B-WaterSmart solutions for Lisbon

Summary Report

Deliverable 2.15

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Summary

This document summarises the work carried out by the Lisbon Living Lab within the B-WaterSmart WP2 – Water-smart technologies and concepts. It is the final deliverable of task 2.4 - Lisbon LL solutions, which was closely coordinated with T3.5, focusing on digital tools that implement the methodologies and frameworks developed in T2.4. The document begins by introducing the Lisbon LL and then presents a portfolio of seven solutions designed to address challenges, meet ambitions and accelerate the transition to a water-smarter society in Lisbon and other regions. It includes key results, progress beyond the state-of-the-art, and references for further reading (related publications). Additionally, the legacy beyond the project is discussed.

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Author Contributions

- LNEC: definition of the document structure, original writing of sections 1 (introduction), 2.1 and 2.3 (related to subtasks 2.4.1 and 2.4.3), editing, and production of the final document.
- CML: general review
- AdTA: original writing of section 2.1 (related to subtask 2.4.1)
- LEN: original writing of section 2.2 (related to subtask 2.4.2)
- ADENE: original writing of section 2.4 (related to subtask 2.4.4)
- BASEFORM: discussion of specification and implementation of the smart water allocation developed solutions in 4 software tools (related to subtask 2.4.3)

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- CML – Fátima Néo, Marina Perdigão, Hélder Dias, José Canedo
- All the participants of CoP sessions developed by the Lisbon LL
- Former Lisbon LL team members.

Date	History of Changes
Oct 2024	Version reviewed: • In Chapter 1, the initial title (Introduction) was replaced by the title of Section 1.1 and the content of this chapter is now limited to the previous Section 1.1. • Creation of Chapter 3 to present the conclusions and outlook on the knowledge generated and methodogies developed at Lisbon LL. The content of Chapter 3 corresponds to the previous Sections 1.2 and 1.3 (now eliminated). • As a result of this change on the text position, the numbering of the Figures was updated. • The submitted paper was published in the meantime and its citation and reference were updated accordingly.

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List of Acronyms and Abbreviations

AdTA	: Águas do Tejo Atlântico, S.A.
BAC	: Biologically active carbon
BV	: Bed volumes
BWS AF	: Water-smartness assessment framework
CAPEX	: Capital expenditure
CCP	: Critical control point or parameter
Cl2	: Chlorine
CML	: Câmara Municipal de Lisboa
CoP	: Community of Practice
CRC	: Climate ready certificate
DOC	: Dissolved organic carbon
DPR	: Direct potable reuse
EBCT	: Empty bed contact time
EU	: European Union
GHG	: Greenhouse gases
IPR	: Indirect potable reuse
ISO	: International Organisation for Standardisation
LL	: Living Lab
LNEC	: Laboratório Nacional de Engenharia Civil, I.P.
O3	: Ozone, ozone oxidation or ozonation
OPEX	: Operational expenditure
ORP	: Oxidation-reduction potential
P	: Phosphorus
PE	: Population-equivalent
QH	: Quadruple helix
RO	: Reverse osmosis
RWDS	: Reclaimed water distribution system
Tech.	: Technological
TOTEX	: Total expenditure (CAPEX + OPEX)
TRL	: Technology readiness level
Tx.y	: Task x.y
UF	: Ultrafiltration
UWC	: Urban water cycle
UWWTD	: Urban wastewater treatment directive
UWWTP	: Urban wastewater treatment plant
W-E-P	: Water-Energy-Phosphorus
WoLL	: Water-Oriented Living Lab
WP	: Work Package
WRR	: Water recovery rate
WRRF	: Water Resource Recovery Facility

Executive summary

Smart water supply and demand management (focused on water efficiency and fit-for-purpose quality) is essential for enhancing the cities' resiliency to water scarcity and climate change. Living Labs provide an effective mechanism and environment for innovation, built on the quadruple helix model (academia, policy, industry, society), grounded in a specific territory and with an extended time horizon (mid- to long-term). The **Lisbon Living Lab** (LL) was established within the scope of the B-WaterSmart H2020 project to promote the transition to a water-smarter economy and society in Lisbon and to facilitate the replication of the developed solutions in other national and international cities, thereby generating and sharing knowledge. The Lisbon LL was set up with seven partners – Lisbon Municipality (LL owner), LNEC (public research institution on civil engineering, LL mentor), Águas do Tejo Atlântico (wastewater utility), ADENE and Lisboa E-nova (national and local agencies for energy efficiency), Baseform (software house) and ICS-UL (university institution in social sciences) – along with a community of practice involving key stakeholders and replicators (other municipalities in Lisbon Metropolitan Area).

Like many European regions and cities, Lisbon, the capital city of Portugal, faces water challenges related to (i) increased population concentration and a growing economy, (ii) the effects of climate change (heat waves, heat islands, droughts), (iii) the need to expand urban green areas, as a green-blue problem-solving infrastructure to ensure citizens' quality of life and the sustainability of urban living, and (iv) the need to reduce the current use of drinking water for non-potable municipal water uses. The Lisbon Living Lab addressed these challenges by focusing its action on smart urban water allocation (i.e. fit-for-purpose), safe reuse and efficiency at the municipal level. The project's key drivers were to (i) reduce dependence on freshwater and eliminate the use of drinking water for municipal non-potable uses, (ii) introduce standards for buildings, and (iii) prepare for potable reuse to anticipate increased water scarcity while building trust and acceptance of this alternative water source for current non-potable uses in Lisbon and beyond.

Within the B-WaterSmart project, the Lisbon Living Lab deployed the following **innovations towards water circularity**:

- smart water allocation tool set (digital tools #17, #24, #25 and #27);
- urban water cycle observatory, for informing and engaging society (digital tool #20));
- climate-readiness certificate for housing, addressing water, water-energy nexus and climate adaptation (digital tool #33);
- protocol for direct potable reuse by craft beer industry, based on a pilot demo of advanced treatment (technology #1).

The Lisbon Living Lab solutions were developed as instruments to pursuit the strategic objectives for accelerating the transformation of Lisbon into a water smarter city, according to the BWS assessment framework (tool #34).

The different elements of this transition process can be achieved as follows:

- Technical feasibility – by demonstrating direct potable reuse at pilot scale (technology #1); by prioritizing strategic and tactical planning options on water management (tools #17 & #25); by mapping and quantifying risk in reclaimed water distribution networks (tool #24); by guiding risk

managers and stakeholders responsible for non-potable water uses (tool #27); by promoting water efficiency in buildings (tool #33).

- Economic feasibility – by providing information for cost-benefit analysis of reclaimed water use, including its phosphorous recovery potential and energy demand (tools #17 & #25) and of direct potable reuse (TP #1).
- Social acceptability – by building the trust on water reclamation and reuse, associated to a pleasant social activity (beer drink events – if water reclamation can be safe and reliable enough for the water to be used in beer production, it must be easier to safely treat it for lower water quality non-potable uses (technology #1); by increasing the citizens' awareness about the local context regarding the water use in the city and informing individual entities about their water consumption (tool #20); by providing an easy to understand and communicate risk assessment method (tool #27).

This document summarises the work developed by the Lisbon LL within the B-WaterSmart WP2 – Water-smart technologies and concepts. It is the final deliverable of Task 2.4 - Lisbon LL solutions. After introducing the Lisbon Living Lab, explaining its challenges, ambition, achievement in numbers and legacy beyond the project, the portfolio of seven solutions is presented, including key results, progress beyond the state-of-the-art, and references for further reading (related publications).

1 The Lisbon Living Lab challenges, ambition and partners

The Lisbon Living Lab (Lisbon LL) was established within the B-WaterSmart project to facilitate the city's transformation into a water-smarter society and economy. Like many European regions and cities, Lisbon, the capital city of Portugal, faces water challenges related to:

- increased concentration of the population and growing economy;
- the effects of climate change (heat waves, heat islands, droughts);
- the need to expand urban green areas as a green-blue problem-solving infrastructure to ensure citizens' quality of life of and the sustainability of urban living.

A key component of Lisbon's adaptation strategy, which aligns with international commitments such as the Paris Agreement, the Covenant of Mayors, and C40 Cities' Deadline 2020 (C40-ARUP 2016), is a well-established and expanding green infrastructure. This infrastructure is structured into nine green corridors, ensuring an ecological continuum that offers various ecosystem services to residents, including shading to combat the urban heat island effect (as illustrated in Figure 1, where the city's green areas and areas subject to heat islands are fully complementary), water retention and infiltration to mitigate floods, increased urban biodiversity, and enhanced air quality (Teixeira *et al.* 2024).

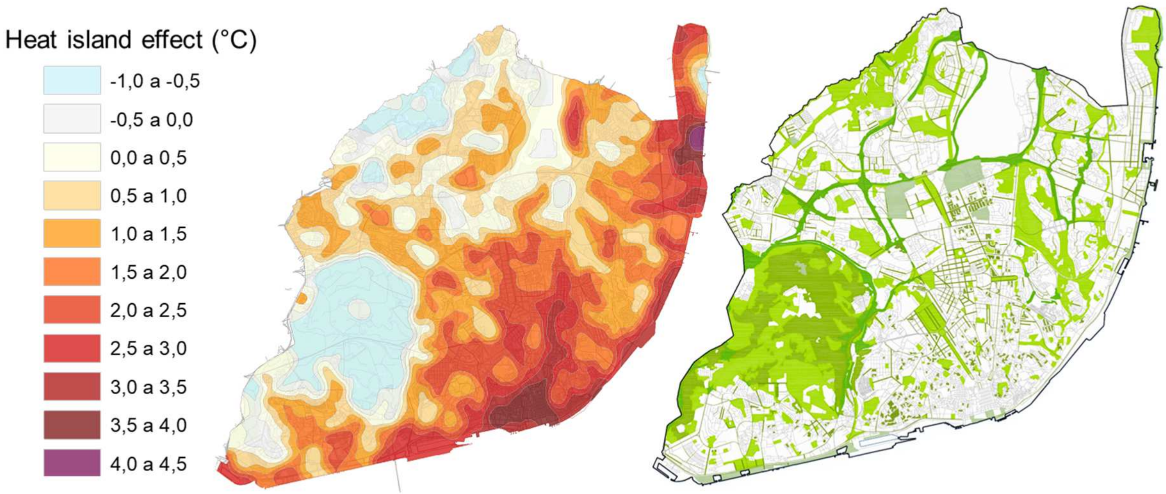


Figure 1: Lisbon green areas and their role fighting the heat islands in the city.

As a crucial service provider, green infrastructure must be continually improved and expanded though bringing no additional pressure on drinking water resources (EC 2018). Between 2014 and 2018, Lisbon Municipality achieved a 50% reduction in water consumption, lowering total municipal consumption from about 8 to about 4 million m³ per year, 75% of which (around 3 Mm³) was used for non-potable purposes (https://observatorios-lisboa.pt/info_agua.html). Recent estimates point to an increase of water for irrigation of municipal green areas from 3 Mm³/year in 2030 to 10 Mm³/year in 2050 to cope with the increase in both the planned green area and the specific irrigation needs associated with the likely climate scenarios (Freitas *et al.* 2023). Currently, a major part of water demand is satisfied by drinking water supply, abstracted and treated around 150 km North of Lisbon. Using reclaimed water, a locally available alternative water resource, largely unaffected by climate uncertainty, can contribute to reducing pressure on strategic drinking water resources and tackle the frequent droughts in Portugal and in the Lisbon area (Viegas *et al.*, 2011, 2015, 2020).

However, and despite several pilot demonstration activities (e.g. those earlier conducted by LNEC and AdTA for unrestricted urban irrigation; Viegas *et al.*, 2011, 2015, 2020) and the pioneer national legislation on water reuse for all types of non-potable uses (Decree-Law 119/2019), urban water reuse remains underdeveloped in Portugal. Lisbon was the first city in Portugal to apply for a permit to use reclaimed water for unrestricted urban irrigation and the licensing of this demanding water reuse project of very high-quality water was a time-consuming process.

The Lisbon LL addressed these challenges by focusing its action on urban water smart allocation (i.e. fit-for-purpose), safe water reuse and efficiency at municipal scale. The driving forces along the project were therefore to (i) reduce freshwater dependency and eliminating drinking water use for municipal non-potable purposes, (ii) introduce standards for buildings, (iii) look ahead to potable water reuse for anticipating increased water scarcity and building the trust and acceptance of this alternative water source for current non-potable uses in Lisbon and beyond.

Within the B-WaterSmart project, the Lisbon LL deployed the following innovations described in chapter 2:

- smart water allocation tool set, integrating four digital tools:
  + ranking/selecting alternatives vs performance-cost-risk over time;
  + fit-for-purpose demand/supply matchmaking (W-E-P balance);
  + health & environmental risk assessment of water reuse;
  + reclaimed water quality model in the distribution network for risk management;
- urban water cycle observatory, for informing and engaging stakeholders & society (one digital tool);
- climate-readiness certificate for households & buildings, addressing water efficiency, water-energy nexus and climate adaptation (one digital tool);
- protocol for direct potable reuse in craft beer industry, based on a pilot demo of advanced treatment technology.

Figure 2 illustrates the Lisbon Living Lab in a nutshell: at the top, the balloons with the city's strategic objectives towards water-smartness; at the figure’s core centre, the solutions (their developers and pilots) organised on an ambition timeframe (short- and mid-term); at the bottom, the grounding governance and social instruments for supporting this transition process.

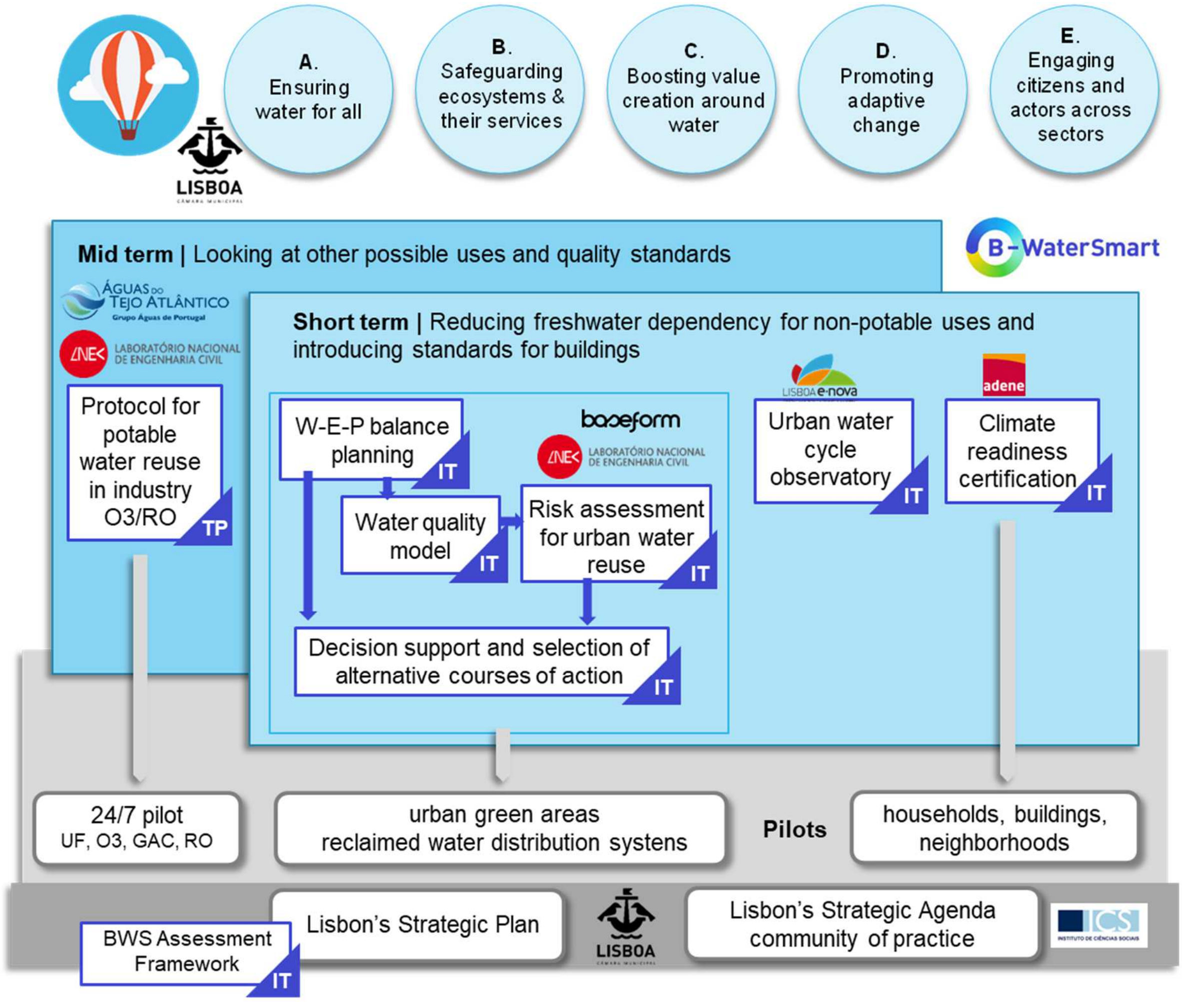


Figure 2: Lisbon LL in a nutshell.

