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Evidence matrix of circular water management and Policy brief addressing barriers of wider NBS adoption for closing water loops

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Brief Description	This document provides an overview of current efforts for a circular water economy in Europe, including demonstration cases and policy initiatives. It also describes barriers to adoption of nature-based wastewater treatment for resource recoveries as experienced by practitioners, as well as strategies to overcome them. Current efforts are provided in an evidence matrix, as well as barriers and mitigation strategies are translated into a policy brief included in this document.
Keywords	Nature-based solutions, water and nutrient reuse, circular economy, drivers and barriers

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EXECUTIVE SUMMARY

Deliverable D8.5 is related to the Task 8.5 “Providing evidence-based knowledge to facilitate a broader transition to a circular economy in the EU “, and it is implemented within the activities of Work Package 8 “Marketing and Exploitation”.

Amid the rapid and widespread technical advances in the field of resource recovery from wastewater, stakeholders may lack an overview of the technological options available and proven today. This may in turn hamper replication of suitable technologies and thus mitigate their contribution to a circular water and nutrient economy in the EU. In order to provide such an overview, an “evidence matrix” was developed and enclosed in this document. It includes key data of 119 innovative demonstration cases of a wide range of water recovery technologies as well as 38 measures contributing to an enabling environment for water reuse. Demonstrated technologies span “green” and “grey” infrastructures and technologies, including biological, physicochemical and nature-based solutions (NBS), highlighting cases demonstrating innovative nature-based solutions.

The International Union for Conservation of Nature (IUCN 2016) defines NBS as *“actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits".* As such, the present report considers NBS as technologies and systems which simultaneously provide biodiverse habitats and the regenerative effect on humans. In this understanding, plants are key agents in these systems, both instrumental for the treatment process and contribute to the functioning of the local ecosystem.

Nature-based solutions (NBS) are a cost-efficient and low-energy wastewater treatment solution, enabling direct reuse of treated wastewater and contained nutrients. NBS, particularly advanced constructed wetlands, have been developed for all major wastewater generating sectors and operational conditions, namely cities and settlements, agriculture and industries. Further, NBS are multifunctional and simultaneously provide several co-benefits for ambient temperature regulation, improvement of air quality, carbon sequestration, biodiversity, production of biomass (industrial crops) and regenerative effects when used to green urban spaces. Constructed wetlands have been found to partly remove organic micropollutants (pharmaceutically active compounds), as a number of processes take place (biodegradation, adsorption, filtration) as opposed to conventional wastewater treatment plants where biological processes are mainly involved.

Despite the multiple co-benefits of nature-based solutions (NBS), which are not provided by conventional wastewater treatment and “grey infrastructures” for water and nutrient recovery, they are deployed far below their potential. In recent years, there have been significant advances in developing NBS for water and wastewater treatment as well as water and nutrient recovery from municipal, agricultural and industrial wastewater. Innovative set-ups and processes have been developed, to reduce previous technical barriers, improve treatment efficiency, reduce the space needed for treatment wetland technologies and enable their better integration into urban built environments. However, a number of institutional and social barriers are keeping available innovative and successfully demonstrated NBS from being replicated more widely.

This deliverable address demo cases, best-practices, barriers and suggested solutions with the aim to support the promotion of NBS to close water and nutrient loops in a cost-efficient and sustainable way, and to generate potential co-benefits for climate, biodiversity and human wellbeing. Besides the mentioned evidence matrix, this deliverable includes a policy brief, which describes the diverse applicability and benefits of choosing NBS as a wastewater treatment and recovery option, as well as major barriers experienced by practitioners, and possible ways to overcome them.

The host of identified barriers span:

i. Infrastructure and system lock-ins: Lack of source separation, points of wastewater generation and reuse are disconnected, existing wastewater infrastructures are usually centralized

ii. Regulatory frameworks and standards in small decentralized systems: Only reuse for agricultural irrigation is regulated through the EU Regulation (741/2020), lack of necessary cross-sectorial management models and partnerships, lack of design standards and cumbersome permit procedures

iii. Economic and financing barriers: Economic factors (yield and return of investment), many societal costs are externalised, lack of public financing support outside the R&I domain, high insurance tariffs and taxation

iv. Knowledge barriers: Lack of interdisciplinary knowledge and practice, lack of awareness and engagement

v. Social barriers: Perceived risks, resistance to new practices, perception of 'modern equals synthetic', distance from the natural world

vi. Public procurement barriers: NBS are often not considered as a potential option in the technical specifications set by municipalities, water utilities.

The policy brief includes a set of policy recommendations. Regulatory adaptations are needed to provide a framework for reuse besides agricultural irrigation. Legal technical design standards must be updated and harmonized across countries; wastewater management standards made technology-agnostic where not yet the case. Regulatory and institutional clarity are needed for distributed (decentralized) water and wastewater services. A reduction and/or simplification of bureaucratic hurdles is needed to facilitate more innovation in Europe.

These measures must be accompanied by financial incentives (tendering, subsidies, taxation) to select NBS over other water and nutrient recovery options, when building new infrastructure, or maintaining (renovating/upgrading) existing infrastructure. These can relate to co-benefits of NBS, such as carbon footprint. For these measures to achieve their intended impact, measures must be taken to raise awareness, facilitate cross-disciplinary communication and collaboration, promote local water and nutrient management models, build capacity and promote transparent and participatory planning.

Finally, further research is needed to provide reference cases in a greater diversity of operational contexts and provide comparable data across these cases to support evaluation and technology selection, planning and design. This includes information on financial aspects, optimal scales, management schemes, as well as logistics and spatial planning innovations. Policy and legal reviews in policy areas beyond water and nutrients will inform adaptation processes to integrate NBS as measures to achieve a diversity of policy goals and support the development of effective targeted communication of relevant opportunities to decision makers.

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ABBREVIATIONS

COM	Communication
CW	Constructed wetland
DWD	Drinking Water Directive
EC	European Commission
EU	European Union
K	Potassium
N	Nitrogen
NBS	Nature-based solutions
IPCC	International Panel on Climate Change
IUCN	International Union for Conservation of Nature
P	Phosphorus
TRL	Technology Readiness Level
UNEP	United Nations Environment Programme
UN WWDR	United Nations World Water Development Report
UWWTD	Urban Wastewater Treatment Directive
WFD	Water Framework Directive
WW	Wastewater
WWTP	Wastewater treatment plant

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1. INTRODUCTION

The general acceleration in resource use (Haas et al. 2015) has been accompanied by a global upward trend in fresh water abstraction and consumption in the last decades (Gerten 2018; UN-Water 2020). At the same time, European countries are experiencing increasing water scarcity and droughts (UN-WATER 2017; EEA 2017), making apparent the enormous potential of water recovery, reuse and recycling (IPCC 2018).

Many sectors, besides agriculture, are facing increasing water shortages. For example, urban economies need to innovate to adapt to water supply challenges. Due to high population density and urban growth, cities are extremely vulnerable to shocks in natural resources availability. In addition, industries, including the energy sector, extract 19% of the world's freshwater resources. Industries' global water demand is projected to increase by up to 24% by 2050 (UNEP 2020). Therefore, water challenges such as water scarcity, floods and droughts are strongly impacting the urban conglomerates, agriculture, tourist, and industrial sectors besides the consequences on the environment at large (UNEP 2020). Reclamation of water sources within the current usage of freshwater resources is of utmost urgency to preserve life on earth.

Wastewater is a largely untapped source of secondary service water and nutrients. Nutrients such as phosphorus (P) and nitrogen (N) that are present in wastewater streams are generally considered "waste" and are therefore most often removed rather than recovered during treatment (Kisser et al. 2020). Currently, only about 2% of treated wastewater is reused in Europe, but its public recognition and reuse rates are increasing (UN-Water 2020). The EU has recognized water reuse as a solution to water scarcity and recently adopted the new Regulation on minimum requirements for water reuse for agricultural irrigation (European Commission Regulation No 741/2020). A reduction of unnecessary water consumption and water losses, as well as the efficient (re)use of water also reduce energy consumption and the resulting carbon emissions (ibid). Emissions related to water are mainly caused by the high energy consumption or biochemical processes in wastewater treatment (ibid). However, water use is not considered a primary field for emission reduction (compared to e.g. agriculture and energy), it rarely appears as a central element of mitigation activities (UN-Water 2020).

Nature-based solutions (NBS) provide near zero-energy options to treat and recover service water and nutrients from wastewater. In addition, they bear manifold co-benefits of green infrastructures, in particular for adaptation to climate change (UN-Water 2020), such as biodiverse habitats, stormwater retention, or heat island abatement in cities. Although NBS have been successfully applied in the water sector for decades, such as constructed wetlands for wastewater treatment, they are not the prioritized option (Kisser et al. 2020). Current data on investment in NBS for water treatment indicates a large upward potential (UN-Water 2020). NBS have been applied to water recovery from municipal, agricultural and industrial wastewater all over the world. Yet, a range of significant barriers remain to the mainstream deployment of existing, proven NBS for water reuse, and thus for NBS to achieve their potential beneficial impact. Such barriers for implementation are institutional in nature, such as managing change, training, transdisciplinary cooperation and securing investments (Somarakis et al. 2019).

The International Union for Conservation of Nature (IUCN 2016) defines NBS as *"actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits"*. As such, the present report addresses NBS applied to wastewater treatment and reuse technologies which simultaneously provide biodiverse habitats and the regenerative effect on humans. In this understanding, plants are key agents in these systems, both instrumental for the treatment process and contribute to the functioning of the local ecosystem.

This report demonstrates the widespread innovation that is currently taking place in the spheres of wastewater reuse in cities, rural settlements, agriculture, coastal areas and industries. Key data of demonstration projects are captured in an “evidence matrix” described in chapter 2. Building on this overview of water reuse innovation in Europe, cases of NBS applications of water reuse and nutrient recovery are highlighted. Barriers and drivers of wider adoption of NBS for circular water and nutrient management are analysed. The findings are presented in a policy brief in chapter 3.

2. EVIDENCE MATRIX

2.1. Methodology

The evidence matrix (see full matrix in the Annex) consists of cases **demonstrating** water reuse and recovery of other resources in cities, rural settlements, agriculture, coastal areas and industries, using technologies with Technology Readiness Level (TRL) 6 and above to recovery resources from wastewater, including NBS and any others. The aim was to identify cases demonstrated in Europe, and if the course of the search yielded cases demonstrated outside of Europe, but transferable to Europe, these were also taken up in the matrix (7 non-European cases, all located in the Southern Mediterranean). Demonstration cases include Horizon 2020 CIRC, WATER and WASTE and other EU-funded projects (total 96 cases), but also nationally funded projects (5 cases) and private sector projects (6 cases).

European and national-level **policy and framework initiatives** for circular water economy were collected, including signed Innovation Deals (1 Innovation Deal for water reuse identified), public strategies, action plans, laws, Directives, Regulations, financing programmes, platforms, tools and frameworks, all at EU level or national level in EU member states. The collection process involved screening of online databases and reports related to circular economy, with a focus on water and wastewater, as well as reports published by the European Commission, the European Environment Agency, EUROSTAT, Cradle to Cradle, the Ellen MacArthur Foundation and Circle Economy, among others.

The cases were categorized with key attributes to provide an overview and allow for filtering and targeted searching by users. Key information was retrieved from project websites, Cordis, reports and online articles.

2.2. Guide to the evidence matrix

The evidence matrix (Appendix A) provides an extensive (though not comprehensive) compilation of latest innovations as demonstration cases of resource recovery from different wastewater flows (119 cases on the first spreadsheet, Table 5.1) as well as framework efforts promoting a more circular water economy (38 cases on the second spreadsheet (Table 5.2), total 157 cases. Total 38 cases use NBS as a treatment step.

The list of demonstration cases includes brief descriptions as well as key attributes categorized (as columns in the matrix) into:

- Project name
- Water source (wastewater and specific wastewater flows such as blackwater, greywater, combined sewer overflows and specified industrial wastewater; rainwater, sea water, brackish water)
- Recoverable resources and products
- Technologies/treatment steps demonstrated

- TRL
- NBS (yes/no)
- Scale (macro: city-wide; meso: district scale, industrial plant; micro: apartment building, household, small farm)
- Challenges addressed (e.g. water scarcity and pollution, loss of valuable resources)
- Target group defined as the user (adopter/operator) of mentioned technologies (cities, rural municipalities and settlements, wastewater treatment plants, households, hotels, farms, specific industries, coastal regions)
- Country in which the case is demonstrated
- Project duration
- Funding source
- Web link
- Contact person
- Contact email address

For other initiatives, besides brief descriptions, the key attribute categories (columns in the matrix) are:

- Initiative title
- Country/region to which it applies
- Type of initiative (e.g. strategy, regulation, funding programme)
- Year of issue, or publication, or adoption, or entry into force
- Web link

2.3 Selection of relevant case studies from the evidence matrix

This section describes six projects that offer an efficient application of NBS within the concept of circular economy. The projects selected span a wide scale with the following sequence city>district>industrial>apartment building> household> small farm.

City: WATINTECH
District: AquaNES-5
Industrial: INCOVER
Apartment building: SUPERLOCAL
Household: HOUSEFUL
Small farm: WETWINE

WATINTECH (City scale)
The WATINTECH project combines reclaimed water production from sewage with treatment of urban run-off in decentralized treatment facilities.
A combination of forward osmosis (FO) and reverse osmosis (RO) is applied to generate concentrated wastewater and reclaimed water. Concentrated wastewater is treated by anaerobic digestion and the resulting residual nutrient rich waste stream is used to meet the wetlands' nutrient needs and water demands. Wetlands are also used to treat urban run-off. Recovery of valuable resources originating from the treatment - including water, methane (heat, energy) and value-added chemicals – is carried out through the integration of various technologies generating value-added products for local reuse. One of the key objectives of the project is to improve the management of centralized wastewater infrastructure under variable weather events (such as heavy rain episodes combined with long dry periods). Proper design of decentralized infrastructure

impacts positively on the existing centralized sewage collection and treatment facilities, an aspect that is analysed in this project. Table 2.1 shows selected project's categories and their description.

Table 2.1 WATINTECH detailed description of specific categories extracted from the evidence matrix.

Project categories	Description
Project full name	Smart Decentralized WATer Management through a Dynamic Integration of TECHnologies (WATINTECH)
Water source	wastewater
Products/recoverable resource	Products/recoverable resource: water, methane, value-added chemicals
Technology	Forward Osmosis; constructed wetland; anaerobic bioreactor; MF/UF membrane
TRL	6-7
Challenges addresses	Variable weather events
Scale	Macro
Target group	Cities
Countries	Spain, Denmark, Portugal

AquaNES (District scale)

AquaNES combines natural treatment processes such as bank filtration (BF), managed aquifer recharge (MAR) and constructed wetlands (CW) with engineered pre- and post-treatment options to provide innovative wastewater treatment processes and management.

The project aims to demonstrate a combination of constructed wetlands with different technical post- or pre-treatment options (ozone or bioreactor systems) as a wastewater treatment option. The project focuses on 13 demonstration sites in Europe, India and Israel covering a representative range of regional, climatic, and hydro geological conditions. Table 2.2 shows selected project's categories and their description.

Table 2.2 AquaNES detailed description of specific categories extracted from the evidence matrix.

Project categories	Description
Project full name	Demonstrating synergies in combined natural and engineered processes for water treatment systems (AquanNES-5)
Water source	Wastewater
Products/recoverable resource	Water for reuse
Technology	Heterogeneous photo-catalysis with TiO_2 as catalyst followed by a constructed wetland, ultrafiltration Ozonation and biological post-treatment by constructed wetlands
TRL	8
Challenges addresses	Standard and emerging Pollutants removal,
Scale	Meso
Target group	Cities and municipalities (small and medium), coastal areas (island)
Countries	Greece, Germany

INCOVER (Industrial scale)

INCOVER aims at developing innovative and sustainable technologies for a resource recovery-based treatment of wastewater. Solutions developed in INCOVER allow the recovery of energy (biomethane) and bioproducts (bioplastic, organic acids, biofertilizers, biochar, and irrigation water) from municipal, industrial and agricultural wastewater, while reducing the overall operation and maintenance of wastewater treatment. Reduction of operation and maintenance cost of wastewater treatment and the energy demand are the outcome of technologies implemented in INCOVER.

INCOVER solutions include monitoring and control via optical sensing and soft-sensors approach.

In addition, strategies to facilitate the market uptake of INCOVER innovations are developed to close the gap between demonstration and end-users. At INCOVER-1 demo-site 3 horizontal photobioreactors (PBR) are operated in series, the biomass from the third PBR is treated together with secondary sewage sludge in an anaerobic digester, the sludge from the digester is treated in a wetland. Table 2.3 shows selected project's categories and their description.

Table 2.3 INCOVER detailed description of specific categories extracted from the evidence matrix.

Project categories	Description
Project full name	Innovative Eco-Technologies for Resource Recovery from Wastewater (INCOVER)
Water source	Urban wastewater, agricultural runoff
Products/recoverable resource	Biogas, water for irrigation
Technology	The INCOVER concept has been designed to move wastewater treatment from being primarily a sanitation technology towards a bio-product recovery industry and recycled water supplier. At this demo-site, 3 horizontal photobioreactors are operated in series, the biomass from the third PBR is treated together with secondary sewage sludge in an anaerobic digester, the sludge from the digester is treated in a wetland.
TRL	7-8
Challenges addresses	Loss of resources
Scale	Macro
Target group	Farmers
Countries	Spain

SUPERLOCAL (Apartment building scale)

The project contributes to a sustainable, low carbon, resource efficient economy by creating high quality and affordable housing opportunities based on innovative materials and social circular solutions. Three vacant high-rise apartment buildings in the suburban areas in the Netherlands are demolished and the harvested materials are used to construct four pilot housing units. In line with circularity principles the harvested materials will be brought back to natural resources in 24 material flows and the innovative techniques for water reuse will be implemented by testing a closed water cycle initiative for social housing.

Table 2.4 shows selected project's categories and their description.

Table 2.4 SUPERLOCAL detail description of specific categories extracted from the evidence matrix.

Project categories	Description
Project full name	Super circular estate (SUPERLOCAL)
Water source	Wastewater
Products/recoverable resource	water for reuse
Technology	Water-aware appliances, rainwater harvesting, greywater recycling, sustainable urban drainage
TRL	7-8
Challenges addresses	Water scarcity and pollution
Scale	Meso
Target group	Cities, municipalities
Countries	The Netherlands

HOUSEFUL (Household scale)
HOUSEFUL project proposes an innovative paradigm shift towards a circular economy for the housing sector, by demonstrating the feasibility of an integrated systemic service composed of 11 circular solutions. HOUSEFUL will introduce solutions to become more resource efficient throughout the lifecycle of a building, taking into account an integrated circular approach where energy, materials, waste and water aspects are considered. The project aims at recycling >90% of rainwater, greywater, and blackwater producing reclaimed water and biogas. Table 2.5 shows selected project's categories and their description.

Table 2.5 HOUSEFUL detailed description of specific categories extracted from the evidence matrix.

Project categories	Description
Project full name	Innovative circular solutions and services for new business opportunities in the EU housing sector (HOUSEFUL)
Water source	Wastewater
Products/recoverable resource	Water for irrigation, biogas
Technology	Multi-level green walls, disinfected using commercial O_3/UV systems, dry anaerobic digestion unit
TRL	6
Challenges addresses	Water scarcity and pollution
Scale	Micro
Target group	Cities, municipality
Countries	Austria (2 demo sites)

WETWINE (Small farm scale)
The project addresses the need to manage the waste generated by the wine industry during the winemaking process and to reduce its impact on the environment. The wastewater and sludge generated by the wine industry is treated via anaerobic digestion and wetland treatment and the solid fraction is reused-recycled as

fertilizer. The goal is to reduce the environmental impact of winemaking by 90% over the natural heritage. Table 2.6 shows selected project's categories and their description.

Table 2.6 WETWINE detailed description of specific categories extracted from the evidence matrix.

Project categories	Description
Project full name	Transnational cooperation project to promote the conservation and protection of the natural heritage of the wine sector in the SUDOE area (WETWINE)
Water source	Wine industry wastewater
Products/recoverable resource	Fertilizer
Technology	Anaerobic digestion, wetland
TRL	6-7
Challenges addresses	Water Pollution
Scale	Micro
Target group	Wine Industry
Countries	Spain

3. POLICY BRIEF

3.1. Summary

Many regions of Europe already struggle with water scarcity, further exacerbated by climate change and population growth. The EU is also highly dependent on imports of nitrogen, phosphorus and potassium fertilisers. In the linear system, valuable water and nutrients travel down food value chains from where they are discharged and lost via wastewater and organic solid waste. The European Union has recognized the need to tap into the great resource potential of wastewater and has adopted the new EU 'Regulation on minimum requirements for water reuse for agricultural irrigation', a measure within the framework of the new European Action Plan for Circular Economy. While water reuse was regulated only in few European countries before, the EU Water Reuse Regulation now directly creates a legal framework for all EU Member States.

