic level, encouraging governance frameworks that help manage trade-offs across water users, rural and urban areas. Tools like the observatory developed by the Lisbon LL will play a vital role in raising awareness by sharing transparent, up-to-date information about water consumption in the future. Public engagement through events—targeting different groups, including students—has been key to promoting a circular culture of reuse. Long-term communication efforts, supported by CoPs, will be needed to foster water literacy and increase awareness of water scarcity in Lisbon.Furthermore, national legislation in Portugal will need to evolve to align with broader EU policies, particularly those concerning the recast of the Urban Wastewater Treatment Directive. The updated legislation should consider water reuse for purposes like surface water augmentation and managed aquifer recharge, and should more explicitly integrate water reuse into local and regional water balances, prioritising its uses.

[10] Gomes et al., 2023.

Policy Recommendations

Creating an enabling environment for water reuse requires joint efforts of the EU Commission and Member States. At the EU level, comprehensive legislation and clear guidance are essential for establishing compatible practices across the EU. While water reuse is a global trend, its success relies on implementing local solutions tailored to local specifications including climate challenges, infrastructure, plant size, and the water-energy-food nexus.

At EU level

Extend the scope of the EU Water Reuse Regulation to urban, industrial, and environmental uses

To enhance water resilience and secure freshwater for more demanding uses, the EU Water Reuse Regulation should be extended to include urban, industrial, and environmental applications, in addition to agricultural irrigation. Limiting water reuse to agricultural irrigation leads to underutilization of treatment capacity and incurs unnecessary operational costs throughout the year. Furthermore, water reuse is most effective and viable when reclaimed water is used near the reclamation facilities.

Moreover, Member States should be provided with guidelines to broaden the use of reclaimed water for both potable and non-potable purposes. As far as direct potable reuse is concerned, the B-WaterSmart Living Labs Lisbon **(Figure 5)**, East Frisia, and Flanders could showcase the successful and safe potable reuse of treated process water or urban wastewater in the food industry (beverage and dairy sectors), and for drinking water supply, respectively.

#1 Water reclamation protocol for potable water reuse in beverage industry (D2.8)

- Pilot (24/7) testing in Beirolas WRRF (Lisbon LL)
- All treatment schemes produce water with an adequate quality to be reused in the beverage industry, complying with the EU and the Portuguese drinking water quality standards - no pathogen indicators: PEAS desinfection by-products, NDMA, and pharmaceutical compounds below the quantification limits (PFAS <0.3 ng/L, THMs < 2pg/L, HAAs <2pg/L bromate <3ng/L, NDMA <3ng/L, PhCs < 100ng/L)
- The operational monitoring results showed higher normalized permeate flowrates for the treatment scheme comprising only ultrafiltration and reverse osmosis

Figure 5. B-WaterSmart protocol for potable water reuse

At EU level

Develop a strategic agenda on water reuse that covers all uses for reclaimed water

Establish a strategic agenda on water reuse (and related resources, e.g., energy and nutrients) that ensures coherence across EU, national, regional, and local levels. This agenda should cover all uses of reclaimed water, including non-potable and potable applications. It should aim to promote a circular water paradigm. Additionally, promote a cross-sectoral integration between water reuse policies and other relevant EU directives and initiatives, such as the Circular Economy Action Plan, Climate Adaptation Strategy, and Biodiversity Strategy, to maximize synergies, minimize trade-offs, and promote holistic water resource management.
As part of B-WaterSmart, each Living Lab has developed a strategic agenda as a pathway for implementing their vision and goals[11] which can support the development of the EU agenda.
The EU should encourage or mandate water organizations across Europe, including water utilities, municipalities, regulators and other stakeholders, to develop their own strategic plans on water smartness. These plans should outline short-, medium- and long-term strategies and actions, while estimating the necessary human, technological, and financial resources required for implementation. The strategic plan should be supported by a quantitative and objective-driven assessment framework similar to that developed in B-WaterSmart[12].

Mandate the integration of water reuse into EU water resources management strategies and provide guidelines for prioritizing the use of fresh and reclaimed water

The EU should establish regulations that integrate water reuse into its broader water resource management plans and strategies. This approach will optimize the use of available water sources, enhance water resilience, and promote sustainable water use practices.

To support this integration, the EU should provide guidelines that help Member States incorporate water reuse into their local and regional water balances. These guidelines should assist in defining context-specific priorities for reclaimed water and freshwater uses. Prioritization should be based on local environmental, technical, economic, and social factors to ensure that water reuse is applied where most beneficial and that investments are directed to areas where they will be most effective and efficient in securing water supply continuity.

[11] Glotzbach et al., 2023.
[12] Silva et al., 2023.

At EU level

Define how to account for indirect water reuse

Establishing an EU-wide position on how to account for indirect water reuse is essential for a more holistic, safe, and transparent water management. During periods of droughts, treated wastewater can constitute a significant portion of streamflow, making the accounting of indirect water reuse critical for effective risk management, treatment requirements, and permit processes. In addition, other water environmental uses (e.g., ecosystems support) and storage, including managed aquifer recharge, should be considered and regulated.

Foster public engagement, raise awareness, and enhance communication on reclaimed water safety

Awareness measures and enhanced communication to build trust in society on the safety of water reuse should be promoted. The focus should be on water quality and not on its origin, and the semantics should ban 'wastewater' and focus on 'water'.

Promote research and pilot studies on direct potable water reuse

Expanding the application of reclaimed water through direct potable reuse can significantly increase water resilience by providing a locally sourced water supply. To support this, further research on direct potable water reuse is needed to facilitate the development of guidelines on water treatment processes and water quality. This entails conducting pilot studies to showcase the safety and feasibility of potable water reuse to the public. The B-WaterSmart pilot for potable water reuse in artisanal beer production in the Lisbon Living Lab marked a significant milestone, fostering trust in the utilization of reclaimed water.

At Member State level

Promote sustainable business models, funding mechanisms, and pricing strategies

Regions that have relied primarily on freshwater (groundwater or surface water) and (too) low water abstraction charges may find that the costs associated with managing and establishing water reuse infrastructure that meets the new minimum water quality standards are higher than their current expenses. To enhance the affordability and willingness to pay of treated water, robust sustainable circular business models for water reuse are required, leveraging Public-Private Partnerships (PPPs) and blended finance.

The B-WaterSmart project's 'Guidelines to Improve New Business Models at Living Labs' assist stakeholders in creating adaptable Circular Business Models (CBMs) tailored to regulated environments, the water sector's needs and the specific contexts of the LLs[13]. These guidelines integrate both economic and financial tools, addressing various stakeholders such as municipal bodies and water treatment utilities.

Below selected recommendations will help create a sustainable and economically viable framework for water reuse in various contexts:

Reommended economic and financial tools: Financing strategies must centralize water reuse projects by securing diverse funding sources, including public-private partnerships, grants, and investment funds. Implementing financial incentives or subsidies for industries, municipalities, and agricultural sectors can encourage the adoption of water reuse technologies and practices. These incentives may include, but are not limited to, tax breaks, non-interest loans, and streamlined licensing processes.

Affordability and willingness to pay: Public awareness campaigns should focus on increasing willingness to pay by highlighting the environmental benefits of water reuse, such as conserving freshwater for other uses. A comprehensive pricing strategy should consider both freshwater and reclaimed water sources, ensuring a fair distribution of costs for the treatment, storage, and distribution infrastructure of reclaimed water. Additionally, adjusting charges for water abstraction or water pollution can encourage the adoption of water reuse practices.

[13] Pérez et al., 2024

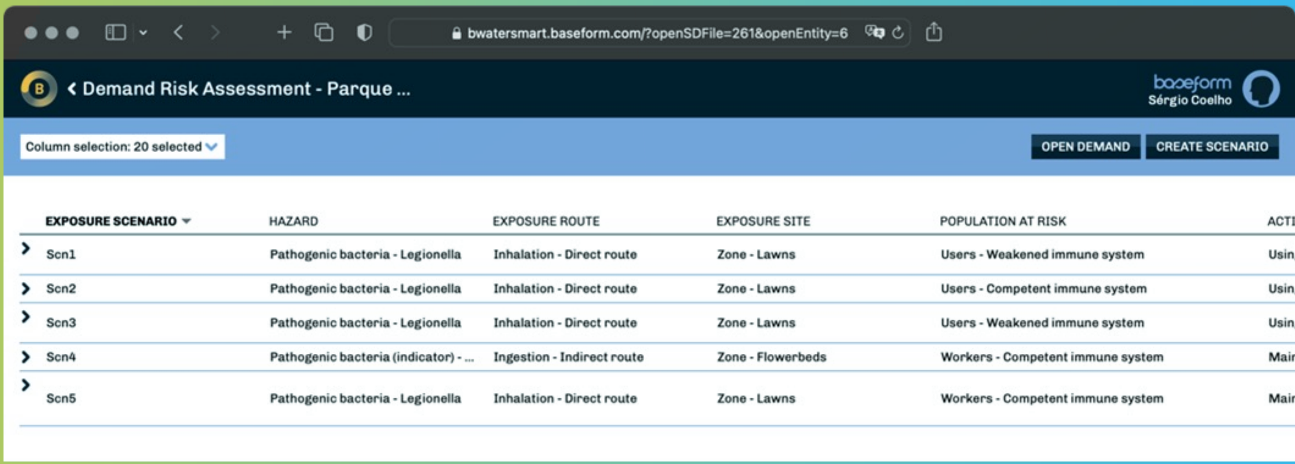

Figure 4. Screenshot of the Risk Assessment tool for urban water reuse developed by Baseform and LNEC in B-WaterSmart

Set up adequate risk management

Future revisions of the Regulation (EU) 2020/741 should provide clearer instructions on the risk assessment process. To assist risk managers in navigating the complex EU guidelines for public health and environmental risks, including Managed Aquifer Recharge processes, the B-WaterSmart project has developed a suite of user-friendly risk assessment tools.