The Lisbon LL innovations were developed within BWS Task 2.4 "Water solution for Lisbon". The output from subtasks 2.4.2,2.4.3 2.4.4 fed the development of the six digital solutions in Task 3.5 "Water-smart applications for Lisbon" through a sequence of specifications' exchange (Ribeiro *et al.* 2022).

The B-WaterSmart Lisbon LL was set up with seven partners and a stakeholders' community of practice that cover the quadruple helix (QH), i.e. academia, government, industry, and society. The description of these partners as well as their role in the Lisbon LL is presented in Table 1.

Table 1 – Lisbon LL partners.

Partners QH	Description	Roles
CML Government	Câmara Municipal de Lisboa Lisbon Municipality, LL problem owner	- Testing the Lisbon LL solutions - Promoting the Lisbon Community of Practice (CoP), which gathers key stakeholders, including society representatives, for the validation of the Lisbon Water strategic agenda and the implementation and replication of the developed solutions - Participating in the B-WaterSmart Innovation Alliance (InAll) with the other 5 LLs in the project to learn by doing and sharing with peers how to develop, monitor and revise a sound strategic plan on water-smartness and to test and improve the water-smartness assessment framework developed within the project - Disseminating and promoting the adoption of the Lisbon LL solutions through its networking platforms
LNEC Academia	Laboratório Nacional de Engenharia Civil Public research institution on civil engineering, LL mentor	- Development of the knowledge, methodologies and analytics behind the smart water allocation tool set (with 4 digital tools) - Participation in the development of the water reclamation protocol for potable water reuse in beverage industry - Mentoring the Lisbon CoP and CML towards the development of the strategic agenda and the strategic plan on water-smartness - Co-development of the water-smartness assessment framework
AdTA Industry	Águas do Tejo Atlântico Wastewater utility	- Conduction of the pilot tests needed to develop the water reclamation protocol for potable water reuse - Provision of data (on wastewater treatment and water reclamation) for several tools
Baseform Industry	Baseform Portuguese software house	- Development of the software for the smart water allocation tool set, i.e. for the risk assessment, reclaimed water quality modelling in the distribution network, W-E-P balance and decision-support tools
Adene Industry	Agência para a Energia National agency for energy efficiency	- Development of the methodology and the tool for climate-readiness certification
LEN Industry	Lisboa E-Nova Local agency for energy efficiency	- Development of the urban water cycle observatory
ICS-UL Academia & Society	Instituto de Ciências Sociais University institution on social sciences	- R&I partner on social sciences and humanities - Lisbon CoP moderator

2 Water-smart solutions for Lisbon

2.1 Protocol for potable water reuse in the beverage industry

Short description

A protocol was developed for safe direct potable reuse of water in the beverage industry (technology #1). It was based on a 24/7 pilot demo of different reclamation schemes including ultrafiltration (UF), ozonation (O3), biologically active carbon filter (BAC) and reverse osmosis (RO). The demo was conducted in Beirolas Water Resource Recovery Facility (WRRF), where reclaimed water started to be produced for unrestricted irrigation of two urban parks located in its close vicinity (68 ha of total irrigated area, project pilots on the reclaimed water distribution safety described in 2.3).

Data and new knowledge were produced, both on the water quality requirements and on the reclamation technologies. The protocol includes (i) a discussion of the three key components — regulatory, technical, and public outreach — of direct potable reuse for craft beer production, and (ii) an analysis of the multi-barrier approach needed for safe direct potable reuse for craft beer production, the Critical Control Points, and the monitoring, based on the results and lessons learned from the pilot demonstration conducted in Beirolas WRRF.

Context

Worldwide, there are several examples of potable reuse, mostly of indirect potable reuse (IPR, i.e. using environmental buffer(s)), while many direct potable reuse installations are still under study, approval or being built, thus with few facilities under operation (USEPA 2017, Lahnsteiner *et al.* 2018, effrey *et al.* 2022). Globally, potable reuse installations are predominantly US based with additionally multiple installations established in Australia, Singapore, and Southern Africa (Namibia and South Africa). For the more numerous IPR plants, the regions with several large installations are Southern California (which has its first installation operating since 1962), Singapore, and Australia (Lazarova *et al.* 2013, Jeffrey *et al.* 2022). In Europe, at least two IPR installations exist, in Belgium (Lazarova *et al.* 2013), which is in operation since 2002, and in Spain (Munné *et al.* 2023). Regarding DPR, the oldest installation is in Namibia, the Goreangab Water Reclamation Plant in Windhoek, which has been in operation since 1969 (Lahnsteiner *et al.* 2013, Jeffrey *et al.* 2022). Other few installations can be found in the USA, South Africa, and Sweden, which, according to Jeffrey *et al.* (2022), is the only DPR installation in Europe. Though acknowledging the key role of water reuse on water resilience, neither IPR nor DPR are included in the EU regulation for water reuse (2020/741), which focused on fostering safe use of treated wastewater for agricultural irrigation across the EU.

In this context, and to anticipate a solution for future aggravated water scarcity, localized needs or emergency situations, the Lisbon LL ambition was to provide scientific evidence of the safety of direct potable use of reclaimed water in the beverage industry, and ultimately to promote the social acceptance of this alternative water source for current non-potable uses in Lisbon and beyond.

This demo was selected due to two-fold reasons. On the one hand, it consists of direct potable reuse (DPR) with additional downstream safety barriers, provided by the beer production steps, and it builds upon earlier experience of the consortium (LNEC and AdTA) on advanced water reclamation for unrestricted urban irrigation (Viegas *et al.* 2015, 2020). On the other hand, based on an earlier Águas do Tejo Atlântico experience, serving the VIRA beer in events promoted by AdTA is an effective awareness campaign on water reuse – its name VIRA (Portuguese for 'turn') has the double meaning of turning (waste)water into enjoyable drinkable water (beer) and turning mindsets – 'water quality matters not its past history'.

Methodology

A pilot unit was installed and operated for one year continuously (24/7), at Beirolas WRRF in Portugal, achieving a Technology Readiness Level (TRL) 7. Beirolas WRRF is one of the largest plants in the country (213,510 PE design capacity), with tertiary treatment for carbon and nutrients removal and sand filtration. The pilot was set in a containerized unit with external cork coating and photovoltaic green energy production. Four advanced treatment technologies were tested on demonstration scale, under the following operating conditions:

- Ultrafiltration: this unit operation was available at Beirolas WRRF for the unrestricted urban irrigation, and it was therefore possible to assess its role for the improvement of the reclaimed water quality without including it in the pilot (Figure 3).
- Ozonation: 1-2 mg O_3/mg DOC, with 45 minutes contact time.
- BAC filtration: approximately 5 minutes empty bed contact time (EBCT), operated for 31 kBV (thousand bed volumes).
- Reverse osmosis: 3-stage RO (2:1:1) with 8-12 bar net driving pressure, 15-25 L/(m^2.h) permeate flux, 60-70% water recovery rate, concentrate recirculation, and 3 mg/L antiscalant dosing.

To compare different RO-based potable reuse schemes regarding water quality and operational performance, four treatment schemes were tested (Figure 3). The system integrity monitoring was designed, including online UF and RO flowrate, pressure and turbidity, and RO pH and electrical conductivity and three critical control points (CCPs) and the associated critical parameters to be monitored were established for the potable reuse schemes, as illustrated in Figure 3.

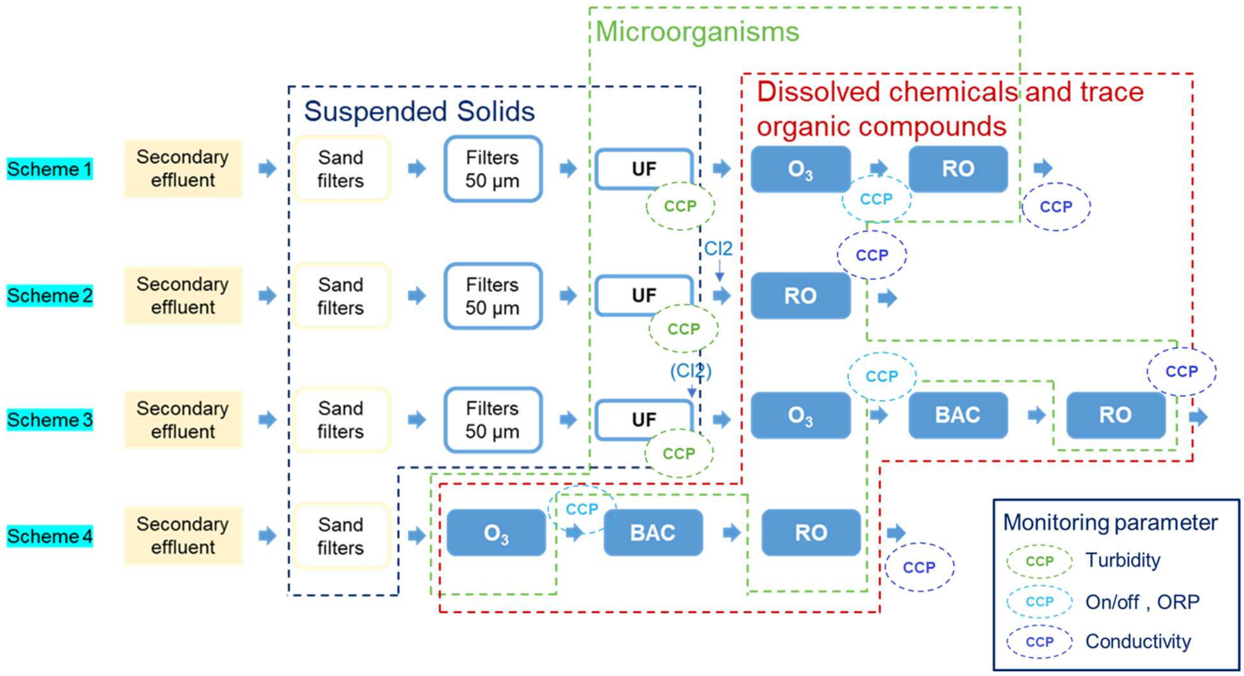


Figure 3: Multi-barrier potable reuse schemes demonstrated in the pilot unit at Beirolas WRRF and critical control points established.

Water quality was regularly analysed (weekly) for parameters such as *E. coli*, organic matter (DOC, A254, A436, SUVA), NH_4^+, NO_3^-, KN, TN, P, hardness, and alkalinity. Additionally, trace compounds were analysed once per treatment scheme, including 54 pharmaceutical compounds (PhCs), 2 hormones, oxidation by-products (N-nitrosodimethylamine (NDMA), bromate, chlorate), 4 trihalomethanes (THMs), 9 haloacetic acids (HAAs), 20 per- and polyfluoroalkyl substances (PFAS), 10 alkylphenols, and toxicity indicators (*Daphnia magna, Vibrio fischeri*). The analyses also covered parameters specified in the EU Drinking Water Directive 2020/2184 (DWD 2020) and indicators of enteric bacteria (*Escherichia coli* and *Clostridium perfringens*), enteric viruses (somatic coliphages/F-specific RNA bacteriophages), and protozoa (*Clostridium perfringens* spores).

Knowledge produced during the project and progress beyond the state-of-the-art

The batch ozone-RO pilot planned in the grant agreement was upgraded to a continuous 24/7 pilot, which was afterwards upgraded to include an activated carbon filter column. We were then able to benchmark the two reclamation schemes established worldwide, reverse osmosis-based (UF-RO) vs. O3/BAC (ozone/biologically active carbon filter; less energy-intensive) towards water quality and treatment redundancy relevance.

All four multi-barrier treatment schemes produced water that complies with EU and Portuguese drinking water quality standards and beyond. In terms of contaminants of emerging concern:

- 32 out of the 54 pharmaceutical compounds analysed were never detected and the remaining compounds were always below the limit of quantification, LOQ (0.1 or 0.3 ug/L);
- 10 per- and polyfluoroalkylated substances (PFAS) were never detected and the remaining 10 PFAS were always below LOQ (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 was below the international guidelines;
- as for regulated oxidation byproducts, total trihalomethanes, haloacetic acids and bromate were always below LOQ, i.e. total THMs < 2 µg/L, HAAs < 2 µg/L, bromate < 3 ng/L;
- pathogen indicators of enteric bacteria, viruses and protozoa were absent.

Key findings include:

- UF ensured complete disinfection of the permeate.
- Ozonation, with a normalised dose of 1-2 mg O_3/mg DOC, oxidized inorganic and organic chemicals.
- BAC filtration, operating with an EBCT of 5 minutes, contributed to the removal of dissolved chemicals; to achieve higher removals, 15-30 minutes EBCT are recommended.
- RO biofouling was reduced by a low-dose chlorination pre-treatment (around 1 mg/L Cl_2) and operating at 60% water recovery rate (WRR).
- RO guaranteed the removal of oxidation byproducts and recalcitrant dissolved organic compounds.
- RO ensured that all finished waters of all schemes, including those with no UF, were free from pathogenic enteric bacteria and viruses (all indicators tested were absent).
- UF and RO were therefore the key barriers for microbial quality safety.
- UF and RO (scheme 2) showed higher normalised permeate fluxes (possibly due to ozone byproducts (Liu *et al.* 2024) or intake water changes), i.e. lower energy demand.
- Despite the above, among the studied schemes, the one comprising UF, O_3, BAC and RO (scheme 3, Figure 3) provided superior multi-barrier risk mitigation, with each family of hazards being targeted by more than one barrier. This redundancy minimizes the severity and likelihood of hazardous events (arising from intake water quality changes), as recommended by WHO (1975) and the State Water Resources Control Board of California (SWRCB, 2024).

Regarding the progress beyond the state-of-the-art, overall, the pilot studies conducted show that the quality of the water produced is in accordance with other studies (Wong *et al.* 2018, Schimmoller *et al.* 2020, Jeffrey *et al.* 2022), namely also regarding contaminants of emerging concern, with most studies showing RO-based systems to provide robust removal of both long and short-chain PFAS compounds while Ozone/BAC-based advanced treatments mostly address long chain PFAS.

With respect to the treatment process efficiency measured as log-reduction values of microbial indicators, our study was conducted with no spiking, to fully represent a real environment. Therefore, the conducted demonstration of the removal of naturally arising pathogens was limited by their low feedwater concentration. For example, regarding *E. coli*, the UF treated water (schemes 1, 2 and 3, in a total 30 analysis) showed *E. coli* values below the LOQ (1 CFU/100 mL) except during the commissioning phase (scheme 2), when a value of 3 CFU/100 mL was observed. The sand-filtered effluent varied from $3x10^3$ to $3x10^5$ and thus the LRVs obtained with UF were limited by these intake values, varying between >3.5 and >5.2, values fully aligned with the indicative LRVs compiled in USEPA (2012), i.e., 4 to >6 LRV. When UF was not part of the treatment train (scheme 4) and ozonation was the first barrier, it was observed that an ozone dose of 2 mg O_3/mg DOC was not always fully effective for *E. coli* inactivation, being observed values between 1 (LOQ) and 23 CFU/100 mL after ozonation. The calculated LRVs were between 1.8 and >3.4, also aligned with the indicative LRVs compiled in USEPA (2012), i.e. 2 to 6.