Nature-based solutions (NBS) are a cost-efficient and low-energy wastewater treatment solution, enabling reuse of reclaimed water and contained nutrients. NBS, in particular advanced constructed wetlands, have been developed for all major wastewater generating sectors and operational conditions, namely cities and settlements, agriculture and industries. Further, NBS are multifunctional and simultaneously provide numerous co-benefits for ambient temperature regulation, improvement of air quality, carbon capture, biodiversity, production of biomass (industrial crops) and regenerative effects when used to green urban spaces. Constructed wetlands can also partly remove organic micropollutants (pharmaceutically active compounds).

The present policy brief is based on an extensive literature review of demonstrations of innovative NBS and drivers and barriers, as well as on total ten qualitative expert interviews providing practical knowledge on NBS for water and nutrient reuse in the urban residential context, food processing, rural communities, coastal tourism and agriculture, in Spain, Greece, Austria and Germany.

The host of identified barriers span:

i. Infrastructure and system lock-ins: Lack of source separation, points of wastewater generation and reuse are disconnected, existing centralized wastewater infrastructures are usually centralized

ii. Regulatory frameworks and standards: Only reuse for agricultural irrigation is regulated through the EU Regulation (741/2020), lack of necessary cross- sectorial management models and partnerships, lack of design standards and cumbersome permit procedures

iii. Economic and financing barriers: Economic factors (yield and return of investment), many societal costs are externalised, lack of public financing support outside the R&I domain, high insurance tariffs and taxation

iv. Knowledge barriers: Lack of interdisciplinary knowledge and practice, lack of awareness and engagement

v. Social barriers: Perceived risks, resistance to new practices, perception of 'modern equals synthetic', distance from the natural world

vi. Public procurement barriers: NBS are often not considered as a potential option in the technical specifications set by municipalities, water utilities.

Further, existing mitigation strategies and suggested measures to overcome these barriers were identified and condensed into a set of policy recommendations. Regulatory adaptations are needed to provide a framework for reuse besides agricultural irrigation. Legal technical design standards must be updated and harmonized across countries; wastewater management standards made technology-agnostic where not yet the case. Regulatory and institutional clarity are needed for distributed (decentralized) water and wastewater services. A reduction and/or simplification of bureaucratic hurdles is needed to facilitate more innovation in Europe.

These measures must be accompanied by financial incentives (tendering, subsidies, taxation) to select NBS over other water and nutrient recovery options, when building new infrastructure, or maintaining (renovating/upgrading) existing infrastructure. These can relate to co-benefits of NBS, such as carbon footprint. For these measures to achieve their intended impact, measures must be taken to raise awareness, facilitate cross-disciplinary communication and collaboration, promote local water and nutrient management models, build capacity and promote transparent and participatory planning.

Finally, further research is needed to provide reference cases in a greater diversity of operational contexts and provide comparable data across these cases to support evaluation and technology selection, planning and design. This includes information on financial aspects, optimal scales, management schemes, as well as logistics and spatial planning innovations. Policy and legal reviews in policy areas beyond water and nutrients will inform adaptation processes to integrate NBS as measures to achieve a diversity of policy goals, and support the development of effective targeted communication of relevant opportunities to decision makers.

3.2. Background

3.2.1. Current water and nutrient challenges in the linear economy

Many regions of Europe are already struggling with water scarcity. In these regions, the availability of freshwater will continue to deteriorate as climate change progresses (Gerten et al. 2018). Europe imports 29% of nitrogen, 58% of phosphorus and 75% of potassium fertilizers consumed here (Fertilizers Europe 2019), and is thus highly import dependent. While the European population produces 3.6 Mt N, 1.7 Mt P and 1.3 Mt K annually as part of human excrement, Europe simultaneously consumes 11 Mt N, 2.9 Mt P and 2.5 Mt K of manufactured fertilizers (Kisser et al. 2020). If P, N and K, are recovered, the use of synthetic fertilizers could be reduced with positive impacts on the natural environment and climate. Meanwhile, in our linear food system, water and nutrients travel through the food value chain to consumers, are discharged with wastewater, nutrients removed during wastewater treatment and treated wastewater discharged to receiving water bodies, lost to potential reuse. Freshwater with drinking water quality is used for the majority of uses even for applications with lower-grade water quality requirements such as in agricultural, although wastewater is a highly reliable and largely untapped source of secondary service water and nutrients.

3.2.2. Wastewater reuse in Europe: Current status and opportunities

Wastewater has a significant function in the efforts to adapt to climate change as well as the transition to a circular economy, as it is a powerful resource flow because of its reuse potential. In addition, the reuse of water often proves to be more cost-effective and energy efficient compared to alternative sources of water supply such as desalination or water transfer, which contribute to greenhouse gas emissions (European Commission 2015). In the EU, more than 40,000 million m^3 of wastewater are treated annually, but only 964 million m^3 of this treated wastewater are reused. This could rise to reuse more than six times the amount of treated water currently reused (European Commission n.a.).

In the EU, water and wastewater are governed by a set of Directives, such as the Water Framework Directive (WFD), the Drinking Water Directive (DWD), the Urban Wastewater Treatment Directive (UWWTD), as well as Directives on bathing water quality and, above all, Water Reuse Regulation. in 2020, the new EU 'Regulation on minimum requirements for water reuse for agricultural irrigation' entered into force, as a measure situated within the new European Action Plan for Circular Economy (European Commission COM (2020)98 final). And this within the 2020 European Green Deal. Previously to the existence of the Water Reuse Regulation, several EU countries applied national reuse legislation. Cyprus, France, Greece, Italy and Spain have already in place water quality standards for reclaimed water in national legislation (Alcalde Sanz and Gawlik 2014).

The development of an improved nutrient management plan to ensure a more sustainable recovery and use of nutrients as well as to stimulate markets for recovered nutrients is one of the objectives of the CE Action Plan (European Commission COM (2020)98 final). According to the RISE Foundation's report on Nutrient Recovery and Reuse in European agriculture (Buckwell and Nadeu 2016), this is an inevitable transition that has the potential to create examples of best practice and open up economic opportunities. As Europe is highly developed with its intensive agriculture and industry, it can take a leading role in improved nutrient management.

To realise the opportunities for water and nutrient recovery, we need technologies that can be scaled in an efficient and sustainable way. Due to climatic changes, the loss of biodiversity and the associated loss of important ecosystem functions, the awareness of sustainability in wastewater treatment has increased (Morelli 2020). NBS can help to enhance biodiversity and provide ecosystem functions. They could provide the missing link for a wide range of resources to be harvested, used, reused and recycled (Langergraber et al. 2020). Wastewater treatment plants should be designed to fit into a material cycle in which waste as such does not exist, but is instead understood as a water resource recovery facility (Robles et al. 2020).

3.2.3. Nature-based solutions can be applied in all wastewater generating sectors

Cities and settlements

NBS, specifically constructed wetlands, can be used to treat various types of wastewater generated in cities, including stormwater runoff, combined sewer overflow, municipal wastewater, industrial wastewater as well as for tertiary treatment of the treated effluent of conventional municipal wastewater treatment plants (e.g. to enhance removal of organic micropollutants). In less densely populated areas, passive wetlands with larger surface area can be installed, and in closer proximity to agricultural fields where reclaimed fertigation water will be reused. But even in city centres, treatment wetlands can be integrated into the built environment. Aerated or electric conductive vegetated biofilters, microbial fuel cell technologies, innovative structural set-ups (e.g. the multi-level (vertically stacked) wetland vertECO® (Zraunig et al. 2019)) and combination with anaerobic digestion or in-vessel composting for solids treatment reduce the space needed, which is otherwise a limiting factor in cities. Green façade panels have been developed and demonstrated for greywater treatment and production of food-safe herbs further "downstream" at the lower levels (Green INSTRUCT 2018). Green roofs and drainage systems are already a widely recognized solution for rainwater management. Further, building-integrated treatment wetland technologies could be installed in currently unutilized or underutilized urban infrastructures, such as rooftops, façades and vacant indoor spaces, and effluents reused on-site for cultivation of vegetables and herbs in field plots on rooftops, or hydroponic green walls.

Agriculture and rural areas

The use of treated wastewater in agriculture represents an alternative practice adopted in different regions of the world that are confronted with water shortages and growing urban populations. Given the decline in surface and groundwater resources caused by climate variability and climate change the use of treated wastewater in agriculture benefits human health, the environment and the economy. Agriculture, the greatest global water user, consumes 70% of available water (Pimentel et al., 2008). Hence, one of the most recognized benefits of wastewater use in agriculture is the associated decrease in pressure on freshwater sources. Furthermore, wastewater reuse increases agricultural production in regions experiencing water shortages, thus contributing to food safety. Another advantage of using treated wastewater in agriculture is ensuring a closed and environmentally favourable nutrient cycle that avoid direct return of macro-(N, P) and micro-elements to water bodies. Adoption of NBS provides opportunities to organize the nexus between agriculture–ecosystem–water to support sustainable food production and reaping the benefits of a well-functioning agro-ecosystem. NBS used in agricultural water management can regulate the movement, storage, and transformation of water, including its quality (Acreman and Mountford, 2009). NBS comprise closely related concepts such as source-to-sea initiatives, eco-hydrology (constructed wetlands), agroecology, and green and blue infrastructure development.

Constructed wetlands can be used for treatment of agro-industrial wastewater from livestock (Akratos et al. 2018a; Vidal et al. 2018) and aquaculture (Tepe and Temel 2018), and household wastewater with direct reuse for irrigation of surrounding fields. Nature-based farming techniques, such as agroforestry can enhance field water efficiency and can also be irrigated with NBS-treated wastewater.

Industries

Constructed wetlands have been used to effectively treat highly contaminated and highly variable complex industrial wastewater, such as landfill leachate (Nivala et al. 2007; Nivala et al. 2010), groundwater contaminated with hydrocarbons (Thullner et al. 2018; Wallace and Kadlec 2005), food and drink processing wastewater including processing of cheese (Wallace 2001), meat, vegetables and soft drinks (Hartl et al. 2018), wineries and breweries (Masi et al. 2018a) and olive mills (Masi et al. 2018b), as well as mine tailings (Higgins 2003; Higgins et al. 2006; Sheridan et al. 2018), residual dye wastewater (Ong et al. 2010; Masi et al. 2019) airport run-off contaminated with de-icer (Murphy et al. 2015; Troesch et al. 2018), wood, leather and textiles processing (Gomes et al. 2018; Kumar and Kumar Choudhary 2018; Akratos et al. 2018b), pharmaceuticals and cosmetics industry (Dordio and Carvalho 2018).

Constructed wetland treated industrial effluents have also been reused, e.g. recycling of carwash water (Torrens et al. 2018) and reuse of treated oilfield produced water for saline irrigation (Stefanakis et al. 2018).

3.2.4. Unique benefits of nature-based solutions for water reuse

Nature-based solutions are multifunctional and provide numerous co-benefits

Besides enabling the recovery of water and nutrients, NBS also provide a range of co-benefits. NBS can be designed and implemented in a way that they treat wastewater, while also enhancing microclimate as their evapotranspiration cools the ambient air. Thus, in cities, NBS are a key solution to mitigate urban heat islands. They can enhance air quality by binding and metabolizing pollutants, producing oxygen. They capture carbon from the atmosphere and store it as biomass. They also provide the general aesthetical and regenerative psychological effects of nature on humans. According to IUCN (2016), the aim of NBS is to ensure human well-being, achieve the sustainable development goals and enhance the resilience and capacity for renewal of ecosystems and their services. By enhancing freshwater availability and regulating local microclimates, NBS already help to overcome major challenges of climate change effects (Kabisch et al. 2016). Green façade panels, which treat greywater and enhance building insulation during hot weather have also been demonstrated. When biodiversity is considered in their design, constructed wetlands can provide highly biodiverse habitats.

Passive and low-energy technologies

Current conventional treatment of municipal wastewater is energy-intensive and contributes to carbon emissions (IPCC 2019). Electricity accounts for 25-50% of the operating costs in traditional activated sludge wastewater treatment plants (Foladori et al. 2015), 25-40% according to Panepinto et al. (2016). The most energy-consuming steps in conventional wastewater treatment plants are aeration, followed by sludge pumping and sludge dewatering (Husmann 2009; Crawford and Sandino 2010). In contrast, NBS are passive systems, can largely use gravity to convey wastewater through the treatment steps and vegetation is powered by the sun. Even the operation of aerated wetlands consumes significantly less electricity than activated sludge treatment plants of the same size (Austin and Nivala 2009).

Highly effective treatment of organic micropollutants

To tackle the challenge of emerging pollutants, wastewater treatment requires continuous innovation (Villarín et al. 2020). Zraunig et al. (2019) state that recently there has been a dramatic increase in concerns about organic micropollutants in water and the environment (such as pharmaceutically active compounds – PhACs, and endocrine disrupting chemicals - EDCs). These usually occur in low concentrations, limiting their effective removal by conventional wastewater treatment technologies (ibid), which are not designed for this task (Kisser et al. 2020). NBS can partly remove micropollutants, and in some cases more effectively than conventional wastewater treatment plants (Kaur et al. 2020; Gattringer et al. 2016). To treat all components effectively, wastewater treatment must become more integrative, e.g. by using technologies based on nature in combination with traditional technologies (Boano 2020). With a view towards reusing reclaimed water for agricultural irrigation, the removal of heavy metals, pharmaceuticals, pesticides and other industrial chemicals becomes of particular interest to avoid their entry in the food chain (Kisser et al. 2020).

Cost-efficient technologies

Constructed wetlands are a generally more cost-efficient treatment solution for wastewater treatment, especially in terms of operational costs (Somarakis et al. 2019; Stefanakis et al. 2014; Ghrabi et al. 2011; Gunes et al. 2011), which can be up to 90% lower than conventional wastewater treatment technologies (Stefanakis et al. 2014). Constructed wetlands operate much more simply and easier and almost autonomously, mostly requiring not even on-site permanent specialized staff (Stefanakis 2020).

Economic benefits also arise from their applicability for efficient water reuse. According to Pistocchi et al. (2018), variability of water reuse costs depends highly on the distance between the wastewater treatment plant and the agricultural land that is being irrigated with reclaimed water. NBS can be integrated into the built environment when reused for urban water services (e.g. urban farming, irrigation of urban green spaces, street cleaning). Passive NBS can be installed off-grid and thus applied to recover water from livestock or households and reused on-site for field irrigation or fertigation. The ability to position NBS close to the point of wastewater generation and reuse further enhances their economic performance and competitive advantage.

In addition to these factors, indirect financial benefits arise from the multiple co-benefits of NBS mentioned above (see 3.3.1) and overall regeneration of natural capital.

3.3. Barriers and drivers of NBS uptake

3.3.1. Methodology

The study by Fatone et al. (2019) and Cipolletta et al. (2021) shows that the barriers slowing progress in closing water loops in Europe are not technological issues, but rather the enabling framework and environment. The present deliverable aims to identify institutional and social barriers hindering the wider adoption of available nature-based solutions for water and nutrient recovery from wastewater, as well as mitigation strategies. "Institutions" are defined here as structures that cause regularity by supporting certain structural characteristics and behaviours. In this context, institutions not only refer directly to social behaviour, e.g. in family, university or mass media, but to the entire structure of a society. They are furthermore linked to decision-making power and governance (Hasse et al. 2008). "Social" is defined as referring to human perceptions and actions around the institutions.

The NBS cases analysed in further detail were selected from the evidence matrix (described in chapter 2). A literature review was conducted to develop a structured interview guide and to design the analysis. Qualitative primary data was collected in eight interviews conducted face-to-face and online, due to the outbreak of the Covid-19 pandemic. Two additional interviews were conducted in written form online. The interviews were conducted to gather the perspectives of project leaders or managers and people who have practical knowledge about the entire project implementation (technology installation) process. The total ten interviews include six interviews with demonstration case leaders as well as four experts in the field of nutrient and water recovery with NBS. The six cases selected for interviews include water and nutrient reuse in Spain, Greece, Austria and Germany. They represent the urban residential context, food processing, rural communities, coastal tourism and agriculture. Specifically, the cases are demonstrated within the following projects:

- HOUSEFUL (EU Horizon 2020): apartment building in Austria with around 50 inhabitants and recovery and reuse of water, nutrients and energy from municipal wastewater generated in the building;
- ROOF-WATER-FARM: residential building and restaurant in Berlin, Germany, use of on-site reclaimed water for aquaponics (integrated vegetable and fish cultivation) on rooftop and supply of the restaurant;
- demEAUmed (EU Horizon 2020): beach hotel in a coastal water-scarce region of Spain, NBS-treated greywater is reused for irrigation of green spaces and toilet flushing;
- WETWINE (EU INTERREG): the wastewater from wine production is treated with NBS and reused for irrigation, in Spain;
- GROWGREEN (EU Horizon 2020): greywater from sinks and showers at a school in Spain is treated in a green wall, which helps to regulate the ambient temperature and enhances soundproofing;
- HYDROUSA (EU Horizon 2020)

The additional four experts interviewed were:

- Günter Langergraber from the Department of Water, Atmosphere and Environment (WAU) at BOKU Vienna;

- Johannes Kisser, trained chemical engineer and technical director of alchemia-nova GmbH;
- Gianluigi Buttiglieri, researcher at ICRA (Catalan Institute for Water Research) and scientific coordinator of the European project demEAumed;
- Nicolas Bedau, landscape designer and architect, co-owner of Tinos Eco Lodge (demonstration site in the HYDROUSA project);

For the interviews that were conducted online, either jitsi.org or skype.com, both open source platforms for video calls, were used. On these platforms, the interviews were recorded and stored with the consent of the interviewed persons in order to proceed with the transcription. The interviews were transcribed using ExpressScribe. For further processing, the transcripts were processed with the MaxQDA coding software for qualitative data analysis. To begin with, the methodology of open coding was used. The transcriptions were inserted into the software and thoroughly examined. Based on the literature research and the results of a workshop held in September 2019 within the framework of the COST Action Circular City, 16 categories of barriers were formed, and 200 sections of the interview protocols were allocated to these categories. In a final step, all codes were exported via MaxQDA's Smart Publisher feature, which systematically orders all selected codes and transfers them into a Word document for further processing according to the constructed code system.

3.3.2. Infrastructure and system lock-ins

Frequently mentioned barriers refer to the existing wastewater infrastructure, confirming Kisser et al. (2020) and Somarakis et al. (2019). Existing infrastructure conditions, limit the possibilities and efficiency of designing NBS-based wastewater treatment and reuse implementations. Firstly, existing sanitation infrastructure prevents source separation of wastewater as double pipe systems are rarely installed (Kisser et al. 2020). Secondly, while NBS can offer high nutrient recovery with substantial additional benefits, the nutrients can only be reused by applying the treatment effluent as fertigation water, or by applying the full cocktail of nutrients (e.g. biogas digestate or compost). NBS are not suitable for separate recovery of water and nutrients. Nor does the use of water and nutrients in agriculture require their separation. However, if water and nutrients are to be reused in combination (fertigation water), the point of recovery must be connected to the point of reuse, which requires rethinking of how wastewater infrastructure is most commonly designed and set up today. The transport of treated effluent across large distances can significantly reduce the energy and cost efficiency that is gained by choosing NBS over another treatment option.

Further, the barrier arising from existing infrastructure is closely related to the aspect of scalability (Table 3.1). Spatial constraints limit the size of NBS and thus the amount of wastewater that can be treated by single NBS installations. Where centralized wastewater management infrastructures are in place, decentralized NBS-based recovery and reuse systems can seldomly be retrofitted in an efficient way, which limits their wider adoption. Although advances have been made in reducing surface area requirements of NBS, lack of space in cities is still an often-cited barrier (Kisser et al. 2020). More demonstrations and comparable evaluations are needed to provide standardized data for surface area required for sufficient functional performance of different technologies and operational conditions to support the planning and design process, as well as research to identify optimal scales, management schemes, logistics and spatial planning innovations to incorporate unutilised and underutilised infrastructures (ibid). Existing planning and design models for conventional wastewater infrastructure do not serve to develop decentralized management or the integration of NBS into urban built environments and contribute to the systems lock-in.