Among these is the Risk Assessment Tool for Urban Water Reuse[14], which aids the evaluation and management of risks associated with safe non-potable urban water reuse **(Figure 4)**. This tool addresses health and environmental risks (including surface and groundwater) in line with the latest ISO standards and EU regulations. Other tools developed in B-WaterSmart offer specialised guidance on risk management in urban reclaimed water distribution[15], and on risk assessment for Aquifer Storage and Recovery[16].

[14] Risk Assessment for urban water reuse module: mp.uwmh.eu/d/Product/67
[15] Reclaimed water quality model in the distribution network water quality model: mp.uwmh.eu/d/Product/51
[16] SuTRa - Subsurface Transport and Removal: mp.uwmh.eu/d/Product/59

Create an efficient permit process for water reuse

Permission processes in EU Member States are often lengthy and complex, involving multiple authorities and causing delays that hinder timely responses to water scarcity. To address this, the permitting process for water reuse should be streamlined to provide clear requirements and enable timely decision-making.

National implementation of the water reuse regulation should facilitate an efficient permitting process with clear guidelines, including the design of a required risk management plan, and protocols for storage, distribution, and third-party use of reclaimed water. Additionally, a clear allocation of responsibilities among the competent authorities is essential.

Improve social acceptance of Water Reuse

Generally, the closer the contact with reclaimed water, the lower the acceptance of its use. Sound risk analysis and transparent information are essential to ensure a sense of safety e.g., among users of green areas irrigated with reclaimed water. Willingness to pay is also a key factor to consider, as increased tariffs, as well as costs of new infrastructures, may hinder the expansion of water reuse, a significant concern among stakeholders in CoPs and the interviewees. The B-WaterSmart project developed a social acceptance model, which guided the analysis of this dimension in the project, resulting in a set of recommendations[17]:

- **Transparent governance** is key, ensuring fairness and public participation in water management decisions.
- **Clear communication** about the safety and quality of reclaimed water, particularly for non-potable uses, helps address concerns, especially where water reuse is perceived as "waste."
- **Building trust in institutions** is crucial, particularly in water utilities and their safety procedures. Renaming wastewater treatment plants as "Water Factories" can help shape positive perceptions. Another option is to create an enabling environment for landmark products that have proven to be able to act as a multiplier for specific population groups.
- **Socio-environmental vulnerability assessments** can help manage trade-offs between sectors with competing water needs.
- **Inclusive engagement of stakeholders**, including agriculture and industry, is necessary to balance costs and benefits. Tools like the Lisbon LL's Urban Water Cycle Observatory and targeted campaigns are key to raising awareness and promoting a circular culture for water.
- **Innovative funding models** such as public-private partnerships can close infrastructure investment gaps. Future business models should ensure a fair distribution of costs and benefits to support broader adoption.

[17] Gomes et al., 2024

Further Reading

Drivers and Barriers – Proposal for a New Governance Model
(B-WaterSmart Deliverable 5.5) (Schmidt et al. 2023)

Guidelines & recommendations for regulation and policy instruments
(B-WaterSmart Deliverable 5.6) (Cardoso et al. 2024)

A reclamation protocol for water reuse in craft beer production
(B-WaterSmart Deliverable 2.8) (Figueiredo et al. 2024)

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See the download section of the B-Water Smart website b-watersmart.eu for further reading.

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Policy Brief

Applying Urban Wastewater and Sludge as Nutrients for Agriculture Use

Recommendations for EU Policy Reforms

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August 2024

Abstract

The European Union (EU) has set an ambitious goal to reduce nutrient losses to the environment (air, water, soil) by 50% by 2030. This reduction aims to address the impact of nutrient pollution on ecosystems and human health, and manage nitrogen (N) and phosphorus (P) better throughout their lifecycle across all sectors. Two key EU policies that influence nutrients recovery and management include the Integrated Nutrient Management Action Plan (INMAP)[1] and the Urban Wastewater Treatment Directive (UWWTD). The INMAP was announced during the publication of this policy brief in 2022 but is yet to be published and operationalized. The INMAP is a comprehensive strategy to improve nutrient management, enhance agricultural practices, and protect the environment. Its implementation will contribute to achieving the EU's Net Zero target and ensuring sustainable agriculture and pollution reduction. The revision of the EU's Urban Wastewater Treatment Directive (UWWTD) has recently been adopted by the European Parliament and awaits formal approval by the Council of the European Union before entering into force. The revision entails changes regarding the way wastewater utilities will have to recover and reuse nutrients from wastewater and sludge[2] including for agriculture. Over 90% of urban wastewater currently meets EU standards but the revision aims to make the wastewater sector energy-neutral, promote water reuse, and utilize sludge for biogas and agriculture production. Under the principles of circular economy, "The Commission will develop an Integrated Nutrient Management Plan, with a view to ensuring more sustainable application of nutrients and stimulating the markets for recovered nutrients. The Commission will also consider reviewing directives on wastewater treatment and sewage sludge and will assess natural means of nutrient removal such as algae[3]."

This policy brief looks at the challenges and opportunities of realising the ambitious target enshrined in both the above policies and provides policy recommendations to stakeholders involved in the implementation process at the EU and national levels. It draws on insights from the EU Horizon 2020 project B-WaterSmart (grant agreement No. 869171), which explores different wastewater-to-agriculture solutions, focusing on Living Labs (LLs) in Spain and Italy and by exploring other ongoing practices within the EU outside the LLs.

[1] Grizzetti et al. 2023).
[2] Sludge is the matter resulting from wastewater treatment, containing water, organic material, nutrients, and valuable resources like carbon, nitrogen, and phosphorus. It can be used for energy production or as a soil conditioner in agriculture.
[3] European Commission 2020.

Background

Nutrient and Sludge Management in Europe: Current status, challenges and opportunities

Current status

Wastewater collection and treatment is governed by the EU Wastewater Treatment Directive. For processing, transporting and using sewage sludge also the EU Waste Framework Directive, the Sewage Sludge Directive and the Industrial Emissions Directive apply. The environmental impacts of sewage sludge are furthermore governed by the Nitrate Directive and the Water Framework Directive including the related directives.

The proposed recast of the EU Wastewater Treatment Directive aims to align the Directive with other EU policies, including the European Green Deal (EGD) which aims to increase circularity and reduce environmental degradation. The wastewater sector currently makes up 0.86% of total CO_2 emissions and 0.8% of energy consumption in the EU[4]. This is addressed in the Directive through nitrogen and phosphorous recycling as well as water reuse (Recast WWTD).

The Recast WWTD requires that sludge has to be treated, recycled and recovered when appropriate according to specifications in the Waste Framework Directive and the Sludge Directive and gives the

[4] Vikolainen 2023.

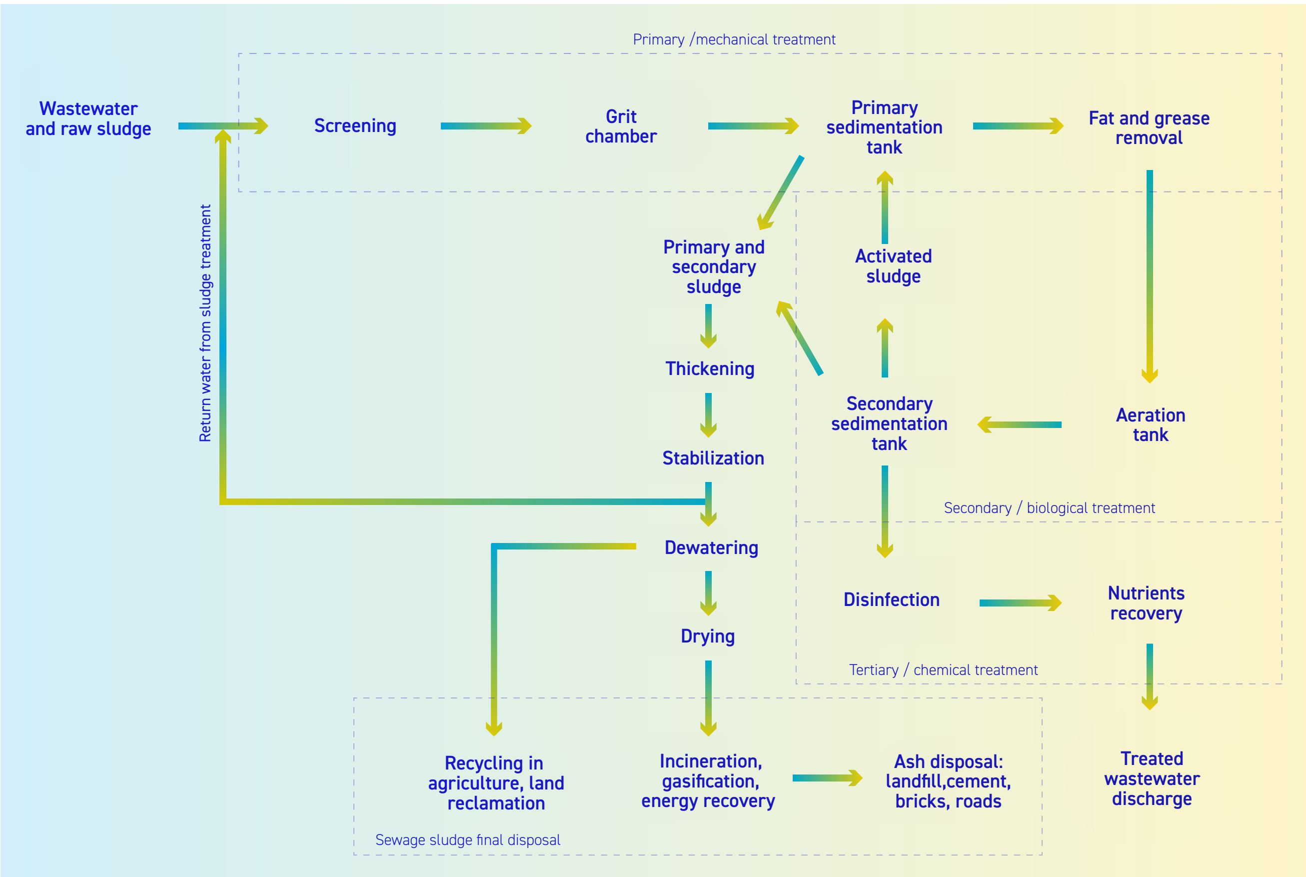
The European Environmental Agency (EEA) estimates that nitrogen and phosphorus losses in Europe exceed safe and sustainable levels by a factor of 3.3 and 2 respectively. This means that the use of nitrogen in agriculture and other activities is unsustainable and contributes to water pollution. The Nitrates Directive aims to protect waters from nitrates from agricultural sources, safeguarding drinking water and preventing damage from eutrophication. In its latest implementation report, the EC (2018) stressed that, while water pollution caused by agriculture nitrates has been reduced across Europe over the last 20 years, some areas show persisting pollution and require action. More than 30% of EU surface water and over 80% of EU marine waters are eutrophic (excessively nutrient-rich). Additionally, 14% of groundwater exceeds legal nitrate thresholds for drinking water (EEA). Overall, nutrient pollution costs the EU approximately €22 billion annually due to water pollution[5].
Recent statistics indicate that the agricultural sector accounts for the largest portion of sewage sludge utilization across the European Union[6]. The Council Directive 86/278/EEC, which regulates the application of sludge in agriculture, was adopted over 35 years ago and remains pertinent, despite ongoing discussions about the need to update the directive.

