Circular Water Solutions

Roadmap to addressing governance and societal challenges to support wider uptake of circular solutions in the water sector

Deliverable D4.4

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Summary

The EU H2020-project NextGen demonstrates innovative technological, business and governance solutions for water in the Circular Economy (CE). This deliverable addresses the governance and societal challenges and presents a roadmap to support wider uptake of circular solutions in the water sector.

Applying CE principles to the water sector requires a holistic vision and an integrated approach. Technological, economic, socio-cultural and regulatory conditions determine the shift from a linear to a circular water economy. At the ten NextGen demo cases, 12 key drivers, 20 key barriers and 20 key support measures to the upscaling of solutions have been identified.

The main driver identified is *Responding to environmental challenges*, and the main barrier is *Lack of clear policy for resource recovery.* Representatives of the demo cases disclosed 20 support instruments that will enable the uptake of their circular water technology (see Table A), with *R&D / Proof of Concept* and *Active stakeholder engagement* listed by all.

Table A: Main support instruments that will enable the further implementation / upscaling of the circular water technology at the ten demo cases

Technology instruments	Economic instruments
R&D / Proof of Concept	Tariff structures that favor reuse and tax water use
Public evidence database of circular water schemes	Subsidies for secondary materials and recycled water
Master list of water quality parameters and risk database	Investment grants (ESG / green bonds)
Quality control and monitoring procedures	Risk sharing in PPP arrangements
Environmental Technology Verification	Market place to connect producers and consumers
Socio-cultural instruments	**Regulatory instruments**
Information sharing and public outreach campaigns	Stricter environmental regulations
Active stakeholder engagement	Improved clarity of Water Reuse Regulation
Socio-political work to push CWT	Planning and building frameworks adapted for small-scale CWT
Independent review panels	Simplified process for achieving end-of-waste status
Positive framing of reused water / recovered product	Better aligned EU directives (with circularity emphasis)

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What emerges from the analysis of needs for a circular transition, is that the conditions are to be analysed together, using a system approach. In a working session with all NextGen partners, the respective planning and sequence on a short to long term was discussed. There was agreement that for an effective transition, simultaneous efforts were needed across all four categories of instruments, starting immediately. Thus, a roadmap for the uptake of circular water solutions would have to consist of a comprehensive 'package' of enabling instruments at short-term.

Establishing such a package of instruments would speed up the implementation of different types of circular water technologies. A roadmap is proposed with the EU wide uptake of *Reduce of resources* in the short term (2020-2025), *Reuse / recycle water* in the short to medium term (2020-2030), and the *Recovery of products* in the medium term (2025-2030). Although *Rethink the CE water system* will most likely take a long term perspective (2030-2050), strategies that legitimise circular water technologies in society and the economy have to be employed already now.

It is concluded that, to support the uptake of circular water solutions, technological, economic, socio-cultural and regulatory instruments are needed. A comprehensive 'package' of enabling instruments is required, as all four conditions for a circular water economy will have to be successfully created simultaneously:

- circular water technologies, that are sustainable at system level
- economic viability, based on circular value chains
- societal acceptance, along with engaged stakeholders
- adapted governance, with supportive regulations.

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Updates from previous version

Reviewer's comments	Correction
The deliverable addresses barriers, drivers and support measures for the upscaling and enabling governance conditions linked to the demo cases and presents a good overview in the form of matrices. Relevant types of support measures and enabling instruments are identified, though rather at a general level. The report presents a clear roadmap, e.g. fig 5.1.	Table 5.1 is added aligning support instruments with steps in the roadmap framework.
The last component in fig. 5.1 is Rethink. This "Rethink the CE water system" is one of the main outcomes of this entire NextGEN exercise and should be elaborated more than the half page of this report.	Rethink the CE water system is elaborated in section 5.1 with elements relevant to a system-level change.
The resulting recommendations remain rather at a theoretical level. In order to be convincing and leading to a "buy in" and practical implementation, recommendations, in particular targeting the policy level, should be as specific as possible, referring to particular results of case studies.	In section 5.2, practical recommendations are proposed to policy and the water sector.
Reviewer's comments	**Correction**
The deliverable has been resubmitted and amended. However, the policy recommendations remain still too vague and do still not explicitly refer to specific case studies as requested in the previous feedback.	In section 4.5 reference to specific demo cases for each policy recommendation are added. Specific recommendations for each demo case are added in section 4.6.

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1. Introduction

1.1 Background and objectives

The circular economy (CE) is an emerging system that moves away from the traditional linear view of 'make, use, and dispose' to one that is restorative and regenerative to keep resources, such as water, at its highest value at all times. Water is essential to the CE due to its importance for human life, its use and value in numerous economic sectors, and because of the energy and material it contains.

While CE concepts are increasingly well established and technological advances have accelerated the adoption of CE models, the implementation is still in the early stages in most sectors. The principal challenges to achieving a CE are not only technological, but also governance related. For instance, in the water sector, emerging technologies allow for many resources to be recovered, but their uptake can be hindered by concerns over economic feasibility, uncertainty around the application of policy and regulatory frameworks, and the need for long-term engagement with key stakeholders and the wider public.

Considering these challenges, the EU H2020-project NextGen takes an integrated approach addressing technological, environmental, economic, business, participatory, societal, regulatory and governance aspects of the circular water economy. NextGen demonstrates circular water technologies (CWT) that work in practice (see Annex A) and creates the conditions for further upscaling and transferring of the technologies.

This deliverable addresses the governance and societal challenges to support wider uptake of circular solutions in the water sector. The objectives are:

- identifying the main barriers and enabling options for upscaling the circular water solutions at the ten NextGen demo cases
- developing a 'roadmap' with a proposed transition route for the water services sector towards the CE in the EU.

Contribution to the NextGen project

This deliverable presents the results of Task 4.3. In this task, we explored evidence-based knowledge from the ten demo cases to identify the barriers to, and enablers for, adopting circular value chains in the water and wastewater sector, upscaling solutions and transferring technologies. Task 4.3 builds on the results from the societal acceptability assessment (Task 4.1), supportive policy and regulatory frameworks (Task 4.2), generic lessons from stakeholder engagement (Task 3.3), and the EU policy engagement activities (Task 6.3).

We have identified at the ten NextGen demo cases 12 key drivers, 20 key barriers and 20 key support measures to the upscaling of solutions (KPI7) and outlined the enabling governance framework conditions for the transition to a CE in the water sector (SO4), including a roadmap for a broader transition in the EU (EI8).

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1.2 Report structure

After a brief overview of the principles of the circular water economy, the CE characteristics of the ten NextGen demo cases are presented in chapter two.

Chapter three describes the technological, economic, socio-cultural and regulatory conditions required for circular water solutions, and presents the key drivers and barriers of the NextGen circular water technologies.

In chapter four, the support instruments that enable the uptake of our solutions are presented. Success factors related to circular water technology, economic viability, societal acceptance and adapted governance are described.

We conclude in chapter five with a roadmap and strategies that support the further uptake of circular water solutions in the EU.

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2. NextGen in the circular water economy

2.1 Circular water economy principles

In 2015, the EC launched an action plan for the transition to a more circular economy, where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimised (EC, 2015). Society and business have started to move away from a linear model of 'make, use and dispose' and instead developed closed looped systems that increase efficiency and optimize reuse. The European Union launched a new circular economy action plan in 2020 (EC, 2020). According to this plan: "To achieve climate neutrality by 2050 and decouple economic growth from resource use, while ensuring the long-term competitiveness and leaving no one behind, the EU needs to accelerate the transition towards a regenerative growth model that gives back to the planet more than it takes and keep its resource consumption within planetary boundaries. Therefore, the EU needs to double its circular material use rate in the coming decade. This progressive, yet irreversible transition to a sustainable economic system is an indispensable part of the new EU industrial strategy".

The Ellen MacArthur Foundation (EMF), who are key leaders in the field of the CE, promote a circular economy based on the principles of designing out waste and pollution, keeping products and materials in use, and regenerating natural systems. "A circular economy is one that is restorative and regenerative by design and aims to keep products, components, and materials at their highest utility and value at all times, distinguishing between technical and biological cycles" (EMF, 2015, p2). The overarching idea is to break down the connection between growth and finite resource consumption.

Also, water has predominantly been viewed in a linear way. Water is withdrawn from rivers, reservoirs and groundwater aquifers; used by agriculture, industry, society and the environment; and then returned to the water basin directly or via a treatment facility. This current system is often inefficient as water is lost, polluted and wasted. Efforts are needed to improve the efficient use of water and reduce water pollution in society and business. The water sector itself is becoming more sustainable and energy efficient in its operation for the production of drinking water and treatment of wastewater. There is a need to shift from the short-sighted and unsustainable linear management approach (take-use-discharge) to more circularity (Brears, 2020). Recently, important circular steps are being taken by closing water systems, reusing water, generating energy and recovering nutrients (e.g. Kakwani & Kalbar, 2020; Kehrein et al., 2020). The next step is to contribute to the overall circular economy, by connecting water and its embedded resources to the circular ambitions of other economic sectors. In fact, water is considered essential to the CE due to its importance for human life and because of the energy and material it contains.