Enhanced participatory and decentralized decision-making could accelerate the adoption of NBS to close water loops. For example, at the municipal or urban level there is actually no knowledge of how the population or community prefers wastewater to be managed. Populations are rarely aware of the technological possibilities, nor are urban inhabitants responsible or involved in decision-making processes. In cities in particular, more transparency and participatory practices for engaging and educating society could drive NBS adoption considering the co-benefits of green infrastructures for the well-being of urban residents (see co-benefits above). Finally, the constructors of WWTPs are often not aware or not experienced on the development of NBS and prefer solutions which they have already developed some experience, mainly the activated sludge process.

Table 3.1 Barriers and solutions related to infrastructure and system lock-ins

Barriers	Target groups to address barriers	Sphere of action	Existing mitigation strategies	Suggested solutions/ mitigation strategies
Lack of source separation Building, sewer network and WWTP infrastructure prevents source separation of wastewater, separate recovery of water and nutrients and limits scalable NBS application.	Cities/ municipal public authorities, architects,	Municipal, building	Planning and installing double pipe systems or solid-liquid separation at the wastewater source (toilets, building WW discharge)	Direct or indirect subsidies for installing double pipe systems (black and greywater separation, or solid liquid) More demo cases and comparable evaluations to support planning and design
Points of WW generation and reuse are disconnected NBS can provide water and plant-available nutrients combined, but efficient reuse requires minimum transport, i.e. local resource loops, but point of wastewater generation in cities is far from point of reuse.	Cities, / municipal public authorities, wastewater utilities, architects, urban and regional planners, farmers	Municipal, building, agri-business or industrial facility	Ecological farming communities locally reuse CW-treated WW; Demonstration sites with public funding or high sustainability interest of building owners reuse NBS-treated WW for urban farming	Real wider integration of distributed NBS for water and nutrient recovery into regional and urban planning; More comparable evaluations and standardized data on treatment performance of different NBS in different operational settings; Research to identify optimal scales, management schemes, logistics and spatial planning innovations to incorporate unutilised and underutilised infrastructures
Existing wastewater infrastructures are usually centralized NBS are most effective in decentralized water and nutrient loops. They can be distributed, and this way widely scaled. But existing sewage infrastructure collects wastewater centrally and conveys to large-scale WWTPs.	Cities, wastewater utilities, urban and regional planners, policymakers	EU, national, regional, municipal	Sites in remote areas use NBS	Change of legislation to allow disconnection from WW grid even if sewage line is accessible to the property; Real wider integration of distributed NBS for water reclamation into regional and urban planning;
Lack of experience in NBS implementation: Local constructors and environmental companies are not experienced with NBS implementation	Environmental companies, contractors, water utilities	Regional, local	Demonstration of NBS and reuse in the real environment through projects such as HYDROUSA	NBS Is included as a potential option in the technical specification of tenders

3.3.3. Regulatory frameworks and standards

The EU and international policy framework relevant to the uptake of HYDROUSA solutions was studied in depth by Fatone et al. (2019). Since the publication of this report, the EU Regulation on minimum requirements for water reuse for agricultural irrigation (European Commission Regulation No 741/2020) entered into force. While regulations specifically governing water reuse previously existed only in few European countries (Spain, Greece, Cyprus, France, Italy and Portugal) and in some EU countries water legislation varies even between sub-national levels, these rules will provide a consistent framework that applies to all Member States. This novelty addresses an identified major barrier preventing wider water reuse in the EU (European Commission 2020). However, the Water Reuse Regulation only regulates the reuse of water for agricultural irrigation and no other reuse application (e.g. street cleaning, industrial process water, etc.), where regulatory gaps and uncertainties persist. Regulations are not always applied in a sustainable way to decentralized and small-scale systems.

Policies and legal frameworks are fundamental to a broader diffusion of NBS and should be reviewed across all policy areas (Katsou et al. 2020), in addition to water and nutrients, to understand and develop an enabling environment for a shift towards more circular and sustainable water and nutrient management. As the scope of NBS is broad and complex, there have been general difficulties in integrating them into regulations and policies (ibid). They are transdisciplinary by nature, while institutional implementation and dissemination are rather isolated (Frantzeskaki et al. 2019).

Closing water and nutrient cycles at small scales requires innovation in management models and new partnerships and cooperation mechanisms among public and private actors (Kisser et al. 2020). The lack of intra-agency cooperation, thus the integration of several sectors (e.g. water and food sector) (Somarakis et al. 2019), makes it difficult for NBS practitioners to apply them, as the poor networking affects the harmonization of national laws.

Further, there is a lack of standards for water treatment NBS, or they are not up to the state-of-the-art, and a lack of awareness of public authorities and administrative bodies, which complicate processes to obtain permits to install non-conventional treatment technologies, even for research purposes (ibid). The interviews confirmed that complexity of legal frameworks, lack of regulation of treatment technologies necessary to complement innovative NBS treatment systems (e.g. small biogas (Kisser et al. 2020)) and bureaucratic hurdles are major barriers to uptake of innovative NBS (Table 3.2). In contrast to innovative solutions, the application of established commercial solutions is significantly eased as there no uncertainties in the area of water or nutrient quality. New solutions have the image of great uncertainty, especially among authorities, which leads to a higher number of mandatory measurements and long processes to undergo. Moreover, the lack of design standards is coupled with time-limited operating licenses, slowed down or even prevented permits (e.g. building permits). This is discouraging planners and builders from constructing NBS technologies. In the Netherlands, the government enables demonstration of innovations by providing a testing space for technical development to which regular permits do not apply, through so-called Green Deals (ibid; Rijksdienst voor Ondernemend Nederland 2019). More evidence-based knowledge on the performance and benefits of enhanced (recently innovated) NBS is required to feed into EU-wide, national-level or even global NBS standards and policies (Somarakis et al. 2019).

Sub-national spheres of action bear high potential to facilitate change of policy and legal frameworks, representing the communication link between populations and other non-institutional, or non-decision-making, stakeholders, and the higher national and EU-level policymakers. This level acts as the one that could exert pressure bottom-up and apply measures top-down. This is a major responsibility for municipalities and countries, which is why decentralization is necessary.

Table 3.2 Barriers and solutions related to regulatory frameworks and standards

Barriers	Target groups to address barriers	Sphere of action	Existing mitigation strategies	Suggested solutions/ mitigation strategies
Only agricultural irrigation regulated at EU level Lack of EU guiding regulations for water reuses other than agricultural irrigation and resulting persisting uncertainties	Cities, wastewater utilities, administration of public green spaces, industrial plants	EU, municipal, industrial site/ business-level	Low-polluted process waters reused	Complimentary Regulation explicitly permitting other uses, or expansion of scope of the existing Water Reuse Regulation; Review policy and legal frameworks in policy areas beyond water & nutrients, and integration of NBS as measures to achieve diverse policy goals
Lack of necessary cross-sectorial management models and partnerships To incentivise leveraging the multi-functionality of NBS; and to facilitate the deployment and management of small-scale/ distributed water and nutrient cycles	Divisions within public administrations (cities, regions)	Municipal, regional	Efforts to communicate multifunctional benefits demonstrated by NBS projects	Facilitation and establishment of intra-agency cooperation; stronger evidence-based communication of co-benefits (especially in terms of economic gains or sustainability indicators); separate (targeted) communication of relevant benefits to decision makers
Design standards and permits Lack of (or outdated) design standards for the various NBS technologies, exclusive technical standards and highly complex, cumbersome bureaucratic procedures to obtain permits, as well as expensive monitoring requirements to maintain permits	EU and national standardization bodies, municipal and regional public authorities	EU and national governments	Recommendations for adaptations, co-creation of official standards	Update standards; Promote technology-agnostic standards; Harmonization of design standards EU-wide (or even globally) to eliminate uncertainties and facilitate technology transfer; create innovation deals (similar to the Dutch Green Deal)

3.3.4. Economic and financing barriers

Frantzeskaki et al. (2019) identified a lack of finance and investment as a major obstacle to conventionalizing NBS. Most investments in NBS have so far been either fully or partially supported by public funding (ibid). However, the effort to deal with funding opportunities is often a challenge, as all criteria for conventional wastewater management must be met - at household level or in larger plants - even if it may not make sense in every single NBS case (Kisser et al. 2020). As mentioned, NBS are suitable solutions for small and decentralized water services. However, local management models and self-supply occur only marginally, while large municipal utilities are prioritized in infrastructure planning and investment strategies (Fatone et al. 2019).

In the area of financing NBS applications, it has become apparent that overarching centralization stands in the way of strengthening local governments and administrations. This is primarily due to a lengthy bureaucratic process in which efforts to obtain funding are often treated inconsistently by its authorities. Furthermore, most EU funding opportunities are only focused on research projects, not on funding for private users. It requires a solid foundation of knowledge about the process and perseverance even in the acquisition of funding for research purposes. This is also reflected in the agricultural sector, where these obstacles make it easier for farmers to follow the conventional path familiar to them to obtain funding. Thus, the further spread of NBS is hindered from the outset (Table 3.3). However, the fact that there are few subsidies in this area also offers the potential that a completely new funding pot could be created to support and thus expand the NBS applications for resource recovery from wastewater on household or municipal level. In addition, a low-threshold access to these funds is necessary to reduce bureaucratic barriers. The public sector plays a key role in catalysing uptake through politics and financial incentives. For example, a redesign of the tax system could help to create the right market conditions for the further adoption of NBS systems, e.g. eco-taxation (Somarakis et al. 2019). Umbrella regulations such as the CAP lead to the systemic inclusion or exclusion of certain actors within the field (e.g. Via Campesina Europe 2020). The direct payments are largely bound to the size of a farm, hence directly favouring large farms. The new CAP (adopted 2020) binds 30% of direct payments to ecological measures implemented by farms, particularly as a step towards achieving the EU Biodiversity Strategy within the EU Green Deal, thus increasing the pressure for environmental and social sustainability (Via Campesina Europe 2020). This is a step into the right direction, but still favouring large farms over ecologically sustainably operating ones, therefore hindering NBS applications in small scale agriculture.

The derived products can deter costs of water, which can be significant, e.g. when water must be pumped from low groundwater tables. On the other hand, recovered products are difficult to commercialize. There is hardly a lucrative market for water and nutrients that are recovered by NBS (Langergraber et al. 2020), especially from small scales. The smaller units, process less water, but the basic costs (planning, installation, etc.) are the same. For commercialization of nutrients as fertilizer, further processing is usually required to ensure product purity (Kisser et al. 2020).

Table 3.3 Barriers and solutions related to economics and financing

Barriers	Target groups to address barriers	Sphere of action	Existing mitigation strategies	Suggested solutions/ mitigation strategies
Economic factors (yield, return of investment) NBS are cost-competitive, but for end-users the installation and operation of NBS is mostly much more expensive than connecting to the central sewage system. Meanwhile, infrastructure planners lack awareness of the savings of choosing NBS over other treatment options.	Private households, agro-businesses, municipalities, small-scale WWTPs	Municipalities, cities, industry and agribusinesses (farms)	Strengthening the evidence base through (comparative) economic evaluations	Providing basic knowledge of the yields and returns of investments (e.g. from municipalities when entering the building permission process); develop and promote local management models
Externalization of societal costs of unsustainable wastewater management practices, lack of internalisation of societal benefits (abatement of costs)	EU, national, regional, municipal policymakers	EU, national, regional, municipal levels	Advocacy for societal co-benefits, building on growing awareness of the benefits of green infrastructures	Internalisation of societal costs and benefits into agricultural and infrastructure planning, tendering, subsidies and taxation
Public funding modalities Little EU or national financing opportunities besides research projects	Private households, industries,	EU and national governments	Dependence on private investment or additional fundraising	Decentralizing EU financing conditions and increasing the money spent for sustainable technology in wastewater

	agriculture, research			treatment; Provision of national financing opportunities for NBS in wastewater treatment, esp. for nutrient- and water recovery
High insurance tariffs due to NBSs' non-commercial usage	EU, national, municipal and regional policymakers	National governments (and EU, through them)	Selection of NBS in cases where economic benefits still outweigh higher costs or out of ideology	A cost cap for insurance tariffs or subsidies for NBS technologies as sustainable and climate-friendly solutions
Higher taxation for decentralized water recovery	EU, national, municipal and regional policymakers	National governments (and EU, through them)	Selection of NBS in cases where economic benefits still outweigh higher costs or out of ideology	Adaptation of water taxation (eco-taxing) and clear regulations from the EU (within the goal of circular economy) on lower taxes and/or subsidies for decentralized recovered water and nutrients; higher taxation of primary resources than secondary resources

3.3.5. Knowledge barriers

Somarakis et al. (2019) mention capacity related barriers such as knowledge gaps, meaning a lack of skills, which hampers the selection and effective implementation of the most appropriate NBS. This is based on inadequate education and poor technical knowledge of planners, developers and construction experts (Table 3.4). Moreover, key figures who have the necessary knowledge would often be left out of the decision-making process (ibid). Knowledge barriers are continued in part due to the difficulty in communicating the financial benefits of NBS due to limited data, little research on quantified benefits and a lack of coordinated knowledge transfer (ibid). There is a lack of awareness for proven capabilities of NBS (Kisser et al. 2020). They are de-prioritized although they perform better than conventional “grey” infrastructures in tackling today’s wastewater challenges (and opportunities). Somarakis et al. (2019) highlight the benefits of promoting knowledge about NBS and its applications at the decentralized level, where infrastructure decision-makers are set.

Further, the multi-functionality of NBS bears benefits, but can also be challenging, especially for people with insufficient skills and experience to implement such technologies (Langergraber et al. 2020). Similarly, since NBS are not one of the widely used technologies, and therefore often not fast and easy to install, small NBS projects may incur higher costs. Demonstration projects of all sizes can help build trust among public authorities and implementers such as urban planners, water and wastewater companies, architects, homeowners, farmers or industries. They can also help to create political willingness to support wider implementation of NBS.

Table 3.4 Barriers and solutions related to knowledge and awareness

Barriers	Target groups to address barriers	Sphere of action	Existing mitigation strategies	Suggested solutions/ mitigation strategies
Lack of interdisciplinary knowledge and practice in planning and/or construction/ implementation of NBS technology for wastewater treatment (or water and nutrient reuse)	Private households, industries, agriculture, research	NGO's, educational institutions, Sustainability movements and organizations	Revision/Research of NBS, raising awareness and building knowledge	Creation of standards as well as establishing a custom of working interdisciplinary
Lack of awareness and engagement NBS generally lack diffusion and dissemination; Networks of interested and engaged people so far, but far from mainstream even in the water or agriculture sectors	Private households, industries, agriculture, research	Decentralized wastewater treatments facilities	Research projects and networks are disseminating NBS	More replication of NBS technology for water and nutrient recovery in the EU

3.3.6. Social barriers

The true economic value of NBS is not reflected in societal decisions and legislation (Langergraber et al. 2020). Identified social barriers behind this include little willingness among key actors to apply novel technologies, which confirms previous findings (Somarakis et al. 2019). Technical development often encounters an awareness and acceptance barrier, because the establishment of a solution always involves the existing consciousness and will of the people (ibid). Public awareness and social acceptance are strongly linked to the successful implementation and dissemination of NBS for water and nutrient recovery (Katsou et al. 2020). According to Kisser et al. (2020), there is also a lack of knowledge concerning financial investment needed and how NBS compare to conventional technologies.

The choice of wastewater management options is also connected to culture. Modernity and innovation tend to be associated with synthetic as opposed to natural solutions. The interviews clearly indicate that the collective awareness and education of society about the nature-human relationship is directly related to the widespread dissemination of NBS. Sewage is not seen as resource with positive characteristics to be recovered and reused, instead it is seen as something bad that should be eliminated (Table 3.5). Therefore, many people are not aware that solutions from nature can do the same job as commercial, conventional water and nutrient recovery systems. Since NBS is often not only about technologies based on natural processes, but explicitly uses elements from nature (Somarakis et al. 2020), it is necessary to have an awareness and understanding of nature.

Due to a lack of examples and the low awareness of NBS for nutrient and water recovery from wastewater, access to experience is limited and the rate of replication is low. NBS systems still seem to be regarded as exclusive and are far from being conventionalized. This intensifies a lack of trust and easily creates a form of disapproval of NBS. Mistrust is also based on a lack of interdisciplinarity in application and maintenance, and the resulting malfunctioning systems on the market. Thus, negative side effects such as smell, water quality or insects are feared. This worsens the reputation of NBS and therefore hinders the development of a broad acceptance of this type of wastewater treatment systems. However, there is a great potential in generating best practice examples and to furthermore disseminate the relevant knowledge to the world.

Table 3.5 Barriers and solutions related to perceptions and acceptance

Barriers	Target groups to address barriers	Sphere of action	Existing mitigation strategies	Suggested solutions/ mitigation strategies
Perceived risks Uncertainties in construction (malfunction) or unwanted side-effects (smell, insects)	Private household, agriculture, small-scale treatment facilities	All	Creation of good/best practice examples	Raising awareness, special trainings/ courses & creation of standards as well as establishing a custom of collaborating across disciplines
Resistance to new practices Set in stone procedures for wastewater treatment & bureaucratic processes; lack of confidence or willingness to invest in new technologies	Farmers, industries, private households, industries, cities, agriculture, research, municipalities	EU and national governments, incl. education institutions, cities, municipalities, farmers, industries, architects, urban and regional planners	Talking to representatives of the agricultural sector and industries;	Providing subliminal access to NBS: free further training, funding opportunities, less bureaucracy, competence support; campaigns to educate and counteract misinformation
Modern equals synthetic and "high-tech", "the more sterile, the better" are engrained in society	Private households, industries, cities, agriculture, research, municipalities	Education intuitions	Alternative education, extramural courses/trainings	Inclusion of ethics and nature-society understanding into curricula and education systems; Greater inclusion of NBS into higher education in related subjects/disciplines
Distance from the natural world Less interaction with nature (especially in urban areas), distance to the natural environment and it's skills	All	Cities	Educating and Awareness raising	Inclusion of ethics and nature-society understanding as well as more campaigning for nature (media)

3.4. Policy recommendations

To conclude, the step taken with adopting the Water Reuse Regulation has been a major recent step to drive forward the transition to a circular water economy, and NBS are already gaining attention, and significant EU financial support for innovation. Yet, many actions could further accelerate the deployment of NBS and help to realize their potential for water and nutrient recovery and reuse, as well as their potential to reduce financial and societal costs of unsustainable water and wastewater management and to contribute to climate change mitigation and adaptation, biodiversity, regenerative cities and future-fit food systems.

Major existing barriers hindering the wider adoption of NBS to close water and nutrient cycles are regulatory gaps with respect to water reuses other than agricultural irrigation, lack of awareness of available NBS technologies, lack of financial incentives, lack of available reference demonstrations (examples of installations) and distrust of innovative natural technologies. These barriers call for policy-level action to:

- Create complimentary regulations explicitly permitting other uses, or the expansion of the scope of the existing Water Reuse Regulation to include other reuses. This will create a tangible framework to refer and rely on when attempting to operationalize various reuses, but also foster awareness of the potential water reuses.

- Update technical design standards for NBS to reflect the state-of-the-art and the range of NBS available, harmonize technical design standards EU-wide (or even globally) to eliminate uncertainties and facilitate technology transfer.
- Create green public procurement criteria for wastewater treatment that will promote NBS
- Adapt existing wastewater management standards to become technology agnostic.
- Create regulatory and institutional clarity, and a conducive enabling environment for distributed, (decentralized) water and wastewater service delivery models.
- Create and/or adapt standards to integrate distributed NBS into regional and urban planning, provide fiscal incentives to water and wastewater infrastructure maintenance projects which retrofit their systems with distributed (or decentralized) NBS.
- Adapt existing legislations (at national, regional levels) to allow decentralized treatment for self-supply of reclaimed water and nutrients, and disconnection of buildings from wastewater grids even if sewage lines are accessible to the property.
- Create innovation deals (at EU, national and regional levels), similar to the Dutch Green Deal model, and other measures to create more enabling environments that ease and encourage sustainable innovation and, above all, demonstration of innovations, and contribute to positioning Europe as a frontrunner in resource recovery and NBS.
- Provide national, regional and municipal financing opportunities for NBS in wastewater treatment, especially for water and nutrient recovery and reuse.
- Promote internalization of societal costs and benefits into agricultural and infrastructure planning, tendering, subsidies and taxation; higher taxation of primary resources than secondary resources and labour.
- Introduce cost caps for insurance tariffs or subsidies for NBS as sustainable, circular and climate-friendly solutions
- Introduce eco-taxation principles to water taxation to favour more ecological treatment and reuse systems, also including lifecycles energy/ carbon dioxide footprints of treatment, recovery and reuse infrastructure to favour more efficient, decentralized recovery and reuse of water and nutrients.
- Provide direct or indirect subsidies for integrating source separation of wastewater into buildings (black and greywater separation, and/or solid-liquid separation).