[5] Mottershead et al. 2021.
[6] Valchev et al. 2024.

Opportunities

Application of sewage sludge in agriculture provides the soil with phosphorous as well as organic matter. A Life Cycle Assessment (LCA) study on nutrient recycling from wastewater highlights the positive environmental outcomes, particularly when chemical inputs are minimized, and human excreta are source-separated. HELCOM's Recommendation 38/1 on sewage sludge handling, adopted in March 2017, emphasizes sustainable agricultural and energy-related uses, avoiding landfilling, and targeted nutrient recycling, particularly phosphorus[7]. It aims to reduce environmentally hazardous inputs, present treatment measures, suggest agricultural application restrictions, and promote cost-effective solutions and regional knowledge exchange, with contracting states reporting regularly on sludge handling, quality, and phosphorus recovery. Among the various sources of nutrients, sludge that is produced across domestic nutrients includes most importantly nitrogen, phosphorous and potassium. Water and wastewater include nitrogen, phosphorous and potassium that can be efficiently reused to support overcoming nutrient pollution in the EU **(see Figure 1)**.

Figure 1: Wastewater and sewage sludge treatment methods in the EU **(Đurđević et al. 2022)**

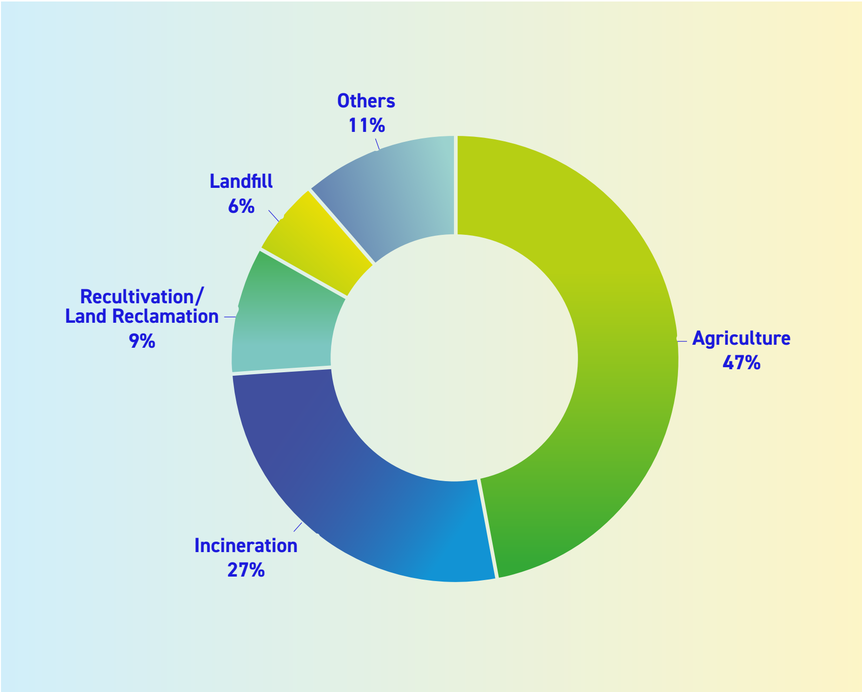


[7] Roskosch and Heidecke 2018.

Challenges

However, the document also identifies challenges such as the spatial disconnect between recycled nutrient products and local factors like soil conditions and types of avoided fertilizers, underscoring the need for tailored approaches to maximize the benefits of wastewater-based nutrient recycling[8]. Unregulated or unknown substances can be contained in sewage sludge and represent health concerns for humans and environment, especially since pollutants may accumulate in the soil. Furthermore, there is a risk of over-fertilization as well as groundwater pollution through nutrient leaching. In 2016, approximately half of the nutrients, predominantly nitrogen and phosphorous, utilized in agriculture were recycled from waste streams. More than 90% were recovered from manure while smaller fractions were recovered from sewage sludge and food waste[9], where manure is a key externality influencing sludge recovery **(See Box: Role of Externalities for sludge recovery)**. In Europe, approximately 8.5 Mio. tonnes (dry solids) of sludge are produced per year. The destination of sludge varies significantly among European countries. Countries with a high fraction of sludge used in the agricultural sector include Cyprus, France, Norway, Portugal, Slovakia and Spain. Germany uses 23.7% of its sewage sludge for agricultural purposes, while Norway uses 61.7% and Spain 74.5%[10]. The abundant availability of manure in Netherlands and Germany are the key reasons why sludge

Figure 2: Sludge use in Europe (EurEau 2021)



[8] Lam et al. 2020.
[9] Buckwell and Nadeu 2016.
[10] Roskosch and Heidecke 2018.

Box: Role of Externalities for sludge recovery

Externalities play a pivotal role in shaping the feasibility and implementation of nutrient recovery practices from wastewater, profoundly influencing the strategies employed by water utilities. Two of the most significant externalities are competition from manure and the availability of land, which greatly impact the recycling and reuse of sludge in agriculture. Understanding these factors is essential for developing effective and sustainable nutrient recovery solutions.

In countries like the Netherlands and Germany, the abundant availability of manure from livestock operations diminishes the perceived value of sludge as a fertilizer. Manure, being a readily available and nutrient-rich resource, directly competes with sludge, making it less attractive for agricultural use. This competition highlights a critical externality that water utilities must consider when promoting sludge-based products. The importance of addressing regional externalities to create new markets for nutrient recovery products is important. These include externalities such as urbanization and land availability when developing nutrient recovery strategies.

Another critical externality is the regulatory environment. While regulations are often perceived as a barrier, they can also provide a framework that supports the safe and effective use of recovered nutrients. However, the emphasis on regulations in discussions about nutrient recovery often overshadows other important externalities. For instance, the economic competition from industrial fertilizers, which are available cheaply and in large quantities, poses a significant challenge. The market value of recovered phosphorus products like struvite is hard to estimate, and farmers may be hesitant to adopt them due to a lack of knowledge and trust in their efficacy. This economic externality needs to be addressed through public education and demonstration of the benefits of nutrient recovery products.

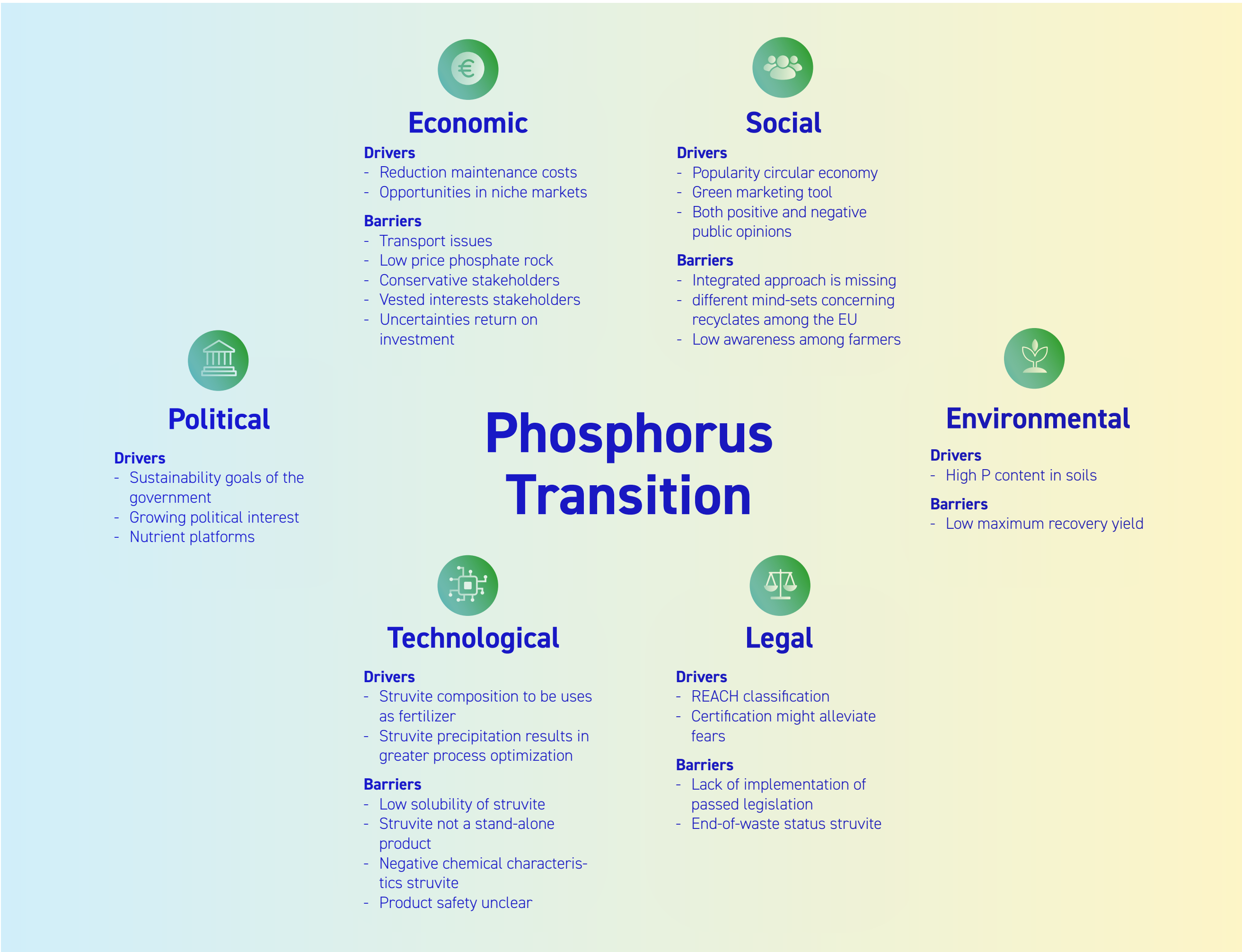
Transport and distribution costs represent significant externalities that can impede the use of sludge-based fertilizers. The high water content of sludge makes it expensive to transport, particularly over long distances from wastewater treatment plants to agricultural fields. This logistical challenge underscores the need for localized solutions and innovations in sludge processing to reduce its volume and improve its marketability.