Regarding the other microbial indicators analysed, i.e. *Clostridium perfringens* and its spores and Somatic coliphages, it was observed that UF was fully effective for their removal. Nevertheless, as the sand filtered effluents were not analysed, the UF LRVs could not be assessed. Again, it was observed in scheme 4 that ozonation was not fully effective for inactivating *Clostridium perfringens* and its spores, as expected (USEPA, 2012), being observed values of 800 CFU/100 mL and 520 CFU/50 mL, respectively. The somatic coliphages were not detected in any of the 11 samples analysed.

The results of this pilot demo were shared in a national conference, the 2023 Portuguese water utilities meeting, and will be shortly presented in national (Águas do Tejo Atlântico' Innovation Pathway 2024) and in international conferences (IWA Reuse 2025, submitted). A master thesis was produced, and a paper is under preparation.

As such, we may finally conclude that the studies conducted in the Lisbon LL and herein reported provide scientific evidence of the safety of direct potable use of reclaimed water in the beverage industry and may therefore support progresses in water reuse regulation and practice in the EU and beyond.

Further reading

- Deliverable D2.8 *A reclamation protocol for water reuse in craft beer production* (Figueiredo et al. 2024) https://b-watersmart.eu/download/d2-8-a-reclamation-protocol-for-water-reuse-in-craft-beer-production/
- Training session https://b-watersmart.eu/download/training-material-a-reclamation-protocol-for-water-reuse-in-craft-beer-production-d2-8/
- Paper in conference proceedings "Produção de água para reutilização na indústria alimentar - demonstração de tratamento avançado à escala piloto" (Figueiredo *et al.* 2023. ENEG)
- Master thesis "Pilot-scale studies of advanced wastewater treatment for direct potable water reuse" (Charrua 2024)
- Scientific paper "Pilot demonstration of direct potable reuse for beer production" (Figueiredo, Viegas *et al.*, under preparation)

2.2 Urban Water Cycle Observatory

Short description

The Urban Water Cycle Observatory (tool #20) is a data visualization instrument for analysing and communicate data related to water consumption, wastewater treatment and reclaimed water production in the city of Lisbon, to support planning and decision making. This tool is part of the 'Lisbon Observatories' and 'E-Nova Utilidados' Platforms.

Following the motto "know to reduce", the main objective of the Observatory is to inform citizens about water demand and efficient water use, for promoting the use of water sources alternative to drinking water and for raising awareness in society. In parallel, this tool supports decision-making on water management, and it is integrated within the scope of Lisbon city policies.

The Lisbon Observatories provides access to a variety of information related to urban management and planning, namely water (potable and non-potable) and wastewater, energy consumption, urban waste, greenhouse gases emissions and mobility.

The Urban Water Cycle Observatory includes two complementary tools:

- A top-down approach tool, with information synthetised from open data respective to the water (Figure 4) and wastewater (Figure 5) management in Lisbon.
  https://observatorios-lisboa.pt/en/info_agua.html - Water consumption, including drinking water, reclaimed water, spring water and groundwater
  https://observatorios-lisboa.pt/en/info_aguasresiduais.html – Wastewater treatment
- A bottom-up approach tool, for individual entities to integrate (Figure 6) and analyse (Figure 7) the water consumption of their facilities and lead to an efficient use of water and increased awareness on sustainability. https://privado.observatorios-lisboa.pt/login

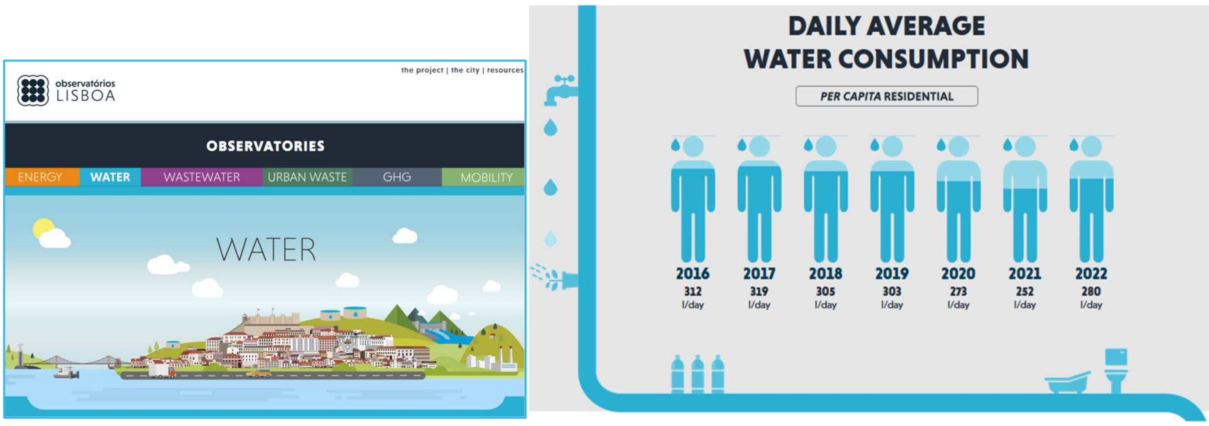


Figure 4: Urban Water Cycle Observatory, top-down approach – Water folder (left image). Per year-information about water consumption: total, by source, daily average (right image), by type of use and by type of consumer.

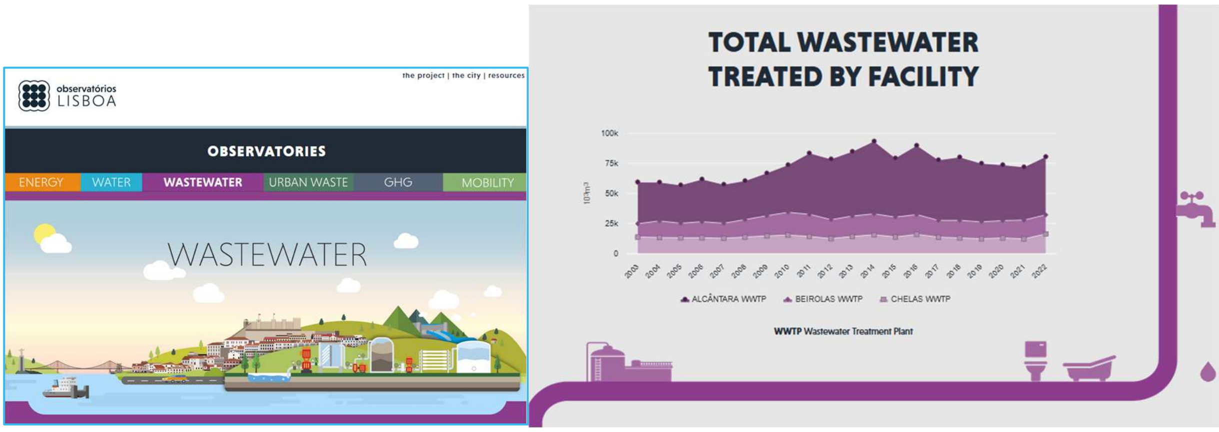


Figure 5: Urban Water Cycle Observatory, top-down approach – Wastewater folder (left image). Per year-information about treated wastewater: total, by source, by facility (right image) and considering the city boundaries.

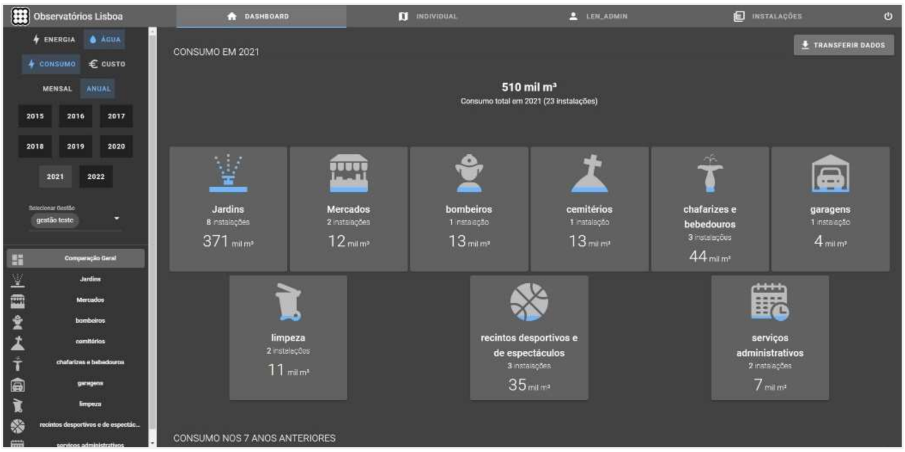


Figure 6: Urban Water Cycle Observatory, bottom-up approach – Smart-data on water consumption, categorised per type of use

Figure 7: Urban Water Cycle Observatory, bottom-up approach – in-depth analysis of water consumption as a function of time.

Architecture of the observatory

In Urban Water Cycle Observatory, the use of infographics is the way used for presenting the information on a more appellative way and for facilitating the visualization of key messages. The goal is to promote the engagement of citizens of water management, based on information about water in the city of Lisbon.

The top-down approach tool provides information on the city's water matrix, on an annual basis, regarding the following main aspects:

- Water consumption – total volume, consumption disaggregated by type of water source (potable, reclaimed water, groundwater and spring water), consumption disaggregated by type of use (residential, non-residential, green spaces, urban hygiene, etc) and consumption disaggregated by type of user (residential, commerce and industry, institutional, central government, municipal local authorities, etc.).
- Water, additional information – per capita indicators, georeferencing of water consumption (administrative area – parish).
- Wastewater treatment – total volume of treated wastewater, total volume of produced reclaimed water, treated volume disaggregated by wastewater treatment plant.
- Wastewater, additional information – per capita indicators, georeferencing of water consumption (administrative area – parish).

The bottom-up approach tool allows the analysis of the water consumption, for a deeper understanding about the water use in the user's facilities. This tool was designed to be used by entities to monitor and analyse their respective water consumption. The water consumption data is presented in time series and is aggregated in categories, namely: per type of use, water source, associated costs, key performance indicators, identify water efficiency opportunities and monitor their impact after implementation. The detail of these analyses depends on the time granularity of the water consumption data (monthly, daily or quarter-hour data from water meters). It is possible to produce automatic reports based on all the data analytics presented for each facility and set up the analysis of customised alerts for abnormal consumption values in each facility.

Knowledge produced during the project and progress beyond the state-of-the-art

The development of the Lisbon's Urban Water Cycle Observatory goes beyond the state-of-the-art by making available in a public platform the information respective to the water use (consumption and treatment) in the city. Because it is updated annually, citizens can be better informed on sustainability matters. This tool is also relevant for the process of public policy development, by providing clear and visually attractive information, as well as by monitoring the impact of the resulting decisions in the city. It also makes available a private area of this platform to entities, such as the Lisbon Municipality, to have access to detailed information of water consumption data and the results of data analysis, to increase the efficiency of water use on those installations. Both approaches of this tool (#20) have a high potential of replicability and go beyond the project life cycle, due to its simplicity of application, its impact and importance for cities.

Tool #20 is a data repository on water use (water consumption and wastewater treatment) in Lisbon, empowering the decision makers, city stakeholders and citizens with information in an analytical but easily accessible format.

Further reading

- Deliverable D3.4 *The monitoring, negotiation and decision support solutions toolkit - Final*

Release, section 5.4 (Clotas *et al.* 2024) https://b-watersmart.eu/download/the-monitoring-negotiation-and-decision-support-solutions-toolkit-final-release-d3-4/.

- Water Europe Marketplace https://mp.uwmh.eu/d/Product/34/
- Training session https://b-watersmart.eu/the-urban-water-cycle-observatory/

2.3 Water-smart allocation for urban non-potable uses

A set of four applications (tools #17, #24, #25 and #27) was designed to jointly provide a complete ability to quantitively and qualitatively match water supply to demand, while managing water volume, cost, energy, nutrients and risk. Figure 8 illustrates the roadmap of the water-smart allocation process for non-potable water uses, such as the irrigation of green areas, involving the following steps:

1. First, definition of the goals for water management in the city or region, preferably by using the B-WaterSmart Assessment Framework (BWS AF, tool #34) while developing the water strategic plan, e.g. by analysing the relevance of water reuse to improve the region's water resilience based on a SWOT analysis and on how the likely climate scenarios and economy and population growth scenarios will affect the water scarcity.
2. Second, identification of the relevant non-potable water uses in the city or region. The irrigation of urban green areas (including gardens, urban parks, green corridors and central separators) is usually the most important use in terms of water demand. Other non-potable water uses, such street cleaning, might be considered but, in this case, phosphorus valorisation is not a goal.
3. Third, definition of parts of the city/region's territory (demand groups) to be associated to a specific assembly of water sources (tool #25, stage_1). Geographical proximity is one of the criteria for defining these groups of non-potable water demands. The idea is to make it easier to plan interventions in the city/region by prioritising areas.
4. Fourth, identification of the water sources (existing and planned) that can be associated with each demand group (tool #25, stage_2). Examples of water sources: a) reclaimed water produced by the "*XYZ*" WWTP; b) groundwater abstracted in the "*ZYW*" well; c) spring water distributed by the aqueduct "*ZXY*"; d) drinking water supplied by the water utility "*YZX*".
5. Fifth, and for each group of non-potable water demands, formulation and assessment (using quantitative metrics) of two or more alternatives, i.e. candidate combinations of one, two or more supplies from the above-exemplified water source set (i.e. reclaimed water, groundwater, spring water and drinking water) for satisfying the different green areas integrated in the group (tool #25, stage_3).
6. Six, and whenever reclaimed water is a candidate option for satisfying a specific water demand, carry out the risk assessment to enable a sound risk management and ultimately safe water reuse (tool #27).
7. Seven, and whenever reclaimed water is a candidate water source and it is necessary to control the reclaimed water quality in the distribution network for managing the risk of bacterial regrowth, modelling of the residual chlorine decay – residual chlorine is a key barrier against the deterioration of water microbial quality between the production and the point(s) of use (tool #24).
8. Finally, comparison/ranking of alternative options applicable to the different parts of the city/region's territory to make the best decisions (e.g. which alternative option to choose, prioritize these areas) towards the achievement of the city's ambition and goals (tool #17, link to BWS AF).

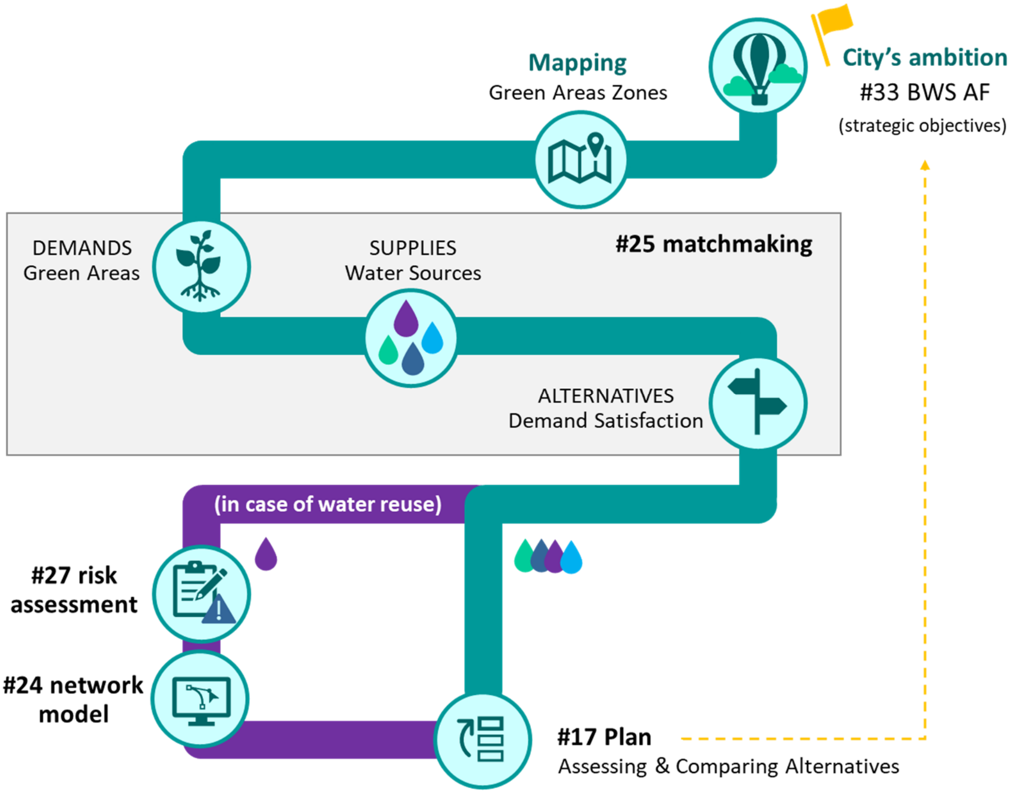


Figure 8: Roadmap for a water-smarter allocation in cities or regions.