For these measures to be taken, and in turn to create the intended impact, supporting measures must be taken, such as:

- Raising awareness for mechanisms by which planning of NBS is embedded in government structures;
- Facilitating and establishing intra-agency cooperation across sectors and disciplines to enable the realization of multifunctional systems and synergies, i.e. co-benefits;
- Developing and promoting local management models;
- Supporting NBS capacity, e.g. through subsidized trainings and competence support, and funding opportunities;

- Conduct campaigns to raise awareness for the applications and benefits of NBS, educate and counteract misinformation and false assumptions;
- Promote the inclusion of ethics and nature-society understanding into curricula and education systems;
- Promote greater inclusion of NBS into higher education in related subjects/disciplines;
- Promote transparency of infrastructure decisions and participatory mechanisms in planning at local and municipal levels;

To support abovementioned measures, further research, innovation and demonstration is needed to:

- Provide reference cases in a greater diversity of operational contexts;
- Conduct comparable evaluations to support planning and design;
- Provide comparable evaluations and standardized data on treatment performance of different NBS in different operational settings;
- Inform potential adopters of the expected yields and returns of investments;
- Identify optimal scales, management schemes, logistics and spatial planning innovations to incorporate unutilised and underutilised infrastructures;
- Review policy and legal frameworks in policy areas beyond water & nutrients, and integration of NBS as measures to achieve diverse policy goals;
- Back-up stronger evidence-based communication of co-benefits (especially in terms of economic gains or sustainability indicators), and to provide evidence and effective targeted (separate) communication of relevant opportunities to decision makers.

3 CONCLUSIONS

Increasing water scarcity and droughts affect many European countries making the enormous potential of water recovery and recycling an evident source of water and one of the underexplored solutions to the issue. Wastewater is a largely untapped source of secondary service water and nutrients. Nutrients such as phosphorus (P), nitrogen (N) and potassium (K) that are present in wastewater streams are generally wasted when instead they could be recovered during treatment. Currently, only about 2% of treated wastewater is reused in Europe, but public recognition of importance to reuse such resource is increasing. Recently, the EU has adopted the new Regulation on minimum requirements for water reuse for agricultural irrigation (European Commission Regulation No 741/2020). Treatment and recovery of lower quality water and nutrients from wastewater should be executed with minimal energy consumption to offset costs and environmental impact. In this respect, nature-based solutions (NBS) are near zero-energy solutions. In addition, NBS offer a manifold of co-benefits via green infrastructures, biodiverse habitats, stormwater retention, or heat island abatement in cities. A specific array of NBS has been applied to water recovery in municipal, agricultural and industrial wastewater treatment facilities all over the world. Constructed wetlands for wastewater treatment are one example of NBS that has been successfully applied in the water sector for decades. However, other NBS applied to wastewater treatment are at the early stages of development and application. In HYDROUSA we compiled an evidence matrix comprising 157 cases of demonstration cases of

resource recovery from different wastewater flows (119 cases) as well as framework efforts promoting a more circular water economy (38 cases). Within this list 38 cases use NBS as a treatment step.
The aim of the matrix is to identify cases demonstrated in Europe or transferable to Europe, if the case was implemented outside the EU. Demonstration cases include Horizon 2020 CIRC, WATER and WASTE and other EU-funded projects (total 96 cases), but also nationally funded projects (5 cases) and private sector projects (6 cases). The lack of a wider application of NBS to wastewater treatment is due to the presence of significant barriers that hinder implementation of these green technologies. Major existing barriers are regulatory gaps with respect to water reuse other than agricultural irrigation, lack of awareness of available NBS technologies, lack of financial incentives, lack of available reference demonstrations (examples of installations) and distrust of innovative natural technologies. Most of these barriers are institutional in nature, such as managing change, training, transdisciplinary cooperation and securing investments. Many actions could further accelerate the deployment of NBS and help to realize their potential for water and nutrient recovery and reuse, as well as their potential to reduce financial and societal costs of unsustainable water and wastewater management and to contribute to climate change mitigation and adaptation, biodiversity, regenerative cities and future-fit food systems.

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5. APPENDIX A

Table 5.1 Compilation of latest innovations as demonstration cases of resource recovery from different wastewater flows.

Project/Initiative Acronym-Case N°	Project full name	Water source	products/ recoverable resource	Short Description	Technology	TRL	NBS	scale	challenges addressed	target group	countries	duration	funding	link	contact	email
AFTERLIFE	Advanced Filtration TEchnologies for the Recovery and Later conversIon of relevant Fractions from wastEwater	wastewater	PHA	The project aims to develop the filtration system for recovering suspended and soluble solids in wastewater by using membrane filtration units; develop the process for recovering and purifying valuable compounds in the extracted concentrates; develop an anaerobic/aerobic process for converting the low value-organic matter into PHAs; optimize the resources in the process, following a circular economy approach.	Filtration (MF+UF+NF/RO)	5	no	meso	loss of resources	food processing plants	Italy, Belgium, Spain, Croatia, Germany, Finland, Portugal	2017-2021	H2020	https://afterlife-project.eu/	Dr. Maria López - Biotechnology Applications IDENER	n.a.
AquanNES-1	Demonstrating synergies in combined natural and engineered processes for water treatment systems	groundwater	drinking water	AquaNES will catalyse innovations in water and wastewater treatment processes and management through improved combinations of natural and engineered components. There are five sites to demonstrate the benefits of post-treatment options after bank filtration for the production of safe drinking water.	combination of nanofiltration of bank filtrate for drinking water production	7	no	meso	production of safe drinking water	cities; municipalities	Germany	2016-2019	H2020	http://www.aquanes.eu/Default.aspx?t=581	Jeannette Jährig - Kompetenzzentrum Wasser Berlin	jeannette.jaehrig@kompetenz-wasser.de
AquanNES-2	Demonstrating synergies in combined natural and engineered processes for water treatment systems	groundwater	drinking water	AquaNES will catalyse innovations in water and wastewater treatment processes and management through improved combinations of natural and engineered components. There are five sites to demonstrate the benefits of post-treatment options after bank filtration for the production of safe drinking water.	membrane pilot plant treating 5-20 m^3/h, it applies ultrafiltration as post-treatment for bank filtrate	8	no	meso	production of safe drinking water	cities; municipalities	Germany	2016-2019	H2020	http://www.aquanes.eu/Default.aspx?t=581	Rüdoger Opitz - Drewag Netz GmbH	n.a.

AquanNES-3	Demonstrating synergies in combined natural and engineered processes for water treatment systems	groundwater	drinking water	AquaNES will catalyse innovations in water and wastewater treatment processes and management through improved combinations of natural and engineered components. The Budapest demo-site benefits from the full-scale Water Works facilities which treat bank filtrate to drinking water using disinfection: UV, Cl_2, NaOCl additional experimental work to assess the feasibility and potential advantages membrane processes will be performed in pilot-scale NUBPS facilities.	Ozonation, Rapid sand filtration, GAC	7	no	meso	production of safe drinking water	cities; municipalities	Hungary	2016-2019	H2020	http://www.aquanes.eu/Default.aspx?t=581	Gabór Till - Budapest Water Works	n.a.
AquanNES-4	Demonstrating synergies in combined natural and engineered processes for water treatment systems	river water	drinking water	AquaNES will catalyse innovations in water and wastewater treatment processes and management through improved combinations of natural and engineered components. There are five sites to demonstrate the benefits of post-treatment options after bank filtration for the production of safe drinking water.	Cascade aeration, rapid filtration, ozonation, activated carbon filtration, disinfection with ClO_2 and NaOCl	7	no	meso	production of safe drinking water	cities; municipalities	Poland	2016-2019	H2020	http://www.aquanes.eu/Default.aspx?t=581	Krzysztof Dragon - Adam Mickiewicz University in Poznan	n.a.
AquanNES-5	Demonstrating synergies in combined natural and engineered processes for water treatment systems	wastewater	water for reuse	AquaNES will catalyse innovations in water and wastewater treatment processes and management through improved combinations of natural and engineered components. Four sites will demonstrate the combination of constructed wetlands with different technical post- or pre-treatment options.	Heterogeneous photo-catalysis with TiO_2 as catalyst followed by a constructed wetland, ultrafiltration	8	yes	meso	pollutant removal	cities; municipalities	Greece	2016-2019	H2020	http://www.aquanes.eu/Default.aspx?t=581	Patricia Stathatou - NTUA	n.a.
AquanNES-6	Demonstrating synergies in combined natural and engineered processes for water treatment systems	wastewater	water for reuse	AquaNES will catalyse innovations in water and wastewater treatment processes and management through improved combinations of natural and engineered components. Four sites will demonstrate the combination of constructed wetlands with different technical post- or pre-treatment options.	Engineered pre-treatment (primary screening and sedimentation), constructed wetland, chlorine disinfection	8	yes	meso	pollutant removal	cities; municipalities	Greece	2016-2019	H2020	http://www.aquanes.eu/Default.aspx?t=581	Patricia Stathatou - NTUA	n.a.

AquanNES-7	Demonstrating synergies in combined natural and engineered processes for water treatment systems	wastewater, sewer overflow	water for reuse	AquaNES will catalyse innovations in water and wastewater treatment processes and management through improved combinations of natural and engineered components. Four sites will demonstrate the combination of constructed wetlands with different technical post- or pre-treatment options.	Retention soil filters, sorbents (activated carbon)	7	yes	micro	pollutant removal	cities; municipalities	Germany	2016-2019	H2020	http://www.aquanes.eu/Default.aspx?t=581	Katharina Knorz - Erftverband	n.a.
AquanNES-9	Demonstrating synergies in combined natural and engineered processes for water treatment systems	wastewater	water for reuse	AquaNES will catalyse innovations in water and wastewater treatment processes and management through improved combinations of natural and engineered components. Four sites will demonstrate the combination of constructed wetlands with different technical post- or pre-treatment options.	Reactive media reed bed, immobilised algae bioreactor	7	yes	meso	pollutant removal	cities; municipalities	United Kingdom	2016-2019	H2020	http://www.aquanes.eu/Default.aspx?t=581	Marc Pidou - Cranfield University	n.a.
DEEP PURPLE-1	Conversion of diluted mixed urban bio-wastes into sustainable materials and products in flexible purple photo-biorefineries	wastewater	PHA, nutrients	End-users from four municipalities will create a consortium to transform diluted urban bio-waste into sustainable bio-products including cosmetics, fertilisers, packaging and self-repairing construction materials. The DEEP PURPLE project will set up and implement at a single site the first Purple Phototropic Bacteria biorefinery in the EU. This production chain will have a processing capacity of 422 t/y of organic fraction municipal solid waste.	Anaerobic photobioreactor for the production of enriched PPB biomass as feedstock for extraction and purification of PHAs; commercial filter solution for cellulose separation from wastewater and sewage sludge	7	no	meso	loss of resources	cities; municipalities	Spain	2019-2023	H2020	https://deep-purple.eu/	n.a.	info@deep-purple.eu
DEEP PURPLE-2	Conversion of diluted mixed urban bio-wastes into sustainable materials and products in flexible purple photo-biorefineries	wastewater	bio-products	End-users from four municipalities will create a consortium to transform diluted urban bio-waste into sustainable bio-products including cosmetics, fertilisers, packaging and self-repairing construction materials. The DEEP PURPLE project will set up and implement at a single site the first Purple Phototropic Bacteria biorefinery in the EU. This production chain will have a processing capacity of 422 t/y of organic fraction municipal solid waste.	n.a.	7	no	meso	loss of resources	cities; municipalities	The Czech Republic	2019-2023	H2020	https://deep-purple.eu/	n.a.	info@deep-purple.eu

EggPlant	A feasibility study, to investigate and verify the commercial and industrial viability of a wastewater processing solution to generate bioplastics from agri-food and municipal wastewater sources	wastewater	bioplastics	The primary value of Eggplant is the reduction of waste from agri-food industrial wastewater from twofold to zero – filtration removes the majority of pollutants and fermentation removes organic contaminants. The resulting concentrate is then processed into PHA and PHB bioplastics. Moreover, an Eggplant, through the use of concentrated substrate can generate 3-4 times as much bioplastic from an equivalent volume of wastewater.	Two-phase water treatment procedure and three-stage post-filtration process	7	no	micro	high costs of bioplastics, reliance on petrochemicals	industries	Italy	2016	H2020	http://www.eggplant.it/what	Eggplant societa a responsabilita limitata	n.a.
GreenInstruct	Green Integrated Structural Elements for Retrofitting and New Construction of Buildings	greywater	water for reuse	The Green INSTRUCT project will develop a prefabricated modular structural building block that consists of over 70% of construction and demolition waste. The prototype will provide acoustic and thermal insulation and it will contribute to on site grey and stormwater management, through the integration of a vertical Green Wall technology, providing additional functionalities.	Green walls for greywater treatment	7	yes	micro	heavy rain events, urban heat island effect	cities; municipalities	Austria	2016-2020	H2020	https://www.greeninstruct.eu/	Ines Kantauer - alchemia-nova	ines.kantauer@alchemia-nova.net
GROW GREEN-1	Green Cities for Climate and Water Resilience, Sustainable Economic Growth, Healthy Citizens and Environment	rainwater	n.a.	GrowGreen works with Manchester, Valencia and Wroclaw to develop demonstration projects for nature-based solutions. Manchester will use green infrastructure to address flood risk in a neighbourhood near the city centre.	Variety of NBS: parks, green streets, trees, rain gardens, community food growing, green roofs, attenuation ponds and drainage channels.	8	yes	macro	heavy rain events	cities; municipalities	United Kingdom	2017-2022	H2020	http://growgreenproject.eu/city-actions/manchester/	Michelle Oddy - Manchester City Council	n.a.
GROW GREEN-2	Green Cities for Climate and Water Resilience, Sustainable Economic Growth, Healthy Citizens and Environment	rainwater	n.a.	GrowGreen works with Manchester, Valencia and Wroclaw to develop demonstration projects for nature-based solutions. Wroclaw is affected by both heat and water risks. The pocket parks, green walls and green streets envisioned as part of the project will be co-designed with local residents.	Pocket parks, green walls, green street	8	yes	macro	urban heat islands	cities; municipalities	Poland	2017-2022	H2020	http://growgreenproject.eu/city-actions/wroclaw/	Michelle Oddy - Manchester City Council	n.a.

GROW GREEN-3	Green Cities for Climate and Water Resilience, Sustainable Economic Growth, Healthy Citizens and Environment	greywater	n.a.	GrowGreen works with Manchester, Valencia and Wroclaw to develop demonstration projects for nature-based solutions. In Valencia the project aims to reduce heat stress and improve connectivity between green spaces in the city, the coast and the nearby rural landscapes As part of the project, traditional urban gardens will be rehabilitated to create opportunities for sustainable urban agriculture, including production of local vegetables and fruit irrigated with recycled grey water.	vertical gardens, greywater filtering, green roofs	8	yes	macro	urban heat islands	cities; municipalities	Spain	2017-2022	H2020	http://growgreenproject.eu/city-actions/valencia/	Michelle Oddy - Manchester City Council	n.a.
GROW GREEN-4	Green Cities for Climate and Water Resilience, Sustainable Economic Growth, Healthy Citizens and Environment	stormwater	n.a.	As part of GrowGreen, Brest Metropole is assessing climate change challenges in the territory to develop a strategy for using nature-based solutions to tackle them. It will also explore new options for financing nature-based solutions and their maintenance.	n.a.	7	yes	macro	heavy rain events	cities; municipalities	France	2017-2022	H2020	http://growgreenproject.eu/city-actions/brest/	Michelle Oddy - Manchester City Council	n.a.
GROW GREEN-4	Green Cities for Climate and Water Resilience, Sustainable Economic Growth, Healthy Citizens and Environment	rainwater	n.a.	Modena is testing nature-based solutions to reduce flood peaks and improve the quality of the canal waters from the urbanised eastern part of the city. The grassy canal and swales will help to remove pollutants and increase water infiltration. On the basis of extensive hydrological modelling and assessments of climate change, as well as experiences from the pilot project, a new strategic approach for nature-based solutions in Modena's particular context will be developed.	n.a.	8	yes	macro	heavy rain events	cities; municipalities	Italy	2017-2022	H2020	http://growgreenproject.eu/city-actions/modena/	Michelle Oddy - Manchester City Council	n.a.
H2AD	Innovative and scalable biotechnology using microbial fuel cell and anaerobic digestion for the treatment of micro-scale industrial and agriculture effluents to recover energy from waste	wastewater	energy	Micro H2AD's modular system uses a semi-continuous flow process. This means material stops in the tank for no longer than 72 hours & low temperature needed is treat waste & convert organic compounds into methane ten times faster than conventional AD processes.	fast anaerobic digestion	7	no	micro	loss of resources	industries	The United Kingdom	2015-2017	H2020	http://h2ad.org.uk/	Martin Rigley	info@h2ad.org.uk

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HYDROUSA-1	Demonstration of water loops with innovative regenerative business models for the Mediterranean region	wastewater	fertiliser, methane water for irrigation/ fertigation	HYDROUSA will provide innovative, regenerative and circular solutions for (1) nature-based water management of Mediterranean coastal areas, closing water loops; (2) nutrient management, boosting the agricultural and energy profile; and (3) local economies, based on circular value chains. At Lesvos HYDRO1 demonstrates a completely circular solution where water, nutrients and the produced sludge are going to be reused	Upflow anaerobic sludge and two-stage vertical flow constructed wetlands (full-scale), electroactive and aerated wetlands (pilot), in-vessel composting system (full scale), UV disinfection 9full scale)	6-7	yes	meso	water scarcity and pollution	Municipalities; water utilites	Greece	2018-2022	H2020	https://www.hydrousa.org/hydro1/	Prof. Simos Malamis - National Technical University of Athens	info@hydrousa.org
HYDROUSA-2	Demonstration of water loops with innovative regenerative business models for the Mediterranean region	Reclaimed water rich in nutrients	fruits, timber, essential oils	HYDROUSA will provide innovative, regenerative and circular solutions for (1) nature-based water management of Mediterranean coastal areas, closing water loops; (2) nutrient management, boosting the agricultural and energy profile; and (3) local economies, based on circular value chains. At Lesvos HYDRO2 is a agroforestry system that will be fertigated using reclaimed water from HYDRO1	Agroforestry system fertigated with reclaimed water	6-7	yes	meso	loss of resources	Farmers; farmer associations; municiapilities	Greece	2018-2022	H2020	https://www.hydrousa.org/hydro1/	Prof. Simos Malamis - National Technical University of Athens	info@hydrousa.org
HYDROUSA-3	Demonstration of water loops with innovative regenerative business models for the Mediterranean region	rainwater	water for irrigation, herbs, essential oils	HYDROUSA will provide innovative, regenerative and circular solutions for (1) nature-based water management of Mediterranean coastal areas, closing water loops; (2) nutrient management, boosting the agricultural and energy profile; and (3) local economies, based on circular value chains. At Mykonos (HYDRO3) a rainwater harvesting system will be implemented. Harvested water will be used to water 0.4 ha of oregano	Sub-surface rainwater collection and storage system	6-7	no	meso	water scarcity	Farmers	Greece	2018-2022	H2020	https://www.hydrousa.org/hydro1/	Prof. Simos Malamis - National Technical University of Athens	info@hydrousa.org

