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Circular Water Economy in the EU: Findings from Demonstrator Projects

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Abstract: Circular economy (CE) for water aims to maximise value derived from water, processes, and practices. As a result, the recovery of wastewater and renewable water resources is used to offset the exploitation and impact of abstracting new water resources. New regulations such as the new circular economy action plan by the European Commission are emerging to promote circularity within the Green Deal agenda. However, there is still a need for research and practical insights into the interaction and integration of CE for water within existing policies and regulations, and its practical application specifically at the project level. This paper presents findings from demonstrator cases used to explore the opportunities and constraints in the policy, process, and procedural frameworks that govern water circularity in important sectors in Europe. Desk reviews are used to examine and compare European legislation against national and regional legislative frameworks within the different member states. Interviews and demonstrator project feedback enabled the exploration of the policy and value constraints at the project level. The findings provide unique insights into the policy and legislative enablers for and barriers to implementing CE for water in key sectors and specifically at the project level. The paper concludes with a five-point route map for new and revised policies and regulations targeting improved uptake of circular water technologies in Europe.

Keywords: circular economy for water; circular water solutions; water ruse; regulations; policymaking

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1. Introduction

Water is essential for survival and well-being and plays a significant role in sustainable development. If the business-as-usual approach to freshwater consumption continues, the global demand for freshwater might exceed our viable resources by 40% in 2030 [1]. Therefore, water reuse and the recovery of embedded valuable products and energy are interesting options to achieve more sustainable water management in the future. Water supply and treatment infrastructure can be centralised or decentralised. In most EU member countries, such infrastructure can be characterized as predominantly centralised [2], whereby freshwater is captured and treated at one location for distribution to a larger municipal region.

Circular economy for water (Figure 1) is concerned with the alternative technologies and practices that allow the shift of focus from exploiting new non-renewable water resources to the recovery of wastewater and renewable water resources [3]. Currently, most human-managed water systems within the EU member countries follow a linear model where used water quality is degraded and becomes unfit to be used again by both humans and nature [4]. Furthermore, water and wastewater generated by human activities are carriers of energy and materials [5]. Decentralised circular water solutions include those systems that harvest and treat rainwater, greywater, and wastewater (blackwater) onsite. The reclaimed water can then be used for non-potable purposes without the need for intensive transportation [6]. Reclaimed water can be a valuable resource for nutrition used in agriculture such as nitrogen, phosphorous, and organic matter [7]. Additionally, energy can be retrieved from grey and wastewater to be used onsite for heating and other purposes [8]. Decentralised circular water solutions can thus provide benefit society by contributing to food security and job creation [9,10]. The principle of circular economy (CE) for water can be applied to two additional scales of decentralised water reuse infrastructure: satellite and onsite [11,12]. In the satellite scenario, raw greywater and rainwater from several dwellings in one or multiple sub-divisions are collected at one satellite treatment plant for treatment and redistribution within the same region. In the onsite scenario, grey and rainwater from each dwelling are collected, treated, and re-supplied using a small-scale treatment unit located within the dwelling [11]. Centralised and decentralised water treatment require different types of infrastructure, and as a result, the economic, environmental, and societal implications vary.

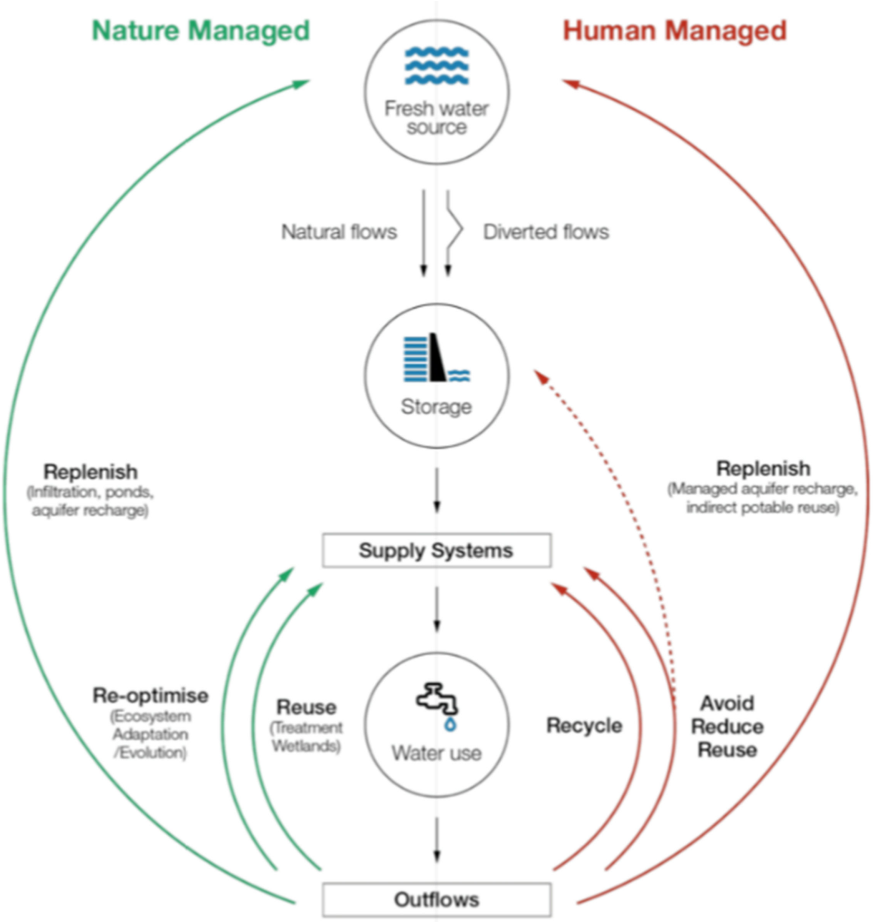

Figure 1. Water in the circular economy [1].