Social acceptance is another crucial externality influencing nutrient recovery. Negative public perception of products derived from sewage can hinder their adoption, necessitating robust public education campaigns to build trust and acceptance. Geographic, climatic, and population factors further complicate the picture, as they affect both the feasibility of traditional recovery methods and the characteristics of the effluent being treated.

Insights from B-WaterSmart

As part of the B-WaterSmart project, two Living Labs (LLs) – the water utilities of Alicante and Venice – have undertaken initiatives to explore the recovery of nutrients from wastewater and sludge for agricultural and other purposes. Alicante's efforts are focused to transform wastewater treatment plants in Alicante into eco-factories through nutrient recovery, specifically ammonia, while addressing technological, regulatory, and market challenges. The case study from Venice focuses on on developing a decision support system (DSS) for sustainable water reuse, nutrient recovery, and sludge management. Their experiences, summarized below, highlight numerous lessons which include barriers and drivers. In addition, literature review of two countries, Germany and the Netherlands, further enriches this policy brief with lessons from nutrient recovery related policies and initiatives **(See Table 1)**. The results, visualised in **Figure 3**, further substantiate the findings of the LLs. Besides policy and regulation related topics, to make nutrient recovery and market access viable for the products, two business case examples from Germany and Norway are elaborated below. These insights necessitate policy, regulatory, technical, and financial solutions to ensure the viability of these initiatives.

Figure 3. An Assessment of the Drivers and Barriers for the Deployment of Urban Phosphorus Recovery Technologies: A Case Study of The Netherlands **(Boer et al. 2018)**



Drivers and barriers identified in the B-WaterSmart Living Labs in Alicante and Venice

Selective electrodialysis: takes RO brine and separates divalent ions from monovalent ions. The stream with divalent ions will serve as reclaimed water. The stream with monovalent ions will serve as feed for the electrochlorinator

CEVAP

Alicante, Spain

Nitrate-selective electrodialysis reversal (EDR) Piloting of novel membrane for nutrients separation from brines and use in fertigation[11].

Brine Electro-chlorination Piloting of technology for on-site production of sodium hypochlorite, used for disinfection.

Ammonia evaporation CEVAP Piloting of a novel low thermal evaporation technology (CEVAP) for ammonia recovery from anaerobic co-digested sludge.

The project is led by Aguas de Alicante that manages the wastewater treatment plant in Alicante. In Alicante, there are demands for nutrients recovery as there is a shortage of ammonia-based products and there exist several potential consumers of the recovered product. Generally, in Spain, approximately 12%[12] of wastewater is reused for agriculture, with significant regional variation. Most sludge in Spain is not treated in composting plants, leading to basic applications that fail to interest agricultural stakeholders due to potential pollution risks. Aguas de Alicante, which operates two wastewater treatment plants in Alicante, is relatively new to nutrient recovery topics.

The project aims to transform wastewater treatment plants into eco-factories or bio-factories, building on an existing strategy developed before the pilot project. Among the various tested technologies, one focuses on nutrient recovery, specifically ammonia. Traditional ammonia production has a high carbon footprint, but the tested process offers a more environmentally friendly alternative, presenting a promising solution. Despite being at the pilot scale and not yet a viable business case, the initiative has engaged with potential nutrient users. The ambition extends to converting wastewater treatment into bio-factories, with ongoing pilots targeting sludge post-digestion and exploring innovative, low-temperature ammonia recovery technologies.

Despite the potential benefits of nutrient recovery from wastewater, several barriers and drivers impede its implementation in Alicante. These barriers span technological, capacity, policy, and business domains, requiring comprehensive solutions to overcome them and realize the project's ambition of transforming wastewater treatment plants into eco-factories.

Technological Barriers

→ Low Ammonia Concentration: Current ammonia concentrations are far below commercial viability (25,000 mg is minimum).

→ pH Adjustment Needs: Processes sometimes require pH adjustments, complicating operations.

[11] Fertigation is an agricultural practice that combines fertilization and irrigation. It involves the application of fertilizers, soil amendments, or other water-soluble products through an irrigation system.
[12] AEDyR 2019.

- → Salinity Issues: The presence of brine complicates nutrient recovery processes.
- → Complex Laboratory Analysis: Analyzing and researching sludge in the lab is difficult due to its complex nature.

Capacity Barriers

- → High Equipment Costs: The necessary equipment for nutrient recovery is expensive.
- → Transport Costs: Product transport costs are high.
- → Energy Consumption: Conventional ammonia production is energy-intensive, but alternative processes offer lower carbon footprints.
- → Lack of Composting Plants: There are few composting plants in the region, leading to low agricultural interest in untreated sludge.

Policy Barriers

- → Inconsistent Regulatory Framework: The current regulatory framework is fragmented and inconsistent, leading to uncertainty and lack of confidence among stakeholders.
- → Lack of Regulation for Sludge Reuse: There is no clear regulation for the reuse of sludge, creating a grey area for nutrient recovery.
- → Missing Nutrient Recovery Definitions: Existing EU directives (Wastewater Treatment Directive, Water Directive) do not address nutrient recovery or set thresholds for nutrients.
- → Need for Regulation Updates: Regulations need updating to incorporate technological advancements, international best practices, and sustainability objectives.

Business Barriers

- → Competitive Market: Market penetration is challenging due to the competitive agricultural sector.
- → Lack of Business Case: Currently, there is no viable business case for nutrient recovery, though contact has been made with potential nutrient users. For now, sludge in Alicante is sent mainly to a cement factory for dewatering and usage, while roughly one third goes to agriculture and composting.
- → Symbiosis with Industrial Partners: There is a need for collaboration with industrial partners, such as fertilizer producers and cement plants, to integrate nutrient recovery into

Recommended Measures

To make nutrient reuse for agriculture more viable in Alicante, several measures need to be implemented. Firstly, it is crucial to develop a supportive regulatory framework that clearly defines nutrient recovery processes and sets thresholds for nutrient content in treated sludge, aligning with technological advancements and international best practices. Financial incentives should be provided to encourage fertilizer producers to adopt these alternative processes, reducing reliance on conventional, carbon-intensive methods. Additionally, efforts should focus on scaling up the nutrient recovery technology, ensuring the concentration of nutrients meets industry requirements for fertilizer production without increasing costs compared to conventional methods. Enhanced collaboration with waste managers and industrial partners, such as cement plants, can facilitate the integration of nutrient recovery into existing processes. Increased funding and support from regional governments are necessary, alongside maintaining a stable operational budget despite savings or alternative income streams from the wastewater treatment plant. Building local leadership and competencies in circular economy practices, along with more comprehensive research and discussions with waste managers, will further promote the successful implementation of nutrient recovery and its contribution to sustainable wastewater management in Alicante.

Venice, Italy

Ammonia stripping technologies to recover nitrogen from the concentrated liquid digestate of the anaerobic digestion. Assessment of the deviation of Liquid Organic Waste (usually oxidatively treated in the main WWTP) to the anaerobic digestion, to produce biogas and energy for supporting the process.

Digital Enablers: Integrated digital support system for Sludge and Effluent management, to create conditions (mainly in terms of an objective and sharable knowledge for quality and risks assessment) to sustain reuse and address resources to the right valorisation paths.

A collaborative, multidisciplinary environment of key stakeholders, established through the Decision Support System (DSS) development, capable of jointly identifying challenges, proposing solutions, and developing tailored strategies to achieve targeted, shared valorization goals.

AIR – stripping

AIR – stripping

COLUMN – stripping

In a public-private partnership, the public water utility VERITAS, Venice and the private company Engineering (ENG) develop together a Decision support system for water reuse and sludge management. The Veneto region, contributing approximately 7% to Italy's national water withdrawal, primarily relies on groundwater (90%) while the complement comes from surface water (mainly rivers). The wastewater, treated by more than 200 WWTPs in the region, allows indirect effluent reuse for agricultural, industrial, and recreational purposes.

Additionally, the Integrated Fusina Project (PIF) is part of the Regional Plan for Lagoon Protection and is located within the VERITAS area. The project employs a range of treatments, including nature-based solutions (NBS), to achieve non-potable reuse of treated municipal wastewater effluent.

The Venice Living Lab's ambition extends beyond immediate regional objectives, aiming to ensure proper resource valorization. Where applicable, it also seeks to enable the direct reuse of effluent for industrial, agricultural, and urban applications as part of a regional plan for climate change mitigation.