HYDROUSA-4	Demonstration of water loops with innovative regenerative business models for the Mediterranean region	rainwater, stormwater, groundwater, surface runoff	water for irrigation, potable water, herbs, essential oils	HYDROUSA will provide innovative, regenerative and circular solutions for (1) nature-based water management of Mediterranean coastal areas, closing water loops; (2) nutrient management, boosting the agricultural and energy profile; and (3) local economies, based on circular value chains. At Mykonos HYDRO4 will upgrade an existing rainwater harvesting system to reclaim water to be stored into the aquifer for multiple uses. The water will be used to cultivate lavender, used for domestic non-potable consumption; A bioswale will be developed to recover surface runoff; A slow sand filter will be developed to produce higher quality water	Slow sand filtration, recharge water into aquifer, bioswale.	6-7	no	micro	seawater intrusion, water scarcity	Municipalities; domestic houses, farmers	Greece	2018-2022	H2020	https://www.hydrousa.org/hydro1/	Prof. Simos Malamis - National Technical University of Athens	info@hydrousa.org
HYDROUSA-5	Demonstration of water loops with innovative regenerative business models for the Mediterranean region	seawater	water for irrigation, salt, tropical fruits	HYDROUSA will provide innovative, regenerative and circular solutions for (1) nature-based water management of Mediterranean coastal areas, closing water loops; (2) nutrient management, boosting the agricultural and energy profile; and (3) local economies, based on circular value chains. At Tinos HYDRO5 is a nature-inspired desalination system based on the principles of evaporation and condensation to produce high quality water from seawater	Evaporation and condensation in a Mangrove system.	6-7	yes	micro	water scarcity; Lack of drinking water quality	Municipalities	Greece	2018-2022	H2020	https://www.hydrousa.org/hydro1/	Prof. Simos Malamis - National Technical University of Athens	info@hydrousa.org
HYDROUSA-6	Demonstration of water loops with innovative regenerative business models for the Mediterranean region	rainwater, grey water, vapour water	water for irrigation, fruits, vegetables, herbs, fertiliser, solar energy	HYDROUSA will provide innovative, regenerative and circular solutions for (1) nature-based water management of Mediterranean coastal areas, closing water loops; (2) nutrient management, boosting the agricultural and energy profile; and (3) local economies, based on circular value chains. In HYDRO6 water loops are integrated within a remote eco-tourist facility, which will be self-sufficient in terms of water, energy and food production.	Drinking water from vapour water using a dehumidifier; wastewater treatment by reedbeds; rainwater harvesting using cisterns; PV-driven energy production and storage.	6-7	yes	meso	water scarcity and pollution	Tourist businesses, rural settlements	Greece	2018-2022	H2020	https://www.hydrousa.org/hydro1/	Prof. Simos Malamis - National Technical University of Athens	info@hydrousa.org

HOOP	Hub of circular cities bOOsting Platform to foster investements for the valorisation of urban biowaste and wastewater	wastewater	bio-based products	The project will offer Project Development Assistance (PDA) to a group of 8 lighthouse cities and city clusters - to build the technical, economic, financial and legal expertise needed to develop concrete investments to valorise OFMSW (Organic Fraction of Municipal Solid Waste) or UWWS (Urban Wastewater Sludge) with the aim of obtaining safe and sustainable bio-based products.	n.a.	n.a.	no	macro	loss of resources	cities	The Netherlands; Italy; Norway; Greece; Finland; Germany; Spain; Portugal	2020-2024	H2020	https://cordis.europa.eu/project/id/101000836	Asociacion empresarial centro tecnologico de la energia y del medio ambiente de la region de murcia	n.a.
HOUSEFUL-1	Innovative circular solutions and services for new business opportunities in the EU housing sector	wastewater	water for irrigation, biogas	HOUSEFUL project proposes an innovative paradigm shift towards a circular economy for the housing sector by demonstrating the feasibility of an integrated systemic service composed of 11 circular solutions. HOUSEFUL will introduce solutions to become more resource efficient throughout the lifecycle of a building, taking into account an integrated circular approach where energy, materials, waste and water aspects are considered.	Multi-level green walls, disinfected using commercial O_3/UV systems, dry anaerobic digestion unit	6	yes	micro	water scarcity and pollution	cities; municipalities	Spain	2018-2022	H2020	https://houseful.eu/de/demos/	Dr. Sergio Martinez Lozano - Leitat Technological Center	coordinator@houseful.eu
HOUSEFUL-2	Innovative circular solutions and services for new business opportunities in the EU housing sector	wastewater	water for irrigation, biogas	HOUSEFUL project proposes an innovative paradigm shift towards a circular economy for the housing sector by demonstrating the feasibility of an integrated systemic service composed of 11 circular solutions. HOUSEFUL will introduce solutions to become more resource efficient throughout the lifecycle of a building, taking into account an integrated circular approach where energy, materials, waste and water aspects are considered.	Multi-level green walls, disinfected using commercial O_3/UV systems, dry anaerobic digestion unit	6	yes	micro	water scarcity and pollution	cities; municipalities	Austria	2018-2022	H2020	https://houseful.eu/de/demos/	Tamara Vobruba - alchemia-nova	tamara.vobruba@alchemia-nova.net
INCOVER-1	Innovative Eco-Technologies for Resource Recovery from Wastewater	urban wastewater, agricultural runoff	biogas, water for irrigation	The INCOVER concept has been designed to move wastewater treatment from being primarily a sanitation technology towards a bio-product recovery industry and recycled water supplier. At this demo-site 3 horizontal photobioreactors are operated in series, the biomass from the third PBR is treated together with secondary sewage sludge in an anaerobic digester, the sludge from the digester is treated in a wetland.	Photobioreactors, anaerobic digestion, nutrients recovery columns based in sol-gel coating and then disinfected by a solar-driven system based on ultrafiltration, sludge treatment wetland.	7-8	yes	micro	loss of resources	farmers	Spain	2016-2019	H2020	https://incover-project.eu/case-study/case-study-1	n.a.incover-contact@oieau.fr	incover-contact@oieau.fr

INCOVER-2	Innovative Eco-Technologies for Resource Recovery from Wastewater	municipal wastewater	biomethane, PHAs, water for reuse	The INCOVER concept has been designed to move wastewater treatment from being primarily a sanitation technology towards a bio-product recovery industry and recycled water supplier. At this demo-site a two-stage anaerobic-photosynthetic high rate algae pond for PHA-production is installed. After PHA-production the remaining biomass is transformed into biogas. Agro waste and sewage-sludge are used as co-substrate.	Two stage anaerobic-photosynthetic HRAP system, thermal pre-treatment and an anaerobic co-digestion process, evaporative system by planted filter, a grit and grease removal, solar anodic oxidation disinfection.	7-8	yes	micro	loss of resources	farmers	Spain	2016-2019	H2020	https://incover-project.eu/case-study/case-study-2	n.a.incover-contact@oieau.fr	incover-contact@oieau.fr
INCOVER-3	Innovative Eco-Technologies for Resource Recovery from Wastewater	greywater	biogas, organic acids	The INCOVER concept has been designed to move wastewater treatment from being primarily a sanitation technology towards a bio-product recovery industry and recycled water supplier. In this case study biomass waste is treated in a three-step process	Citric acid production with Yarrowia Lipolitica (C) UFZ (co-digestion with industrial C-rich substrate), hydrothermal carbonization (HTC)	7-8	no	micro	loss of resources	farmers	Spain	2016-2019	H2020	https://incover-project.eu/case-study/case-study-3	n.a.incover-contact@oieau.fr	incover-contact@oieau.fr
INNOQUA-1	Innovative Ecological on-site Sanitation System for Water and Resource Savings	farm wastewater	water for reuse	INNOQUA is promoting sustainable water sanitation technologies capable of performing a whole water treatment cycle. The technologies are based on the purification capacity of earthworms, zooplankton and microalgae.	Lumbrifilter, primary settlement tanks	6-7	no	micro	management of wastewater at dairy farms	farming industry	Ireland	2016-2020	H2020	https://innoqua-project.eu/ireland-craughwell/	Louise Hannon - NUI Galway	louise.hannon@nuigalway.ie
INNOQUA-2	Innovative Ecological on-site Sanitation System for Water and Resource Savings	wastewater	water for reuse	INNOQUA is promoting sustainable water sanitation technologies capable of performing a whole water treatment cycle. The technologies are based on the purification capacity of earthworms, zooplankton and microalgae.	Septic tank, lumbrifilter, daphniafilter, retention tank, UV purification.	6-7	no	meso	pollutant removal	rural municipalities	Ireland	2016-2020	H2020	https://innoqua-project.eu/ireland-tuam/	Eoghan Clifford - NUI Galway	eoghan.clifford@nuigalway.ie
INNOQUA-3	Innovative Ecological on-site Sanitation System for Water and Resource Savings	wastewater	water for reuse	INNOQUA is promoting sustainable water sanitation technologies capable of performing a whole water treatment cycle. The technologies are based on the purification capacity of earthworms, zooplankton and microalgae.	Lumbrifilter, daphniafilter installed outside on a concrete platform.	6-7	no	micro	pollutant removal	rural municipalities	France	2016-2020	H2020	https://innoqua-project.eu/france-anglet/	n.a.	info@innoqua-project.eu
INNOQUA-4	Innovative Ecological on-site Sanitation System for Water and Resource Savings	wastewater	water for reuse	INNOQUA is promoting sustainable water sanitation technologies capable of performing a whole water treatment cycle. The technologies are based on the purification capacity of earthworms, zooplankton and microalgae.	Lumbrifilter installed on the outflow of a septic tank. The system is completed by a UV lamp.	7	no	micro	missing connection to sewer network	rural settlements	Italy	2016-2020	H2020	https://innoqua-project.eu/italy/	Pietro de Cinque	pietro.decinque@de5.it

iMETland-1	A new generation of Microbial Electrochemical Wetland for effective decentralized wastewater treatment	wastewater	water for reuse	iMETl and project aims at unleashing the small community economies potential through innovative wastewater treatments technologies, creating a virtuous circle connecting water, energy, ICT , land resources and safeguarding the environment.	Pre-treatment, Imhoff tank, pumping station, iMETland filtering media (electrically conductive biofilter), disinfection camera, electro-disinfection.	6-7	yes	meso	water pollution	municipalities	Spain	2015-2018	H2020	http://imetland.eu/project/	Abraham Esteve-Núnez - IMDEA Water	imetland@imdea.org
iMETland-2	A new generation of Microbial Electrochemical Wetland for effective decentralized wastewater treatment	wastewater	water for reuse	iMETland project aims at unleashing the small community economies potential through innovative wastewater treatments technologies, creating a virtuous circle connecting water, energy, ICT, land resources and safeguarding the environment.	Primary settling tank, iMETland unit (electrically conductive biofilter).	6-7	yes	meso	water pollution	municipalities	Denmark	2015-2018	H2020	http://imetland.eu/project/	Abraham Esteve-Núnez - IMDEA Water	imetland@imdea.org
MADFORWATER-1	DevelopMent AnD application of integrated technological and management solutions FOR wasteWATER treatment and efficient reuse in agriculture tailored to the needs of Mediterranean African Countries	wastewater	water for irrigation	The project is focused on solutions on wastewater treatment and efficient reuse in agriculture in North Africa. The developed technologies will be adapted to the social and technical context of the countries involved and will be able to produce irrigation-quality water from municipal and industrial wastewaters, as well as from drainage canals.	Nitrifying trickling filters with innovative high specific-surface carriers.	6	no	meso	water scarcity	farmers	Egypt, Marocco, Tunesia	2016-2020	H2020	https://www.madforwater.eu/	Dr. Dario Frascari - University of Bologna	dario.frascari@unibo.it
MADFORWATER-2	DevelopMent AnD application of integrated technological and management solutions FOR wasteWATER treatment and efficient reuse in agriculture tailored to the needs of Mediterranean African Countries	municipal wastewater with heavy metals	water for irrigation	The project is focused on solutions on wastewater treatment and efficient reuse in agriculture in North Africa. The developed technologies will be adapted to the social and technical contest of the countries involved and will be able to produce irrigation-quality water from municipal and industrial wastewaters, as well as from drainage canals.	Horizontal subsurface flow CW mesocosms made from stainless steel, filled with gravel and planted with *Juncus acutus*.	6	yes	meso	water scarcity	municipalities, rural settlements	Egypt, Marocco, Tunesia	2016-2020	H2020	https://www.madforwater.eu/	Dr. Dario Frascari - University of Bologna	dario.frascari@unibo.it

MADFORWATER-3	DevelopMent AnD application of integrated technological and management solutions FOR wasteWATER treatment and efficient reuse in agriculture tailored to the needs of Mediterranean African Countries	olive mill wastewater	water for irrigation	The project is focused on solutions on wastewater treatment and efficient reuse in agriculture in North Africa. The developed technologies will be adapted to the social and technical context of the countries involved and will be able to produce irrigation-quality water from municipal and industrial wastewaters, as well as from drainage canals.	1) Suspended solids removal by microfiltration, polyphenol recovery from filtrate by adsorption and final BOD removal by bio-methanation 2) aerobic biological treatment in sequenced batch reactor with lime addition.	6	no	meso	water scarcity	olive mills	Egypt, Marocco, Tunesia	2016-2020	H2020	https://www.madforwater.eu/	Dr. Dario Frascari - University of Bologna	dario.frascari@unibo.it
MADFORWATER-4	DevelopMent AnD application of integrated technological and management solutions FOR wasteWATER treatment and efficient reuse in agriculture tailored to the needs of Mediterranean African Countries	textile industry wastewater	water for irrigation	The project is focused on solutions on wastewater treatment and efficient reuse in agriculture in North Africa. The developed technologies will be adapted to the social and technical context of the countries involved and will be able to produce irrigation-quality water from municipal and industrial wastewaters, as well as from drainage canals.	Moving bed biological reactor, dyes enzymatic degradation in packed bed reactors with immobilized laccases, dyes adsorption/desorption with innovative magnetic resins.	6	no	meso	water scarcity	textile industry	Egypt, Marocco, Tunesia	2016-2020	H2020	https://www.madforwater.eu/	Dr. Dario Frascari - University of Bologna	dario.frascari@unibo.it
MADFORWATER-5	DevelopMent AnD application of integrated technological and management solutions FOR wasteWATER treatment and efficient reuse in agriculture tailored to the needs of Mediterranean African Countries	fruit and vegetable packaging wastewater	water for irrigation	The project is focused on solutions on wastewater treatment and efficient reuse in agriculture in North Africa. The developed technologies will be adapted to the social and technical context of the countries involved and will be able to produce irrigation-quality water from municipal and industrial wastewaters, as well as from drainage canals.	Aerobic moving bed reactor, integrated flotation & flocculation, UV-oxidation with TIO_2-coated beds.	6	no	meso	water scarcity	fruit and vegetable packaging industry	Egypt, Marocco, Tunesia	2016-2020	H2020	https://www.madforwater.eu/	Dr. Dario Frascari - University of Bologna	dario.frascari@unibo.it

MADFORWATER-6	DevelopMent AnD application of integrated technological and management solutions FOR wasteWATER treatment and efficient reuse in agriculture tailored to the needs of Mediterranean African Countries	drainage canal water	water for irrigation	The project is focused on solutions on wastewater treatment and efficient reuse in agriculture in North Africa. The developed technologies will be adapted to the social and technical contest of the countries involved and will be able to produce irrigation-quality water from municipal and industrial wastewaters, as well as from drainage canals.	Facultative, canalised lagoon.	6	no	meso	water scarcity	rural settlements	Egypt	2016-2020	H2020	https://www.madforwater.eu/	Dr. Dario Frascari - University of Bologna	dario.frascari@unibo.it
NextGen-1	Towards a next generation of water systems and services for the circular economy	wastewater	water for irrigation	NextGen will demonstrate innovative technological, business and governance solutions for water in the circular economy in ten high-profile, large-scale, demonstration cases across Europe, and we will develop the necessary approaches, tools and partnerships, to transfer and upscale.	Sewer mining modular unit with membrane bioreactor and disinfection.	7	no	micro	water scarcity	cities; municipalities	Greece	2018-2022	H2020	https://nextgenwater.eu/demonstration-cases/athens/	Jos Frijns - KWR	jos.frijns@kwrwater.nl
NextGen-2	Towards a next generation of water systems and services for the circular economy	wastewater	energy, nutrients	NextGen will demonstrate innovative technological, business and governance solutions for water in the circular economy in ten high-profile, large-scale, demonstration cases across Europe, and we will develop the necessary approaches, tools and partnerships, to transfer and upscale.	direct industrial water reuse in a thermal power plant	7	no	micro	loss of resources	cities; municipalities	Romania	2018-2022	H2020	https://nextgenwater.eu/demonstration-cases/bucharest/	Jos Frijns - KWR	jos.frijns@kwrwater.nl
NextGen-3	Towards a next generation of water systems and services for the circular economy	wastewater	water for reuse	NextGen will demonstrate innovative technological, business and governance solutions for water in the circular economy in ten high-profile, large-scale, demonstration cases across Europe, and we will develop the necessary approaches, tools and partnerships, to transfer and upscale.	Regenerate end-of-life RO membranes to obtain different molecular cut-offs to be used in the multipurpose fit-for-use reclamation system.	7	no	meso	water scarcity, seawater intrusion	coastal regions	Spain	2018-2022	H2020	https://nextgenwater.eu/demonstration-cases/costa-brava-region/	Jos Frijns - KWR	jos.frijns@kwrwater.nl

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NextGen-4	Towards a next generation of water systems and services for the circular economy	rainwater	water for reuse	NextGen will demonstrate innovative technological, business and governance solutions for water in the circular economy in ten high-profile, large-scale, demonstration cases across Europe, and we will develop the necessary approaches, tools and partnerships, to transfer and upscale.	drainage system, urban reuse of water, heat recovery from sewer system	6-7	no	meso	water scarcity and pollution	cities; municipalities	The United Kingdom	2018-2022	H2020	https://nextgenwater.eu/demonstration-cases/filton-airfield/	Jos Frijns - KWR	jos.frijns@kwrwater.nl
NextGen-5	Towards a next generation of water systems and services for the circular economy	wastewater	water for reuse	NextGen will demonstrate innovative technological, business and governance solutions for water in the circular economy in ten high-profile, large-scale, demonstration cases across Europe, and we will develop the necessary approaches, tools and partnerships, to transfer and upscale.	Rainwater harvesting using automatic floodgates to replenish aquifers; decentralised membrane treatment of raw wastewater for reuse; climate neutral desalination.	7	no	macro	water scarcity	cities; municipalities	Sweden	2018-2022	H2020	https://nextgenwater.eu/demonstration-cases/gotland/	Jos Frijns - KWR	jos.frijns@kwrwater.nl
NextGen-6	Towards a next generation of water systems and services for the circular economy	wastewater	water for reuse, nutrients, biogas	NextGen will demonstrate innovative technological, business and governance solutions for water in the circular economy in ten high-profile, large-scale, demonstration cases across Europe, and we will develop the necessary approaches, tools and partnerships, to transfer and upscale. At the Spernal WWTP merging technologies compatible with a low energy, circular economy approach will be evaluated.	Anaerobic membrane bioreactor (AnMBR), membrane degassing unit; nutrient removal and recovery through adsorption or ion exchange technologies	7	no	macro	loss of resources	cities; municipalities	The United Kingdom	2018-2022	H2020	https://nextgenwater.eu/demonstration-cases/spernal/	Jos Frijns - KWR	jos.frijns@kwrwater.nl
Project Ô-1	Demonstration of planning and technology tools for a circular, integrated and symbiotic use of water	brackish water	drinking water	Project Ô demonstrates how local, small loops of water management can be beneficial in alleviating the pressures over a water management system while allowing for a circular economy vision of the resource "water". ADV.ERT is a mobile plant to treat brackish water with microbial contamination and low levels of biodegradable contaminants.	Nanofiltration system in series with a high voltage pulsed electric fuel.	7	no	micro	water scarcity and pollution	coastal regions	Italy	2018-2022	H2020	http://eu-project-o.eu/adaptablemodules	n.a.	info@eu-project-o.eu

Project Ô-2	Demonstration of planning and technology tools for a circular, integrated and symbiotic use of water	wastewater	water for reuse	Project Ô demonstrates how local, small loops of water management can be beneficial in alleviating the pressures over a water management system, while allowing for a circular economy vision of the resource "water" MOBILE3TECH is a mobile plant integrating 3 technologies. The combination of the 3 processes will allow 1) degradation of toxic organic pollutants; and 2) fine treatment of wastewater, acting as a tertiary process.	Solar photo-Fenton, advanced adsorption technology, bacterial stress based closed loop control.	7	no	micro	water scarcity and pollution	cities; municipalities	Spain	2018-2022	H2020	http://eu-project-o.eu/	n.a.	info@eu-project-o.eu
Project Ô-3	Demonstration of planning and technology tools for a circular, integrated and symbiotic use of water	textile industry wastewater	water for reuse	Project Ô demonstrates how local, small loops of water management can be beneficial in alleviating the pressures over a water management system while allowing for a circular economy vision of the resource "water". PHOTO.CAT is a modular water treatment pilot plant able to abate non-biodegradable pollutants in the presence of relevant amount of sulphates, with the possibility of reuse water in dyeing.	Photocatalysis	7	no	micro	toxic wastewater	textile industry	Croatia	2018-2022	H2020	http://eu-project-o.eu/adaptablemodules	n.a.	info@eu-project-o.eu
REMEB	Eco-friendly ceramic membrane bioreactor based on recycled agricultural and industrial wastes for wastewater reuse	wastewater	water for reuse	The project developed and validated a low-cost ceramic membrane bioreactor for wastewater treatment, manufactured with agro-industrial wastes, such as olive oil solid wastes and marble dust.	low-cost ceramic membrane bioreactor	7	no	micro	loss of resources	farming industry	Spain, Turkey	2015-2018	H2020	https://cordis.europa.eu/project/id/641998/de	Sociedad de fomento agricola castellonense, S.A.	n.a.