Matchmaking of urban water supply/demand

Short description

The B-WaterSmart Water-Energy-Phosphorus Balance Planning Module (tool #25, task 3.5) implements a matchmaking framework entirely conceived and designed in T2.4.3 for enabling a smart combination of the water sources and water demand points existing or planned in a city or region. This matching tool allows the design of supply solutions to a set of potential users of non-potable water. The different alternative combinations produced are further made available to tools #24, #27, and #17.

The basic idea of the water supply/demand matchmaking is simple – use fit-for-purpose water source whenever justifiable in terms of performance (volume availability, water quality, energy demand, phosphorus reclamation), cost, and risk. Local entities, such as green area owners, which manage non-potable water demand provide their requirements (in terms of water quality and water needs throughout the year) to this matchmaking environment. The available water sources present different water quality, such as for example, potable water quality, class-A reclaimed water (on a scale A to D being A the best quality, Reg. (EU) 2020/741) and groundwater quality monitored in the "*ZYW*" well. The information about the water quality and volume availability of each water source is provided to the tool for allowing the demand/supply matching. The water supply/demand alternative combinations are then assessed using quantitative metrics of performance, characterising the resource recovery and efficiency towards water, energy, and phosphorus (W-E-P) and cost along a pre-defined time scale (present to planning horizon).

It is important to note that the water supply/demand matchmaking framework does not address mixture of waters of different qualities to better fit the purpose. Candidates should have the minimum quality compatible for the purpose. Based on these two underlying assumptions, the application therefore asks for quantity (accounting for seasonal variability); phosphorus and energy.

The main features of the water supply/demand matchmaking solutions are:

- Geographic representation of water sources and demand, for a more intuitive decision making.
- Simple-to-use analysis (formulation and characterisation by quantitative metrics) of candidate combinations of one, two or more supplies, including reclaimed water, for satisfying non-potable water demands in urban or regional contexts, over a targeted period.
- Calculation of metrics related to sustainability (environmental and economic), circular economy (water reuse, phosphorus valorisation) and climate change (carbon neutrality), based on input monthly (or other time interval considered adequate to characterise the time variation) variables of water volume, energy, phosphorus and other nutrients, and cost.
- Alignment between strategic and tactical planning options defined for the city or region ('strategic' meaning a decision/measure for the overall city/region on the long term; 'tactical' meaning a decision/measure taken for a given area of the city/region to implement on the mid-short term).

Architecture of the matchmaking framework

The framework for water supply/demand matchmaking integrated in the B-WaterSmart Tool #25 includes three main elements:

1. DEMANDS (Figure 9), to define the requirements (water volume and phosphorus fertilization) for each non-potable water use (note: the aim is to use fit-for-purpose water).
2. SUPPLIES (Figure 10), to define the attributes (water volume, specific energy, phosphorus content and cost) of the available water sources (note: each supply has its own water quality).
3. ALTERNATIVES (Figure 11), to design the solution for the demand problem at stake and, in parallel, to contribute for the implementation of the city/region's water management strategy (e.g. promotion of water reuse, decrease of drinking water consumption and of freshwater abstraction). A baseline alternative relative to the existing situation (status quo) should always be considered for comparison purposes (new alternatives vs existing situation). For each alternative, the matchmaking environment allows to design the satisfaction the different water demands translated as time series of required monthly water volumes over a targeted period. The supply and demand alternative combinations are assessed and matched through a range of user-selected metrics characterising the W-E-P balance (e.g. volume availability, energy content, carbon footprint, phosphorus content, cost, water losses during distribution).

The B-WaterSmart Tool #25 runs in BASEFORM's environment as an individual application.

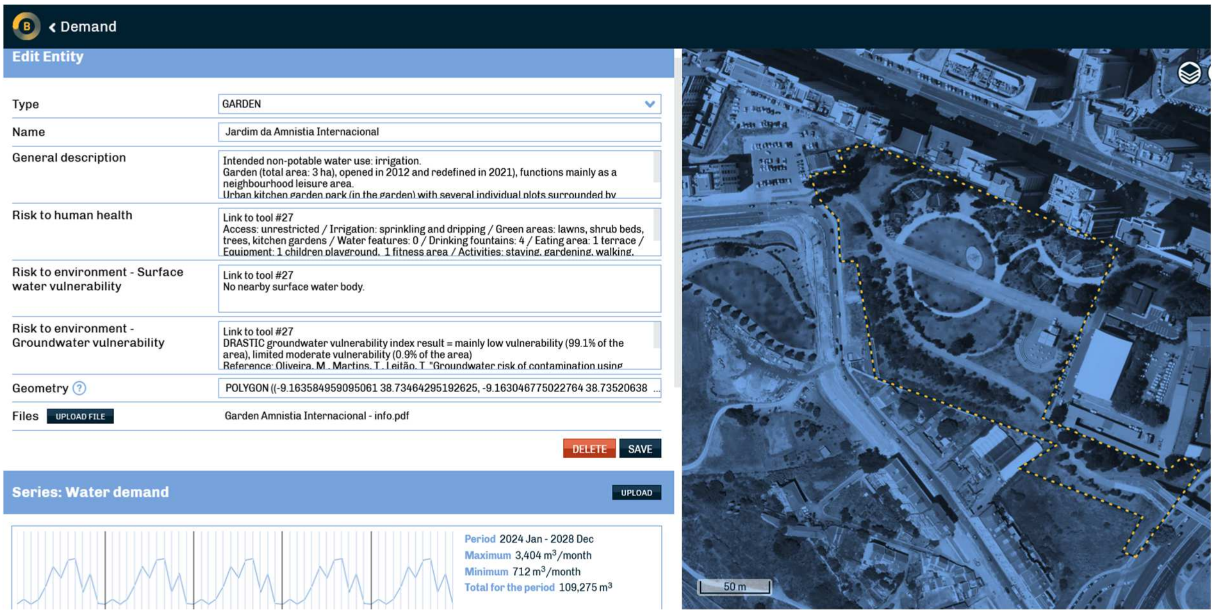


Figure 9: Tool #25 screenshot – Water Demand description. Provided information: general characteristics, geographical position, aspects relevant to risk management in case of water reuse; time series data: water and fertiliser needs.

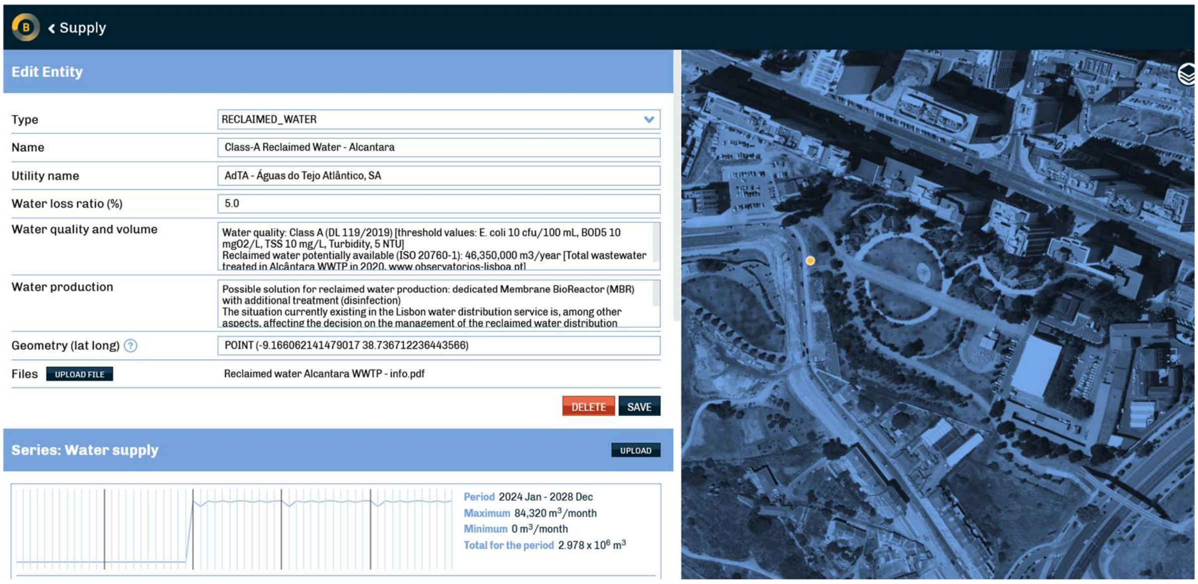


Figure 10: Tool #25 screenshot – Water Supply description. Provided information: general characteristics (inc. water quality and production), water losses (distribution network), geographical position (supply point); time series data: water volume, water price and phosphorus content.

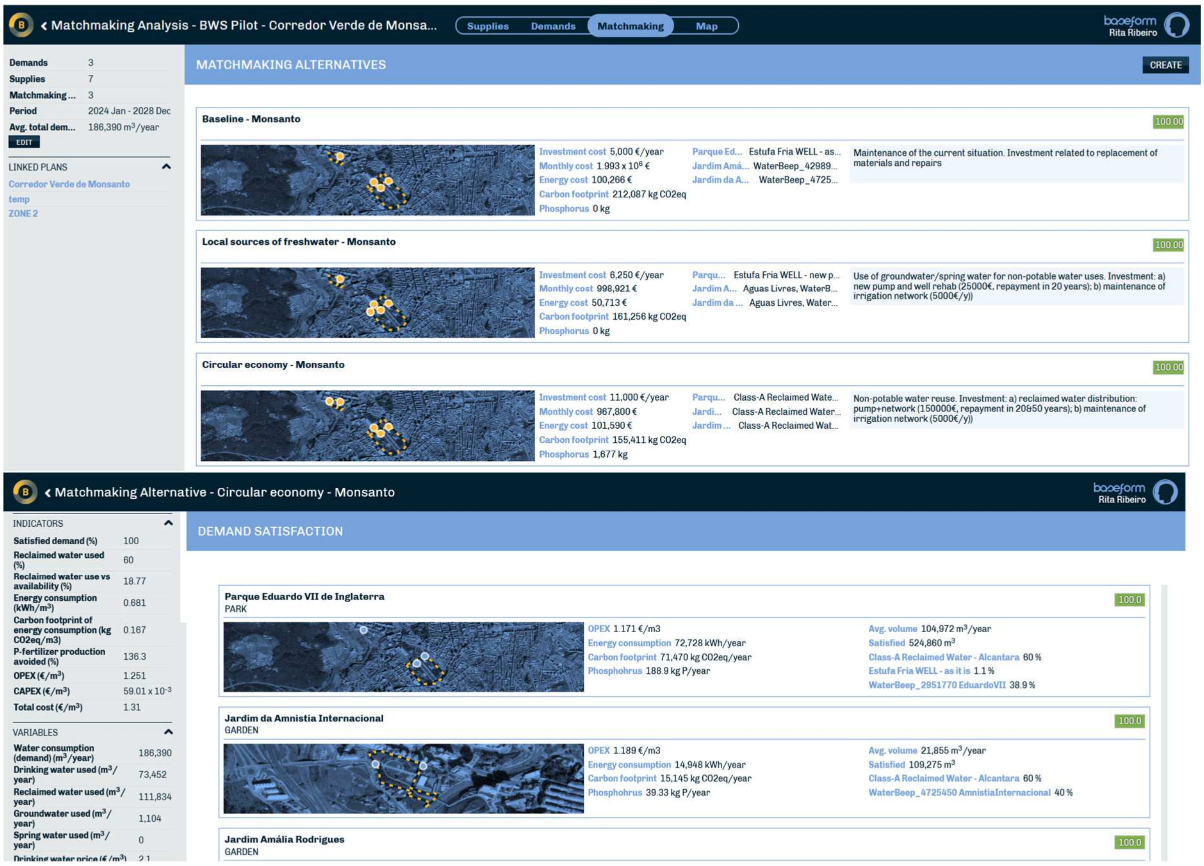


Figure 11: Tool #25 screenshot – Matchmaking Alternatives (upper image) and Demand Satisfaction within an alternative, with the presentation of metrics (lower image).

Knowledge produced during the project and progress beyond the state-of-the-art

The deployment of Water-Energy-Phosphorus Balance Planning Module goes beyond the state-of-the-art as it provides a new and sound ability to match water supply to demand, while managing water volume, energy, nutrients, cost, and risk, with full GIS-compatible georeferenced capabilities. This solution was conceived and developed from scratch within the B-WaterSmart project, based on the concept created by the LNEC team in task T2.4. The digital tool #25 was developed by BASEFORM jointly with LNEC in task T3.5.

Table 2 presents the architecture and data configuration of the matchmaking framework that was implemented by BASEFORM in tool #25, the Water-Energy-Phosphorus Balance Planning Module.

Table 2 – Architecture (supplies, demands, alternatives, and matchmaking) of the matchmaking framework, implemented by tool #25, the W-E-P balance planning module – input and calculated variables and automatically calculated indicators.

Elements	Variables	Indicators
Candidate Supplies[1]	- Water supply (m^3/month) [S, I] - Water price for this supply (€/m^3) [S, I] - P concentration in water (g P/m^3) [S, I] - Water loss ratio (%) [V, I]	N/A
Demands	- Water demand (m^3/month) [S, I] - Total P used as fertilizer (irrigation) (kg P/year) [S, I]	N/A
Matchmaking alternatives	- Investment cost during the life time (€/year) [V, I] - Energy price (€/kWh) [V, I] - Unit operation cost with chlorination, monitoring & others (CMO) (€/m^3) [V, I] - Energy consumption per supply for a given demand (kWh/m^3) [V, I] - Local energy mix per supply (kgCO_2eq/kWh) [V, I] - Water consumption (m^3/year) [V, C] - Drinking water used (m^3/year) [V, C] - Reclaimed water used (m^3/year) [V, C] - Groundwater used (m^3/year) [V, C] - Spring water used (m^3/year) [V, C] Annual weighted averages (cost acquisition) - Drinking water cost (€/m^3) [V, C] - Reclaimed water cost (€/m^3) [V, C] - Groundwater cost (€/m^3) [V, C] - Spring water cost (€/m^3) [V, C] - P concentration in reclaimed water (mg/L) [V, C] - Total P used as fertilizer (kg P/year) [V, C]	Per alternative - Satisfied demand (%) [V, C] - Reclaimed water used (%) [V, C] (BWS AF, metric C.3.3) - Reclaimed water use vs availability (%) [V, C] - Energy consumption (kWh/m^3) [V, C] - Carbon footprint of energy consumption (kg CO_2eq/m^3) [V, C] (BWS AF, metric B.3.2) - P-fertilizer production avoided (%) [V, C] - OPEX (€/m^3) [V, C] water + energy + CMO - CAPEX (€/m^3) [V, C] - TOTEX (€/m^3) [V, C]

[1] e.g. Class-A reclaimed water, groundwater, spring water, drinking water

Legend: S – series (time series), V – value, I – input, C – calculated

BWS AF – BWS Assessment Framework (Tool #34) (Silva *et al.* 2023)

Whitin task T2.4.3, the Water-Energy-Phosphorus Balance Planning Module was tested by the Lisbon Living Lab in 10 public green area pilots, organized in 4 demand groups as presented in Figure 12. Each demand group represents neighbour irrigated areas treated as an overall demand to be associated to a specific assembly of water sources, as follows:

- Group A "Corredor Verde de Monsanto": green areas: Eduardo VII (park), Amália Rodrigues (garden) and Amnistia Internacional (garden); considered water supplies: reclaimed water, groundwater, spring water and drinking water.
- Group B "Eixo Alvalade": green areas: Campo Grande (garden) and Alameda da Cidade Universitária (central separator); considered water supplies: water, groundwater, spring water

and drinking water.