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The Ellen MacArthur Foundation have defined the following three CE principles applicable to water systems (Tahir et al., 2018):

1. Design out waste and pollution: both by optimising the amount of energy and chemicals used in operation of water systems, and by substituting the need for water itself in agriculture and industry.
2. Keep products and materials in use: through the recovery and reuse of energy (heat, biogas) and materials (e.g. nutrients) from (waste)water.
3. Regenerate natural systems: by reducing water use and ensuring minimum disruption to natural water systems from human intervention.

All possible externalities linked to the use of water must be integrated: water as a service (consumption, production, process), water as energy (kinetic, thermal, bio-thermal), and water as a carrier (of nutrients, chemicals, minerals). The challenge is to better align the human water cycle with the natural water cycle through the following measures: avoid use, reduce use, reuse, recycle and replenish water.

In line with EMF is the World Bank framework linked to resilience: the Water in Circular Economy and Resilience (WICER) Framework (Delgado et al, 2021). The WICER framework is divided into three primary outcomes with corresponding actions:

1. Deliver resilient and inclusive services: diversifying supply sources, optimising the use of existing infrastructure, and planning and investing for climate and non-climate uncertainties.
2. Design out waste and pollution: being energy efficient and using renewable energy; optimising operations and recovering resources.
3. Preserve and regenerate natural systems: incorporating nature-based solutions; restoring degraded land and watersheds; and recharging and managing aquifers.

The International Water Association (IWA, 2016) develop a framework of three interrelated pathways – water, materials and energy – that aim to help utilities identify integration points within systems that enable their transition to the circular economy. It expresses the role water utilities can take in identifying practices, approaches and business models that can lead to greater efficiency of water use, lower carbon-based energy consumption and providing valuable materials for manufacturing and agriculture.

NextGen partner KWR has specified the strategies that realise the CE to water, as water is considered a special case in the CE because it is a resource, product or service with no equivalent in the economic systems (Morseletto et al, 2021). The most common strategies that realise the CE in the literature are: Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle and Recovery (known as the R-strategies; see Moraga et al., 2019). However, some of these strategies refer to general resources and industrial productions that do not fit adequately the water context. Our analysis revealed some of the CE strategies need to be re-calibrated for water.

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Except for Rethink, which is considered as a stand-alone and overarching strategy, the (re-calibrated) strategies have been organised into three blocks (see Figure 2.1):

- Decreasing: avoid, reduce, replace
- Optimising: reuse, recycle, cascading
- Retaining: store, recovery

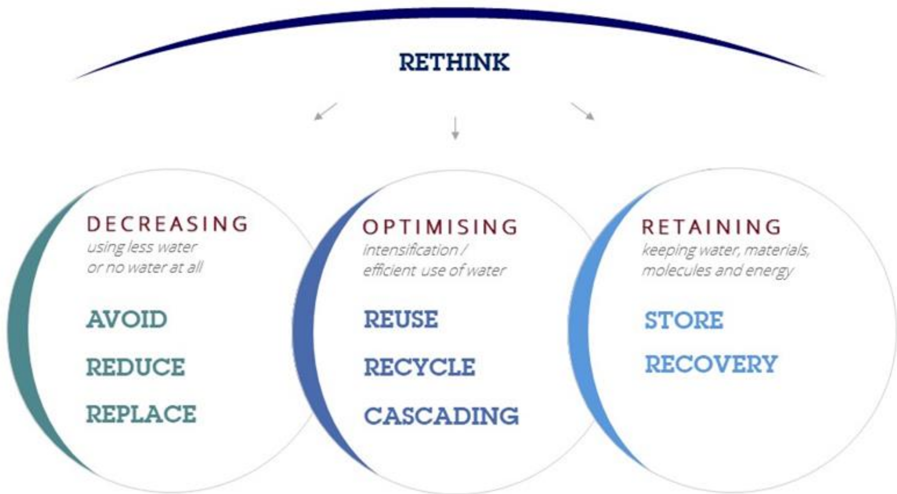

Figure 2.1: Strategies in the circular water economy
Source: Morseletto et al. (2021)

Rethink means reconfiguring and re-conceptualizing the water system, together with all water using sectors, to favour a more circular utilisation of water. It implies the re-design/restructuring of the contextual setting and potentially every operative aspect of the water use such as practices, processes, policies, facilities, technologies and way of thinking (Eneng, 2018); a systematic change in the whole water value chain (Smol et al., 2019). This transformational change implies a system thinking at multiple levels (from individual to international) in which solutions are applied (Iacovidou et al., 2020). Water Europe urges to consider the real 'value of water' to develop systemic solutions and changes towards a circular water-smart society (Water Europe, 2017).

NextGen partner KWR included the rethinking strategy as a system-level characteristic of the circular water economy, building on Rockström et al (2009) *Planetary Boundaries*. Moreover, we added societal values as a key characteristic for a circular economy, in line with Raworth (2017) *Doughnut Economics*. Figure 2.2 presents the three categories of characteristics defined for the delineation of the concept of circular economy for the water sector (Segrave et al., 2020):

1. Resource flows: physical characteristics of (parts of) the water cycle in relation to the environment
2. Societal values: socio-political characteristics of (parts of) the water cycle
3. System properties: system-level characteristics of (the whole) water cycle.

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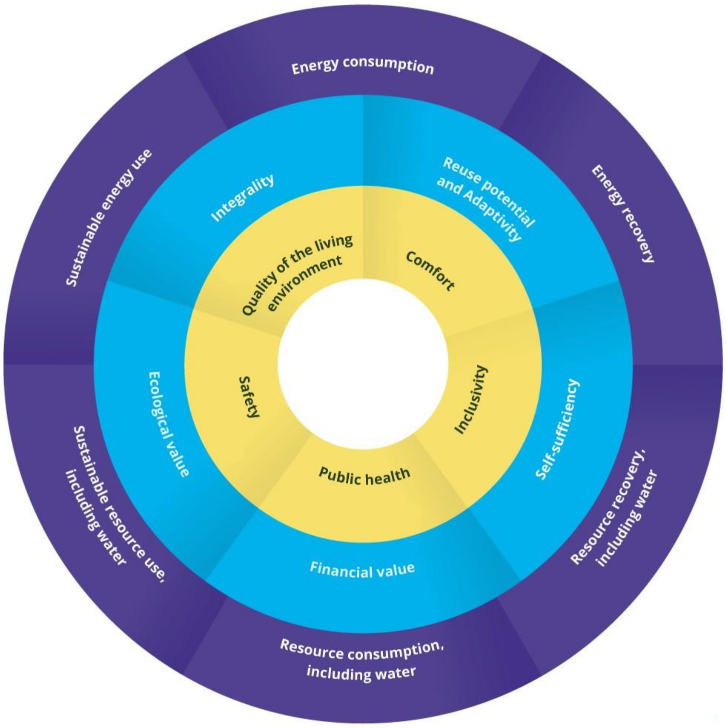

Figure 2.2: Characteristics of circular water economy
Source: Segrave et al. (2020)

2.2 Legitimation of circular water solutions

The circular water paradigm challenges the linear management approach with its current legal and social norms and practices. To overcome such challenges, we need to focus on legitimising circular water technologies in society and the economy. Legitimacy differs from public acceptance by providing a more holistic approach. Harris-Lovett et al. (2015) and Binz et al. (2016) distinguish the following legitimation dimensions:

- Regulative legitimacy (legal frameworks and regulations) is the capacity to set up rules and assess others' congruence to them;
- Normative legitimacy (norms and values) is the active judgment of whether a solution fits social values and norms in a manner that enhances societal welfare;
- Cognitive legitimacy (knowledge and capabilities) is a passive assumption that an organisation is comprehensible and taken for granted;
- Pragmatic legitimacy (social, economic, and environmental benefits) is based on the self-interest calculations of benefits brought by a circular solution to its end users.

In Task 4.1, the concept of legitimacy with its four dimensions, provided for a holistic understanding of public acceptance, societal reactions and expectations towards circular solutions (see D4.2).

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In Task 4.3, a framework has been developed to access the transition to water circularity, with a central role for legitimation actions (see the NextGen journal paper of Afghani et al., 2022). The framework consists of the following stages:

1. describing and understanding the water context, based on the Multilevel Perspective Framework (Geels, 2002)
2. assessment of the selected technologies' circularity level, based on the WICER framework, see section 2.1 (Delgado et al, 2021)
3. assessment of the alternative circular technologies' legitimacy, identifying barriers and enablers, see chapters 2 and 3
4. identification of the legitimation actions to support the upscale of alternative circular technologies (Harris-Lovett et al., 2015; Binz et al., 2016)

In this report, we build on this framework in the identification of barriers and enablers, and the legitimation strategies to rethink the CE water system (see Figure 2.3).