Special emphasis is placed on applying nutrient recovery technologies to wastewater treatment plants and developing shared evaluation model tools for a sustainable valorisation of WWTP effluents and sludge.

The specific key objectives are: i) to demonstrating both indirect and incentivising direct reuse of treated municipal wastewater; and ii) to identify and promote best practices in carbon and nitrogen recovery. These strategic objectives are pursued through the implementation of ammonia stripping technologies for nitrogen recovery, the development of two integrated, transferable, and interoperable DSS systems for sludge and effluent management and valorization, and the establishment of a Community of Practice (CoP) comprising key stakeholders working collaboratively on assessment and planning.

Technology Barriers

→ Complexity of technologies, different in dependence of technology applied (such as pre-treatment requirements for CS technology or high energy consuming for AS technology) hamper the implementation of nitrogen recovery through ammonia stripping.

→ Energy consumption is an implication common to both technologies studied

Capacity Barriers

→ Fragmented knowledge and a lack of objective data on the risks and benefits of resource reuse, leading regulators to adopt overly cautious approaches. This, in turn, prevents the extraction of value from resources and reinforces negative perceptions, creating a significant barrier to fully exploiting reuse potential. Developing tools like the DSS to provide traceability, objectivity, and transferability in the evaluation process can help overcome these barriers.

Policy Barriers

→ Fragmented and unclear regulatory framework at national and regional levels for circular economy development.

→ Lack of interlinkage between water and waste policies, affecting resource valorisations; The presence of contradictions between policies at different levels, makes goal achievement difficult.

Business Barriers

→ Ambiguity among the several regulations regarding sludge use (as described in current status), hampering viable business models. This situation leads to uncertainty allows room to economic speculation (which in turns determines the utilities choices), reinforcing prejudices.

→ Lack of specific regulations for nutrient recovery, creating uncertainty concerning technological standards and hampering financial incentives. In this field, the choice has been delegated to the arbitrariness of different local authorities with the result of hindering the identification of a business model and the implementation of recovery itself.

Recommended Measures

To address policy and capacity barriers in the Venice case study, it is crucial to develop a cohesive regulatory framework that aligns water and waste policies at national and regional levels, ensuring clarity and consistency for nutrient recovery and sludge reuse. Introducing specific regulations with clear standards for nutrient recovery can reduce uncertainty and support viable business models. Enhancing collaboration between regulators, utilities, and industry stakeholders can help update regulations in line with technological advancements. Additionally, building knowledge-sharing mechanisms, like DSS, can provide objective data on resource reuse, while training programs can enhance stakeholders' understanding of nutrient recovery technologies. Encouraging regional partnerships can further support joint investments, helping to address energy consumption and technology complexity in nutrient recovery efforts. To address business barriers identified within the case study, fostering collaboration among water supply chain stakeholders can reduce ambiguity and regulatory uncertainty regarding sludge use and nutrient recovery. Leveraging EU and national incentives, such as the ARERA's MTI4 tariff method[13], helps make nutrient recovery and treated effluent reuse more financially viable by providing clear support and recognition for resource reuse efforts. Implementing nature-based solutions where feasible can reduce reliance on costly, energy-intensive technologies, making nutrient recovery more cost-effective and appealing to businesses. Additionally, optimizing upstream wastewater control through direct collaboration with industries can ensure consistent and high-quality inputs for nutrient recovery, creating a more stable environment for developing business models around treated sludge and nutrient recovery.

[13] The ARERA's MTI4 tariff method is a regulatory framework established by the Italian Regulatory Authority for Energy, Networks, and Environment (ARERA) that sets guidelines for water service tariffs, including incentives for utilities to invest in resource valorization and sustainable water reuse practices.

A brief review of two country case studies from literature

Germany
(Roskosch and Heidecke 2018)

A paper titled "Sewage Sludge Disposal in the Federal Republic of Germany" by the German Environment Agency aims to provide an in-depth analysis of sewage sludge management practices in Germany, focusing on environmental impacts, regulatory frameworks, and technological advancements. It seeks to promote sustainable sludge treatment and phosphorus recovery, ensuring safe and efficient recycling methods. The key findings of the report are highlighted below.

Policy & Regulation

- Amended Sewage Sludge Ordinance mandates the phase-out of direct sewage sludge utilization on soil by 2029/2032.
- Recovery of phosphorus is mandatory when levels reach ⩾ 20g, with 80% recovery required when sludge is thermally treated.

Benefits and Drivers

- Reduced dependence on mineral phosphate imports amid rising demand and prices.
- New market opportunities and employment potential.

Barriers

- Lack of specific hygiene guidelines, except for salmonellae, leading to heavily restricted sludge application.

Netherlands
(Boer et al. 2018)

The study titled "An Assessment of the Drivers and Barriers for the Deployment of Urban Phosphorus Recovery Technologies: A Case Study of The Netherlands" aims to evaluate the key factors influencing the adoption of phosphorus recovery technologies in urban settings. By using the Netherlands as a case study, the research identifies the primary drivers and barriers from various stakeholders' perspectives, focusing on economic, technological, legislative, and social aspects to better understand the transition towards sustainable phosphorus management in wastewater treatment facilities.

Policy and Regulation

- The Dutch Nutrient Platform: Has positively promoted wastewater-based nutrient recycling.
- Fertilizer Regulations and End-of-Waste (EoW)[13] Status: Implementation has been a lengthy process, creating delays in the market acceptance of recovered nutrients.
- Shipment of Waste Regulation: Requires time-consuming contracts and authorizations for cross-border export, giving phosphate ore a market advantage due to fewer regulatory hurdles.
- Phosphorus EoW Status: Phosphorus lacks EoW status, which classifies Wastewater Treatment Plants (WWTPs) as waste management facilities subject to stricter rules.

Benefits and Drivers

- Reduced Maintenance Costs: For WWTPs through struvite precipitation, leading to cost savings.
- Process Optimization: Enabled by struvite precipitation, improving efficiency.
- Sustainable Labeling: For phosphorus recovery fertilizers, appealing to environmentally conscious consumers.
- Struvite Approval under REACH Regulation: Facilitates market acceptance.
- Geopolitical Tensions and Potential Scarcity: Future scarcity of phosphate rock increases the strategic importance of recycled phosphorus.

Barriers

- Transportation Issues: Limits the application of recycled nutrients outside the Netherlands due to phosphate-rich soils in the region.
- Low Sludge Production: In WWTPs, reducing the availability of raw material for nutrient recovery.
- Low Prices for Competing Phosphate Rock Products: Makes it difficult for recycled products to compete economically.

[13] In the context of nutrient recovery from wastewater sludge, under the Waste Framework Directive (2008/98/EC), achieving EOW status means that the recovered nutrients (such as nitrogen and phosphorus) are no longer considered waste but are recognized as valuable products that can be safely and effectively used, for example, as fertilizers in agriculture.

Germany (Roskosch and Heidecke 2018)	**Netherlands** (Boer et al. 2018)

Barriers

- Regulations on phosphorus and nitrogen limit the permissible amount of sewage sludge fertilization.
- Technological limitations for advanced phosphorus recovery.

Recommendations

- Complete withdrawal from sewage sludge utilization on soil.
- Effective separation of pollutants from sewage sludge.
- Wastewater treatment systems should support phosphorus recovery.
- Expand incineration capacities.
- Implement cost- and energy-efficient sewage sludge drying solutions.
- Provide financial assistance for phosphorus recovery.
- Facilitate market access for newly developed fertilizers.

Barriers

- High Investment Costs: Initial setup and maintenance costs for nutrient recovery technologies are substantial.
- Lack of Common Interest and Differing Mindsets: Across the EU, there is a varied approach and interest in recyclates.
- Low Awareness and Preference for Traditional Fertilizers: Among farmers, leading to slower adoption of recycled nutrients.
- Infrastructure Limitations: Such as the lack of urine/rainwater separation, which limits the maximum recovery yield.
- Low Solubility of Recovered Nutrients: Affecting their effectiveness as fertilizers.
- Overly Complex Solutions: Researchers sometimes develop solutions that are not market-oriented.
- Investment Return Uncertainty: Prevents long-term contracts with water boards, creating financial instability.

Recommendations

- Accelerate Regulatory Processes: Streamline the implementation of fertilizer regulations and the EoW status for phosphorus to reduce market entry barriers for recycled nutrients.
- Enhance Infrastructure: Invest in infrastructure improvements, such as urine/rainwater separation, to maximize nutrient recovery yields.
- Increase Awareness: Conduct targeted campaigns to raise awareness among farmers about the benefits and availability of recycled nutrients.
- Subsidize Initial Investments: Provide financial incentives or subsidies to lower the initial investment costs for nutrient recovery technologies.
- Promote Collaboration: Foster collaboration between researchers, policymakers, and industry stakeholders to ensure that solutions are market-oriented and address practical needs.
- Encourage Long-Term Contracts: Develop mechanisms to reduce investment return uncertainties, encouraging water boards to enter into long-term contracts.
- Leverage Geopolitical Advantages: Highlight the strategic importance of phosphorus recovery in the context of global supply uncertainties to attract investment and policy support.
- Facilitate Cross-Border Trade: Simplify the Shipment of Waste Regulation processes to make it easier to export recycled nutrients, levelling the playing field with phosphate ore.