- Group C “Frente Ribeirinha”: green areas: Ribeira das Naus (garden), Campo das Cebolas (garden) and Lateral da Avenida Infante D. Henrique (Estação Fluvial) (road strip); considered water supplies: reclaimed water and drinking water.
- Group D “Tejo Trancão”: green areas: Parque Tejo (park) and Parque das Nações North (park); considered water supplies: reclaimed water and groundwater.

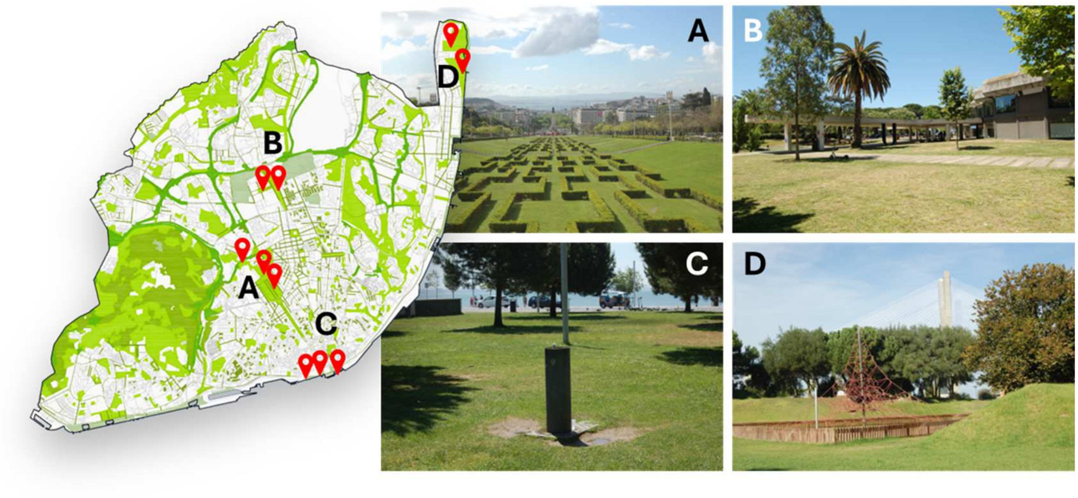


Figure 12: Lisbon LL green area pilots for tool #25 organized in 4 demand groups.

Tool #25 implements a novel matchmaking framework for formulating and assessing candidate combinations of two or more supplies, including reclaimed water, in satisfying non potable water demands in urban or regional contexts, to enable prioritizing strategic and tactical planning options. The targeted end users are water demand planners and decision makers in urban management, municipal and water utility contexts.

Further reading

- Deliverable D3.5 *The Water Cycle Modelling and Assessment Solutions Toolkit - Final Release*, section 5.4 (Lykou *et al.* 2024) https://b-watersmart.eu/download/the-water-cycle-modelling-and-assessment-solutions-toolkit-final-release-d3-5/
- Water Europe Marketplace https://mp.uwmh.eu/d/Product/55
- Training session https://b-watersmart.eu/training-material-for-three-tools/

Risk assessment of non-potable water reuse

Short description

The Risk Assessment for Urban Water Reuse module (tool #27) implements a user-friendly risk assessment framework for water reuse in non-potable uses, which was newly developed within T2.4.3 based on the relevant ISO standards (especially, ISO 31000:2018, ISO 20426:2018, and ISO 16075-2:2020) and the Regulation (EU) 2020/741 on minimum requirements for water reuse. The risk assessment methodology was conceived and designed for evaluating the human health and environmental (groundwater and surface water) risks incurred by the supply/demand combinations produced by tool #25, in case of water reuse. Each alternative tested for human risk and for environmental risk undergoes a sequence of steps and receives a risk grade. Depending on the targeted risk level, the alternative will either be rejected (and potentially returned to tool #25 for redesign) or approved and forwarded to tool #17.

The ISO 31000:2018 and ISO 20426:2018 standards define risk as a function of magnitude and likelihood. However, risk is often perceived only in terms of the severity of the consequences, leading to a risk amplification. In municipal non-potable water reuse projects (e.g. urban irrigation, street cleaning), the qualitative risk assessment process can act as tool to improve risk perception by describing how certain actions may affect the achievement of the objective – safe water reuse. To facilitate the identification of the circumstances generating exposure to risks, the methodology developed for the risk assessment of non-potable water uses includes in the scenario building stage (risk identification) the description of regular activities developed, for example, on the green area irrigated with reclaimed water and during the operation of the water reuse system (reclaimed water treatment and distribution). This is an addition to the framework for health risk assessment and management defined in ISO 20426:2018 standard. The B-WaterSmart methodology considers an additional initial step for establishing the context, in line with the risk assessment process defined in ISO 31000:2018.

Main features of the BWS Risk Assessment for Urban Water Reuse framework are:

- Expert-knowledge available for risk managers and stakeholders responsible for non-potable water uses, guiding the user through the inherently complex context of public health and environmental risk guidelines and ensuring compatibility with the latest concepts in ISO standardization and EU regulations.
- Innovative methodology for building hazard exposure scenarios within the human health and environment (groundwater and surface water) risk assessment.
- Standardized and easy-to-use tool to learn how to develop and to replicate the risk assessment of non-potable water reuse tested in urban applications.

Architecture of the risk assessment framework

The procedure for non-potable water reuse risk assessment is based on the ISO 20426:2018 standard, which establishes the basis for the process of assessing and managing the risk to human health associated with non-potable reuse of reclaimed water. ISO 20426:2018 considers the qualitative risk assessment as the most appropriate and economically viable methodology for non-potable water reuse projects. This international standard was used as a guideline both for the European Regulation (EU) 2020/741 on minimum requirements for water reuse in agricultural irrigation and for the national legislation, i.e. the Portuguese Decree-Law 119/2019.

ISO 31000:2018 and ISO 20426:2018 provide a structured approach for understanding and managing risk. These standards have similarities regarding the risk management process, as follows:

- Risk Identification, for the identification of perturbations likely to have an impact on the achievement of the objectives (safe water reuse), namely hazards and hazardous events.
- Risk Analysis, for each risk, its potential impact and likelihood of occurrence are rated. The combination of these rating determines the severity of the risk.
- Risk Evaluation, for each risk, its tolerability is determined by comparing the severity of the risk against the level of risk that an entity is willing to accept.
- Risk Treatment, for each risk, a decision should be made on risk mitigation for reducing the residual risk to an acceptable level; risk control measures (source, treatment and end-use).

The risk assessment framework integrated in tool #27 is presented in Figure 13 (inside the yellow frame).

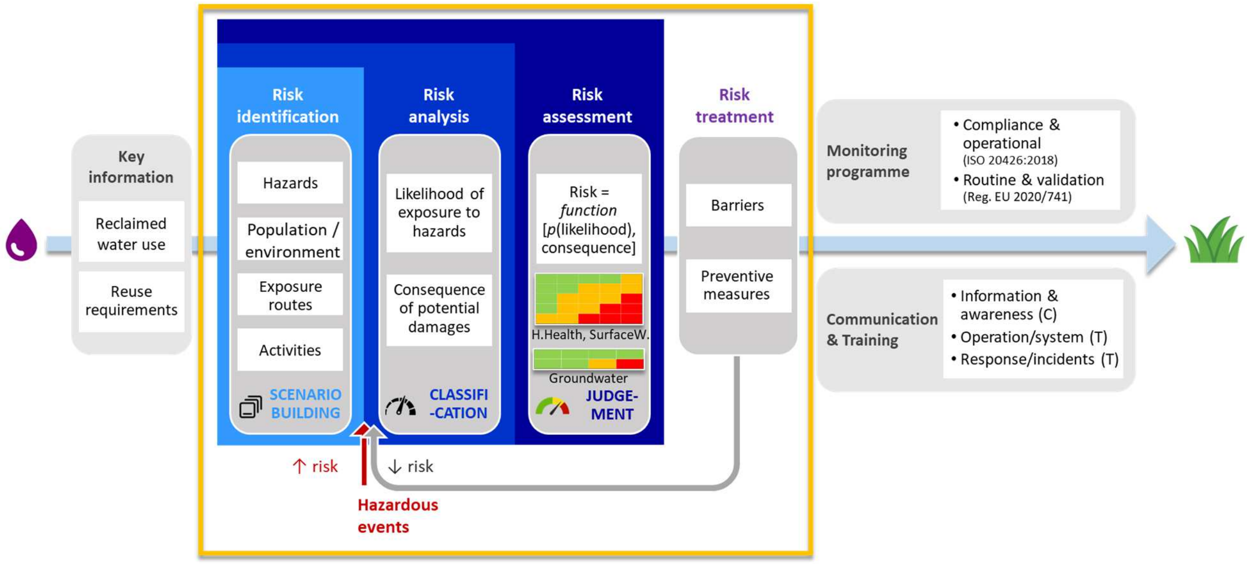


Figure 13: Framework of the risk management process for urban non-potable water reuse.

The framework for Risk Assessment for Urban Water Reuse integrated in the Tool #27 includes two main elements:

1. CONFIGURATION (Figure 15), for description of the risk management model structured around four elements: Components (referring to Hazards, Exposure Routes, Exposure Sites, Activities, Population and Environment at Risk), Hazardous Events and Barriers (both organised in terms of hazards' occurrence and likelihood of exposure to hazards), and Prevention Measures.
2. ANALYSIS or the risk assessment process itself (Figure 15). It starts with the Risk Identification for building the risk scenarios, followed by the Baseline Risk Analysis for assessing the risk referring to the risk control measures in place, i.e. corresponding to the maximum inherent risk level. If this risk level is not acceptable (i.e. if it is moderate or high), then additional or improved risk control measures need to be considered (Risk Treatment) to ensure a safe water reuse. The Final Risk Analysis delivers the assessment of the residual risk, resulting from the enhanced risk control. If the risk level is acceptable (i.e. low), the scenario's risk assessment is concluded. If the risk level remains unacceptable, the risk treatment requires further improvement. The risk is assessed for each risk scenario. The conditions for water safe reuse are defined only when all scenarios present a low level of risk.

The B-WaterSmart Tool #27 runs in BASEFORM's environment as an individual application.

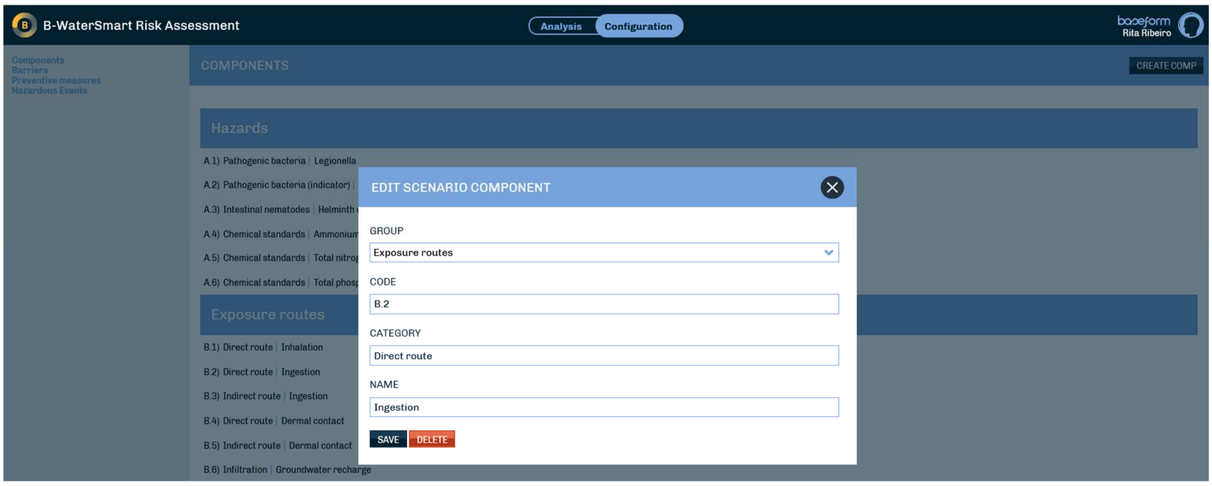


Figure 14: Tool #27 screenshot – Configuration. List of the elements that describe the water reuse system (background image) and menu to introduce these elements (front image).

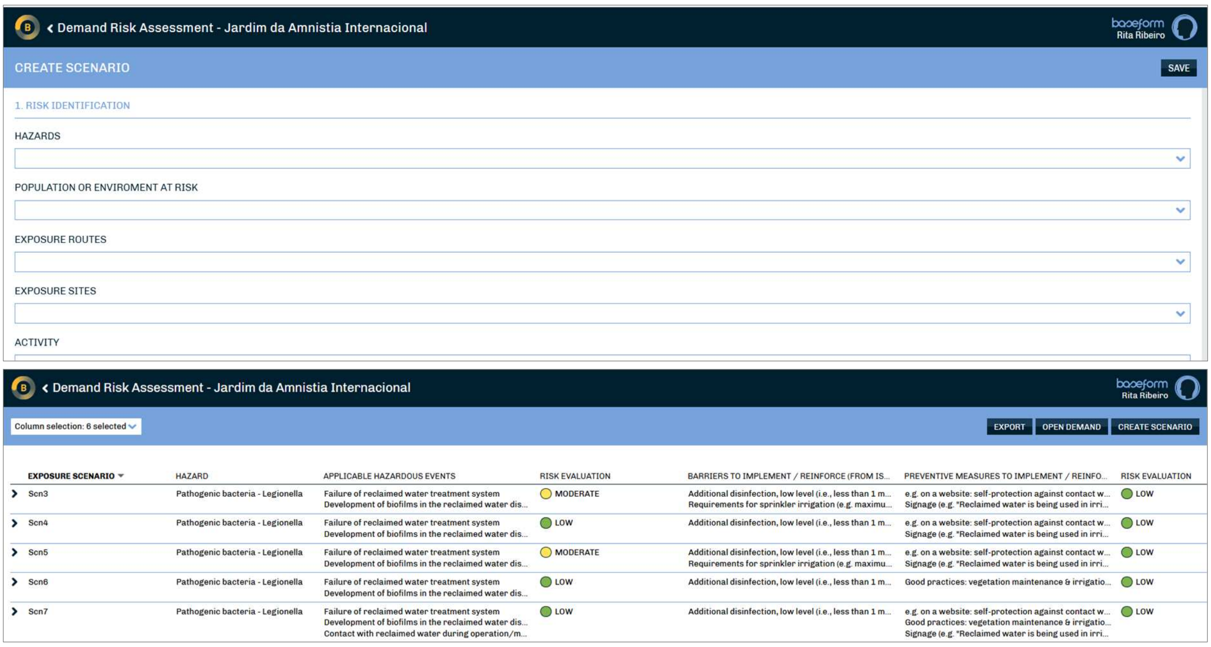


Figure 15: Tool #27 screenshots – Risk Analysis. Menu to build the risk scenarios (upper image) and some of the information that is presented in the risk scenarios (lower image).