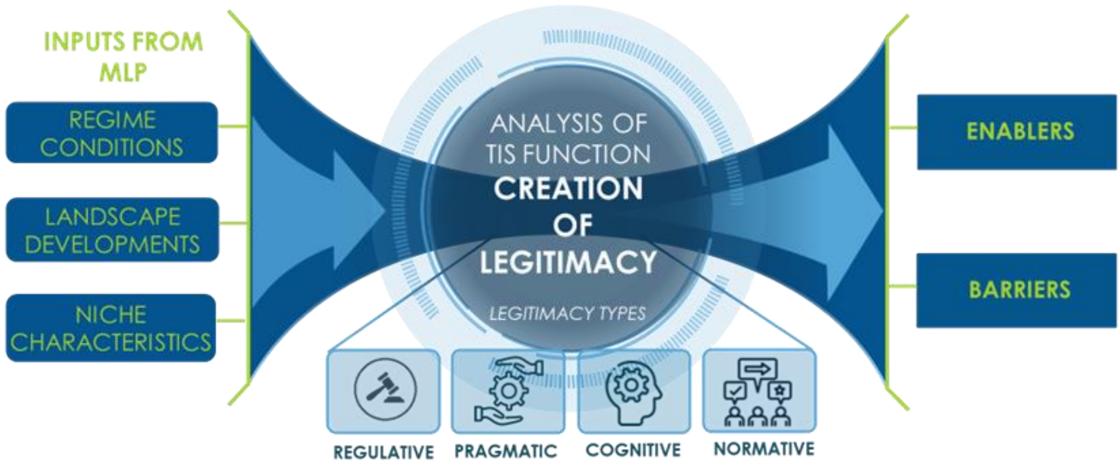

Figure 2.3: Legitimacy assessment of circular water technologies
Source: Afghani et al. (2022)

2.3 CE characteristics of the NextGen demo cases

By embracing circular economy principles and technological innovation, the NextGen demo cases preserve natural capital, optimise resources and improve system efficiency. Our approach is thus in line with the definition of the Ellen MacArthur Foundation of CE for water systems and the WICE framework, with a focus on keeping resources in use.

The characteristics of the circular water technologies differ at the NextGen demo cases. The R-strategies for the water sector (Morseletto et al., 2021) show that emphasis is on the demonstration of technologies for Recycling (treating previously used water for the benefit of further uses) and Recovery (extracting nutrients, other valuable materials and energy from water), see Table 2.1.

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Table 2.1: Recalibrated R-strategies for the NextGen technologies at the demo cases

DEMO CASE	TECHNOLOGY	RETHINK	AVOID	REDUCE	REPLACE	REUSE	RECYCLE	CASCADING	STORE	RECOVERY
Braunschweig (DE)	Two-stage digestion and sludge hydrolysis						✓			✓
	Nutrient recovery: Ammonia stripping; Struvite precipitation									✓
Costa Brava (ES)	Multi-purpose water reclamation and reuse						✓		✓	
	Membrane filtration with regenerated RO membranes					✓				✓
Westland Region (NL)	Alternative water sources / ASR for horticulture	✓		✓			✓		✓	
	HT-ATES: high temperature aquifer thermal energy storage								✓	✓
	Material brokerage									✓
Altenrhein (CH)	Ammonia membrane stripping									✓
	P-recovery by thermochemical treatment of sludge									✓
	Granulated activated carbon via pyrolysis									✓
Spernal (UK)	Multi-stream anaerobic MBR for decentralized water reuse						✓			
	Energy recovery from AnMBR									✓
	Nutrient recovery from AnMBR via adsorption and ion exchange									✓
La Trappe (NL)	Metabolic Network Reactor to produce fit-for-purpose water						✓			
	Protein production in Bio-Makery									✓
Gotland (SE)	Rainwater harvesting and decentralized membrane treatment						✓		✓	
	Energy efficient reclamation of wastewater						✓			
Athens (EL)	Sewer Mining mobile wastewater treatment for decentralized reuse						✓			
	Heat recovery from MBR									✓
	Nutrient recovery for urban agriculture									✓
Filton Airfield (UK)	Integrated drainage system for urban water reuse	✓					✓			
	Heat recovery from sewer									✓
	Eco-sanitation systems with nutrients recovery									✓
Timisoara (RO)	Sludge management with production of by-products / energy									✓
	Reuse of effluent for urban, industry and agriculture applications						✓			

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The NextGen demo cases are not only about technologies, but they demonstrate the implementation of circular solutions for a radical redesign of water services. A Rethinking strategy that includes resource flows, societal values, and system properties (Segrave et al, 2020). NextGen brings new market dynamics throughout the water cycle, addressing social and governance challenges to ensure long-term adoption and support for circular economy solutions. For that reason, an integrated approach is taken within the NextGen project, as reflected in the different Work Packages. Such an integrated approach is essential in the further uptake of circular water solutions in Europe (see next chapters).

Finally, an important characteristic of NextGen is that the circular water solutions at the demo cases are, in one way or the other, connected to other sectors such as agriculture, energy, industry, housing (see figure 2.4). It is indeed the very essence of circularity, which unlike the notion of sustainability, creates interdependencies between sectors. This interconnection to other sectors is even more necessary in the field of water, since it is present in many, if not nearly all sectors of activity (Nika et al., 2020; Smol et al., 2020).

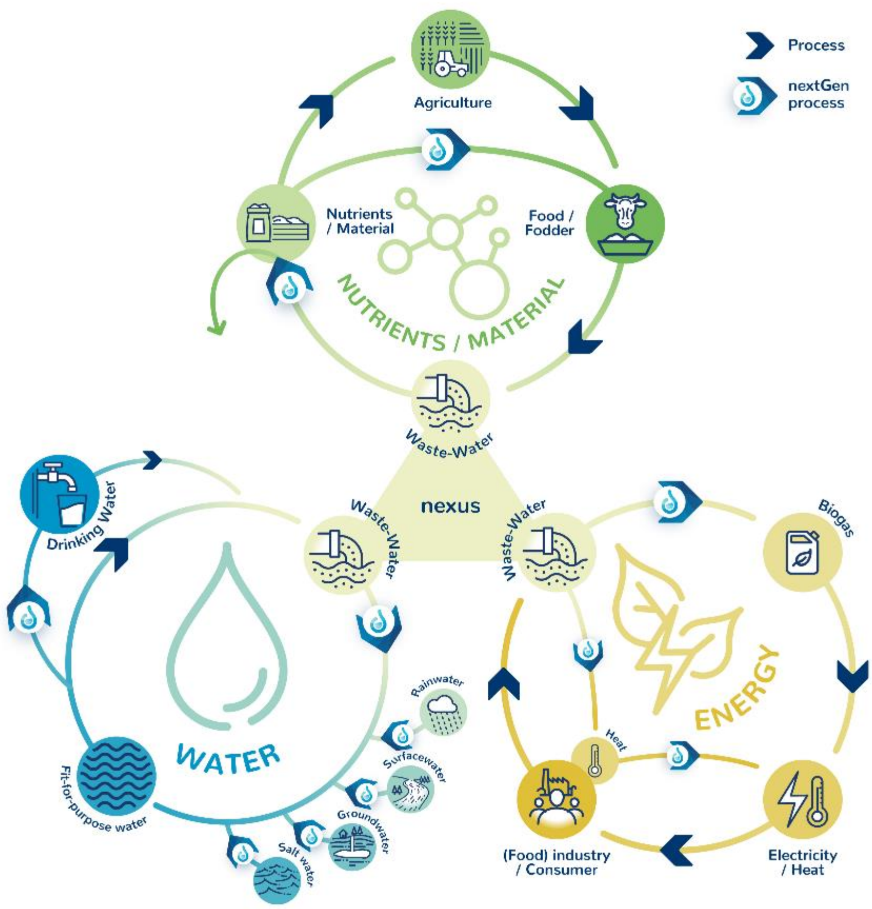

Figure 2.4: NextGen in the CE Nexus

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3. Conditions needed for circular water solutions

While CE concepts are increasingly well established, they remain largely in the early stages of implementation in most sectors (Ghisellini et al., 2016). Technological advances have accelerated the adoption of CE models in some areas, but progress is often slow. Some now suggest that the principal challenges to achieving a CE are not technological, but governance related. For instance, in the water sector, current and emerging technologies allow for many resources to be recovered, but their uptake can be hindered by concerns over economic feasibility, and uncertainty around the application of policy and regulatory frameworks (Owen & Liddell, 2016). Previous work around water reuse has also identified a number of governance related challenges to further development in the sector (Frijns et al., 2016). These relate to uncertainty over regulatory requirements, and the need for long-term engagement with key stakeholders and the wider public.

Applying CE principles to the water sector requires a holistic vision to pick the most circular solution (Viles et al., 2020). The circularity of water follows a fit-for-purpose approach. This approach means creating new water loops, new water sources and qualities, new actors, new responsibilities, but also potential health and environmental risks. Thus, as emphasised in the previous chapter as well, the move from a linear to a circular water system requires an integrated approach.

The need for an integrated approach is also evident from an extensive literature review (see our reports Lasseur, 2020; Afghani, 2021; Sahondo, 2022), from which we identified four categories that define the conditions required for circular water solutions (see Figure 3.1). The technology, economic, socio-cultural and regulatory drivers and barriers (see e.g. Kakwani & Kalbar, 2020; Kehrein et al., 2020; Salminen et al, 2022) are described in the sections below, and their enabling conditions in the next chapter.