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REMIND	Renewable Energies for Water Treatment and Reuse in Mining Industries	wastewater	n.a.	The Project aims to develop an innovative framework of interplay between Renewable Energy Sources and Water Treatment Technologies in the logic of a sustainable growth for mining industries. The activities aim to: i) implement a rational use of water resources in the logic of circular economy; ii) promote a carbon-free technological approach (water-energy nexus) for reducing conventional energy resources requirements, and iii) mitigate health environmental risk in two demonstration sites	n.a.	n.a.	no	meso	release of untreated wastewater	mining industries	Italy, Spain	2018-2022	H2020	https://cordis.europa.eu/project/id/823948/de	University della Calabria	n.a.
REWAISE	Resilient Water Innovation for Smart Economy	wastewater; seawater; rainwater; brackish water;	water, energy, nutrients, materials	The project will create a new “smart water ecosystem”, integrating an intelligent digital framework for decentralized water services and decision making. A network of nine living labs, demonstrates real-life, large-scale operational environments for technological innovations and new governance methods to secure a resource-efficient water supply for the EU	Hybrid grey and green infrastructure, innovative water technologies, digital water - smart management.	n.a.	Yes	macro	loss of resources	cities; industries	Sweden; Poland; Czech Republic; Spain; Great Britain;	2020-2025	H2020	http://rewaise.eu/the-project/	FCC Aqualia SA	n.a.
RUN4LIFE-1	Recovery and utilization of nutrients 4 low impact fertilizer	blackwater	biogas, nutrients	This demonstration site has been one of the first pilot projects introduced in the Netherlands to treat vacuum collected black water (toilet wastewater) Furthermore, the demo site aims to recover valuable products from the wastewater. Biogas will be produced during the HTAD and the effluent and solid fraction of the HTAD can directly be used as NPK fertilisers (thus recovering the nutrients from the black water).	New type of vacuum toilet, (Hyper) Thermophilic Anaerobic Digestion	7	no	meso	loss of resources	cities; municipalities; rural settlements	The Netherlands	2017-2021	H2020	https://run4life-project.eu/demosites/demonstration-site-sneek/	FCC Aqualia SA	n.a.

RUN4LIFE-2	Recovery and utilization of nutrients 4 low impact fertilizer	wastewater	water for reuse, nutrients	This demo accommodates an innovative waste and wastewater management system for 430 houses and a variety of other buildings. Toilet wastewater (black water), organic kitchen waste and other domestic wastewater (grey water) will be collected and treated. The goal is to reuse all the wastewater, by recovering nutrients and energy and reusing the treated wastewater in the neighbouring industry. At full deployment, the Nieuwe Dokken district, will be a prime example of circular economy with synergies between water, nutrients and energy, as well as private households and industries.	Anaerobic digestion, struvite precipitation and N recovery. The effluent will be further treated together with the grey water, after which the flow will be polished for reuse as process water in a nearby industry	7	no	meso	loss of resources	cities; municipaliti es	Belgium	2017-2021	H2020	https://run4life-project.eu/demosite s/demonstration-site-sneek/	FCC Aqualia SA	n.a.
RUN4LIFE-3	Recovery and utilization of nutrients 4 low impact fertilizer	wastewater	water for reuse, nutrients	The aim of this demo site is to recover nutrients from wastewater to produce fertilisers and to reuse cleaned wastewater. The grey water is treated and reused after disinfection for toilet flushing, reducing the water footprint of the building. Within the Run4Life project, black water is treated to recover nutrients for fertigation or other fertiliser products.	Separate treatment for greywater (aMBR) and blackwater (AnMBR); bio-electrochemical systems for nitrogen recovery from blackwater.	7	no	meso	loss of resources	cities; municipaliti es	Spain	2017-2021	H2020	https://run4life-project.eu/demosite s/demonstration-site-sneek/	FCC Aqualia SA	n.a.
RUN4LIFE-4	Recovery and utilization of nutrients for low impact fertilizer	wastewater	biogas, nutrients	This demo site will accommodate an innovative waste and wastewater management system for around 320 apartments and several office buildings; black water and grey water will be separately collected and treated, aiming for maximum resource recovery. The Reco Lab (recovery laboratory, test-bed facility) and an educational showroom will be implemented together with the treatment plant.	Vacuum collection system for toilet wastewater, UASB reactors, recovery of struvite.	7	no	meso	loss of resources	cities; municipaliti es	Sweden	2017-2021	H2020	https://run4life-project.eu/demosite s/demonstration-site-sneek/	FCC Aqualia SA	n.a.

SABANA	Sustainable Algae Biorefinery for Agriculture and Aquaculture	wastewater, marine water	nutrients, bio-stimulant, bio-pesticides	SABANA aims at developing a large-scale integrated microalgae-based biorefinery for the production of bio-stimulants, biopesticides and feed additives, in addition to biofertilizers and aquafeed, using only marine water and nutrients from wastewaters. The objective is to achieve a zero-waste process at a demonstration scales up to 5 ha.	mircoalgae-based biorefinery	6-7	no	macro	sustainability of food production	farming industry	Spain	2016-2021	H2020	http://www.eu-sabana.eu/	Universidad de Almeria	info@eu-sabana.eu
SMART-Plant-1	Scale-up of low-carbon footprint Material Recovery Techniques in existing wastewater treatment PLANTs	wastewater	cellulose, PHA	SMART-Plant scales-up in real environment eco-innovative and energy-efficient solutions to renovate existing wastewater treatment plants and close the circular value chain by applying low-carbon techniques to recover materials that are otherwise lost. At Smartech1 cellulose is recovered from used toilet paper	Activated sludge WWTP; Upstream dynamic fine-screen and cellulose recovery with dynamic sieving as primary treatment.	6-7	no	meso	loss of resources	cities; municipalities	Netherlands	2016-2020	H2020	https://www.smart-plant.eu/index.php	Francesco Fatone - Universita politecnica delle marche	smart-plant@univpm.it
SMART-Plant-2	Scale-up of low-carbon footprint Material Recovery Techniques in existing wastewater treatment PLANTs	wastewater	Biogas	SMART-Plant scales-up in real environment eco-innovative and energy-efficient solutions to renovate existing wastewater treatment plants and close the circular value chain by applying low-carbon techniques to recover materials that are otherwise lost. At Smartech2A biogas is produced from wastewater	Secondary mainstream biogas recovery by poly-foam biofilter.	6-7	no	meso	loss of resources	cities; municipalities	Israel	2016-2020	H2020	https://www.smart-plant.eu/index.php	Francesco Fatone - Universita politecnica delle marche	smart-plant@univpm.it
SMART-Plant-3	Scale-up of low-carbon footprint Material Recovery Techniques in existing wastewater treatment PLANTs	wastewater	struvite, PHA	SMART-Plant scales-up in real environment eco-innovative and energy-efficient solutions to renovate existing wastewater treatment plants and close the circular value chain by applying low-carbon techniques to recover materials that are otherwise lost. At Smartech2B nutrients in the form of struvite and PHA are recovered	SCEPPHAR - short-cut enhanced phosphorus and PHA Recovery.	6-7	no	meso	loss of resources	cities; municipalities	Spain	2016-2020	H2020	https://www.smart-plant.eu/index.php	Francesco Fatone - Universita politecnica delle marche	smart-plant@univpm.it

SMART-Plant-4	Scale-up of low-carbon footprint Material Recovery Techniques in existing wastewater treatment PLANTs	wastewater	compounds for chemical and fertilizer industries	SMART-Plant scales-up in real environment eco-innovative and energy-efficient solutions to renovate existing wastewater treatment plants and close the circular value chain by applying low-carbon techniques to recover materials that are otherwise lost. At Smartech3 nutrients that can be safely reused in the chemical and fertilizer industries are recovered.	Anion exchange process used for the removal and recovery of nutrients as a tertiary treatment process.	6-7	no	meso	loss of resources	cities; municipalities	United Kingdom	2016-2020	H2020	https://www.smart-plant.eu/index.php	Francesco Fatone - Universita politecnica delle marche	smart-plant@univpm.it
SMART-Plant-5	Scale-up of low-carbon footprint Material Recovery Techniques in existing wastewater treatment PLANTs	wastewater	PHA, struvite	SMART-Plant will scale-up in real environment eco-innovative and energy-efficient solutions to renovate existing wastewater treatment plants and close the circular value chain by applying low-carbon techniques to recover materials that are otherwise lost. Smartech4A recovers PHA and nutrients in the form of struvite that can be valorised and used as fertilizer	Side stream SCENA (short-cut enhanced nutrients abatement) fermentation of thickened sewage sludge; solid/liquid separation of fermented sewage sludge; sequencing batch reactor for nutrient removal via nitrite.	6-7	no	meso	loss of resources	cities; municipalities	Italy	2016-2020	H2020	https://www.smart-plant.eu/index.php	Francesco Fatone - Universita politecnica delle marche	smart-plant@univpm.it
SMART-Plant-6	Scale-up of low-carbon footprint Material Recovery Techniques in existing wastewater treatment PLANTs	wastewater	PHA, nutrients	SMART-Plant will scale-up in real environment eco-innovative and energy-efficient solutions to renovate existing wastewater treatment plants and close the circular value chain by applying low-carbon techniques to recover materials that are otherwise lost. Smartech5 recovers precursors for bioplastics and nutrients	Activated sludge WWTP; side stream SCEPPHAR (short-cut enhanced phosphorus and PHA Recovery)	6-7	no	meso	loss of resources	cities; municipalities	Italy	2016-2020	H2020	https://www.smart-plant.eu/index.php	Francesco Fatone - Universita politecnica delle marche	smart-plant@univpm.it
SMART-Plant-7	Scale-up of low-carbon footprint Material Recovery Techniques in existing wastewater treatment PLANTs	wastewater	P-rich sludge	SMART-Plant will scale-up in real environment eco-innovative and energy-efficient solutions to renovate existing wastewater treatment plants and close the circular value chain by applying low-carbon techniques to recover materials that are otherwise lost. Smartech4B removes nutrients and produces P-rich sludge	Side stream thermal hydrolysis-SCENA (short-cut enhanced nutrients abatement)	6-7	no	meso	loss of resources	cities; municipalities	Greece	2016-2020	H2020	https://www.smart-plant.eu/index.php	Francesco Fatone - Universita politecnica delle marche	smart-plant@univpm.it

ULTIMATE	indUstry water-utiLiTy symbIosis for a sMarter wATer society	wastewater	water for reuse, nutrients, high-added value compounds, energy	The project will implement 9 Water-Smart Industrial Symbiosis (WSIS) case studies in 4 different geographical settings: Western, Central and Southern Europe and the South-East Mediterranean. The main objectives are to evaluate and demonstrate the performance at large scale the technical feasibility of innovative technologies and symbiosis strategies.	n.a.	6-7	no	macro	loss of resources	Biotech industry; heavy chemical/petrochemical industry; agro-food processing; beverage industry	Spain; The Netherlands; Italy; Greece; Czech Republik; United Kingdom; France; Denmark	2020-2024	H2020	https://ultimatewater.eu/the-project/	KWR - Water Research Institute - Dr. Gerard van den Berg	gerard.van.den.berg@kwrwater.nl
URBAN GreenUP	New Strategy for Re-Naturing Cities through Nature-Based Solutions	wastewater	water for irrigation	Urban GreenUP aims at obtaining a tailored methodology (1) to support the co-development of Renaturing Urban Plans focused on climate change mitigation and adaptation and efficient water management, and (2) to assist in the implementation of NBS in an effective way. NBS classification and parameterization will be addressed and some resources to support decision making will be established as part of the project activities.	electrowetlands, drainage systems, smart soils	7	yes	meso	variable weather events, urban heat islands	cities	Spain; United Kingdom; Turkey	2017-2022	H2020	https://www.urbangreenup.eu/about/about.kl	CARTIF Technology Centre - Raúl Sánchez	rausan@cartif.es
WATER-MINING	Next generation water-smart management systems: large scale demonstrations for a circular economy and society	wastewater; seawater	water, nutrients, minerals, energy	The project shows and validates innovative next generation water resource solutions. These solutions combine water management services with the recovery of value-added renewable resources extracted/mined from alternative water resources. Different layouts for urban wastewater und seawater desalination are proposed.	Innovative next generation water resource solutions at pre-commercial demonstration scale. The solutions combine water management services with the recovery of value added renewable resources extracted/mined from alternative water resources.	7-8	No	meso	loss of resources	cities; industries	The Netherlands; Spain; Cyprus; Portugal; Italy	2020-2024	H2020	https://cordis.europa.eu/project/id/869474	TU Delft - Prof. Mark van Loosdrecht	M.C.M.vanLoosdrecht@tudelft.nl

Water2Return	Recovery and Recycling of nutrients turning wastewater into added-value products for a circular economy in agriculture	slaughterhouse wastewater	fertiliser, biostimulants	The project proposes a full-scale demonstration process for integrated nutrients recovery from wastewater from the slaughterhouse industry using biochemical and physical technologies and a positive balance in energy footprint. The project novelty rests on the use of an innovative fermentative process designed for sludge valorisation which results in a hydrolysed sludge (with a multiplied Biomethane Potential) and bio-stimulants products, with low development costs and high added value in plant nutrition and agriculture.	Biological aeration systems, membrane technologies, anaerobic processes for bio-methane production, algal technologies.	7	no	meso	water pollution	slaughterhouses	Spain	2017-2020	H2020	https://water2return.eu/	n.a.	info@water2return.eu
Water4Crops-3	Integrating Bio-Treated Wastewater Reuse with Enhanced Water Use Efficiency to Support the Green Economy in EU and India	secondary effluent from WWTP	water	Water4Crops provides a combination of technical improvements in the field of bio-treatment and agricultural water use within a transdisciplinary identification of novel agri-business opportunities. In Italy hydraulic and hydrologic aspects of CWs were optimized to increase the lifespan of the systems. Particular attention was paid to evaporation dynamics of the planted vegetation and to mechanisms and consequences of clogging.	CW with four horizontal sub surface flow CW beds.	7	yes	micro	water pollution	municipalities; farms	Italy	2012-2016	FP7	http://www.water4crops.org/	Prof. Attilio Toscano - UNICT	attilio.toscano@unibo.it
Water4Crops-4	Integrating Bio-Treated Wastewater Reuse with Enhanced Water Use Efficiency to Support the Green Economy in EU and India	wastewater	irrigation water	Water4Crops provides a combination of technical improvements in the field of bio-treatment and agricultural water use within a transdisciplinary identification of novel agri-business opportunities. In Germany coupling slow and sand filters to CWs as a post-treatment were tested towards reaching required outflow qualities concerning pathogen loads	Two step-system consisting of a CW horizontal or vertical flow and a slow sand filter.	7	yes	micro	water pollution	municipalities; farms	Germany	2012-2016	FP7	http://www.water4crops.org/	Jochen Müller	
WIDER UPTAKE-1	Achieving wider uptake of water-smart solutions	wastewater	PHA, nutrients, water for reuse	The overall objective of WIDER UPTAKE is to co-develop a roadmap for widespread implementation of water smart symbiotic solutions for wastewater reuse and resource recovery, based on the principles of circular economy. At the demonstration sites in Italy the project will focus to recover materials and water for reuse in agriculture.	Process line for PHA production/extraction, installation of final filters filled with biochar and zeolites for nutrients adsorption.	6-7	no	meso	loss of resources	cities; municipalities; farmers	Italy	2020-2024	H2020	https://wideruptake.unipa.it/home	UNIPA	wideruptake@unipa.it

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WIDER UPTAKE-2	Achieving wider uptake of water-smart solutions	wastewater	fertiliser, energy	The overall objective of WIDER UPTAKE is to co-develop a roadmap for widespread implementation of water smart symbiotic solutions for wastewater reuse and resource recovery, based on the principles of circular economy. At the demonstration site in Norway fertiliser and soil improver by wastewater resource recovery will be tested.	Phosphorus recycling based on innovative continuous MBBR process for EBPR, P-recovery by struvite precipitation.	6-7	no	meso	loss of resources	farming industry	Norway	2020-2024	H2020	https://www.sintef.no/projectweb/wider-uptake/	SINTEF - Herman Helness	herman.helness@sintef.no
WIDER UPTAKE-3	Achieving wider uptake of water-smart solutions	wastewater	bio-composite material	The overall objective of WIDER UPTAKE is to co-develop a roadmap for widespread implementation of water smart symbiotic solutions for wastewater reuse and resource recovery, based on the principles of circular economy. At the demonstration site in The Netherlands production of new bio-composite material by water resource recovery will be tested.	Optimisation of the value chains to quantify the improved resource efficiency and economic benefits, also with respect to future applications.	6	no	meso	loss of resources	construction and traffic industries	The Netherlands	2020-2024	H2020	https://www.sintef.no/projectweb/wider-uptake/	SINTEF - Herman Helness	herman.helness@sintef.no
WIDER UPTAKE-4	Achieving wider uptake of water-smart solutions	wastewater	water for irrigation	The overall objective of WIDER UPTAKE is to co-develop a roadmap for widespread implementation of water smart symbiotic solutions for wastewater reuse and resource recovery, based on the principles of circular economy. At the demonstration site in the Czech Republic the reuse of wastewater for greening urban areas will be tested.	UV disinfection, micro- and nanofiltration membranes, advanced oxidation processes and sorption, grey-green solutions.	6	yes	meso	water scarcity, urban heat islands	cities	Czech Republik	2020-2024	H2020	https://www.sintef.no/projectweb/wider-uptake/	SINTEF - Herman Helness	herman.helness@sintef.no
Billund Biorefinery	Billund Biorefinery Resource Recovery for the future	wastewater	energy, nutrients, biogas, bioplastic	Billund Biorefinery combines a wide range of technologies in a unique way so that less energy is applied for wastewater treatment. At the same time, much more energy is recovered from the wastewater and waste, and the amount of the sludge is reduced and refined to an odourless, easily manageable and very efficient organic fertiliser for agricultural purposes.	n.a.	7	no	meso	loss of resources	wastewater treatment plants	Denmark	2013-2016	n.a.	http://www.billundbiorefinery.dk/en/about-the-project/wastewater-plant#.X60A-NtCeYU	Ole P. Johnsen	opj@billundvand.dk

CLEaN-Tour	Circular economy to ease urban water reuse in a touristic city: centralised or decentralised management?	wastewater	water for reuse	The main objective is to develop knowledge, technologies and tools on wastewater treatment in order to facilitate expanding urban water reuse in touristic regions. The project tackles the issues of the removal of pathogens and micropollutants, the evaluation of the potential risks of water reuse and the difficulties in selecting the most adequate scenario (centralized or decentralized) and related treatment technologies.	Osmotic membrane bioreactors, hydroponic technologies, solar electro-oxidation.	n.a.	Yes	macro	risks of water reuse	cities; municipalities	Spain	2018-2021	MINECO	http://www.lequia.udg.edu/research/ongoing-projects/item/2570-clean-tour.html	ICRA	
CarbonNextGen	Carbon neutral next generation wastewater treatment plants	wastewater	PHA	CarbonNextGen is developing a new approach in carbon neutral wastewater treatment plants. The core technology is an improved fermentation process that treats the both wastewater and sludge and creates value (approx. 600 BSEK/year for Sweden) by producing energy, commercially valuable fatty acids and bioplastics. Our bio-based technology could be taken to the market as a combination of products and services that can be integrated into existing wastewater treatment plants.	Improved fermentation process.	6-7	no	micro	loss of resources	cities; municipalities	Sweden	n.a.	Swedish Energy Agency	https://www.kth.se/sv/ket/resource-recovery/carbonnextgen-carbon-neutral-next-generation-wastewater-treatment-plants-1.978529	Zeynep Cetecioglu - KTH	zeynepcg@kth.se
Cressy	Cressy	wastewater	water for reuse, nutrients	The Equilibre cooperative wanted from the outset to create a building with a low environmental impact over its entire life cycle, from its construction to its deconstruction through its operation. No wastewater discharge will be put into the sewer, a first in Switzerland for a rental building.	Composting dry toilets, phyto-purification system for grey water.	7	yes	micro	water pollution	municipalities	Switzerland	2008-2010	private	https://www.cooperative-equilibre.ch/projets/cressy/	Benoit Molineaux - Coopérative Equilibre	info@cooperative-equilibre.ch