Knowledge produced during the project and progress beyond the state-of-the-art

The deployment of tool #27 goes beyond the state-of-the-art because it provides the new and sound ability to develop urban water risk assessment in a user-friendly way, fully aligned with the relevant ISO standards and the EU regulation on water reuse. This solution was conceived and developed from scratch within the project, based on the concept created by the LNEC team in task T2.4.and the corresponding digital tool (tool #27) was developed by BASEFORM jointly with LNEC in T3.5.

Table 3 presents the architecture and data configuration of the risk assessment framework for Urban Water Reuse Module that was implemented by BASEFORM in tool #27.

Table 3 – Configuration of the risk management framework for urban non-potable water reuse (tool #27).

Element	**Group**	**Category** (examples)	**Designation** (examples)
Components	Hazards	- Pathogenic bacteria - Pathogenic bacteria (indicator organism) - Intestinal nematodes - Chemical standards	- *Legionella* - *Escherichia coli* - Helminth eggs - Ammonium
	Exposure routes	- Direct route - Indirect route - Surface run-off - Infiltration	- Inhalation / Ingestion / Dermal contact - Ingestion / Dermal contact - River recharge - Groundwater recharge
	Exposure sites	- Vegetated area - Non-vegetated area - Equipment - Water body	- Irrigated area (lawns, etc.) - Paths - Drinking fountains, fitness area - River
	Activities	- Stay - Pass by - Work	- Lie/sit down, play sports, eat, etc. - Walk, cycle, etc. - Operation of the irrigation system, maintenance of the vegetation, etc.
	Population and environment at risk	- Users - Workers - Surface water - Aquifer	- Immune system: immature, competent, weakened - Immune system: competent - Vulnerability: high and low to moderate - Vulnerability: idem
Hazardous events	Occurrence of hazards	- Increase of hazards: source water - Increase of hazards: reclaimed water - Increase of hazards: points of use	- Due to an undue industrial discharge - Due to a failure of the reclaimed water treatment system - Due to e.g. excessive biofilm development or chlorine decay in the reclaimed water distribution network
	Likelihood of exposure	- Inadvertent misuse - Accidental exposure - Cross connection	- Due to potential misuse, e.g. drink from an unidentified reclaimed water tap - Due to design or operational deficiencies, e.g. inadequate irrigation timing - Due to an improper connection, e.g. to a drinking water network, leading to its contamination by reclaimed water
Barriers	Occurrence of hazards	- Decrease of hazards: reclaimed water	- By additional disinfection, low level (ISO 16075-2:2020)
	Likelihood of exposure	- Reduce the potential for accidental exposure	- By access control (ISO 16075-2:2020)
Preventive measures	Awareness	- Reduce the potential for inadvertent misuse	- By signage, e.g. "Reclaimed water is being used in irrigation", "Water not suitable for drinking" (ISO 20469:2018)
	Information	- Reduce the potential for accidental exposure - Reduce the potential for cross connection	- By information (e.g. on a website) about self-protection against contact with reclaimed water - By clear identification of the reclaimed water network pipes and accessories
	Training	- Reduce the potential for accidental exposure - Reduce the potential for cross connection	- By good practices in vegetation maintenance & irrigation, e.g. using personal protective equipment - By adoption of procedures for detection of cross-connections between water distribution networks

Whitin Task T2.4.3, tool #27 was applied by the Lisbon LL to the previously referred 10 public green area pilots (Figure 16).

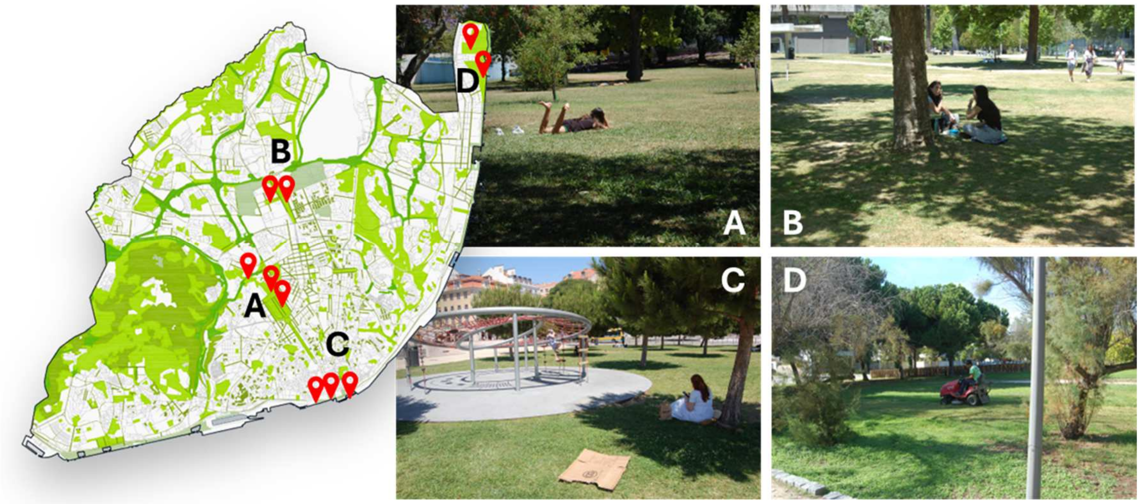


Figure 16: Lisbon LL green area pilots – water reuse (4 examples of risk exposure situations).

A risk matrix was developed (Figure 17), integrating the four classes of vulnerability of the DRASTIC index and two classes of likelihood of potential groundwater contamination. This risk matrix is integrated in Tool #27. The results showed that all pilots have low (>50% of each pilot area) to medium groundwater vulnerability which ultimately, using the risk assessment matrix developed in this study, classify the areas as low risk of contamination (Oliveira *et al.* 2023).

Risk Level	Consequence (i.e. aquifer vulnerability to contamination) - DRASTIC index			
Likelihood of potential groundwater contamination	Low vulnerability (<120)	Moderate vulnerability (120-159)	High vulnerability (160-199)	Very high vulnerability (>200)
RW concentration ≤ groundwater standards and threshold values	Low	Low	Low	Low
RW concentration > groundwater standards and threshold values	Low	Low	Moderate	High

Figure 17: Developed risk matrix for groundwater in case of water reuse (Oliveira *et al.* 2023)

The environmental (groundwater) risk assessment is based on the DRASTIC index method for the evaluation of the groundwater vulnerability to contamination and is fully detailed in Oliveira *et al.* (2023). The DRASTIC groundwater vulnerability index was calculated for five pilot areas, which include the 10 green area pilots (Figure 18).

The developments on health risk assessment were shared in two national conferences and published in a scientific paper. The developments on environmental (groundwater) risk assessment are the subject of one report and a communication to a national conference.

Figure 18: Groundwater Lisbon LL pilots (Oliveira *et al.* 2023).

Tool #27 makes expert-knowledge available for risk managers and stakeholders responsible for non-potable water uses, guiding the user and ensuring compatibility with the latest concepts in ISO standardization and EU regulation. The targeted end users are the managers of irrigated green areas or other non-potable water uses where water reuse is an option to consider. Other users are water demand planners and decision makers in urban management.

Further reading

- Deliverable D3.5 *The Water Cycle Modelling and Assessment Solutions Toolkit - Final Release,* section 5.6 (Lykou *et al.* 2024) https://b-watersmart.eu/download/the-water-cycle-modelling-and-assessment-solutions-toolkit-final-release-d3-5/
- Water Europe Marketplace https://mp.uwmh.eu/d/Product/67
- Training session https://b-watersmart.eu/training-material-for-three-tools/
- Report *Groundwater risk of contamination using reclaimed water in Lisbon pilot areas* (Oliveira *et al.* 2023)
- Scientific paper "The role of scenario building in risk assessment and decision-making on urban water reuse" (Ribeiro and Rosa 2024, https://doi.org/10.3390/w16182674)
- Paper in conference "Metodologia para avaliação do risco para a saúde humana associado à reutilização de água em usos urbanos não potáveis" (Ribeiro and Rosa 2024, APRH/UAlg)
- Paper in conference "Avaliação do risco para a saúde humana associado à reutilização de água: construção de cenários de exposição" (Ribeiro and Rosa 2022, ENASB)

- Paper in conference proceedings "Groundwater Risk of Contamination using Reclaimed Water in the Irrigation of the Campo Grande Garden and Alameda da Universidade de Lisboa – a contribution of the B-Watersmart Project" (Oliveira et al 2022, SAS)

Water quality modelling in reclaimed water distribution systems' tool

Short description

The Reclaimed Water Quality Model in the Distribution Network (tool #24) is a complete hydraulic and water quality extended-period simulation model for pressure flow networks. By modelling the decay of residual chlorine (bulk and wall decay), the key barrier for water microbial stability, it aims primarily at mapping and managing risk in reclaimed water distribution networks.

The model was developed, implemented and applied in four Reclaimed Water Distribution Systems (RWDSs) pilots (Figure 19). Pilots 3 and 4 are two big parks in Lisbon, summing up 68 ha of total irrigated area with reclaimed water, both licensed during the B-WaterSmart project, pilot 3 changing from groundwater to reclaimed water and the new pilot 4 designed in 2023 to be irrigated with reclaimed water.

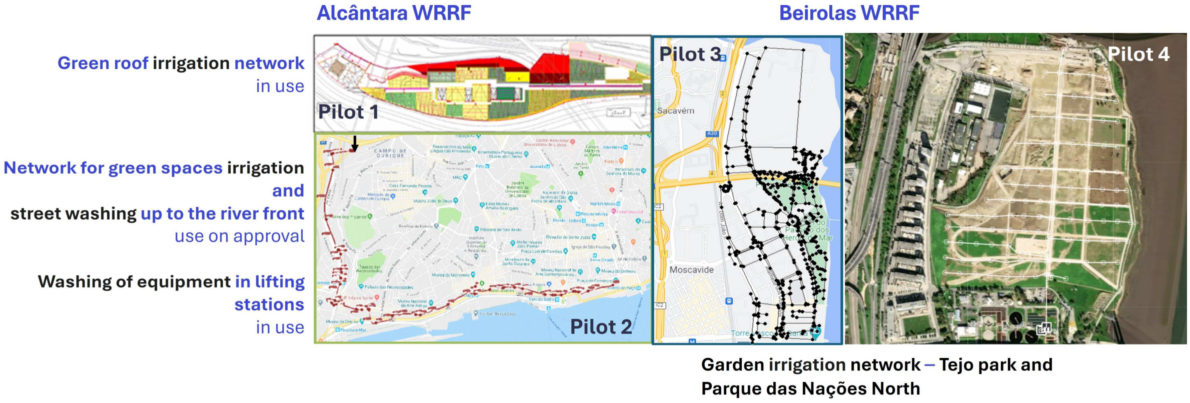


Figure 19: Lisbon LL reclaimed water distribution systems pilots.

The model runs in BASEFORM's environment as an individual application (Figure 20). The primary input for the hydraulic model is an EPANET.INP file, and, for the water quality, an EPANET.MSX file. The latter is based on a detailed formulation developed specifically for the project by the LNEC team, which is described in detail in documentation produced by task T2.4 and briefly described below, in "Knowledge produced during the BWS project".

The model runs based on those two files and the interface allows for querying of results as well as full visualisation in BASEFORM's 3D environment. The properties of physical elements such as pipes can be queried by clicking on a pipe. Besides using the EPANET.INP file standard, the model can also be exported to an Excel® format that facilitates section-by-section editing.

<u>Step-by-Step Guide for using the tool #24</u>

1. Infrastructural model of the network (data required) implemented in ArcGIS or other format compatible with EPANET open-access software.
2. Import the network diagram to EPANET and calibrate the model with water consumption profile data (data required, hydraulic engineering experts).

3. Validate the use of the water quality model (chlorine bulk decay) available or adjust it to the specific water based on lab data — (chlorine demand and organic matter & nitrogen content characterization — (data required).
4. Implement the water quality model (MSX) in the EPANET-MSX software.
5. Calibrate the chlorine wall decay by performing flowrate and water quality measurement campaigns.
6. Assess the water velocities and age in the network, as well as the chlorine residual in critical points for water safety.
7. Manage the network to have a safe water supply, i.e. to have the right chlorine residuals to minimize water contamination and biological regrowth.

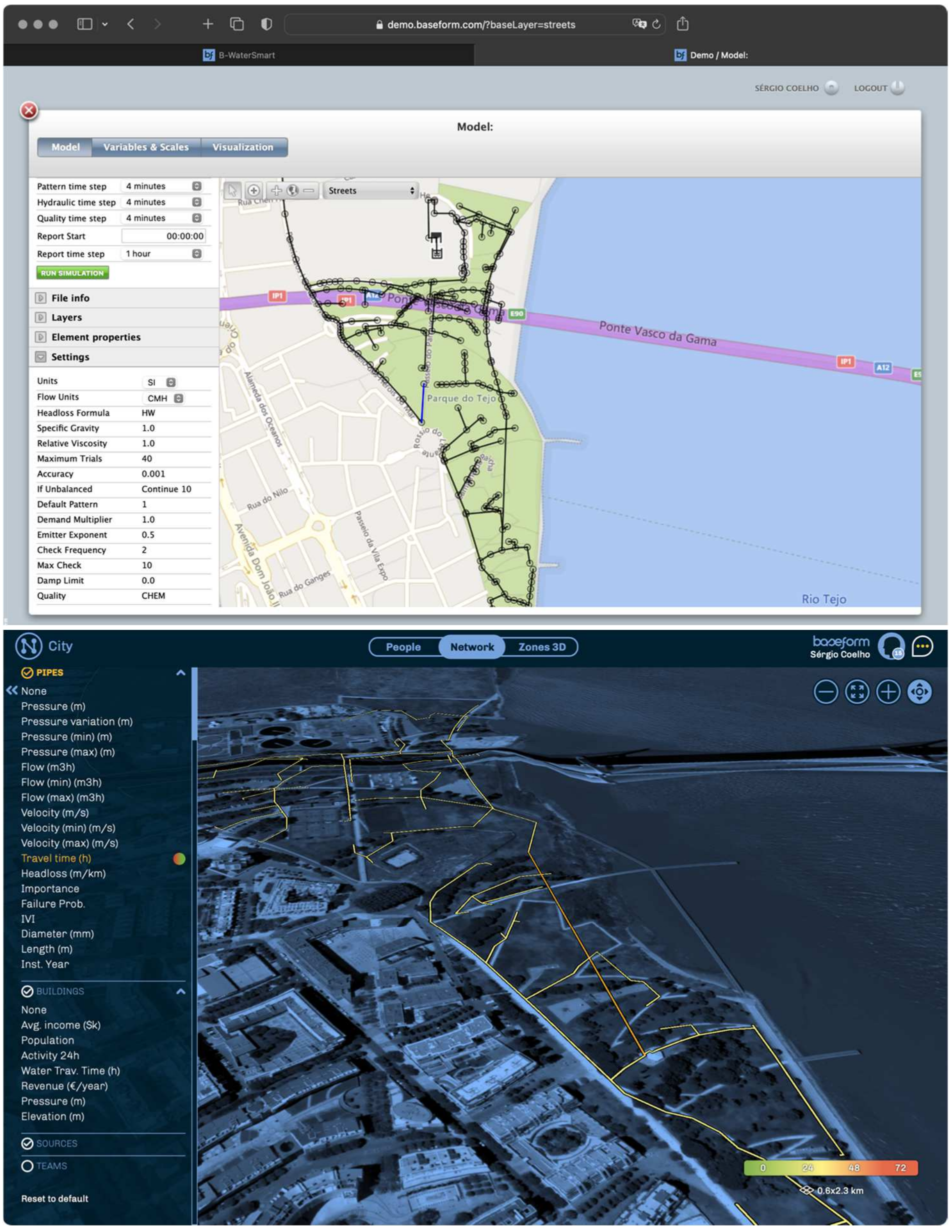


Figure 20: Tool #24 screenshots – RWDS3 network (upper image) and model results (lower image).