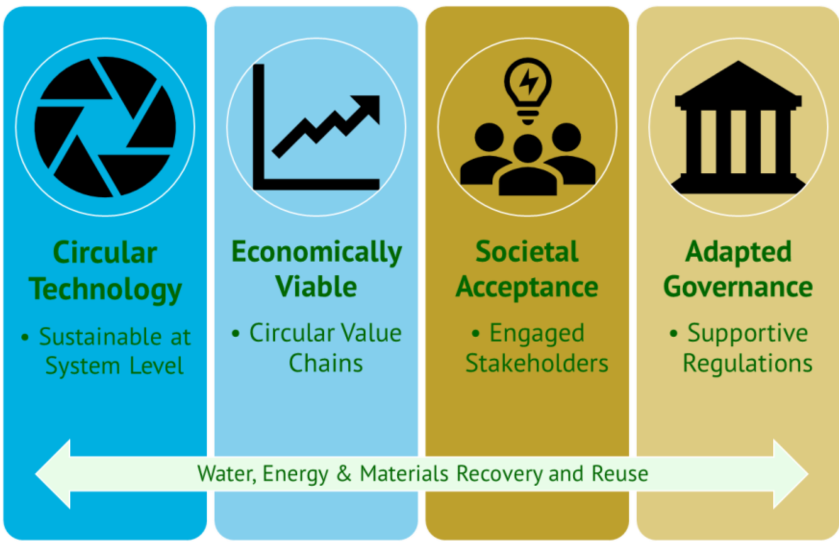

Figure 3.1: Conditions needed for circular water solutions

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3.1 Technology conditions

The first condition, obviously, is to have innovative, operational circular water technologies (CWT). Assembly of efficient technologies concerns the optimization of existing ones in view of the development of new innovative circular systems, regarding the recovery of water, resources and energy. Some of these CWTs are already well developed and proved efficient today, while others, and the circular system in general are still at the prototype stage (Kakwani & Kalbar, 2020; Kehrein et al., 2020). The maturity of the technology needs to be demonstrated. Innovation, price and knowledge & expertise (e.g. accessible data, Liu et al., 2021) are key drivers and barriers for the development of CWT. Physical conditions, i.e. fit to existing infrastructure, considerations on space, odour, noise, are relevant to CWT uptake as well.

Technological innovation turns wastewater treatment plants into energy and raw materials factories. Specific for the recovery of products, a key barrier is that either the quality (e.g. due to contaminants or impurities) or the quantity (compared to conventional production systems) is not yet adequate or sufficient for a successful market uptake (Gherghel et al., 2019; Kehrein et al., 2020).

Attention should be paid to the environmental purpose of circular technologies. Developing closed-loop production processes should not increase the pressure on the environment and create negative effects outside the process. The recovery process may cause emissions and the risk of accumulating contaminants needs to be prevented seeing the impacts contaminants can have on the environment and human health (Guerra-Rodríguez et al., 2020; Kehrein et al. 2020). In short, the circular technologies should be sustainable at a system level, taking multidimensional benefits and impacts at the system level into account (Iacovidou et al., 2020). This is in particular valid for balancing greenhouse gas emissions (e.g. through energy required for recovery processes) with environmental benefits from circular systems.

Table 3.1: Technology drivers and barriers

Technology driver	Technology barrier
Technology innovation	Immaturity of the CWT
Price and affordability of CWT	Lack of knowledge and expertise
Ageing infrastructure	Associated environmental and health risks
	Existing infrastructure
	Inadequate quality or quantity of recovered product

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3.2 Economic conditions

The transition to a CE is becoming increasingly important in the business strategy of water companies as an economic or market driver (Salminen et al., 2022). Savings can be achieved by reduced treatment of discharge costs, and benefits are envisaged from reduced use and recovered products. However, this business strategy often requires high upfront investments, and the economic merits are challenged by the current low prices of water and linear resources and high market prices of the recovered products that are not yet competitive (van Leeuwen et al., 2018). On the other hand, as the technology develops its economic balance sheet should improve; perceived economic viability changes as the TRL level improves.

An often mention and rather obvious precondition is, that the CWT are economically viable (Mallory et al., 2020; Mannina et al, 2022). However, CWTs do not have to be economically viable per se. In many asset decision making frameworks, there can be an overemphasis on the need for selected technologies to be economically viable, and that in itself can present a barrier to the uptake of CWTs when they are considered alongside other, more established technologies. In order to 'level the playing field' for CWTs, decision making frameworks need to give greater weight to strategic environmental and social priorities (Sahondo, 2022).

Additionally, in a circular economy, new value chains need to be developed, with circular business models that include societal values within economic cost-benefit analyses. However, finding partners in the circular value chain is difficult (Kehrein et al., 2020).

Table 3.2: Economic drivers and barriers

Economic driver	Economic barrier
Business strategy	Poor economic viability
Reducing costs of wastewater discharge or treatment	Low price of water and virgin materials
Financial benefits of reduced water use / recovered by-products	High upfront investment costs
	High price of recovered products
	Challenges in finding partners in new value chain

3.3 Socio-cultural conditions

One of the main drivers for the CE is the urgent climate change crisis. Pressure from society to respond to environmental challenges such as climate change, including the increased awareness of water quantity and quality problems, drive the water sector towards a more sustainable and circular operation (Salminen et al, 2022).

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At the same time, circular solutions such as water reuse are hampered by fears of negative attitudes and low acceptance by the public and by water professionals. This has to do with perception (e.g. the yuck factor) but also with a lack of trust in the water organisations and involved governmental institutions (Smith et al., 2018).

Another socio-cultural barrier relates to the challenge for new collaboration and business models, that require new competences, partnerships with other sectors and interaction (communication) with authorities (Kakwani & Kalbar, 2020).

Table 3.3: Socio-cultural drivers and barriers

Socio-cultural driver	Socio-cultural barrier
Increased water awareness	Negative attitudes towards CWT
Responding to environmental challenges	Communication challenges with authorities
Positive brand image	Reluctance to collaborate with other sectors
	Hesitant culture in water organization
	Lack of trust in institutions (for monitoring and control)

3.4 Regulatory conditions

The regulatory framework can be both an important driver for CWT (i.e. strict environmental standards push advanced treatment processes) as well as a key barrier (e.g. recovery and reuse of by-products not allowed) (Salminen et al, 2022).

Unfortunately, current regulations act mainly as barrier due to e.g. cumbersome permit practices, lengthy end-of-waste status procedures, restrictive conventional urban planning, and lack of comprehensive (EU water) policies (Cipolletta et al. 2021, Qtaishat et al. 2022).

There is also a lack of capacity and governmental incentives and poor understanding of responsibilities (Ddiba et al., 2020), but at the same time the availability of public financing can drive R&D and investment in CWT.

Table 3.4: Regulatory drivers and barriers

Regulatory driver	Regulatory barrier
Regulatory requirement	Current legislation hinders reuse
Demands set in environmental permit	Lack of clear policy for resource recovery
Availability of public financing	Complexity of environmental permits
	Unpredictability of (future) legislation
	Variation in regulations in EU countries

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3.5 Drivers and barriers at the NextGen demo cases

In a NextGen WP4 visioning and strategic planning meeting with all partners (at PSB05 Barcelona), the respective representatives of each demo case, scored their top 3 drivers (Table 3.5) and main barriers for one of their key circular water technologies (Table 3.6).

The findings are in accordance with literature. All drivers identified from literature were selected by at least one demo case as a top 3 driver for their CWT. The distribution over the 4 categories is quite even. *Responding to environmental challenges* is listed the most as demo case representatives emphasised climate change as an important driver.

All barriers identified from literature were selected by at least one demo case for their CWT. The distribution over the 4 categories is quite even. However, 4 demo cases (Braunschweig, Altenrhein, Athens, Filton Airfield), did not select socio-cultural aspects as a barrier for their CWT.

The barrier selected most is *Lack of clear policy for resource recovery* (selected by all except Westland Region, i.e. as this is irrelevant for their CWT ATES). Most demo cases also selected *Low price of water and virgin materials* and *High upfront investment costs* as main barriers. *High price of recovered products* and *Negative attitudes towards CWT* were selected only ones.