Dairy, no water!	A dairy industry which is self-supporting in water	dairy process water	water for reuse	Closing the internal water cycle of a new diary park. Instead of using drinking water, the water out of the whey water was extracted in several stages and used again as process water	Membrane technology, polishers and necessary management system.	6	no	micro	high water consumption	dairy industry	The Netherlands	2005	Life	https://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=search.dspPage&n_proj_id=2373&docType=pdf	n.a.	info@dockaas.nl
De Ceuvel-1	sustainable office park for creative industries	greywater	water for discharge	A sustainable office park built on the site of a former shipyard in Amsterdam North, has become an internationally acclaimed circular economy case study. Home to 17 workspaces and a popular community cafe, the site was conceptualized as a 'cleantech playground' with numerous living examples of decentralized technologies and recycling of local resources.	Biofilter	7	yes	meso	water pollution	cities; municipalities	The Netherlands	n.a.	n.a.	https://deceuvel.nl/en/	n.a.	info@deceuvel.nl
De Ceuvel-2	sustainable office park for creative industries	urine	nutrients	A sustainable office park built on the site of a former shipyard in Amsterdam North, has become an internationally acclaimed circular economy case study. Home to 17 workspaces and a popular community cafe, the site was conceptualized as a 'cleantech playground' with numerous living examples of decentralized technologies and recycling of local resources.	Struvite reactor	6-7	no	meso	water pollution	municipalities	The Netherlands	n.a.	n.a.	https://deceuvel.nl/en/	n.a.	info@deceuvel.nl
demEAUmed	Demonstrating integrated innovative technologies for an optimal and safe closed water cycle in Mediterranean tourist facilities	greywater	water for reuse	The proposed demEAUmed solution integrates innovative water treatment technologies, TICs and water management tools in a hotel resort in Spain. Greywater is treated with a vertical constructed wetland and reused.	Vertical constructed wetland	7-8	yes	micro	water scarcity and pollution	hotels	Spain	2014-2017	FP7	http://www.demeaumed.eu/	Gianluigi Buttiglieri - ICRA	gbuttiglieri@icra.cat

DESSIN-1	Demonstrate Ecosystem Services Enabling Innovation in the Water Sector	wastewater	water for irrigation	The project demonstrates and promotes innovative solutions for water scarcity and water quality related challenges and demonstrates a methodology for the evaluation of ecosystem services. In Greece the deployment of innovative management options and technologies for water reuse to irrigate green urban areas are tested.	sewer mining, distributed reuse within urban environment, ICT-solutions for distributed monitoring and management of multiple sites, testing reused water characteristics on soil, irrigation onsite peri-urban green	7	no	macro	water scarcity	cities	Greece	2014-2017	FP7	https://dessin-project.eu/	Prof. Christos Makropoulos - NTUA	cmarko@mail.ntua.gr
DESSIN-2	Demonstrate Ecosystem Services Enabling Innovation in the Water Sector	wastewater	n.a.	The project demonstrates and promotes innovative solutions for water scarcity and water quality related challenges and demonstrates a methodology for the valuation of ecosystem services. In Germany work on innovations in treatment of combined sewer overflow structures and real time control of large-scale sewer systems is demonstrated to support the Emscher re-conversion process.	Cross-flow lamella settles as additional treatment of CSOs	7	no	meso	water scarcity and pollution	municipalities	Germany	2014-2018	FP7	https://dessin-project.eu/	Nadine Gerner - EG	gerner.nadine@eglv.de
DESSIN-3	Demonstrate Ecosystem Services Enabling Innovation in the Water Sector	wastewater, sewer overflow	n.a.	The project demonstrates and promotes innovative solutions for water scarcity and water quality related challenges and demonstrates a methodology for the valuation of ecosystem services. In Norway treatment solutions from CSOs will be demonstrated, combining technologies at local and system level.	Local treatment solutions for overflow from CSOs.	7	no	meso	sewer overflow discharge	cities; municipalities	Norway	2014-2019	FP7	https://dessin-project.eu/	Herman Helness - SINTEF	herman.helness@sintef.no
DESSIN-4	Demonstrate Ecosystem Services Enabling Innovation in the Water Sector	different treated water qualities	water	The project demonstrates and promotes innovative solutions for water scarcity and water quality related challenges and demonstrates a methodology for the valuation of ecosystem services. In Spain the project will maximize the use of existing deep injection systems in the drinking water treatment plant, aquifers will receive different water qualities.	Deep injection system for ASR	7	no	meso	water scarcity	cities	Spain	2014-2020	FP7	https://dessin-project.eu/	Pere Camprovín - Cetaqua	pcamprovin@cetaqua.com

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DESSIN-5	Demonstrate Ecosystem Services Enabling Innovation in the Water Sector	rainwater	water	The project demonstrates and promotes innovative solutions for water scarcity and water quality related challenges and demonstrates a methodology for the valuation of ecosystem services. The water buffer Showcase demonstrates how innovative, small-scale aquifer storage and recovery (ASR) in combination with desalination can be used to safeguard a sustainable fresh water supply in coastal areas.	Aquifer storage and recovery, reverse osmosis desalinisation	7	no	meso	seawater intrusion	coastal regions	The Netherlands	2014-2021	FP7	https://dessin-project.eu/	Koen Zuurbier - KWR	koen.zuurbier@kwrwater.nl
Dinxperlo Nereda WWTP	n.a.	wastewater	alginates	Nereda alginate is a substance with unique characteristics and potentially high-quality applications. By extracting this and other raw materials such as phosphate from wastewater, water authorities are taking concrete steps towards achieving a circular economy.	Royal HaskoningDHV's Nereda® treatment technology. Alginate extraction from granular excess sludge	6	no	meso	loss of resources	cities; municipalities	The Netherlands	n.a.	n.a.	https://www.royalhaskoningdhv.com/en-gb/news-room/news/water-authorities-working-hard-to-achieve-circular-economy/7123	Paul Roeleveld - Royal Haskoning DHV	paul.roeleveld@rhdhv.com
EdiCitNet	Edible Cities Network Integrating Edible City Solutions for social resilient and sustainably productive cities	stormwater	water for irrigation	Edible Cities Network (EdiCitNet) wants to make cities around the world better places to live through the real-life implementation and institutional integration of Edible City Solutions (ECS). Such activities result in an overall increase of social welfare via improvements of climate and biodiversity conditions, enhancement of social cohesion in our cities, support of the local Green Economy, and sustainable maintenance of local raw material cycles by closed system techniques.	Green facades	7	yes	meso	heavy rain events	cities	Norway	2018-2023	EASME	https://www.edicitnet.com/what-is-edicitnet/	Ina Säumel - Humboldt Universität zu Berlin	ina.saeumel@hu-berlin.de

HAMBURG WATER Cycle	HAMBURG WATER Cycle	wastewater	energy, nutrients	The most critical component of the HAMBURG WATER Cycle® is the separate treatment of the different wastewater streams, the so-called partial flow treatment. Stormwater, wastewater from the toilet, and wastewater from the kitchen and bathroom (when washing hands or using the washing machine for example) are separately collected and then separately treated.	Vacuum toilets and collection, AD, Fixed bed reactor, heat exchange, district heating	7-8	no	macro	water pollution	cities; municipalities	Germany	2011-ongoing	EU Life+; German Federal Ministry of Education and Research; Federal Ministry for Economic Affairs and Energy	https://www.hamburgwatercycle.de/en/hamburg-water-cycler/	Wenke Schönfelder - Hamburg Wasser	wenke.schoenfelder@hamburgwasser.de
KAUMERA	Kaumera production	wastewater	Kaumera Nereda® Gum (formerly: Neoalginate)	Kaumera Nereda® Gum is a new bio-based raw material that is extracted from the sludge granules that form during the Nereda® purification process. By removing Kaumera from the purified sludge, 20-35% less sludge needs to be removed and processed. This has a positive effect on energy consumption and CO_2 emissions.	Nereda® purification proces	7-8	no	macro	loss of resources	industries	The Netherlands	n.a.	n.a.	https://kaumera.com/english/kaumera/	Rijn en IJssel Water Authority	info@wrij.nl.
Koningshoeven BioMakery	Koningshoeven BioMakery	wastewater	water for reuse	The Koningshoeven BioMakery is the first Biopolus Water Treatment facility in the Netherlands and was fully integrated into the historical monument of the Koningshoeven Trappist Abbey and Brewery. The facility treats industrial wastewater from the brewery and municipal wastewater from the Abbey and Visitor centre to re-use quality. The facility provides a long-term sustainable solution for water management, with a space to study and showcase water circularity.	Metabolic Network Reactor - integrated fixed-film activated sludge water treatment technology	9	yes	meso	water pollution	cities; industries	The Netherlands	2018	n.a.	http://www.biopolus.net/project/trappist-abbey-brewery-koningshoeven-the-netherlands/	n.a.	info@biopolus.net

LooPi	LooPi - beta version	yellow water	water for reuse, nutrients	"LooPi – the plant-based public urinal for women and men" is the latest innovation in the series of functional green walls. LooPi is a combination of wastewater management & green infrastructure: wastewater is treated via the integrated green wall and re-used for flushing.	vertical constructed wetland	6	yes	micro	water pollution	cities	Austria	2019-2021	Austrian Research Promotion Agency	https://www.alchemia-nova.net/projects/loopi/	Julia Edlinger - alchemia-nova	edlinger@alchemia-nova.net
L'Oreal	treating and reusing wastewater on site	wastewater	water for reuse	Since 2014, the L'Oréal plant in Settimo has been treating its wastewater by evapoconcentration. This technology involves heating the effluents so as to recover water and concentrates. The factory therefore installed the necessary amenities to reuse a heat source already available onsite – the compressors. As a result, evapoconcentration does not consume any additional energy.	evapoconcentration	8	no	meso	water scarcity and pollution	cosmetic industry	Italy	2014-ongoing	private	https://www.loreal.com/en/articles/italia-the-settimo-plant-adopts-evapoconcentration/	n.a.	n.a.
NEWBIES	Low footprint waste water treatment, enabling sustainable recovery of organic nitrogen into valuable fertilizer	wastewater	nutrients	The LIFE NEWBIES project aims to demonstrate a novel technique to extract ammonium from wastewater in an economic, effective and energy-efficient way. Researchers will assemble the equipment for this process and prove that it can recover 1 kg of ammonia-nitrogen each day from different kinds of wastewater, including sewage and urine. They will house the pilot system in a transportable container and deploy it to locations where wastewater can be tapped on site.	ElectroDialysis stack, gas membrane stripper (TransMembraneChemiSorption)	6-7	no	micro	water pollution	cities; municipalities	Spain	2018-2021	EU Life	https://newbies.eu/	Philipp Kuntke - Wetsus	info@newbies.eu

PHARIO	PHARIO	wastewater	PHA	The PHARIO concept creates a high and controllable quality PHA with fewer process elements and significant lower manufacturing costs. The source is municipal wastewater and organic residuals from households or food industry: an abundant flow of valuable biomass, available globally.	Mixed microbial cultures, activated sludge at WWTP, bioprocess facilitating feast and famine conditions, biomass is fed with VFA-rich liquors, pure acetic and propionic acids	6-7	no	meso	loss of resources	wastewater treatmant plants	The Netherlands	n.a.	Dutch Water Authorities and industrial partners	http://phario.eu/concept/	L. Korving - Waterschap Brabantse Delta	l.korving@brabantsedelta.nl
Phosphogreen	recycle phosphorus from effluent to produce a valuable fertilizer	wastewater	fertiliser	Phosphogreen is a process that recovers phosphorus from wastewater and converts it into an agricultural fertilizer: struvite. At this demo-site (Villiers-Saint-Frédéric) the treatment plant has a capacity of 42.000 PE with biological P-removal and anaerobic digestion	phosphogreen reactor (based on precipitation-crystallization reaction)	7	no	meso	peak phosphor	wastewater treatment plants		n.a.	n.a.	https://www.suezwaterhandbook.com/degremont-R-technologies/sludge-treatment/recovery/recycle-phosphorus-from-effluent-to-produce-a-valuable-fertilizer-Phosphogreen	Mathieu Delahaye - SUEZ	innovation.mailin@degremont.com
Pioneer_STP	The Potential of Innovative Technologies to Improve Sustainability of Sewage Treatment Plants	wastewater	biogas, nutrients	The project has the aim of optimizing sustainable sewage treatment plant (STP) by including new and promising technologies at different points of the plant layout, taking into account the strong interdependencies between them. In Pioneer_STP a set of innovative technologies for the treatment of wastewater, sludge and concentrate will be developed and assessed from a holistic and global perspective.	n.a.	7	no	macro	water pollution	cities; municipalities	Spain	2016-2019	Water Joint Programming Initiative	https://www.kt.dtu.dk/english/research/prosys/projects/pioneer-stp	Professor Gürkan Sin - DTU Chemical Engineering	gsi@kt.dtu.dk
Productive On-site Sanitation System	New Value Chain for Urine Based Fertilizer	yellow water	fertiliser	The overall purpose of this project is to develop a urine drying system for implementation in urine diverting toilets and urinals. The aim of the urine drying system is to provide an affordable urine treatment system	alkaline unit, dehydration container	6-7	no	micro	water pollution	households	Sweden	2015-2018	Swedish Research Council	https://www.slu.se/en/departments/energy-technology/projects/kretslopp/productive-on-site-sanitation-system/	Prof. Björn Vinneras - SLU	bjorn.vinneras@slu.se

RESILIO	Resilience nEtwork of Smart Innovative cLImate-adaptive rOoftops	rainwater	n.a.	The RESILIO project aims to address critical urban climate challenges by repurposing the rooftops of climate-vulnerable neighbourhoods of Amsterdam. The smart blue green roofs are expected to help the city adapt to climate change by reducing impacts of heavy rain, urban heat island effect and drought while improving building insulation, biodiversity and quality of life.	10.000 m^2 of smart green roofs with enhanced water retention.	8	yes	meso	heavy rain events, urban heat island effect	cities	The Netherlands	2018-2021	ERDF	https://www.uia-initiative.eu/en/uia-cities/amsterdam	Age Niels Holstein	a.holstein@amsterdam.nl
Rijskantoor	Rijskantoor	Yellow water	Biogas, nutrients	About 6,000 civil servants are housed in the new government office on Rijnstraat. The waste (water) flows are processed in the building itself. Part of the urine is collected separately with anhydrous urinals. This yellow water is processed on site in a struvite reactor into phosphate fertilizer. The black water from the vacuum toilets is combined with organic waste processed in a fermentation plant. The biogas that is released during this process is used to heat the building.	Urinals without water, struvite reactor, vacuum toilets, fermentation plant.	7	no	meso	Loss of resources	Cities	The Netherlands	ongoing	n.a.	https://www.saniwijzer.nl/projecten/rijkskantoor-rijnstraat-8/detail=94		n.a.
RIWAC	Recovery of Industrial Water and Chromium	industrial wastewater	water, Ammonium sulphate, Calcium Sulphate	Project for recovery and reuse of industrial waters and trivalent chromium generated by tannery waste processing. The target of ammonia-containing industrial water recovery and reutilisation was positively achieved. Then, the condensation water generated in evaporation plants of shavings processing are totally recycled in the production process, instead of being discharged to the wastewater treatment plant	n.a.	6	no	micro	loss of resources	tannery industry	Italy, Spain, Portugal	2005-2008	Life	https://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=search.dspPage&n_proj_id=2853&docType=pdf%20%20No%20NBS	Massimo Neresini	neresini@sicit2000.it

ROOF WATER-Farm	Cross-sectoral use of water resources for building-integrated farming	wastewater	food	ROOF WATER-Farm combines wastewater treatment technology with food production. Hydroponics and aquaponics are used as building-integrated, water-based farming strategies.	Hydroponics, aquaponics, decentralized water treatment.	7	yes	micro	loss of resources	cities	Germany	2013-2016	German Federal Ministry of Education and Research	http://www.roofwaterfarm.com/en/ueber/	Dr. Grit Bürgow - TU-Berlin	g.buergow@isr.tu-berlin.de
Slough Trading Estate	Slough Trading Estate	wastewater	Fertiliser (struvite)	A reactor that turns sewage into fertiliser has been installed by Thames Water at a plant in Berkshire. The nutrient-recovery facility takes wastewater from the Slough Trading Estate and turns the phosphorous in it into crystalline fertiliser pellets.	Ostara Pearl, nutrient recovery technology, Ostara WASSTRIP (Waste activated Sludge Stripping to Remove Internal Phosphorus).	8	no	meso	loss of resources	cities; municipalities	The United Kingdom	n.a.	n.a.	https://ostara.com/nutrient-management-solutions/	Ostara	info@ostara.com
SUPERLOCAL	super circular estate	wastewater	water for reuse	The ambition of SUPERLOCAL circular area development is to reuse the materials from two empty towers for the construction of 130 new homes and the layout of the public area. The project is experimenting with innovative solutions that promote a circular economy. A closed water cycle will be created in the project area to provide the 130 households with drinking water, which is collected and purified in the area	Water-aware appliances, rainwater harvesting, greywater recycling, sustainable urban drainage.	7-8	yes	meso	water scarcity and pollution	cities; municipalities	The Netherlands	n.a.	European Regional Development Fund, Life	https://www.superlocal.eu/sce-en/	Maurice Vincken	info@superlocal.eu
Thermal power plant and greenhouse symbiosis	thermal power plant and greenhouse symbiosis	hot water generated by thermal power plant	energy	Electricité de France (EDF) Group uses hot water generated by a thermal power plant to heat a greenhouse for tropical plants. On one side of a road is Edison Candela's combined cycle gas turbine power station. On the other side are 90 hectares of greenhouses owned by Ciccolella, the world's largest grower of the tropical flower Anthurium. The win-win partnership conserves water, a scarce resource in the Italian region of Puglia.	Water distribution system, heat exchangers, irrigation, steam engines.	7	no	macro	high energy consumption	thermal power plants, greenhouse production	Italy	n.a.	private	n.a.	n.a.	n.a.