Knowledge produced during the project and progress beyond the state-of-the-art

The deployment of tool #24 goes beyond the state-of-the-art because this tool implements a new, innovative algorithm for modelling chlorine decay, as a function of key water quality parameters, as the reclaimed water travels in distribution networks, on top of a standard hydraulic model. Tool #24 is part of a sequence of four apps that jointly provide a complete ability to match water supply to demand, while managing water volume, cost, energy, nutrients and risk, with full GIS-compatible georeferenced capabilities. This tool adds full reclaimed water quality modelling capabilities to the BASEFORM software universe. It works in conjunction with tool #25 by assessing transport and distribution risk of reclaimed water in candidate supply/demand combinations.

The newly developed mechanistic model comprises bulk and wall residual chlorine decay. The chlorine bulk decay accounts for reactions with water species (organic matter, ammonia and other oxidizable species) and is function of the chlorine dose, pH and alkalinity. The chlorine wall decay may account for reactions with the pipes (material and biofilm) and with sediments. Figure 21 depicts the components of the reclaimed Water Quality Model in the Distribution Network applied in tool #24.

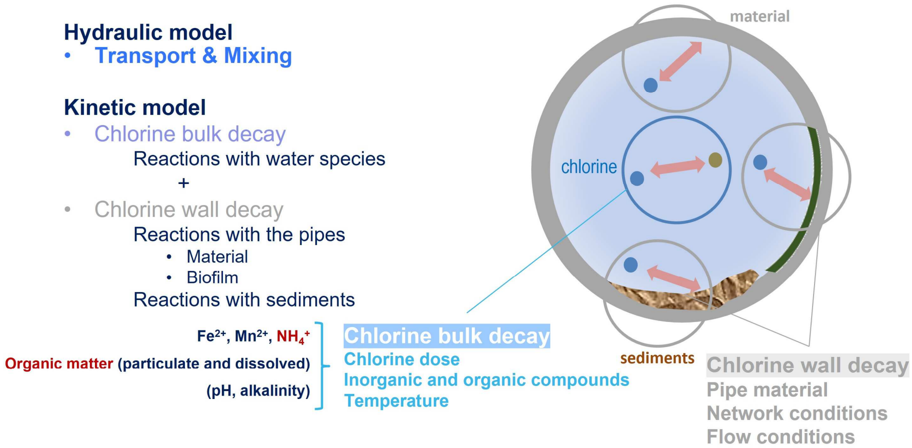


Figure 21: Components of the reclaimed Water Quality Model in the Distribution Network (tool #24).

For implementing the model, the methodology involved lab and full-scale experiments, and development, building and calibration of the model, as depicted in Figure 22.

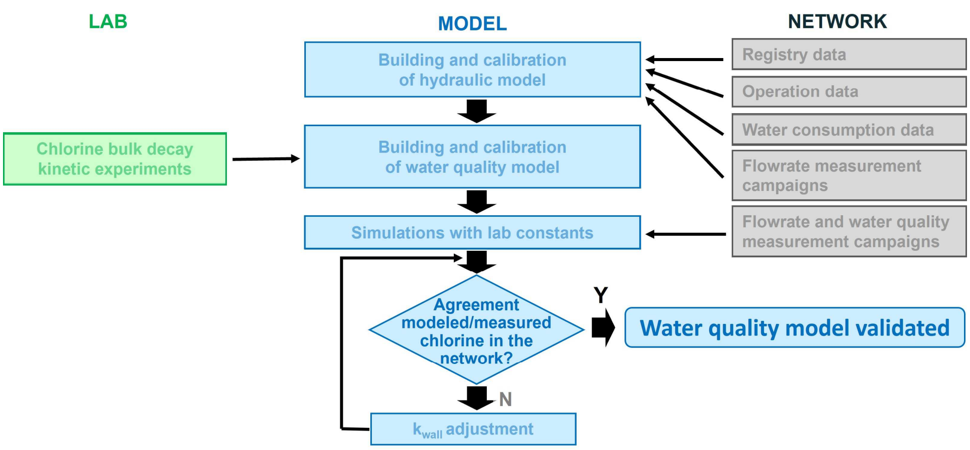
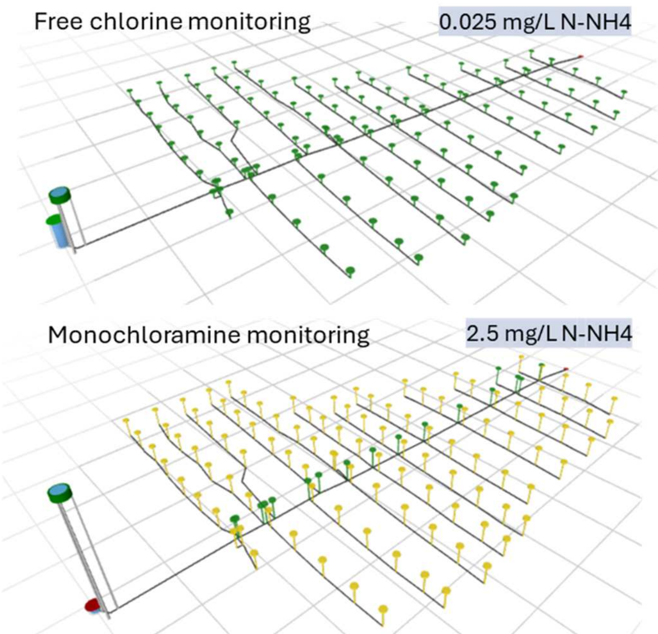


Figure 22: Methodology for implementing tool #24.

The model also allowed highlighting the importance of ammonia for managing chlorine residuals in RWDSs. As shown in Figure 23, for a free chlorine dosing of 2 mg/L, in the case of a reclaimed water with a very low ammonia content (0.025 mg/L), free chlorine should be monitored in the RWDS and its levels will mostly be in “good” state, meaning no risk for its reuse, while, in the case of a reclaimed water with a medium ammonia content (2.5 mg/L), monochloramine should be monitored and its levels will mostly be in “alert” state, meaning there is a risk for its reuse that should be considered.



	Free Chlorine mg/L	Monochlorine mg/L
Interrupt	0 – 0.1	0 – 0.5
Action	0.1 – 0.2	0.5 – 1
Alert	0.2 – 0.5	1 – 1.5
Good	0.5 – 1.5	1.5 – 3
Adequate	1.5 – 3	3 – 5

Figure 23: Residual chlorine (as free or chloramine) in the RWDS pilot 3 for the case of a reclaimed water with a very low ammonia content (0.025 mg/L) (upper image) and with a medium ammonia content (2.5 mg/L) (lower image), depicted in tool #24.

The results of the development, implementation and demonstration of the model of the tool were and are to be (in late 2024 and early 2025) widely disseminated, namely through:

- three scientific papers, two concerning the reclaimed water quality modelling algorithm (Costa *et al.* 2021, https://doi.org/10.3390/su132413548; Costa *et al.* 2022, https://doi.org/10.22181/aer.2022.1102) and one regarding its application in the Lisbon LL pilots (Costa *et al.* 2023, https://doi.org/10.3390/su152316211)
- six communications in national (SEREA 2019, ENEG 2023, ENASB 2024) and international conferences (IWA Reuse 2023, Winter School 2024, IWA Reuse 2025 - submitted);
- one PhD thesis – Joana Costa (2023) Modelling chlorine decay in reclaimed water distribution systems, PhD in Civil Engineering, IST/UL (Costa 2023);
- one MSc thesis – Francesca Mangiagli (2022) Wastewater disinfection for reclaimed water production and distribution – a lab study for assessing the chlorine reactivity, MSc in Environmental Engineering, IST/UL (Mangiagli 2022).

Tool #24 is a new, dedicated solution to the problem of analysing and assessing the environmental and public health risks posed by using pipe networks for transporting and distributing reclaimed water. This specialized reclaimed water quality model is best used by hydraulic engineering experts, usually working as part of consultancy in urban management or water utility contexts or used by the utility staff.

Further reading

- Deliverable D3.5 *The Water Cycle Modelling and Assessment Solutions Toolkit - Final Release*, section 5.4 (Lykou *et al.* 2024) https://b-watersmart.eu/download/the-water-cycle-modelling-and-assessment-solutions-toolkit-final-release-d3-5/
- Water Europe Marketplace (https://mp.watereurope.eu/d/Product/51)
- Training session https://b-watersmart.eu/the-reclaimed-water-distribution-network-water-quality-model/
- Two open access scientific papers assessed through https://b-watersmart.eu/results-downloads/dissemination-material/.

Decision support and selection of alternative courses of action tool

Short description

The Environment for Decision Support and Selection of Alternative Courses of Action (tool #17) is an intuitive numerical and visual decisional environment that enables non-experts to easily comprehend the decisional problem involved in prioritizing and to make decisions based on factual evidence/data.

Main features of this solution are:

- Implements a set of specifically designed metrics for the strategic and tactical prioritization of regional or urban supply/demand combinations involving potable and non-potable water (BWS Assessment Framework, tool #34).
- Tailored to the decisional problem laid out by tool #25, which produces candidate supply/demand combinations.

Architecture of the alternatives' compare and ranking framework

Water-smart allocation for urban non-potable uses implies the assessment and ranking of planning alternatives through objective-guided metrics. The impact of each alternative is quantified over time. The supply and demand alternative combinations are assessed through a range of standardized, user-selected metrics of performance and cost, complementing those employed to qualify the initial selection in tool #25 (e.g. volume availability, cost, energy content, carbon footprint, nutrient content), and are further qualified for risk, through risk assessment in tool #27 as well as potentially tool #24, if applicable.

The Environment for Decision Support and Selection of Alternative Courses of Action (tool #17) consists of three components:

1. The DATA is where the decision-making problem is formulated by setting Objectives, Timesteps, Metrics and Alternatives (Figure 24, upper image). Because this tool was tailored to the decisional problem laid out by tool #25, either the alternatives (i.e. candidate supply/demand combinations) as selected performance and cost metrics are automatically available for analysis. The values of risk metric result from the water reuse risk assessment (tool #27) and, if applicable, from the water quality modelling in the RWDS (tool #24).
2. The RANKING allows examining Alternatives vs. Metrics vs. Time (Figure 24, lower image).
3. The 3D CUBE offers an inclusive view of the problem (all dimensions are presented), facilitating the decision-making process (Figure 25).

The B-WaterSmart Tool #17 runs in BASEFORM's environment as an individual application.

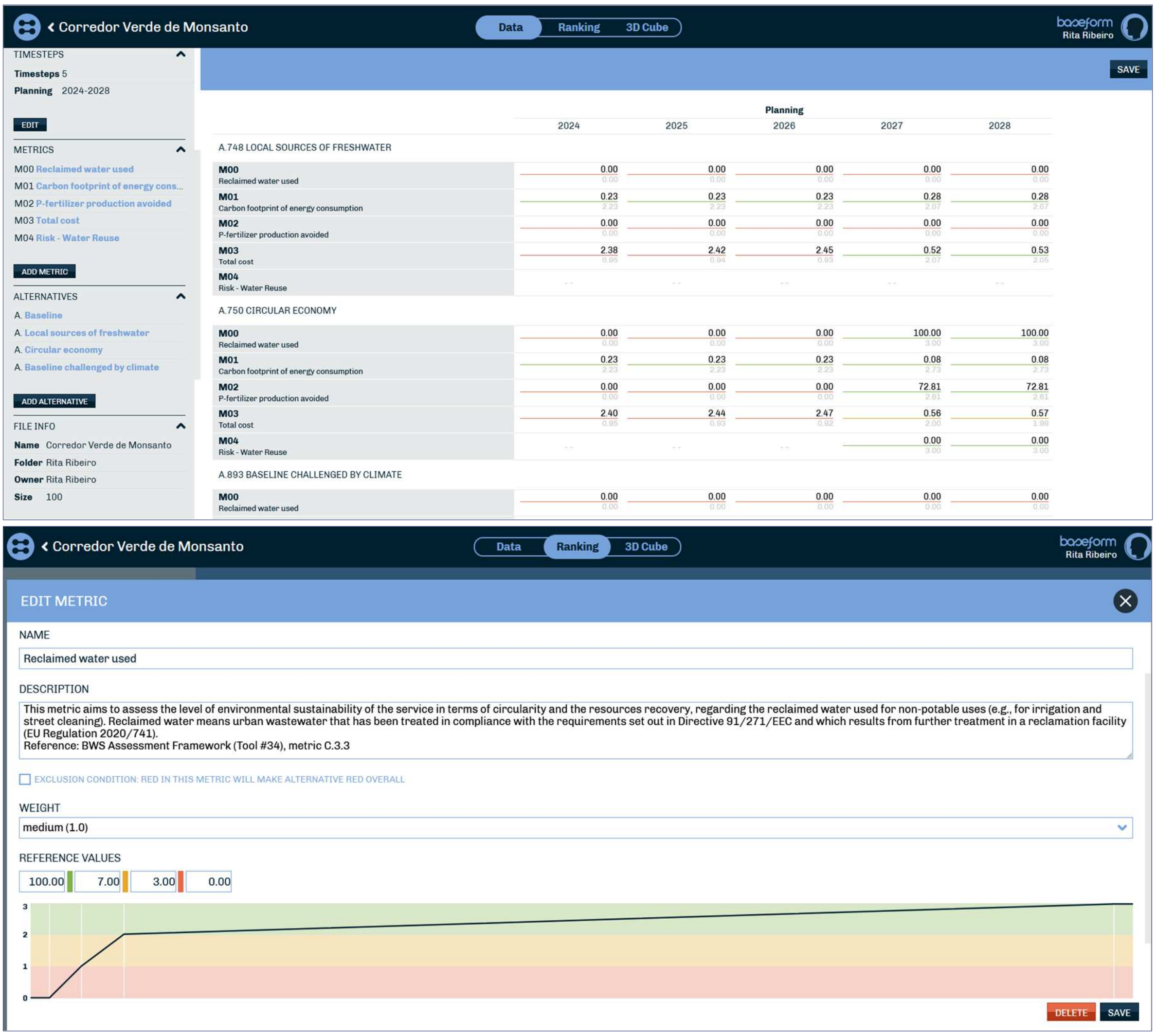
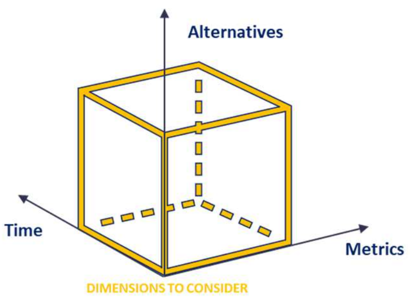


Figure 24: Tool #17 screenshots – calculated metrics (upper image) and metric edition (lower image).



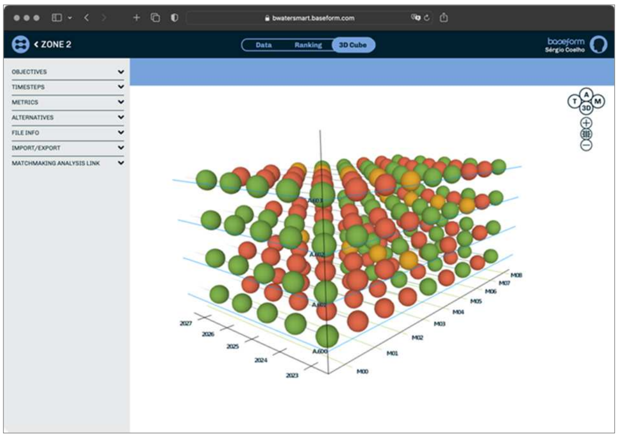


Figure 25: Decision-making dimensions (left image) and Tool #17 screenshot: 3D comparison (right image).

Knowledge produced during the project and progress beyond the state-of-the-art

The deployment of tool #17 goes beyond the state-of-the-art because it provides the ability to match water supply to demand, while managing water volume, energy, nutrients, cost and risk. This tool adds to the BASEFORM software universe a strategic and tactical prioritization environment specific to the planning of urban non-potable water uses with a focus on water reuse.

Table 4 presents the metrics defined for comparing and ranking the smart-water allocation alternatives that was implemented by BASEFORM in tool #17, Environment for decision support and selection of alternative courses of action.