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Table 3.5: Drivers: main reasons to introduce the CWT at the demo cases (top 3)

Demo cases	Braun-schweig	Costa Brava	Westland Region	Alten-rhein	Spernal	La Trappe	Gotland	Athens	Filton Airfield	Timisoara
Technology driver										
Technology innovation										
Price and affordability of CWT										
Ageing infrastructure										
Economic driver										
Business strategy										
Reducing costs of wastewater discharge or treatment										
Financial benefits of reduced water use / recovered byproduct										
Socio-cultural driver										
Increased water awareness										
Responding to environmental challenges										
Positive brand image										
Regulatory driver										
Regulatory requirement										
Demands set in environmental permit										
Availability of public financing										

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Table 3.6: Barriers: main factors that act as barriers in implementing / upscaling the CWT at the demo cases

Demo cases – CWT	Braunschweig – TPS and nutrient recovery	Costa Brava – regenerated membranes for water reuse	Westland Region - ATES	Altenrhein – ammonia membrane stripping	Spernal - AnMBR	La Trappe - MNR	Gotland – membrane filtration	Athens – sewer mining	Filton Airfield – rainwater harvesting	Timisoara – water reuse
Technology barrier										
Immaturity of the CWT				■	■		■	■		■
Lack of knowledge and expertise	■				■	■				■
Associated environmental and health risks		■	■							■
Existing infrastructure		■			■			■		■
Inadequate quality or quantity of recovered product				■		■		■		
Economic barrier										
Poor economic viability				■					■	
Low price of water and virgin materials		■	■	■		■	■	■		■
High upfront investment costs	■		■		■	■	■	■	■	
High price of recovered products										■
Challenges in finding partners in new value chain		■	■		■	■	■			■

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Demo cases – CWT	Braunschweig – TPS and nutrient recovery	Costa Brava – regenerated membranes for water reuse	Westland Region - ATES	Altenrhein – ammonia membrane stripping	Spernal - AnMBR	La Trappe - MNR	Gotland – membrane filtration	Athens – sewer mining	Filton Airfield – rainwater harvesting	Timisoara – water reuse
Socio-cultural barrier										
Negative attitudes towards CWT							■			
Communication challenges with authorities		■	■			■	■			■
Reluctance to collaborate with other sectors		■			■					■
Hesitant culture in water organization			■		■	■	■			■
Lack of trust in institutions (for monitoring & control)						■	■			■
Regulatory barrier										
Current legislation hinders reuse		■	■	■	■	■				■
Lack of clear policy for resource recovery	■	■		■	■	■	■	■	■	■
Complexity of environmental permits	■	■	■		■		■			
Unpredictability of (future) legislation	■	■	■		■		■			
Variation in regulations in EU countries	■	■			■	■	■			

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4. Enabling the uptake of circular water solutions

For the implementation and further uptake of the circular water solutions, the drivers and barriers presented in the previous chapter need to be addressed. In this chapter, the enabling technology, economy, socio-cultural and regulatory conditions are described.

Enabling support instruments have been identified from an extensive literature review (see our reports Lasseur, 2020; Afghani, 2021; Sahondo, 2022; and e.g. Shaddel et al., 2019; Salminen et al, 2022). The main support instruments have been selected by representatives of each demo case for one of their key circular water technologies (CWT). These results are presented in section 4.1, followed by the description of the enabling conditions in the following sections.

4.1 Enabling CWT at the NextGen demo cases

In the NextGen WP4 visioning and strategic planning meeting with all partners, the respective representatives of each demo case, indicated which of the support instruments enable the further implementation and upscaling of one of their key circular water technologies (Table 4.1).
All support instruments identified from literature were selected by at least one demo case for their CWT. The distribution over the 4 categories is quite even.

All demo cases listed as main support instruments *R&D / Proof of Concept* and *Active stakeholder engagement*.
Subsidies for secondary materials and recycled water, Socio-political work to push CWT, and *Positive framing of reused water / recovered product* are listed by 9 of the 10 demo cases.
Market place to connect producers and consumers is listed by only 3 demo cases.

In the plenary discussion, it was concluded that a combination of support instruments, related to all 4 categories, will be most beneficial in the further uptake of the CWTs.

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Table 4.1: Support: main support instruments that will enable the further implementation / upscaling of the CWT at the demo cases

Demo cases – CWT	Braunschweig – TPS and nutrient recovery	Costa Brava – regenerated membranes for water reuse	Westland Region - ATES	Altenrhein – ammonia membrane stripping	Spernal - AnMBR	La Trappe - MNR	Gotland – membrane filtration	Athens – sewer mining	Filton Airfield – rainwater harvesting	Timisoara – water reuse
Technology instruments										
R&D / Proof of Concept	■	■	■	■	■	■	■	■	■	■
Public evidence database of circular water schemes	■			■	■	■		■		■
Master list of water quality parameters and risk database		■				■	■	■		■
Quality control and monitoring procedures	■	■	■			■	■	■		■
Environmental Technology Verification		■			■	■		■		
Economic instruments										
Tariff structures that favor reuse and tax water use	■			■	■	■	■	■	■	■
Subsidies for secondary materials and recycled water	■	■		■	■	■	■	■	■	■
Investment grants (ESG / green bonds)	■	■			■	■	■		■	
Risk sharing in PPP arrangements			■		■	■			■	■
Market place to connect producers and consumers		■						■		■

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Demo cases – CWT	Braunschweig – TPS and nutrient recovery	Costa Brava – regenerated membranes for water reuse	Westland Region - ATES	Altenrhein – ammonia membrane stripping	Spernal - AnMBR	La Trappe - MNR	Gotland – membrane filtration	Athens – sewer mining	Filton Airfield – rainwater harvesting	Timisoara – water reuse
Socio-cultural instruments										
Information sharing and public outreach campaigns										
Active stakeholder engagement										
Socio-political work to push CWT										
Independent review panels										
Positive framing of reused water / recovered product										
Regulatory instruments										
Stricter environmental regulations										
Improved clarity of Water Reuse Regulation										
Planning and building frameworks adapted for small-scale CWT										
Simplified process for achieving end-of-waste status										
Better aligned EU directives (with circularity emphasis)										

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4.2 Circular water technologies

For the uptake of circular water technologies, it will be a key prerequisite that 1) the CWTs are effective and efficient with a high technological readiness level, and 2) that they are sustainable at a system level (see section 3.1). Successfully demonstrating a CWT, with proof of concept, quality control, performance data, and technology verification, will support the implementation and upscaling of CWT. Likewise, possible environmental and health risks need to be addressed, for which an integrated risk management approach needs to be adopted.

For the support of NextGen CWTs, we refer to the results of the demonstrations in WP1 and environmental assessments in WP2. The different demonstrated innovative solutions displayed that technically we can transform wastewater into valuable and high-quality products such as reclaimed water, energy (biogas and heat), and/or recovered materials (including nitrogen and phosphorous). We demonstrated that CE concepts and technologies can lead to a lower environmental footprint of wastewater treatment, and we demonstrated the potential for safe implementation of water reuse applications. Our results have been assembled in the Technology Evidence Database (as part of the Water Europe online Marketplace) and the available evidence of the technology performance and experience in demo cases contribute to the further uptake: Water Europe Marketplace / TEB.

Table 4.2: Technology support instruments

Technology instruments
R&D / Proof of Concept
Public evidence database of circular water schemes
Master list of water quality parameters and risk database
Quality control and monitoring procedures
Environmental Technology Verification

4.3 Economically viable

Next to operational technologies, an important requirement is that the CWTs are economically viable. However, we need to keep in mind that system services such as water reuse, climate mitigation or reduction of pollution are not profitable. At the same time, the most cost-effective solutions need to be selected (see D2.3 of WP2, in which the economic assessment of the NextGen CWTs at the demo cases is reported). Although most of our nutrient recovery systems are not profitable at this stage, the cost effectiveness of the assessed technologies will change as they are further developed and reach market maturity. Moreover, more advanced use of economic instruments such as pricing, taxing and subsidies can improve the competitiveness of circular products (Salminen et al., 2022).

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To further support the uptake of CWT, new business models are required across the whole water value chain, for water utilities and technology suppliers. Moving from a linear to a circular economy entails a shift from a financial cost-benefit approach to a business model based on circular value chains. In WP5, a circular business canvas has been established (D5.1) and 23 circular value chains from the 10 NextGen demo cases have been identified (D5.2). For selected CWTs, a market assessment and business plans for spinoffs have been developed (D5.3, D5.4).

Our work on circular business models has resulted in the following lessons learned and required instruments to enable further market uptake:

- To ensure an efficient development of circular business models, it is essential to be innovative and to develop products with high added value. However, the lack of investment remains an obstacle to the development of those models. To overcome market difficulties, government subsidies or incentive regulation (e.g. carbon tax) can be a solution.
- Concerning products with higher added value, they can become profitable by establishing themselves in niches, on a small scale. Niche markets are highly specialized and often dependent on production quality. Niche markets are guided by economies of scope rather than by economies of scale.
- Organizing new efficient collaborations and business arrangements that distributes optimally risks and benefits among public and private sectors is proven to be efficient for the development of circular business models

De-risked financing can be used to support investment in CWTs and progress the technological development. In Task 4.2 we assessed innovative financing options for circular solutions, and reported in D4.3 the following recommendation:

- Support an effective regulation which provides encouraging financial incentives targeted toward water reuse schemes and circular water technologies. Utilities must be given better incentives for using sustainable water solutions. Utilities must also be rewarded for investing in creative and innovative ways for implementing circular water solutions. Adapt the EU ESG (Environmental, Social and Governance) / green financing system to ensure that circular water solutions can fall within the landscape of green bonds, especially covered green bonds.

Finally, every economy needs a market place where producers and consumers meet and trade. Therefore, NextGen developed an online marketplace for the circular water economy: Water Europe Marketplace.