Barriers to implementation

The integration of nutrient recovery from wastewater sludge into agricultural applications faces multifaceted technological, capacity, policy, and business barriers, as evidenced by examples from Venice, Alicante, Germany, and the Netherlands. Technologically, low ammonia concentrations, pH adjustment needs, and high salinity complicate the recovery processes, while the complex nature of sludge further hinders laboratory analyses and contaminant separation. These issues are exacerbated by the high costs and energy consumption associated with nutrient recovery equipment. Capacity barriers include scattered data, lack of decision support systems, and insufficient coordination among stakeholders, all of which impede the implementation of circular economy initiatives. Additionally, the limited number of composting plants and high transport costs restrict the viability of untreated sludge use in agriculture, leading to low agricultural interest in utilizing recovered nutrients. Policy and business barriers are equally significant in linking nutrient recovery to agricultural applications. The fragmented and inconsistent regulatory frameworks create uncertainty, lack of clear guidelines for sludge reuse, and no specific regulations for nutrient recovery, making it challenging to develop a viable business model for agricultural use. The absence of interlinked water and waste policies further complicates the classification and valorization of recovered nutrients, impacting their acceptance in agriculture. Business-wise, market penetration is difficult due to low awareness and preference for traditional fertilizers among farmers, compounded by the economic challenge posed by the low prices of competing phosphate rock products. High investment costs and the lack of financial incentives deter new investments, while the need for collaboration with industrial partners and the uncertainty surrounding investment returns further impede progress. Externalities outside of the utilities and wastewater processes are important to be considered while formulating an enabling environment, policies and businesses for sludge recovery and usage. Analysing the externalities can convert some of the barriers into opportunities. These barriers collectively highlight the need for comprehensive strategic planning, regulatory updates, and targeted incentives to foster the development of nutrient recovery and reuse markets, specifically tailored for agricultural applications.

Box: Business case for nutrient recovery and reuse

Despite the numerous barriers pointed out above, the business of nutrient recovery from organic waste streams is gaining momentum due to several factors. This includes the need to feed a growing global population with limited resources, climate change, diminishing global nutrient reserves (such as peak phosphorus), rising fertilizer prices, and stricter environmental regulations[14]. Examples of business cases, both on nitrogen and phosphorus, highlight the potential for companies to invest in nutrient recycling. The examples also refer to some of the challenges that businesses encounter for nutrient recovery and their application within the agro-food industry.

Phosphorus Recovery (UK and Germany)

The first phosphorus recovery plant in Europe was established through a public-private partnership (PPP) between Thames Water, a London utility, and Ostara Nutrient Recovery Technologies, a Canadian firm[15]. Ostara designed, built, and financed the facility, receiving monthly payments from Thames Water based on the cost savings from eliminating struvite build-up in the infrastructure. This arrangement enhanced the efficiency of wastewater treatment and improved environmental compliance.

In Dinslaken, Germany, a large-scale demonstration plant for phosphorus recovery and indoor food production exemplifies the business case[16]. By reclaiming phosphorus from waste streams, this cooperative venture funded by the BMBF (Regionales Phosphor Recycling) addresses resource scarcity and legal challenges. However, market access remains an obstacle due to recycled products still being classified as waste. Similarly, SF-Soepenberg GmbH plans a small-scale phosphorus recovery plant. Legal complexities persist, but the economic benefits—such as cost savings and revenue from hydroponics—make a compelling case.

Nitrogen Recovery (Norway)

In Norway, VEAS-Yara's nitrogen recovery from wastewater demonstrates a successful business model[17]. Ammonium nitrate solution is sold directly to industrial users, with surpluses recycled in fertilizer production. The alignment of economic gains, environmental benefits, and health considerations strengthens the case.

[14] Otoo 2018.
[15] Water World 2010; Jenks 2024.
[16] Agrobusiness Niederrhein e.V. 2023.
[17] Buckwell and Nadeu 2016.

Opportunities and Recommendations

The opportunities for sludge management and nutrient recovery in the EU are substantial, bolstered by policy support and funding from initiatives such as the LIFE ENRICH project, Water2Return project, and WalNUT program. These efforts highlight the potential for turning waste into valuable resources, transforming wastewater treatment plants into revenue-generating entities. For instance, the annual sewage sludge volume in Germany alone could yield 50,000 tons of phosphorus, significantly reducing the need for imported fertilizers and enhancing food security[18]. Moreover, successful examples like the Oslo wastewater treatment plant, which recovers 750 tons of nitrogen annually, underline the potential for similar projects to decrease operational costs and attract private investments[19]. With sludge treatment and disposal accounting for up to 60% of a plant's operating costs, integrating nutrient and energy recovery processes, such as co-digestion, can substantially enhance efficiency and sustainability in the sector.

At EU level

Policy and regulations

Develop an EU Roadmap for Biosolids/Sludge Management

Co-produce a comprehensive roadmap that includes societal benefits, nutrient bioavailability, and energy content considerations.

Harmonize policies

Ensure coherence between biosolids recovery and biogas production policies and targets.

Revise Biosolids Directives

Update the EU directive on biosolids use in agriculture, setting clear standards and responsibilities along the biosolids value chain. Exclude biosolids from waste legislation to foster a circular economy.

Create comprehensive regulations

Establish EU-wide regulations for organic fertilizers from urban wastewater, ensuring market acceptance and clear responsibility allocation.

Monitor Phosphorus as a critical material

Implement ongoing monitoring and update regulations to adjust phosphorus recovery targets from urban wastewater.

Promote nutrient recovery research

Encourage research on nutrient recovery technologies and their impacts on soil, vegetation, animals, and humans.

[18] European Commission 2024 (a,b,c).
[19] Buckwell and Nadeu 2016

At EU level

Finance

Investment incentives

Provide financial incentives for water utilities and private firms to invest in nutrient recovery technologies.

Funding for Research

Allocate EU funds for research on advanced nutrient recovery technologies and their environmental impacts.

Technical

Standardize technology

Develop and promote standards for nutrient recovery technologies to ensure compatibility and efficiency across the EU.

Promote advanced technologies

Support the development and deployment of technologies that recover nutrients in concentrated forms, improving reuse potential and transportation efficiency.

At Member state level (national, regional, local)

Policy and regulations

Local adaptation

Integrate local specificities into nutrient and biosolids management systems to ensure context-appropriate solutions. This can include withdrawal of direct sludge based on the availability, externalities and specific recommendations at a member state level

Sludge round table

Establish a "Sludge Round Table" to monitor and evaluate sludge management practices, involving all relevant stakeholders to update regulations and address legal concerns.

Address Externalities

Assessment of externalities, which are mostly local or regional should inform formulation of policies and businesses for sludge recovery and usage. Externalities can become opportunities instead of barriers

Finance

Optimize existing infrastructures

Prioritize the adaptation of existing sludge infrastructures for co-digestion, maximizing resource use and benefits.

Regional funding

Provide regional funds for the optimization and upgrade of existing sludge management facilities, rather than solely focusing on new infrastructure.

Technical

Infrastructure upgrades

Focus on upgrading existing sludge treatment facilities to incorporate co-digestion processes, enhancing efficiency and resource recovery.

Local solutions

Develop tailored technical solutions that address the specific needs and conditions of different regions, ensuring effective nutrient and biosolids management.

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B-WaterSmart

Policy Brief

Fostering circular water infrastructure

Boosting a circular water economy by creating an enabling environment for large-scale systems and infrastructure to support the development of alternative resources

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Abstract

Transitioning to a circular water economy—characterized by the efficient, effective, equitable, and safe circular use of water and related resources—presents a promising solution to the pressing issues of water scarcity and pollution. The transition to water-smart societies requires amongst other things the deployment of large-scale infrastructure, encompassing extensive systems, facilities and technologies designed to support the sustainable management of water resources and the recovery of valuable by-products.

This policy brief argues the critical need to accelerate the adoption of a circular water economy by creating an enabling environment for the deployment and operation of large-scale infrastructure. Drawing on insights from two Living Labs (LLs) from the B-WaterSmart EU Horizon 2020 project, East Frisia and Flanders, the document highlights both challenges and enablers and offers targeted recommendations for the EU Commission to foster innovation, investment, and collaboration. By driving forward an enabling environment, these efforts aim to facilitate the widespread implementation of circular water infrastructure on a large scale, thereby boosting water resilience in Europe.

Key messages

Boost investments in circular water infrastructure

Despite projected investments of €438 billion by 2030, EU water reuse rates remain below 3 %. Significant innovation and financial support are required to scale up water reuse infrastructure, including advanced treatment plants and distribution systems to enhance the circular use of water.

Innovative industrial water reuse in East Frisia

The East Frisia Living Lab demonstrates how wastewater from the dairy industry can be recycled through cutting-edge infrastructure such as biological-ultrafiltration-reverse osmosis (Biology-UF-RO) systems. This process not only reduces freshwater demand but also illustrates how infrastructural solutions can optimize resource recovery for large-scale water reuse in industrial processes.

Innovative stormwater infrastructure for agriculture in Flanders

The Flanders Living Lab highlights the potential of integrating stormwater retention basins with existing underground drainage infrastructure to enhance water security for agriculture. By upgrading urban water infrastructure, treated stormwater can be stored, infiltrated, and reused, reducing flood risks, recharging aquifers, and providing a sustainable irrigation supply.

Expand comprehensive funding for water infrastructure projects

To scale innovative projects beyond pilot stages, it is essential to secure comprehensive and sustainable funding mechanisms. Expanding financial support for infrastructure—such as storage, treatment, and delivery systems—will help bridge the gap between small-scale pilots and full-scale implementations of circular water systems.

Reduce bureacucratic hurdles

Clear guidelines on infrastructure approval processes, streamlined permitting, and effective communication with local authorities will ensure smoother implementation and public acceptance.

Enhance public awareness of infrastructure's role in circular water systems

Promoting the role of infrastructure in sustainable water management is essential to foster shared responsibility. Highlighting the benefits of investing in water reuse and stormwater management systems can enhance public understanding and support for necessary infrastructural upgrades. stakeholders across the value chain is critical for scaling up sustainable practices.

Background

Circular water infrastructure, as defined in this policy brief, refers to systems that align with circular economy principles by closing water loops, reducing resource use, and transforming waste into valuable products. This includes water treatment and recycling facilities, stormwater management systems, and resource recovery systems that convert wastewater, brines, and sludge into resources such as nutrients and energy. Achieving water resilience will require significant technological innovations and their large-scale implementation, along with other complementary strategies that optimize usage efficiency and preserve water quality, ensuring environmental protection and conservation.