Table 4 – Metrics defined for comparing and ranking the smart-water allocation alternatives (tool #17).

Metric	What is assessed	Formulation	Notes
Reclaimed water used	Contribution of water reuse to meeting demand	Reclaimed water used / Water consumption (%)	BWS Assessment Framework (Tool #34), metric C.3.3 (Silva et al. 2023)
Carbon footprint of energy consumption	Contribution to meeting carbon neutrality	Energy consumption * Local energy mix (kg CO_2eq/m^3)	BWS Assessment Framework (Tool #34), metric B.3.2 (Silva et al. 2023)
P-fertilizer production avoided	Contribution to reclaim the critical nutrient phosphorus and reduce the use of P chemical fertilizers	P conc. in reclaimed water used (g P/m^3) * reclaimed water used (m^3/month) / Total P used as fertilizer /1000 (kg P/month), (%)	BWS Assessment Framework (Tool #34), metric C.3.2 (Silva et al. 2023)
Total Cost	Total cost per alternative	TOTEX = OPEX + CAPEX (€/m^3)	The user inputs all CAPEX (investments during the lifetime) entries over time
Risk	Risk to health and environment per non-potable water reuse	Risk assessment - Tool #27 (low, moderate or high)	--

Tool #17 is an intuitive numerical and visual decisional environment enables non experts to easily comprehend the decisional problem involved in prioritizing, and to make decisions based on factual evidence. This tool implements a curated set of specifically designed metrics for the strategic and tactical prioritization of regional or urban supply/demand solutions involving potable and non-potable water. The targeted end users are water demand planners and decision makers in urban management, municipal and water utility contexts.

Further reading

- Deliverable D3.4 *The monitoring, negotiation and decision support solutions toolkit - Final Release*, section 5.2 (Clotas *et al.* 2024) https://b-watersmart.eu/download/the-monitoring-negotiation-and-decision-support-solutions-toolkit-final-release-d3-4/
- Water Europe Marketplace https://mp.uwmh.eu/d/Product/66/
- Training session https://b-watersmart.eu/training-material-for-three-tools/.

2.4 Climate Readiness certification

Short description

The Climate Readiness Certification (CRC) (tool #33) is an innovative assessment tool that integrates in one certificate the evaluation of real estate developments in three domains: Water Efficiency, Water-Energy Nexus, and Climate Adaptation. It can be applied to new or existing dwellings, residential and small service/commercial buildings, as well as to "neighbourhoods" considering both buildings and outdoor areas within the frontier established for the certification object. It can also be applied in the different stages of the development, from design to construction or rehabilitation and during operation. The certificate classes are established from F (worst) to A+ (the best) and the result are four classifications: one global classification, balancing the contribution of each dimension, and one sub-classification for each evaluated dimension.

The methodology of CRC expanded from the AQUA+® system, a commercial and voluntary water performance classification managed by ADENE that evaluates the water efficiency dimension of buildings. The work developed within the B-WaterSmart project added to the water efficiency dimension two additional ones: water-energy nexus and climate adaptation. For the 57 criteria assessed in the water efficiency dimension, 33 criteria were defined for the water-energy nexus dimension and 19 to the climate adaptation one. An example is provided in Figure 26.

Figure 26: Example of a climate ready certificate.

The methodology was applied to several pilots – dwellings, buildings and neighbourhoods – in Lisbon to calibrate and improve the final methodology. The certificate identifies not only the classification but also the strengths and opportunities to exploit and to improve the overall classification in the different dimensions, acting as a support decision tool to improve the performance of the certificate object.

With the final methodology established, an online platform was developed for the auditor's to easily access, introduce the data on the certification object and produce the certificate. This platform is publicly available at [Start - Climate Ready Certificates (adene.pt)] and any user can access and apply the methodology additional dimensions: water-energy nexus and climate adaptation.

For the easiness of application of this methodology, a digital platform was established and is publicly available. The platform is open to all users that can freely test the water-energy nexus and climate adaptation dimensions and issue a "draft" certificate, with the classification in these two dimensions. The overall assessment is also possible to certified auditors, via the AQUA+ commercial system.

Complementarily research was also conducted on financing mechanisms for the water-energy nexus. Financing mechanisms play a crucial role in implementing efficiency measures in buildings, encompassing both energy and water considerations. Understanding the various financing options is essential to effectively target the most appropriate resources for specific initiatives. Finally, an overview of potential financing mechanisms that the Lisbon Municipality could use for private and public buildings in the context of energy and water efficiency improvements was shared with CML.

Methodology developed for the assessment of housing climate-change adaptation

The methodology deployed in the development of the CRC certificates considered four steps: i) literature review; ii) pilot application; iii) Lisbon LL feedback; iv) focus group with experts.

The primary focus of the literature review was green building and labelling standards, as water efficiency has become a more prominent component of these. This preliminary study allowed the identification and comparison of other methodologies which are used for assessing and classifying the water-use efficiency in buildings. The search strategy followed the direct selection, sort, and review of papers related to this topic. For the initial search, the EBSCO Discovery Service search engine was used, using as keywords "water nexus buildings", "water efficiency buildings", "water certification buildings", water rating buildings, and water label buildings and limited to full academic papers, with peer review, from January 2010 to July 2020. After the screening of titles, abstracts and results, a set of 37 papers were selected and analysed, and the relevant information systematized. Therefore, a set of 22 methodologies were collected, and the main water-related domains of applications identified.

In parallel, six methodologies of green building certification were selected to be analysed in detail: BREEAM, LEED, DGNB, Beam Plus, CASBEE, and BCA Green Mark, applied to both new and existing buildings. These methodologies were selected for the following reasons. BREEAM and LEED are the most widely used and are the most represented green building certifications schemes worldwide. DGNB model is an internationally adaptable certification system with the ability to assess various types of buildings and districts, being more comprehensive and complex than BREEAM and LEED certifications. Beam Plus, CASBEE, and Green Mark were selected because they are international green building design systems that have established their criteria based on existing national standards and codes, complemented with other sustainability criteria. These methodologies were compared based on their domain of applicability and only their water-related criteria were analysed, including the energy consumption related to water use. And finally, their strengths and omissions guided the proposal of a new methodology structure that better fits the objectives to assess the performance in the uses of water and energy in residential buildings.

To test, evolve and validate the CRC methodology, a pilot application was deployed, covering different building typologies:

- one residential neighbourhood (Av. Sanches Coelho lots 4A and 4B, and common garden);
- two different multifamily buildings (Av. Sanches Coelho Lots 4A and 4B, and Rua da Magnolias Bloc D), one office building (ADENE's headquarters), three single family detached houses (Rua 6 Lots 5I, 15F and 16C);
- fourteen households/dwellings in multi-family (8 flats in Av. Sanches Coelho Lot 4A, 4 flats in Rua da Magnolias Bloc D, and one flat in Rua Lyon de Castro nº 14 2B).

This pilot application allowed identifying additional criteria (e.g. energy sources) and maintenance of some of the evaluated equipment, as well as harmonizing the classification scale of some indicators.

The 3rd step was the Lisbon Living Lab feedback. After periodic interactions with the Lisbon LL partners, and having shared the CRC methodology in advance, an internal session was organized to present the CRC methodology in detail, simulate an application to ADENE's office building and gather feedback from the partners. The session took place on the 6th of June 2023 and had the participation of CML, LNEC, ICS-UL and LEN. The session included a brief presentation of the water efficiency dimension and a detailed presentation of the water-energy nexus and climate adaptation. The partners' feedback was very relevant and allowed eliminating some non-essential indicators, and adding new indicators, namely to the climate adaptation dimension addressing the water "fit for purpose" topic. This session also included brainstorming around the weights allocated to the different indicators.

The 4th and final step was the Focus Group with Experts. A Focus Group was organized on the 12th of September 2023, hosted by ICS-UL, to which more than 15 experts attended (Figure 27). The session's agenda included a presentation of the methodology, focusing the dimensions water-energy nexus and climate adaptation. Next, the experts participated in 3 round tables to discuss the indicators and respective weights applicable to the "water-energy nexus" and "climate adaptation" dimensions, and the scale of application to neighbourhood, building and dwelling. This discussion had a script for providing feedback on the indicators. It also included an online exercise to allocate weights, which were adopted in the final methodology, to different dimensions and indicators. Questions were raised regarding the data needed to perform the evaluation and the exploitation potential to other regions.

Figure 27: Focus Group meeting with Experts.

New financing mechanisms

Having in mind the applicability of the CRC methodology to the city of Lisbon and the expected results from its application, which is the identification of potential improvement measures for housing climate-change adaptation, a study was conducted to identify financing mechanisms that can be appropriate to foster the implementation of such measures. Understanding the various financing options is essential to effectively target the most appropriate resources for specific initiatives. Traditional and specialised financing mechanisms are available as instruments, each impacting private and public investments differently. Given the range of measures identified in the climate-ready certification methodology, there are numerous opportunities available for the Lisbon Municipality to foster the adoption of efficiency measures within the water-energy nexus framework. These efforts could encompass financing initiatives for municipal investments in housing and initiatives aimed at encouraging private homeowners and real estate developers to adopt similar measures. Some suggestions are: (i) the Lisbon Municipality adopting the CRC methodology as an evaluation tool for new construction or retrofitting projects to ensure a minimum level of performance across three evaluated dimensions; (ii) setting up a one-stop-shop to provide support in various areas, including basic energy literacy, information and application assistance for national funding and subsidy programmes, addressing the multi-family/multi-owner dilemma; and, (iii) testing innovative financing mechanisms to mobilise commercial capital towards sustainable investments and foster partnerships with banks for green loans specifically dedicated to houses located in the Lisbon Municipality, particularly within Retrofit Urban Areas. Additionally, several initiatives were identified as potentially interesting for the Municipality to evaluate, such as the technical assistance under the ELENA programme, *Fundo Nacional de Reabilitação do Edificado* and *Portugal* 2030 programmes for urban retrofit, amongst others.

The future of the CRC is to establish a design thinking process for the definition of the commercial strategy to adopt. The basis of this work has been established within WP7, in cooperation with Adelphi. Additionally, the input oof national stakeholders and interested professionals is necessary to establish the business model.

As for the methodology, this should be checked for the alignment with the European Taxonomy that introduced a new framework for financing mechanisms, aiming to ensure the funding for sustainable projects. Supported by a harmonised evaluation board, this framework can be applied across a wide range of initiatives, and it is essential, for the CRC success, to guarantee its alignment and compliance with the European Taxonomy, namely with the Environmentally Sustainable Activities dimension. This alignment is essential for ensuring projects meet rigorous sustainability standards and can attract financing and investment aligned with EU sustainability goals.

Knowledge produced during the project and progress beyond the state-of-the-art

The most relevant result of Task 2.4.4. was the establishment of the CRC methodology, that offers a comprehensive solution, providing a certification that addresses water use in buildings in a holistic perspective, combining three dimensions, i.e. water efficiency, water-energy nexus and climate adaptation, applicable to residential buildings, namely dwellings, single and multi-family houses, small service or commercial buildings, as well as to “neighbourhoods”, and in three distinct phases, design phase, new construction or rehabilitation and operational buildings, resulting in a cross-cutting performance analysis that allows for the consideration and adoption of water efficiency and climate adaptation measures. The final methodology was applied to 2 neighbourhoods, 3 buildings (two multi-family and one office) and 30 households/dwellings in multi-family buildings, with the classification and issuing of the complete certificate via the digital platform. The predominant classification was D for existing buildings and C for new developments. It was possible to observe a positive evolution in the group of buildings evaluated, since it was found that new developments tend to incorporate systems that promote more efficient use of water and a better water-energy nexus. The fact that onsite water reuse is still in its early stages in Portugal, and, to a certain extent, climate adaptation has not yet been formalised in architectural programmes justifies the C rating for new developments.

Exploitation activities: During the BWS project an exploitation initiative was conducted within the framework of the MEETMEDII project (start-end dates). This project is financed by the European Neighbourhood Instrument and targets eight countries of the Southern Mediterranean Basin: Algeria, Egypt, Jordan, Lebanon, Libya, Morocco, Palestine and Tunisia, working on energy efficiency strategies and policies to accelerate the energy transition of the Mediterranean area. The CRC methodology was revised and adapted to the Mediterranean reality and applied in three countries: Jordan, Morocco and Algeria. The CRCs were applied both to multi-residential and small service buildings, serving as the main step to identify intervention opportunities to improve the water-energy performance of the buildings. The measures identified will be implemented during the MEETMED II lifetime and duly monitored. The results will be further exploited in the other countries and in potential new editions of the MEETMED project. Furthermore, within the work conducted in WP7, an exploitation and business plan was derived for the CRCs in cooperation with Adelphi.

Communication and dissemination activities:

- BEHAVE Conference, November 2023 – abstract and full presentation to an R&D audience
- BWS Webinar, December 2023 – to the BWS partners
- Public webinar, May 2024 – the agenda considered the presentation of AQUA+, the BWS project and the CRC methodology and digital platform, open to a professional audience

The main strength of Tool #33 is its capability to allow transversal analysis of water, energy and climate adaptation measures. Additionally, the tool allows citizen engagement as an added value feature.

Further reading

- Deliverable D3.4 *The monitoring, negotiation and decision support solutions toolkit - Final Release*, section 5.5 (Clotas *et al.* 2024) https://b-watersmart.eu/download/the-monitoring-negotiation-and-decision-support-solutions-toolkit-final-release-d3-4/.
- Water Europe Marketplace https://mp.uwmh.eu/d/Product/31/
- Training session https://b-watersmart.eu/the-climate-ready-certificates/

3 Conclusions and the legacy beyond B-WaterSmart

Summing up, the achievements of the work carried out in Lisbon LL from September 2022 until August 2024 may be translated by the following key numbers selected:

- 7 partners
- 1 technological tool
- 6 digital tools
- 20 pilots
- 2 municipal parks, 68 ha of total irrigated area with reclaimed water
- 2 new business opportunities, reclaimed water distribution for non-potable uses in Lisbon and climate-ready certificates
- 1 tailored water-smartness assessment framework
- 1 Strategic Agenda
- 1 Strategic Plan for the next 25 years (Lisbon Strategic Plan 2050 on Water Smartness)
- 1 Innovation Alliance with 6 LLs
- 1 local Community of Practice
- 5 CoP meetings (including the pilot meeting) and 3 Focus Group meetings
- 1 public event "B-WaterSmart Lisbon Living Lab Event" on 2024 World Water Day
- 7 citizen engagement sessions in 3 elementary schools (2nd, 3rd and 4th grades) in Lisbon
- 5 training sessions on the Lisbon LL tools
- scientific and peer reviewed publications: 4 papers published, 2 under preparation
- 22 oral presentations in conferences
- 7 lectures
- 1 successful WOLL application.

'The work undertaken by B-WaterSmart formed the basis for establishing a Water-Oriented Living Lab in Lisbon, aligning with the criteria set forth by Water Europe and embraced by the Water4All European partnership. The Lisbon Water Smart Living Lab (**Lisbon WOLL**) integrated the first set of 15 WOLLs included in the "Atlas of EU water-oriented living labs" (updated edition):

"*The Lisbon WOLL represents an ambitious initiative aimed at enhancing the quality of life in Lisbon, in the face of climate change challenges such as droughts, heatwaves, and floods, through innovative green-blue infrastructure solutions. Central to its mission is the enhancement of the city's water-smartness, achieved by optimising water demand/supply management for non-potable uses and fostering water-energy-phosphorus efficiency alongside climate-resilient housing. Lisbon WOLLs strategy encompasses strategic, governance, and social frameworks, along with digital tools and technological solutions, to advance water circularity. With ongoing innovation actions and EU missions, Lisbon WOLL is poised to continue its trajectory towards a water-smart future, serving as a model for urban centres globally.*"

On the 2024 Word Water Day– Water for Peace, the Lisbon WOLL was presented in the B-WaterSmart Lisbon LL Public Event (Figure 28).

Figure 28: Lisbon LL team and message for the future, taken from the World Water Day B-WaterSmart Event (22/March/2024).

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