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Table 4.3: Economic support instruments

Economic instruments
Tariff structures that favor reuse and tax water use
Subsidies for secondary materials and recycled water
Investment grants (ESG / green bonds)
Risk sharing in PPP arrangements
Market place to connect producers and consumers

4.4 Societal acceptance

Active stakeholder engagement and public participation will enable the societal acceptance of circular water solutions.

Within WP3, stakeholder engagement is organised through Communities of Practice (CoP) at the demo cases. In these CoPs the circular technologies are discussed within their institutional contexts through open dialogue and social learning among the stakeholders (see the NextGen journal paper by Fulgenzi et al., 2020). These CoPs extend beyond the exchange of information to actual consultations, making it possible to co-design the technologies and fit the innovations to the local needs and settings. Further stakeholder integration in the development and transition process could be organised through Water Oriented Living Labs (WoLL). WoLL's are "Water-Oriented, real-life demonstration and implementation instrument that brings together public and private institutions, government, civil society, and academia to jointly build structured grounds to develop, validate, and scale-up innovations that embrace new technologies, governance, business models, and advancing innovative policies to achieve a Water-Smart Society" (Water Europe, 2022).

An important stakeholder that should not be left out in the transition towards the CE is the general public. This is particularly relevant for circular water solutions as the people are end-users of water and its recovered resources. Proper public engagement from the start will be needed to ensure public acceptance and overcome the 'yuck' factor. Information sharing and public campaigns will enable acceptance, but early consultation and ensuring long-term collaboration will be necessary as well. Building confidence and gaining trust through consultation and independent review panels allows for a location specific approach that deals with uncertainty regarding risks and their perception.

In WP3, citizen engagement and public acceptance has been effectively built through a Augmented Reality app and a Serious Game in which the general public can visualise and experience circular water solutions.

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In contrast to the general belief, most people are positive towards reclaimed water and recovered products for agriculture. In Task 4.1, a large survey was conducted in the U.K., the Netherlands and Spain, that revealed a generally positive attitude, i.e., 60-70% of the respondents indicated to (strongly or somewhat) support using recycled water for drinking purposes and eating food grown with recovered nutrients (see D4.2). Public acceptance can be further enhanced by legitimisation strategies such as the use of long-term narratives and positive framing around the benefits of circular water solutions so that recycled water becomes 'normalised' (see next chapter).

Table 4.4: Socio-cultural support instruments

Socio-cultural instruments
Information sharing and public outreach campaigns
Active stakeholder engagement
Socio-political work to push CWT
Independent review panels
Positive framing of reused water / recovered product

4.5 Adapted governance

Supportive regulations are essential for an efficient circular transition. Regulations must first of all authorize the development of the CWT, and set standards regarding product quality and its use. The regulations should, however, also be supportive and go beyond only authorizing the technologies. The key challenge in developing circular regulations is to balance between sustainability gains and environmental protection, i.e. to compromise between excessive precaution and insufficient safety. Overly stringent quality standards need to be avoided as they could discourage the development of CWT by imposing burdensome treatment and/or costly monitoring requirements.

In a European context, where water can be considered as a transnational good, a harmonized regulation is essential for the development of a European circular market. The EU Circular Economy Action Plan (EC, 2020) aims to streamline regulations made fit for a sustainable future. With relevance to the water sector, the EU CE Action Plan will facilitate water reuse and efficiency, and a new Water Reuse Regulation is put into place (although for agricultural purposes only). The current review and legislative proposals of the Urban Wastewater Treatment Directive and the Industrial Emissions Directives go in the right direction. Moreover, the revised Fertilising Products Regulation, the announced review of the Sewage Sludge Directive, and the development of an Integrated Nutrient Management Plan can ensure more sustainable application of nutrients and stimulate the markets for recovered nutrients.

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The EU relevant stakeholders should consider circular water challenges beyond traditional sectoral governance paths. Indeed, the CE brings together a number of policy and regulatory regimes resulting in potential gaps and overlaps that affect the feasibility of circular water solutions. Tensions between different regulatory frameworks need to be reconciled as the CE is very much a transition from waste management and disposal towards value creation within and between sectors. A holistic approach through an EU strategy for water-smart management can reduce the tension and adapt the governance to unleash the benefits of water management in a circular economy approach.

In Task 4.2 we assessed the regulatory framework for circular water solutions, and reported policy recommendations in D4.3, a related Policy Brief, and in a NextGen journal paper of Qtaishat et al. (2022). The following policy recommendations are relevant to specific demo cases:

- Improve alignment between directives and incentivise circularity – *all demo cases*.
  The NextGen findings show that the policy and regulatory requirements covering circular economy technologies and their products are split between many different directives (urban wastewater, waste framework, water framework, energy efficiency, renewable energy, sludge, industrial emissions, etc.) and alignment between them is still poor. In the case of potential gaps or conflict, there is little guidance on which legislation should take priority, and it is unclear whether the order of importance needs to be decided upon at a national or regional level. Furthermore, while the uptake of circular systems is generally encouraged, it is not directly incentivised.
- Include the water / wastewater sector in energy efficiency and renewable energy strategies (water-energy nexus), but improve alignment with environmental ambitions (e.g. the zero-pollution strategy) – *Braunschweig, Spernal*.
  NextGen demo cases showed there is considerable potential for production of biogas from sludge treatment, contributing to the EU ambitious targets for the production of renewable energy. Greater alignment is needed between the Renewable Energy Directive (RED II) and Sewage Sludge Directive regarding the production and application of biosolids that goes hand-in-hand with production of biogas.
- Adopt the water fit-for-purpose principle – *Costa Brava, Westland, La Trappe, Gotland, Filton Airfield, Timisoara*.
  In addition to reducing the unnecessary water abstraction and treatment processes and streamline water quality requirements. It will engender a new and innovative wastewater service innovation model, which will better reflect the value of water, in any form, and promote its circular life cycle use. Moreover, policy, guidelines, processes, and protocols for circular water should reflect the context, application (quality), and scale (system).
- Introduce reporting requirements for recovered products – *Braunschweig, Westland, Altenrhein, Spernal, La Trappe, Athens, Timisoara*.
  While some transparency requirements have been introduced for water recycling schemes under the Water Reuse Regulation, there are no reporting requirements for other types of circular schemes (e.g. those focused on nutrient, materials or energy

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recovery). The revision of the UWWTD, for instance, could introduce a requirement to make information on such schemes publicly available, which could help build awareness of schemes, and help incentivise their adoption.

- Extensive application of digital solutions to increase reporting - *Braunschweig, Costa Brava, Westland, Altenrhein, Spernal, La Trappe, Gotland, Athens, Filton Airfield*. Through constant monitoring of determinate parameters (specific pollutants, water pressure, energy usage), sensors can help optimise energy usage and warn of contaminations and leakages, ensuring the availability of the right quality and quantity of water for different uses. Digital solutions would allow for a more effective and systemic approach to emerging pollutants, allowing for rapid remediation and facilitating prevention. Monitoring can be expensive and difficult for micro-pollutants and hence should be coupled with talking pollution at source.
- Create simpler and less costly routes to market for recovered resources - *Braunschweig, Westland, Altenrhein, Spernal, La Trappe, Athens, Timisoara*.
  One of the key barriers to the uptake of circular schemes is the cost and complexity of achieving legal 'end of waste' (EoW) status for materials recovered from water and wastewater systems (e.g. nutrient products, cellulose fibres). This legal status is often required to ensure the products can be brought to market. While some regulatory instruments have attempted to create smoother routes to EoW status and to market for some products (such as in the revised Fertilising Products Regulation), many gaps and hurdles still exist. The resulting confusion and risk act as deterrents for potential scheme developers.
    - Create viable EoW routes for all products recovered from wastewater and sludge. While the EoW process is typically governed under the Waste Framework Directive, another alternative process could be created under a revised UWWTD, which could specifically manage risks as more of a 'one-stop-shop' for products recovered from municipal wastewater and sludge, including those not used in fertilisers (which could then be exempted from the EoW process under the Waste Framework Directive, similar to the exemption created under the updated Fertilising Products Regulation).
    - Ensure that EoW status can be recognised across Member States. One of the concerns raised by participants in this study was that, for some recovered products, EoW status had to be achieved on a country-by-country basis, adding significantly to the cost. If existing EoW status could be recognised across multiple Member States, it could lower the cost and risk associated with these schemes.

The European Commission is currently taking encouraging steps to support the transition to a circular water economy:

- To support the application of the Water Reuse Regulation (2020/741), guidelines have been established by the EU Minimum requirements for water reuse - guidelines

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and JRC: [Technical guidance - water reuse risk management for agricultural irrigation schemes in Europe]
- The revised Fertilising Products Regulation (2019/1009) opens the single market for fertilisers produced from recovered or organic materials, including those from (waste)water: EUR-Lex - 32019R1009 - EN - EUR-Lex
- A proposal for a revised Urban Wastewater Treatment Directive is published. It includes essential points, such as the energy-water nexus, nutrients recovery and new requirements for microplastics and other micropollutants in line with the Circular Economy Action Plan. The sector is supposed to become energy-neutral by 2040: Proposal for a revised Urban Wastewater Treatment Directive

Regulations should go hand-in-hand with a supportive institutional framework. Circular water schemes often span the jurisdictions and responsibilities of multiple regulatory and administrative bodies. Fragmentation of responsibilities constrains the wider adoption of for example water reuse practices. Transitioning to a circular economy requires policy coherence, coordination and collaboration among stakeholders across governance levels. Studies showed that since CE creates interdependence between stakeholders and goods, a multi-level governance or a hybrid governance structure could be an effective solution for a circular transition (Maaß & Grundmann, 2018; Bauwens et al., 2020).