The European Commission (EC) is proactively advancing circular economy strategies and initiatives within the water sector. At the UN 2023 Water Conference, the EC emphasized that "promoting circularity in the use of water for industry, energy and agriculture by increasing water efficiency and water reuse" would be treated as a top priority (European Commission 2024). Examples of relevant policies include the Circular Economy Action Plan (CEAP), the EU Climate Adaptation Strategy, the EU Green Deal, Water Reuse Regulation and the revised Urban Wastewater Treatment Directive (UWWTD), which promote circular economy approaches including water reuse and energy and nutrient recovery. The European Council has recently prioritized water resilience for 2024-2029, calling for a EU Blue Deal, representing a comprehensive water strategy for Europe. In the context of the EU Blue Deal it will be necessary to help the most water-consuming industries to gradually adopt technologies to become more water-efficient without compromising and ideally enhancing their competitiveness.

EU legislation indirectly supports the implementation and wider adoption of circular water infrastructure through various measures. These include setting standards for urban wastewater treatment, sewage sludge disposal (Urban Wastewater Treatment Directive), and water quality for reuse in agriculture (Water Reuse Regulation (EU) 2020/741), as well as requiring environmental quality standards for water bodies (Water Framework Directive). Funding for research, testing, and demonstration of innovative circular water technologies is provided through financing programmes from, among others, the European Investment Bank (EIB), Horizon Europe, LIFE programme, and the European Regional Development Fund (ERDF). These programmes offer various financial instruments including grants, loans, and support for innovative technologies, aiming to promote sustainable water management aligned with circular economy principles. Platforms such as the Water Europe Marketplace and Circular Economy Stakeholder Platform promote the exchange of best practices on business models and innovative solutions. The EU taxonomy for sustainable activities guides investments towards eco-friendly initiatives aligned with the European Green Deal, enhancing market transparency and protecting against greenwashing. Furthermore, the EU Corporate Sustainability Reporting Directive (CSRD), effective from January 2023, promotes corporate responsibility and sustainable practices among companies, including water reuse.

Although the ambition of a circular economy is increasingly promoted and the principles well-established, meaningful progress remains elusive across most sectors (Ghisellini et al. 2016). And despite rising investments in water reuse infrastructure by European municipalities - it is projected that capital expenditures will reach €438 billion EUR between 2024 and 2030, with the water and wastewater market expected to grow by 2% annually (Bluefield Research 2024) - water reuse rates in the EU still remain below 3% (WRE 2020; WISE Freshwater 2024). The EU's Water Reuse Regulation (EU 2020/741) acknowledges significant barriers, such as high investment costs and insufficient financial incentives. It advocates for innovative schemes and economic incentives to promote water reuse and potentially avoid less sustainable measures such as desalination and water shipping.

Insights from B-WaterSmart

Despite comprehensive EU policy strategies promoting a circular water economy, scaling up circular water infrastructure faces practical challenges related to financing and permitting processes. This section highlights challenges and enablers encountered in two Living Labs of the EU Horizon 2020 project B-WaterSmart. The project developed and demonstrated technologies and circular economy approaches accelerating the transformation to water-smart economies and societies in coastal Europe and beyond.

The East Frisia Living Lab is committed to identifying and utilizing alternative water sources to meet increasing demand across various sectors. The Oldenburgisch-Ostfriesischer Wasserverband (OOWV) is a leading water utility in Lower Saxony serving approximately one million customers with freshwater from groundwater resources. The water demand in the OOWV supply area has been rising constantly over the past years, necessitating exceptional conservation measures beyond the usual practices. The rising pressure on freshwater supplies has brought some areas close to their water abstraction limits, a situation further exacerbated by climate change.

Water demand is expected to continue growing, partly due to Northern Germany's hydrogen strategy. By 2032, OOWV anticipates needing to supply an additional 30 million cubic meters of water annually, representing a significant increase of almost 40% in water consumption volumes over a short period. To proactively ensure a sustainable water supply, OOWV is exploring and developing alternative water resources, including seawater, surface water, and treated wastewater from sewage treatment plants. The process of purifying these sources to produce ultra-pure water generates by-products such as wash waters, concentrates, and eluates, which must be carefully managed.

One of the notable pilot projects within the B-WaterSmart initiative is the East Frisia Living Lab, which focused on reusing 'cow water' from the dairy industry. This project enhanced the treatment of whey vapor condensate through a combined biological-ultrafiltration-reverse osmosis (biology-UF-RO) process. By transforming process water into a reusable water resource, the project supports circular economy principles by closing resource loops (see Figure 1). The results of the B-WaterSmart pilot demonstrated the potential to reduce freshwater demand in dairy food processing from 1 million cubic meters to about 500,000 cubic meters annually. Given that the dairy industry is one of the largest consumers of water in the food and drink sector across Europe, this technology could be replicated to significantly reduce water usage in other regions and industries. These innovative practices contribute to a more sustainable and resilient water supply.

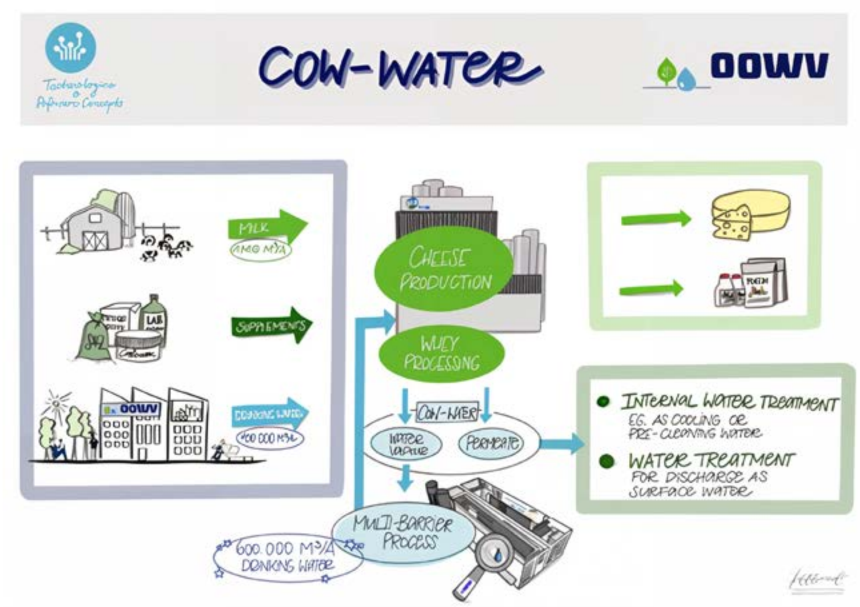


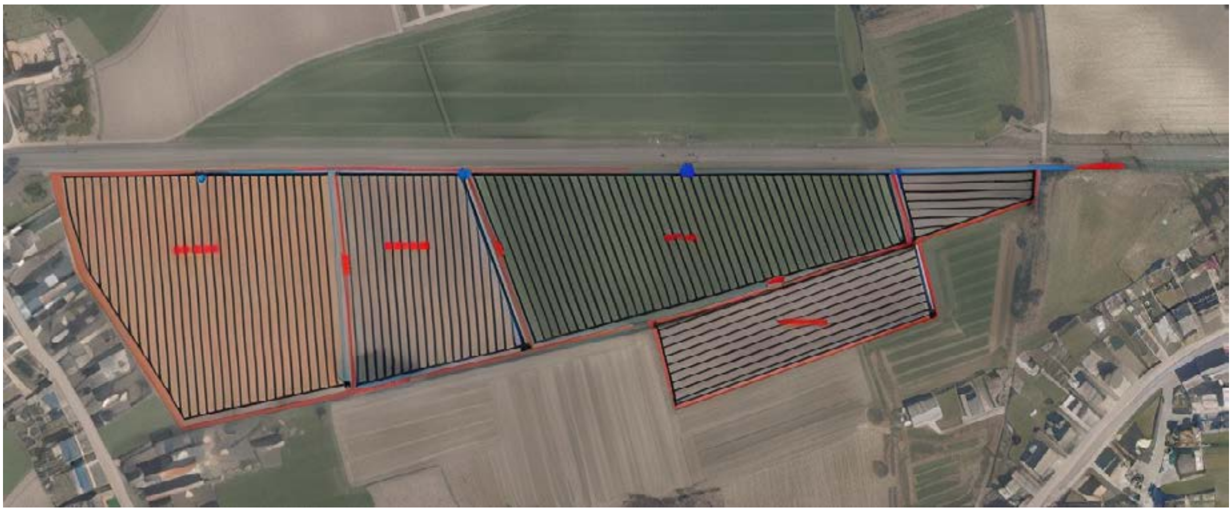
Figure 1: Overview of the Cow-Water quantities.

Flanders LL and piloted infrastructure

In the Flanders Living Lab (LL), a collaborative effort among local water utilities, the municipality, research institutes and technology providers is demonstrating innovative urban stormwater reuse for agriculture, introducing alternative water resources. As climate change intensifies, local farmers are increasingly demanding more irrigation water. At the same time, the region faces more extreme rain events, causing short-term flooding in Flanders and reducing soil infiltration capacity. This has prompted the LL municipality of Mechelen to enhance flood protection and recover groundwater tables. Despite these challenges, urban stormwater remains a largely untapped resource for local water supply.

To address these challenges, a newly installed stormwater retention basin will store rainwater for agricultural use during water demand. The rainwater is then used for subirrigation of nearby fields by converting the existing drainage system into controlled drainage, allowing water to flow into drainage pipes and infiltrate the soil. This water is partially absorbed by plants through capillary rise for evaporation, with the rest replenishing the groundwater. By this, the subirrigation system effectively serves a dual purpose: draining excess water and adding water to the system when needed. The pilot set-up is visualised in **Figure 2**. To optimize the system's performance, the B-WaterSmart pilot project developed a management tool to control water levels in the basin to distribute the water to the irrigation system based on water level, water demand, and prediction of precipitation events. This initiative not only reduces urban flooding and protects ecosystems via increased groundwater recharge, but also benefits farmers, who have access to a more reliable water supply for irrigation, increasing water security and thus climate resilience by improving water reuse in the region.