UPPER	Urban productive Parks for the development of NBS related technologies and services	rainwater	n.a.	Creating the first urban Productive Parks devoted to research, development and self-production of Nature Based Solutions (NBS) to tackle the identified environmental, socio-economic and governance challenges. UPPER project proposes a wider approach to the concept of NBS, which will include greenery and green infrastructures on one hand and innovative outdoor services and activities	Plants for phytoremediation of water and soil.	7	yes	meso	water pollution	cities	Italy	2019-2022	ERDF	https://www.uia-initiative.eu/en/uia-cities/latina	Angelica Vagnozzi	angelica.vagnozzi@comune.latina.it
UrinExpress	UrinExpress	yellow water	fertiliser	With the Vuna process, the world's first urine fertilizer is made from urine. With official approval for all plants, from vegetables to houseplants.	Activated carbon filter, distiller to reduce liquid volume.	8	no	micro	loss of resources	cities; municipalities; rural settlements	Switzerland	n.a.	n.a.	https://vuna.ch/	Vuna GmbH	info@vuna.ch
Water4Crops-1	Integrating Bio-Treated Wastewater Reuse with Enhanced Water Use Efficiency to Support the Green Economy in EU and India	olive mill wastewater	PHA, polyphenols	Water4Crops provides a combination of technical improvements in the field of bio-treatment and agricultural water use within a transdisciplinary identification of novel agri-business opportunities. In Italy the project is dedicated to the valorisation of olive mill wastewaters by developing a process for the continuous-flow extraction of polyphenols, with particular attention to the possibility of recycling both the adsorbing phase and the extraction solvent	Phenolic compounds adsorption in a continuous flow column.	7	no	micro	water pollution	olive mills	Italy	2012-2016	FP7	http://www.water4crops.org/	Dr. Dario Frascari - University of Bologna	dario.frascari@unibo.it
Water4Crops-3	Integrating Bio-Treated Wastewater Reuse with Enhanced Water Use Efficiency to Support the Green Economy in EU and India	secondary effluent from WWTP	water	Water4Crops provides a combination of technical improvements in the field of bio-treatment and agricultural water use within a transdisciplinary identification of novel agri-business opportunities. In Italy hydraulic and hydrologic aspects of CWs were optimized to increase the lifespan of the systems. Particular attention was paid to evaporation dynamics of the planted vegetation and to mechanisms and consequences of clogging.	CW with four horizontal sub surface flow CW beds	7	yes	micro	water pollution	municipalities; farms	Italy	2012-2016	FP7	http://www.water4crops.org/	Prof. Attilio Toscano - UNICT	attilio.toscano@unibo.it

Water4Crops-4	Integrating Bio-Treated Wastewater Reuse with Enhanced Water Use Efficiency to Support the Green Economy in EU and India	wastewater	irrigation water	Water4Crops provides a combination of technical improvements in the field of bio-treatment and agricultural water use within a transdisciplinary identification of novel agri-business opportunities. In Germany coupling slow and sand filters to CWs as a post-treatment were tested towards reaching required outflow qualities concerning pathogen loads	Two step-system consisting of a CW horizontal or vertical flow and a slow sand filter.	7	yes	micro	water pollution	municipalities; farms	Germany	2012-2016	FP7	http://www.water4crops.org/	Jochen Müller	
WATINTECH	Smart Decentralized WATer Management through a Dynamic INtegration of TECHnologies	wastewater	water, methane, value-added chemicals	WATINTECH proposes a combination of novel sewer mining technologies with urban run-off treatment in decentralised facilities to enhance the local recovery of valuable resources. It is postulated that this combination improves the management of centralized wastewater infrastructures under variable weather events.	Forward Osmosis; constructed wetland; anaerobic bioreactor; MF/UF membrane;	6-7	Yes	macro	variable weather events	cities	Spain; Denmark; Portugal	2016-2019	MINECO	http://www.lequia.udg.edu/research/main-projects-completed/item/2380-watintech.html	ICRA - Prof. Ignasi Rodriguez-Roda	irodriguezroda@icra.cat
Welsh Water project	Welsh Water project	combined sewer overflows	water for discharge	The Welsh Water project is using the WWETCO FlexFilter™, an innovative but proven, high-rate multi-cell filtration system requiring no chemicals and no internal mechanical components. Its simple unmanned operation makes it ideal for satellite treatment of combined sewer overflow and sanitary sewer overflow as well as a dual-use process at the main treatment plant for both wet weather and dry weather tertiary treatment.	WWETCO FlexFilter™, high-rate filtration system that uses synthetic compressible media.	8	no	meso	sewer overflow discharge	cities; municipalities	The United Kingdom	2020	n.a.	https://www.waterenvironmenttechnology-digital.com/waterenvironmenttechnology/april_2020/MobilePagedArticle.action?articleId=1576125#articleId1576125	n.a.	info@westech-inc.it
WETWINE	Transnational cooperation project to promote the conservation and protection of the natural heritage of the wine sector in the SUDOE area	wine industry wastewater	fertiliser	The WETWINE project is a pilot experiment based on anaerobic digestion and wetland treatment of water and sludge, which puts into value the rational use of resources and their revaluation, as a result in a Fertilizer for the vineyard that will limit the generation of waste and the contamination of soils and waters of our territory.	Anaerobic digestion, wetland.	6-7	yes	micro	water pollution	wine industry	Spain	2016-2019	ERDF	http://wetwine.eu/en/	AGACAL	agacal@xunta.gal

Nestlé Fawdon factory	Nestlé Fawdon factory	wastewater	water for reuse, biogas, fertiliser	The overall objective was to contribute to the 'low carbon and renewable energy' strategy adopted by the Fawdon factory. Initially, the effluent had to be sent to the municipal treatment plant. Solution: both solid and liquid waste via biological digestion to produce clean water and biomethane --> reduced effluent volumes, reduced solid waste, reduced CO_2 emissions, reduced cost; instead of landfilling, 4 tonnes/day food waste is digested anaerobically to produce green energy and fertiliser	Anaerobic digestion; further biological treatment to produce clean water.	8	no	meso	water pollution	food processing plants	The United Kingdom	n.a.	private	n.a.	n.a.	n.a.
EnVFAPro	Enhancement of volatile fatty acid production from dairy wastewater	dairy industry wastewater	volatile fatty acids	The aim of EnVFAPro is to develop a microbial consortium for maximizing VFA production from dairy industry wastewater. For this purpose, engineering and microbiological tools in combination with a modelling approach will be used. This project will increase the knowledge of the microbial community, their interactions and the operational conditions to maximise VFA production from dairy industry waste streams.	Batch reactors, anaerobic modelling, bioaugmentation, fermenters.	6-7	no	micro	loss of resources	dairy industry	Sweden	2017-2018	Marie Curie, Vinnova	https://www.kth.se/sv/ket/resource-recovery/envfapro-1.703273	Zeynep Cetecioglu - KTH	zeynepcg@kth.se

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Table 5.2 Compilation of public policy initiatives and strategies efforts promoting a more circular water economy

Strategy/Initiative Acronym-Case	country/region	Type	Description		link/source	Additional documentation
European Green Deal	EU	action plan	The European Green Deal provides an action plan to boost the efficient use of resources by moving to a clean, circular economy, to restore biodiversity and decrease pollution. The plan outlines investments needed and financing tools available. It explains how to ensure a just and inclusive transition. The EU aims to be climate neutral in 2050. The EU will also provide financial support and technical assistance to help those that are most affected by the move towards the green economy. This is called the Just Transition Mechanism. It will help mobilise at least €100 billion over the period 2021-2027 in the most affected regions	2019	https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en	
EC Circular Economy Action Plan	EU	action plan	The European Commission has adopted a new Circular Economy Action Plan in 2020 - one of the main blocks of the European Green Deal, Europe's new agenda for sustainable growth. Legislative and non-legislative measures	2015	https://ec.europa.eu/environment/circular-economy/	
EIB funding for circular economy	EU	awareness raising, advisory support, finance	The EU bank embraces the potential of a circular economy and we support the public and private sector in their circular transition. Includes awareness raising, advisory support in CE project pipeline development (via InnovFin advisory and European Investment Advisory Hub), provision of finance to CE projects/promoters with typically higher risk profile		https://www.eib.org/en/about/initiatives/circular-economy/index.htm	
Farm to Fork Strategy	EU	strategy	The Farm to Fork Strategy is at the heart of the European Green Deal aiming to make food systems fair, healthy and environmentally friendly. It includes 2030 target to reduce nutrient losses by at least 50%	2020	https://ec.europa.eu/food/farm2fork_en	
2018 Circular Economy Package	EU	strategies, communications, reports	EU Strategy for Plastics in the Circular Economy, Monitoring framework for the circular economy, Report on critical raw materials, Report on oxo-plastics, Eurobarometer: SMEs and the circular economy, etc.	2018	https://ec.europa.eu/environment/circular-economy/first_circular_economy_action_plan.html	
The new Bioeconomy Strategy	EU	strategy	The new bioeconomy strategy is part of the Commission's drive to boost jobs, growth and investment in the EU. It aims to improve and scale up the sustainable use of renewable resources to address global and local challenges such as climate change and sustainable development.	2018	https://ec.europa.eu/commission/news/new-bioeconomy-strategy-sustainable-europe-2018-oct-11-0_en	
Circular Bioeconomy Thematic Investment Platform	EU	financing initiative	To unleash the potential of the bioeconomy to modernise the European economy and industries for long-term, sustainable prosperity, the Commission will: establish a €100 million Circular Bioeconomy Thematic Investment Platform to bring bio-based innovations closer to the market and de-risk private investments in sustainable solutions; facilitate the development of new sustainable bio-refineries across Europe.	2018	https://ec.europa.eu/commission/news/new-bioeconomy-strategy-sustainable-europe-2018-oct-11-0_en	
Circular Economy Stakeholder Platform	EU	platform	The European Circular Economy Stakeholder Platform was launched as a joint initiative by the European Commission and the European Economic and Social Committee (EESC) in March 2017. The two institutions are working closely together to develop the Platform as a space for the exchange of ideas and a growing body of information, and to make the circular economy happen faster to the benefit of all. The Platform brings together stakeholders active in the field of the circular economy in Europe.	2017	https://circulareconomy.europa.eu/platform/strategies	
Regulation (EU) 2020/741 on minimum requirements for water reuse for agricultural irrigation	EU	Regulation	The Regulation sets out: harmonised minimum water quality requirements for the safe reuse of treated urban wastewaters in agricultural irrigation; harmonised minimum monitoring requirements, notably the frequency of monitoring for each quality parameter, and validation monitoring requirements; risk management provisions to assess and address potential additional health risks and possible environmental risks; permitting requirements; provisions on transparency, whereby key information about any water reuse project is made available to the public.		https://ec.europa.eu/environment/water/reuse.htm	
European Innovation Partnership Water - Strategic Implementation Plan	EU	partnership, strategic implementation plan	The vision for this EIP Water is: To stimulate creative and innovative solutions that contribute significantly to tackling water challenges at the European and global level, while stimulating sustainable economic growth and job creation.	2012	https://www.eip-water.eu/sites/default/files/sip.pdf	
ReSOLVE		framework	McKinsey / Ellen MacArthur Foundation; The ReSOLVE framework provides an overarching approach that exemplifies the concepts of circular economy. Some of other existing frameworks are listed in the highlighted table.	2015	Growth Within	

AWS Standard		standard, framework	Alliance for Water Stewardship; Water resources, water quality, AWS standard framework is built around five steps: gather and understand (data on shared water challenges), commit and plan, implement, evaluate, communicate and disclose	2019	https://mk0a4wsorgk6akjsiboq.kinstacdn.com/wp-content/uploads/2019/03/AWS_Standard_2.0_2019_Final.pdf	
True Cost of Water Toolkit		toolkit	Beverage Industry Environmental Roundtable (BIER); Water resources, economics, performance of beverage industry in watershed context. This interactive tool can help facilities within the beverage industry and beyond to better determine direct costs associated with their most water-intensive processes. The toolkit defines a set of pinch points or processes within a typical beverage facility with high water cost variability. For each pinch point, a true cost of water tip sheet and easy-to-use calculation worksheet has been developed.	2015	http://www.bieroundtable.com/wp-content/uploads/True-Cost-of-Water-Toolkit.xlsx	
Disclosure Initiatives for Cities and Water		framework	Carbon Disclosure Project (CDP); Water footprint, sustainable water use; CDP's work with water security motivates companies to disclose and reduce their environmental impacts by using the power of investors and customers. The data CDP collects help influential decision makers to reduce risk, capitalize on opportunities and drive action towards a more sustainable world.		https://www.cdp.net/en/water	
Water Risk and Action Framework (WRAF)		framework	International Water Stewardship Programme (IWaSP); Sharing of resources in participatory manner; set of tools for flexible application; tools address various themes, such as building relationships, assessing water risks and options for water risk mitigation measures, and making the business case for water stewardship.	2013	https://ceowatermandate.org/water-risk-action-framework/	
Resource Investment Optimization System model (RIOS)		tool	Natural Capital (NatCap) Project; Ecosystem services, carbon and economics of solutions; for hydrological ecosystem service modelling	2017	https://hess.copernicus.org/preprints/hess-2017-436/hess-2017-436.pdf	
Soil and Water Assessment Tool (SWAT)		tool	for hydrological ecosystem service modelling	2017	https://hess.copernicus.org/preprints/hess-2017-436/hess-2017-436.pdf	
WBCSD Business Guide to Circular Water Management		framework	The Business Guide to Circular Water Management outlines the current barriers to circular water management, key success factors, solutions and tools for implementation. The Guide also showcases successful examples of circular water management solutions from EDF Group, Vale, Procter & Gamble (P&G), L'Oréal, Nestlé, ENGIE, Heidelberg Cement, Shell, Aditya Birla Group (ABG) and BP.	2017	http://docs.wbcsd.org/2017/06/WBCSD_Business_Guide_Circular_Water_Management.pdf	
Guidelines on Integrating Water Reuse into Water Planning and Management in the context of the WFD	EU	guidelines	Proposes a common strategy for the development and implementation of reuse schemes including sources, uses, benefits, planning steps, public and stakeholder interaction and funding.	2016	https://ec.europa.eu/environment/water/pdf/Guidelines_on_water_reuse.pdf	
Standards for the reuse of treated wastewater for irrigation	Cyprus	standards	Standards for the reuse of treated wastewater for irrigation, Decree no. 296/03.06.05 adopted in 2005 along with a Code of Good Agricultural Practice (P.I. 263/2007). Issuing institutions: Ministry of Agriculture, Natural resources and Environment Water development Department	2005	https://www.water-reuse-europe.org/about-water-reuse/policy-and-regulations/#page-content	https://cor.europa.eu/en/engage/studies/Documents/Water-reuse.pdf
Regulation for water reuse for agricultural and green areas irrigation	France	regulation	Regulation for water reuse for agricultural and green areas irrigation. Official Journal of the French Republic. Decree n◦0153 du 4 of July 2014 Page 11059 Text No. 29, by which the Previous Decree is Modified for the Use of Treated Effluents for Irrigating Crops or Green Areas. Issuing institutions: Ministry of Ecology, sustainable development and energy; Ministry for Social Affairs and Public Health; Ministry of Agriculture, Agri-Food and forests "The quality standards for reclaimed water in France are strongly linked to the national legislation on the agricultural spreading of sewage sludge resulting in quality monitoring of not only the reclaimed water but also of the sewage sludge and agricultural soils30."	2014	https://www.water-reuse-europe.org/about-water-reuse/policy-and-regulations/#page-content	https://cor.europa.eu/en/engage/studies/Documents/Water-reuse.pdf
Common Ministerial Decision regulating reuse of treated wastewater	Greece	Decision	Common Ministerial Decision No 145116 (354B)/08.03.11: Measures, Limits and Procedures for Reuse of Treated Wastewater. Issuing institution: Hellenic Ministry of Environment, Energy and Climate Change.	2011	https://www.water-reuse-europe.org/about-water-reuse/policy-and-regulations/#page-content	https://cor.europa.eu/en/engage/studies/Documents/Water-reuse.pdf
Regulations for water reuse	Italy	regulations	Italian regulations for water reuse, MINISTERIAL DECREE of the 12 June 2003, no. 185 Issuing institutions: Ministry of Environment; Ministry of Agriculture, Ministry of Public Health	2003	https://www.water-reuse-europe.org/about-water-reuse/policy-and-regulations/#page-content	https://cor.europa.eu/en/engage/studies/Documents/Water-reuse.pdf

Regulations for water reuse for irrigation purposes	Portugal	official standard	Regulations for water reuse for irrigation purposes. Portuguese Standard NP 4434. Issuing institution: Portuguese Institute for Quality; NP 4434:2005 – norma portuguesa para reutilização de águas residuais urbanas tratadas na rega	2006	https://www.water-reuse-europe.org/about-water-reuse/policy-and-regulations/#page-content	https://cor.europa.eu/en/engage/studies/Documents/Water-reuse.pdf
Regulations for Water Reuse	Spain	regulations	Regulations for Water Reuse – Royal Decree RD 1620/2007 of 7 December, State Official Journal, BOE no. 294, of 8 December 207, pages 50,639 to 50,661. The decree establishes a legal framework for the reuse of treated wastewater, ensuring wastewater recycling and reuse is performed under principles ensuring optimum health and environmental protection. Issuing institutions: Ministry of Environment; Ministry of Agriculture, Food and Fisheries, Ministry of Health	2007	https://www.iwa-network.org/filemanager-uploads/WQ_Compendium/Database/Selected_guidelines/042_2.pdf	https://cor.europa.eu/en/engage/studies/Documents/Water-reuse.pdf
Report on Urban Water Reuse	EU	report	Report on industrial and urban water reuse best practices and permitting process, promoted and disseminated by the project IMPEL. The aim of this part of the project is, on the one hand, to enhance the guidelines on industrial water management best practices for three industrial sectors (Refinery, Pulp & Paper, Textile) developed in the previous project and test one sector in practice with a selected industrial operator and, on the other hand, to exchange current best practices with respect to water reuse of treated urban waste waters.	2018	https://www.impel.eu/wp-content/uploads/2019/01/FR-2018-07-Urban-Water-Reuse-1-1.pdf	
Guidelines for the safe use of wastewater, excreta and greywater	global	guideline	WHO Report 2006? Volume 4 of the Guidelines for the safe use of wastewater, excreta and greywater provides information on the assessment and management of risks associated with microbial hazards. It explains requirements to promote the safe use of excreta and greywater in agriculture, including minimum procedures and specific health-based targets, and how those requirements are intended to be used.	2006	https://www.who.int/water_sanitation_health/publications/gsuweg4/en/	
Guidelines for municipal wastewater reuse in the Mediterranean region	Mediterranean	guideline	UNEP 2005.	2005	file:///Users/alchemia-nova/Downloads/05wg270_inf19_eng.pdf	
Development of performance indicators for the operation and maintenance of wastewater treatment plants and wastewater reuse	global	guideline	UNEP 2011. In the context of a continuously increasing development of wastewater treatment and reuse, the main objective of this document is to provide comprehensive compliance indicators for the operation and maintenance of wastewater treatment plants and reuse facilities. The target audience is broad, including supervisors and/or operators of treatment plants, as well as competent representatives of the end-users and decision-makers.	2011	https://wedocs.unep.org/bitstream/handle/20.500.11822/6623/11wg357_inf9_eng.pdf?sequence=1	
Proceedings of the UN Water project "Safe use of wastewater in agriculture"	global	guideline	The "Safe Use of Wastewater in Agriculture" project is a joint activity carried out under UN-Water and coordinated by the UN-Water Decade Programme on Capacity Development (UNW-DPC)	2013	https://collections.unu.edu/eserv/UNU:2661/proceedings-no-11_WEB.pdf	
ISO/TC282 Water reuse	global	standard	ISO, excludes limit of allowable water quality in water reuse; published standards and standards under development		https://www.iso.org/committee/4856734.html	
Water quality for agriculture	global	guideline	FAO 1994. The document is presented as a field guide for evaluating the suitability of a water for irrigation. Included are suggestions for obtaining maximum utilization of an existing or potential water supply. Guideline values given identify a potential problem water based on possible restrictions in use related to 1) salinity, 2) rate of water infiltration into the soil, 3) a specific ion toxicity, or 4) to some other miscellaneous effects. Discussions and examples are given along with possible management alternatives to deal with these potential problems.	1994	http://www.fao.org/3/t0234e/t0234e00.htm	
water tax scheme	Netherlands	fiscal measure	To stimulate the reuse of water tax are raised on the use of fresh ground water while the use of reused treated wastewater has a discount. Despite these measures two major industries currently use only fresh ground water: agriculture and thermal energy storage in cities, since there is no shortage of fresh ground water to trigger these industries to also reuse treated ground water. Examples of water reuse: horticulture area Nieuw-Prinsenland, Greenhouse water recycling, in the galvanic industry.		http://www.moa.gov.cy/moa/environment/environmentnew.nsf/all/413CA90AB497F4DEC22582820029C689/$file/Impel%20Urban%20Water%20Reuse%20Report.pdf?openelement	
86/278/EEC Sewage Sludge Directive	EU	Directive	The Sewage Sludge Directive 86/278/EEC seeks to encourage the use of sewage sludge in agriculture and to regulate its use in such a way as to prevent harmful effects on soil, vegetation, animals and man. To this end, it prohibits the use of untreated sludge on agricultural land unless it is injected or incorporated into the soil. The Directive also requires that sludge should be used in such a way that account is taken of the nutrient requirements of plants and that the quality of the soil and of the surface and groundwater is not impaired.	1991	https://ec.europa.eu/environment/waste/sludge/	
Regulation (EU) 2019/1009 on EU fertilising products	EU	Regulation	Fertilizing Product Regulation and Recent Reports on Digestate and Compost: HYDROUSA deliverable report on policy: "Partial constraint found for EC-marked and labelled compost"	2019	https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R1009&from=EN	

The Joint Declaration of Intent for the INNOVATION DEAL on sustainable waste water treatment combining anaerobic membrane technology and water reuse	EU	Joint Declaration of Intent, voluntary cooperation agreement	The Innovation Deal is about the shift from the conventional treatment of urban wastewater to using it as a water resource. The intense reuse of treated wastewater will contribute to overcoming the challenge of water scarcity.	2017	https://ec.europa.eu/research/innovation-deals/pdf/jdi_anmbr_042017.pdf	
Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 on the establishment of a framework to facilitate sustainable investment	EU	financing initiative	Transition to a circular economy; climate change mitigation and adaptation; and protection and restoration of biodiversity and ecosystems are among its 6 objectives		https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:32020R0852	
Circular Economy Finance Support Platform	EU	facilitation initiative	To support the EU's circular economy action plan. The platform was intended to boost investment in the circular economy by drawing on both public and private resources and utilising tools such as the European Fund for Strategic Investments (EFSI).		https://www.eea.europa.eu/publications/circular-economy-in-europe-insights	