Table 4.5: Regulatory support instruments

Regulatory instruments
Stricter environmental regulations
Improved clarity of Water Reuse Regulation
Planning and building frameworks adapted for small-scale CWT
Simplified process for achieving end-of-waste status
Better aligned EU directives (with circularity emphasis)

4.6 Specific recommendations for the NextGen demo cases

Table 4.1 presented the support instruments relevant for each demo case. From this Table, recommendations for each demo case can be derived, such as:
- Provide proof of concept – *all demo cases*
- Ensure active stakeholder engagement – *all demo cases*

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- Arrange for subsidies for secondary materials – *all except Gotland*; and for recycled water – *all except Altenrhein*
- Lobby to put circular solutions on the socio-political agenda – *all except Spernal*
- Build a positive storyline around reused water – *all except Altenrhein*; and around recovered products - *all except Costa Brava and Gotland*

In addition, the following specific recommendations were prioritised for each demo case (Table 4.6):

Table 4.6: Specific recommendations for the demo cases

Demo Case	Specific recommendations
Braunschweig (DE)	• Tax primary sources, than circular solutions will become attractive. • Provide clear policy for GHG reduction and CE solutions. • Include all renewable materials originating from sewage sludge and/or wastewater in the Fertilising Products Regulation. • Simplify the procedure to bring secondary fertilisers to the market. • Include a wider range for crystal sizes in the German fertilizer regulation. • Include recovered products in the regulation on organic farming in order to label it as a “green” fertiliser.
Costa Brava (ES)	• Set clear water reuse legislation, especially concerning trace organics and health issues. • Apply stricter regulation for waste recycling. • Improve the collaboration with local and regional administrations.
Westland Region (NL)	• Develop and implement a regional water cycle policy (water saving, prevention of pollution, wastewater separation, reuse of water). • Set a new stricter standard for current technology of RO and emission of brines. • Provide EU unified guidelines for approval of ATES in the EU (depending on aquifers). • Make the use (blending) of residuals in market products mandatory.
Altenrhein (CH)	• Develop national regulations to promote resource recovery. • Apply full environmental pricing of fossil fertilizers. • Include all renewable materials originating from sewage sludge and/or wastewater in the Fertilising Products Regulation. • Convince companies of the advantage to blend renewable fertilisers with the traditional fertilisers.

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Spernal (UK)	• Show proof of concept. • Engage with regulators. • Build a supply chain for AnMBR technology. • Take the ecological benefits and impacts of costly circular economy solutions into account.
La Trappe (NL)	• Set reporting requirements on the implementation of circular solutions. • Set stricter regulations regarding drinking water usage, the water savings, and pollution prevention. • Include recovered products in the regulation on organic farming in order to label it as a "green" fertiliser.
Gotland (SE)	• Develop regulations to promote water and nutrient reuse. • Demonstrate that technology works well and show cost-benefits. • Ensure approval from landowners and administration through early communication.
Athens (EL)	• Set CE targets and have utilities report on their implementation. • Ensure active stakeholder engagement. • Provide investment grants for sewer mining units.
Filton Airfield (UK)	• Set higher water tariffs. • Introduce national requirement for all house builders and developers to implement and deliver circular water technologies. • Convince investors for a viable business case.
Timisoara (RO)	• Establish cooperation between dedicated stakeholders at local level, and improve knowledge about water reuse practices. • Conduct research on the long-time effects on health. • Include all renewable materials originating from sewage sludge and/or wastewater in the Fertilising Products Regulation.

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5. Roadmap to support wider uptake

What emerges from the analysis of needs for a circular transition is that, the conditions found are to be analysed together, using a system approach. The conditions identified all come together and are interconnected. Contrary to what it seems, the technological aspect alone is not the only, nor even the main challenge faced. Indeed, the system and its environment around the development of the CWT must be favourable. Elaboration of a system approach around this multi-disciplinary field is probably the main challenge to overcome.

Such an integrated approach is also advocated by the Ellen MacArthur Foundation in their *Universal Circular Economy Policy Goals* (EMF, 2021):

- Stimulate design for the circular economy
- Manage resources to preserve value
- Make the economics work
- Invest in innovation, infrastructure, and skills
- Collaborate for system change

The European Circular Economy Stakeholder Platform (ECESP) gathers policies for the transition to a circular economy adopted at the national and local level. So far, although water is part of the circular roadmaps as it contributes to the overall resource circularity in many sectors, there is still scope for roadmaps where water takes a central position in the transition towards a CE (Mannina et al., 2022).

In this final chapter, we present a roadmap to support the further uptake of circular water solutions in the EU.

5.1 Transition towards a circular water economy

As our NextGen case studies have demonstrated, technologies at high TRL are already becoming available for the reuse of water and recovery of products. However, support will be needed for the wider uptake of circular solutions in the water sector in the EU. Establishing a comprehensive package of instruments would speed up the implementation of different types of CWTs (chapter 2). Therefore, we propose a roadmap (see Figure 5.1) with the EU wide uptake of *Reduce use of resources* occurring in the short term (2020-2025), *Reuse / recycle water* occurring in the short to medium term (2020-2030), and the *Recovery of products* occurring in the medium term (2025-2030). Over the long term (2030-2050), *Rethink the CE water system* will be needed.

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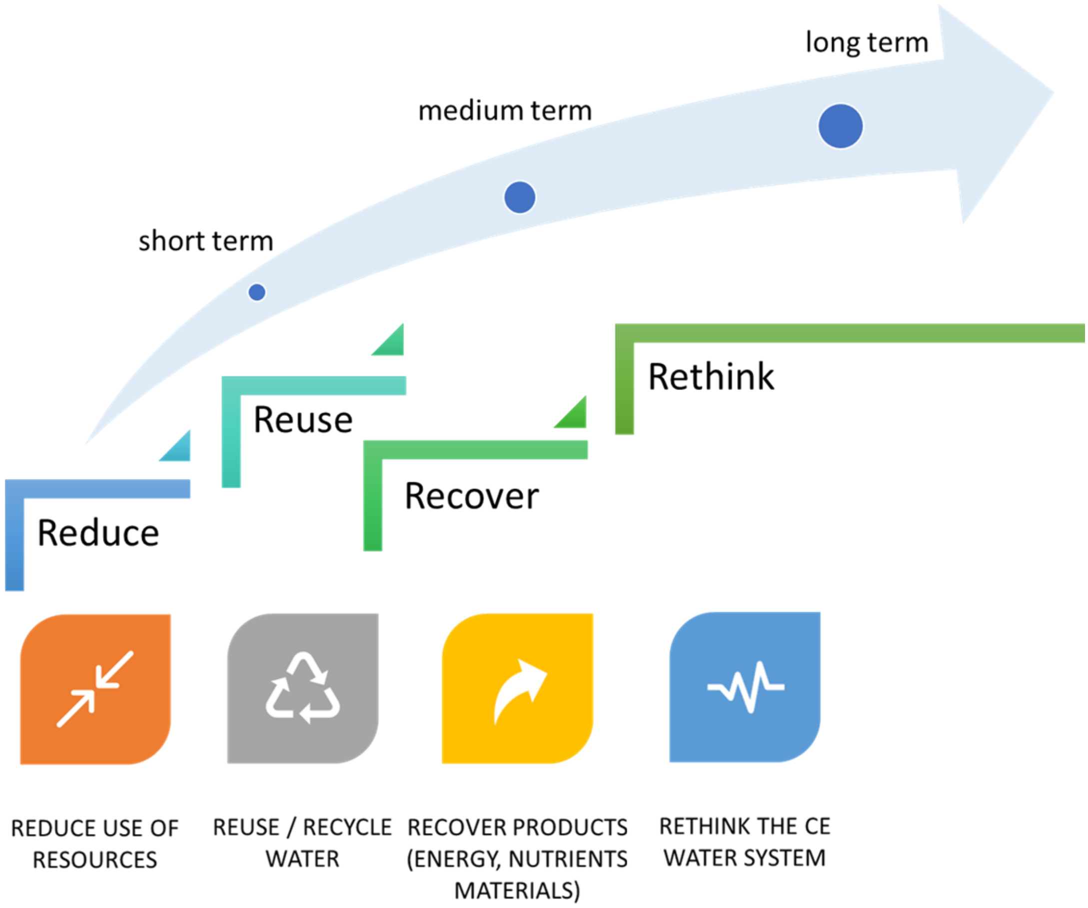

Figure 5.1: Roadmap on the EU wide uptake of circular water solutions

To enable the shift from a linear to a circular water economy, we identified technological, economic, socio-cultural and regulatory support instruments (chapter 4). This roadmap provides an overarching framework against which we can map those support instruments (Table 5.1). This provides a starting point of recommended actions in the roadmap over short-, medium- and long-term timeframes. In a working session with all NextGen partners (at PSB06 Athens), the respective planning and sequence of identified support instruments was discussed. There was agreement that for an effective transition, simultaneous efforts were needed across all four categories of instruments, starting immediately. However, Table 5.1 provides an initial indication of the likely timeframe over which these instruments could be realised. It is recognised that some instruments are associated with more than one roadmap stage (indicating more continuous activity), and that progress in some instrument categories will affect progress in others – e.g. regulatory changes and economic incentives can be strong drivers for technological development. Therefore, Table 5.1 is not intended to provide a concrete timeline of actions, nor is it intended to limit the range of actions required. Instead, it serves to highlight the multi-faceted and inter-connected nature of a transition towards circular systems across the water sector.