Figure 2: Involved fields for subirrigation (blue dots: water supply position from basin, black dots: remote controlled drainage pit, blacklines are drainage/infiltration pipes.)



Gaps, challenges and enablers for large-scale infrastructure implementation in the B-WaterSmart LLs

Financing

High initial investment makes it challenging to develop attractive business models

A primary barrier to water infrastructure investment in both Living Labs is financial. High upfront costs, coupled with limited access to funding sources and unfavorable financing terms, present significant obstacles. Traditional financial models—relying on a balance of tariffs, public funds, and external subsidies—often fail to generate sufficient income to cover both operational and capital expenses, making it difficult to ensure long-term financial sustainability (Machete and Marques 2021). In both LLs, the lower pricing of conventional freshwater supply compared to alternative water resources, particularly reclaimed water, has presented challenges to increasing demand for the latter. For example, without any funding in East Frisia LL, the price of reclaimed cow water could be twice as high as the current drinking water price due to high investment costs. However, there are successful examples in other regions where circular water infrastructure projects have achieved financial sustainability, suggesting that, with the right funding mechanisms and policies, these systems can become viable alternatives. In both LLs, traditional business models have struggled to cover high initial investments and ongoing operational costs, highlighting the need for tailored financial solutions to support the development of alternative water resources.

Short-term financial goals and quick decision-making among industrial customers increase financial risks for public water utilities

Industrial customers typically seek a return on investment within three to five years. However, water reuse projects often require longer-term commitments, with capital investments depreciating over a period of 10 years or more. This difference in financial expectations can place public water providers at risk, especially when they are involved in managing or maintaining infrastructure that requires substantial private investment. If such projects fail to generate expected returns, public utilities may face operational challenges or financial strain in ensuring the infrastructure remains functional.

Grants and subsidies at EU and national levels were received in both LLs but were insufficient to cover initial investments

Securing additional financing is crucial to address the upfront capital expenditures and costs associated with new water infrastructure projects. However, at both Living Labs (LLs), grants and subsidies from EU and national sources were found to be insufficient to cover all the financial needs related to implementing new water infrastructure. Private funding is often limited due to the high risks and uncertainties associated with technological innovation, compounded by regulatory challenges and the complexities of tariff setting and contract procurement processes. This highlights the urgent need for stronger public sector involvement to bridge the financing gap and manage risks, especially during the early stages of technology development. However, despite a broad public funding landscape for research and innovation, both LLs report that pilot projects aiming for replication and full-scale implementation face inadequate support. In East Frisia, current funding programs only cover up to 20-25% of the necessary capital expenditure, usually even lower. Furthermore, most funding programs support innovations only once, reducing the likelihood of securing similar grants in the near future. Stakeholders in Flanders LL consider payments for ecosystem services as promising, but they have not yet been implemented due to the lack of a comprehensive legal and financial framework, which would include clear legal guidelines, stable funding mechanisms, and institutional support to ensure effective implementation and sustainability. Currently, project partners are not aware of any additional funding opportunities that could sufficiently reduce investment risks. To ensure the successful implementation of water reuse projects, it will be crucial to develop more robust and accessible funding mechanisms, which could include both public and private sector solutions, such as forgivable loans or risk-sharing partnerships.

Legislation

Little established approval process

In East Frisia, recent amendments to the Drinking Water Ordinance and the Food and Hygiene Ordinance in June 2023 have improved conditions for water reuse projects by allowing deviations from the drinking water quality requirements if the food product is not adversely affected. However, significant bureaucratic hurdles persist in order to obtain this permission. The approval process for water reuse schemes is still unclear, with no detailed guidelines for obtaining related permits for food production. The involvement of multiple authorties makes the coordination and communication between them challenging, which further complicates decision-making. This lack of clarity can result in approval times of up to two years and result in inconsistent decisions between federal states, creating considerable uncertainty for solution providers and private investors. The same applies to LL Flanders, where project partners criticized the extensive effort required to obtain a permit, even for demonstrating technologies at a very small scale.

Few examples of circular water infrastructure

As circular economy approaches are still relatively new, authorities have only little regulatory experience in areas such as the approval of water reuse schemes / systems and the discharge of wastewater, concentrates, and eluates into surface waters and the sea, leading to costly and time-consuming consultations and audits.

Unclear role allocation due to lack of a mandated problem-owner

While national documents highlight the importance of water reuse, specific measures and clearly assigned tasks from the state have yet to be established. This has presented challenges, but it also offers an opportunity to promote more collaborative, 'bottom-up' initiatives. These collaborative approaches foster cross-sector stakeholder engagement, which is essential for effective water governance and resilience. In LL Flanders, the reuse of stormwater has highlighted the need for clearer role allocation among stakeholders to manage risks from extreme weather and ensure sustainable financing for flood protection and drought resilience solutions. Strengthening the coordination and capacity of regional and local governments to support these new solutions would be a valuable step forward.

Lack of regulation for stormwater reuse in Flanders

Presently, Flanders lacks specific legislation for stormwater reuse to enable effective exploitation of this resource. Clear definitions are needed to classify stormwater preferably as rainwater, as a classification as wastewater reuse involves stringent quality standards that result in prohibitively high costs. However, stormwater quality can vary significantly depending on the source, and water collected from areas such as road surfaces, industrial sites, or agricultural runoff may contain contaminants like heavy metals, hydrocarbons, or pesticides, requiring adequate treatment before reuse. Results from the B-WaterSmart pilot project indicate that natural infiltration of stormwater, when sourced appropriately and following basic treatment, does not require the stringent quality standards typically associated with wastewater reuse.

Stakeholder engagement and awareness raising

Stakeholder engagement and awareness raising

Education and stakeholder engagement have proven crucial for successful technology implementation. The B-WaterSmart project highlighted that transparent communication among participants is essential for harnessing synergies and coordinating solutions, particularly in water reuse projects. Activities in both LLs stressed the importance of clear communication about public benefits and impacts, especially in terms of environmental sustainability, while also addressing safety and health concerns. In Flanders, stakeholder engagement has been key to securing investment and fostering collaborative arrangements. These arrangements have the potential to serve as meaningful contributions to the development of new water governance models, offering lessons for future governance frameworks that integrate cross-sector collaboration and participatory approaches. Additionally, the Community of Practice model used in the project was well-received, enabling more in-depth dialogue with authorities and between sectors, strengthening legitimacy, and paving the way for future innovations in water governance.

Opportunities and policy recommendations

Addressing the gaps and challenges identified in the B-WaterSmart Living Labs requires a multifaceted approach that combines enhanced financing mechanisms, streamlined legislation, and robust stakeholder engagement. By implementing these recommendations, the EU can facilitate the successful development and scaling of circular water infrastructure, thereby advancing sustainability and resilience in water management across Europe.

Extend funding opportunities for scaling pilot projects, including grants, subsidies and investment incentives.

Expand and diversify grant and subsidy programs to cover a larger proportion of capital expenditures for large-scale infrastructure. Ensure that funding is more comprehensive and adaptable to different stages of project development, including early-stage innovations and full-scale implementations. Provide better financial risk-sharing mechanisms such as insurance schemes or government-backed guarantees to reduce the financial burden on public utilities and encourage private sector investment. However, solution providers must also proactively engage with investors and financial institutions to better understand how risks are priced in circular economy projects. This includes recognizing that circular supply chains often entail longer-term relationships, which require more comprehensive risk evaluations. Investors are increasingly considering factors such as the resilience of circular supply chains, the strength of collaborative models, and long-term agreements that align incentives across stakeholders. By aligning project development with these risk assessment practices, solution providers can better attract private investment and enhance their financial strategies. Agreed ways of calculating the full costs and value of water, ecosystem services, and water-smart innovations are also needed to ensure market compatibility and incentivize investment. Other incentives may include, but are not limited to, tax breaks, non-interest loans, and streamlined licensing processes. This is particularly important, as the EU can act as a trendsetter and thereby unlock similar national funds.

Provide detailed guidelines for permission processes to reduce bureaucratic hurdles, especially for small pilot plants.

Lengthy permission processes, even for small pilot plants, cause unnecessary high transaction costs and often exceed local capacities. While EU-wide guidelines can help streamline these processes, it is crucial to recognize that risks are highly context-dependent. Therefore, allowing for flexibility in how these guidelines are implemented at the local level would help ensure that they address the unique challenges of different regions. Providing a Europe-wide framework with adaptable recommendations could clarify responsibilities while enabling Member States to modify the approach according to local conditions, reducing bureaucratic hurdles without compromising on regional needs.

Organise and facilitate knowledge exchanges formats and integration between both relevant authorities and other circular water solutions in Member States, the EU and beyond.

As of today, circular water innovations are mainly stand-alone initiatives that would benefit substantially from knowledge exchange formats with similar practices across sectors to exploit synergies. The same applies to a closer integration with and exchange among relevant authorities to support approval processes.

Promote public engagement, awareness, and communication to scale innovative circular water management solutions.

Raising awareness about the public benefits of circular water management is crucial for scaling innovative solutions and increasing acceptance of water reuse, which often involves significant public health risks. It is important to engage value chain actors, both upstream and downstream, to enhance shared problem ownership and encourage investment. The Community of Practice (CoP) model used in B-WaterSmart was particularly effective as a 'door opener' for meaningful consultations, including with local approval authorities, and serves as a strong example for establishing efficient communication channels. Further support of the development of CoP and other participatory approaches are recommended to facilitate dialogue among stakeholders, including authorities, industry, and the public.

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Further Reading

Guidelines on Financing CE projects (B-WaterSmart Deliverable 4.5)

Guidelines & recommendations for regulation and policy instruments (B-WaterSmart Deliverable 5.6) (Cardoso et al. 2024)

Final report on social acceptance and behaviors towards water-smart solutions (B-WaterSmart Deliverable 5.7)

See the download section of the B-Water Smart website b-watersmart.eu for further reading.

Imprint

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