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Table 5.1: Aligning support instruments with steps in the roadmap framework

	Reduce	Reuse	Recover	Rethink
Technology instruments	- R&D / Proof of Concept - Public evidence database of circular water schemes	- R&D / Proof of Concept - Public evidence database of circular water schemes - Master list of water quality parameters and risk database - Quality control and monitoring procedures	- R&D / Proof of Concept - Public evidence database of circular water schemes - Environmental Technology Verification - Quality control and monitoring procedures	- R&D / Proof of Concept
Economic instruments		- Tariff structures that favor reuse and tax water use - Subsidies for secondary materials and recycled water	- Subsidies for secondary materials and recycled water - Market place to connect producers and consumers	- Risk sharing in PPP arrangements - Investment grants (ESG / green bonds)
Socio-cultural instruments	- Information sharing and public outreach campaigns	- Active stakeholder engagement - Independent review panels - Positive framing of reused water / recovered product	- Active stakeholder engagement - Independent review panels - Positive framing of reused water / recovered product	- Socio-political work to push CWT
Regulatory instruments	- Stricter environmental regulations	- Stricter environmental regulations - Improved clarity of Water Reuse Regulation	- Stricter environmental regulations - Simplified process for achieving end-of-waste status	- Planning and building frameworks adapted for small-scale CWT - Better aligned EU directives (with circularity emphasis)

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Rethink the system
Experience from the NextGen demo cases regarding the enabling conditions, as presented in this report, underscores the need to *Rethink the CE water system*. The circular water paradigm challenges the fundamental linear approach that sits at the heart of the current policy frameworks, economic systems and social norms that surround water and wastewater. The linear approach is built on the guiding premise that we should source raw water from the environment, use it, and dispose of associated wastewater back in the environment, with the dual overarching aims of maximising public health protection and minimising cost. Rethinking the system requires rethinking those overarching aims. While we cannot dismiss the need to protect public health, new objectives (environmental improvement, generating wider social value) need to be considered alongside and given greater weight. Rather than minimising costs, the emphasis should shift towards developing longer term economic potential. Shifting those fundamental guiding premises would alter the basis on which we design policy and regulatory frameworks, economic governance models and operational strategies for the water sector. But achieving such a shift is (to say the least) a complex process.

A system-level change has to come from all actors across the whole water value chain. First, the water sector (encompassing water and wastewater utilities and associated knowledge and consulting sectors) is in the driver’s seat. Over the last decade, the water sector has shifted towards providing services in a more sustainable way by using fewer resources (e.g., fewer material and, most noticeably, energy inputs). The next step is to do so in a more circular way by recovering and reusing water, materials (e.g., nutrients) and energy, not only within the water sector itself, but also as part of the overall circular economy. NextGen successfully demonstrated technologies for the recovery and reuse of water-embedded resources, leading the way to a circular water economy. Wider uptake will be enhanced through further rethinking of the decision-making processes around asset planning, which could give greater emphasis to objectives around circularity and environmental enhancement.

Second, governments will play an essential role in unlocking the transition toward sustainable and circular business models. The transition towards value creation within and between sectors requires an adapted regulatory framework that incentivises circular water solutions. Both the EU and national governments need to provide policy coherence, and facilitate coordination and collaboration among stakeholders and across governance levels. Governments are requested to not only encourage research and innovation and provide funding, but to rethink the support system based on circular value chains.

Although rethinking the CE water system requires a long-term perspective, actions can and should start immediately on all fronts. A good first step is to aim for small wins that can help to energise a variety of stakeholders to build momentum for a wider transformation. We need to focus on legitimising circular water technologies in the eyes of society, policy and the economy. Legitimacy touches upon end users’ personal evaluations (pragmatic legitimacy), the cultural order (cognitive legitimacy), the moral rules (normative legitimacy) and the regulative arrangement (regulative legitimacy) (section 2.2).

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To help build legitimacy around the CE water system, we recommend using a variety of **legitimation strategies** such as:

- Advocacy: lobbying with politicians, the public or investors for the need of CWT; mobilising regulatory support and economic incentives
- Political work: using political power to push CWT implementation
- Changing normative associations: associating water reuse with its positive applications instead of its source; positive framing of recovered products
- Constructing normative networks: creating independent review panels for CWT schemes; certification for treatment technologies or water quality
- Theorizing: scientifically explain the benefits of CWT, and its cause-and-effect chains
- Educating: providing information about CWT; publishing results from water testing; conducting tours of treatment plants**.**

Ultimately, these legitimacy processes will build widespread trust in circular water solutions, enabling its further uptake.

5.2 Conclusion and recommendation

To support the uptake of circular water solutions, technological, economic, socio-cultural and regulatory instruments are needed. A comprehensive ‘package’ of enabling instruments is required, supporting different stages of the roadmap (summarised in Table 5.1), as all four conditions for a circular water economy will have to be successfully created simultaneously:

- circular water technologies, that are sustainable at system level
- economic viability, based on circular value chains
- societal acceptance, along with engaged stakeholders
- adapted governance, with supportive regulations

Establishing that package of instruments is the central recommendation from this report. A kind of ‘EU CE blue deal’ could provide such an enabling package, acting as a framework to coherently integrate CE policy frameworks. The EU CE Action Plan and Horizon Europe already provide for a good basis for this, and the NextGenerationEU economic recovery package could also back up the transition to a CE. This will further enhance innovation in the water sector, developing and implementing circular water solutions in consultation with stakeholders and other sectors (e.g. through Water-Oriented Living Labs). Additionally, joint efforts are needed, e.g. through legitimation strategies, to rethink the system and transform to a circular water economy.

Based on the findings from the NextGen demo cases, the following recommendations are proposed to policy (governments) and the water sector:

For EU and national governments:

- Adapt the regulatory framework to incentivise circular water solutions and align directives and regulations around the water sector to support a sector that balances

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public health protection, environmental enhancement, economic potential, and wider social value.

- Support research and innovation, as the successful demonstration of circular water technologies, with proof of concept, will continue to lead the way in supporting the legitimisation of a circular water economy.
- Provide subsidies for secondary materials and recycled water, and encourage financial investments and de-risked financing that take a circular value chain perspective.

For the water sector:

- Make use of existing evidence and tools around circular water technologies, and adapt asset decision-making frameworks to give greater emphasis to circularity, environmental enhancement and longer-term social value (as well as public health protection).
- Aim for recovered products with high added value that are of interest to niche markets.
- Ensure, from the start, active stakeholder engagement across the circular value chain.

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Annex A: Circular water technologies at the NextGen demo cases

Demo Case	Technologies		
#1 Braunschweig (DE)	Two-stage digestion and sludge hydrolysis	Nutrient recovery: Ammonia stripping; Struvite precipitation	
#2 Costa Brava Region (ES)	Multi-purpose water reclamation and reuse	Membrane filtration with regenerated RO membranes	
#3 Westland Region (NL)	Alternative water sources, i.e. Aquifer Storage & Recovery for horticulture	HT-ATES: high temperature aquifer thermal energy storage	Material brokerage
#4 Altenrhein (CH)	Ammonia membrane stripping	P-recovery by thermochemical treatment of sludge	Granulated activated carbon via pyrolysis
#5 Spernal (UK)	Multi-stream anaerobic MBR for decentralized water reuse	Energy recovery from AnMBR	Nutrient recovery from AnMBR via adsorption and ion exchange
#6 La Trappe (NL)	Metabolic Network Reactor to produce fit-for-purpose water	Protein production in Bio-Makery	
#7 Gotland (SE)	Rainwater harvesting and decentralized membrane filtration	Energy efficient reclamation of wastewater	
#8 Athens Urban Tree Nursey (EL)	Sewer Mining mobile wastewater treatment for decentralized reuse applications	Heat recovery from MBR	Nutrient recovery for urban agriculture
#9 Filton Airfield (UK)	Integrated drainage system for urban water reuse	Heat recovery from sewer	Eco-sanitation systems with nutrients recovery
#10 Timisoara (RO)	Sludge management with production of by-products and/or energy	Reuse of effluent for urban, industrial and agricultural applications	

** blue = water, yellow = energy, green = materials*

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