According to the United Nations, wastewater is an untapped source of water globally [13]. The market uptake for CE for water is still not widespread despite the recognition of the inherent value of this recourse. Thus, more research and practical insights are needed on the inherent systemic nature, integration materialization, and operation of circular value models [14]. Further is the need for research and practical insights on the interaction and integration of CE for water within existing policies and regulations and their practical applications at the project level. For example, the focus of literature in relation to decentralised and circular solutions is geared to and mostly concerned with technologies, processes, selection criteria, and other technical aspects related to these systems [2,6,8,9,15,16]. Others deal with the economic assessment and feasibility aspects of these systems [17–19]. Few investigate the policy and legislative frameworks related to the use of decentralised and circular water solutions [20–22]. Further, previous research focused on EU frameworks and legislation without studying local regulations for EU member states nor researching the unique situation and issues faced by each country. The practical barriers and enablers faced with the use of such systems that could contribute to low uptake are often overlooked.

Applying circular innovation for water within the built environment and on a smaller domestic level is also often neglected. Cipolletti et al. [23] stated that the current EU legislative framework does not provide adequate guidelines for closing the water loops for a small decentralized system, highlighting the lack of an enabling environment for small-scale decentralized technologies at the community level. Implementation is often hampered by a lack of knowledge, including knowledge of how to implement it in business models. The barriers also show inadequate awareness, understanding, and insight into CE, especially within the built environment, housing, and related practices and industries [14]. Therefore, research and practical insights into the inherent systemic nature, integration materialization, and operation of its circular value models are still needed [14]. Thus, this paper aims to use demonstrator cases to explore the opportunities and constraints in the policy, process, and procedural frameworks that govern water circularity in important sectors in Europe.

2. Circular Economy for Water in Europe

Water is an essential limited resource that is continuously being contaminated and consumed by human activities [24]. Water is therefore one of the most discussed topics when it comes to sustainability [25]. In the European context, water stress issues are being brought to the front by the European Commission due to increasing demand and climate change recently with many regions in Europe being at high risk of water shortage [26,27].

Domestic circular water solutions have significant potential for many regions and applications in Europe that require non-potable water [20]. However, this usage requires a set of accompanying measures to address the financial costs of these systems, health concerns, water quality monitoring, and compliance with local regulations. The Circular Economy Action Plan, published by the European Commission on 11 March 2020, is a promising continuation of the EU executive's ambition from 2015. The plan acknowledges the need to address the EU's resource consumption and to reduce environmental pressures driven by consumption [28]. This Circular Economy Action Plan presents a set of interrelated initiatives to establish a strong and coherent product policy framework that will make sustainable products, services, and business models the norm and transform consumption patterns so that no waste is produced in the first place.

The EU aims to progressively roll out the product policy framework and exploit product value chains as a matter of priority. Further measures include policies to reduce waste and ensure that the EU has a well-functioning internal market for high-quality secondary raw materials. The capacity of the EU to take responsibility for its waste will also be strengthened. Additionally, the CE action plan introduces a set of legislative and non-legislative measures aimed at encouraging circular approaches to water in various sectors.

From a regulatory point of view, the reuse of treated wastewater, as well as implementing circular decentralised solutions, still represents a challenge, posing uncertainties that national and regional authorities in Europe have aimed to address in recent years. Thus, the EU recognises that the integration and implementation of circular water solutions in the EU need to occur at different scales, under various forms, including [29]

- Local regulations to make circular water solutions mandatory or defining requirements for its integration within the local practice;
- Technical requirements for buildings and planning established by an institutional actor, such as minimum water quality requirements and the sizing process of components of rainwater- and greywater-reuse systems;
- Financial incentives for the purchase of circular water systems or in the form of tax reduction;

- Experimental projects, including in newly developed residential areas;
- Communication with the public and stakeholders to raise awareness and increase acceptance of circular water solutions.

Projects similar to the one reported in this paper fall within the last category two categories and explored:

- Water reuse at multiple scales supported by nature-based storage, optimal management strategies; advanced treatment technologies, engineered ecosystems, and compact/mobile/scalable systems.
  a. Specific to wastewater reuse, the European Parliament recently released Regulation (EU) 2020/741 [19], establishing the minimum requirements for water reuse, to "facilitate the uptake of water reuse whenever it is appropriate and cost-efficient, thereby creating an enabling framework for those Member States who wish or need to practice water reuse".
  b. Other significant related regulations for circular water solutions and the description of the CE Action Plan and relevant regulations are summarised in Table 1.
- Energy (combined water-energy management, treatment plants as energy factories, water-enabled heat transfer, storage and recovery for allied industries and commercial sectors) and materials (nutrient mining and reuse, manufacturing new products from waste streams, regenerating and repurposing membranes to reduce water reuse costs, and producing activated carbon from sludge to minimise costs of micropollutant removal).

The desktop review of EU regulations relating to CE for water found variations in regulating decentralised circular water solutions between European countries. For instance, water reuse remains relatively low in Greece, even though the country adopted quality standards and regulations for the use of treated wastewater for a variety of purposes (e.g., agricultural, recreational, industrial, and domestic) [30]. Current regulations and practices in Greece do not include domestic or decentralised water solutions such as rainwater and greywater harvesting. Economic (e.g., illegal water abstraction for irrigation), technical (e.g., the complexity of the national standards), and social (e.g., limited acceptance of water reuse) reasons are thought to limit and delay the broader uptake of water reuse in Greece [22,31].

In Romania, the wastewater treatment system is characterized by a low percentage of the population connected to the sewerage and wastewater treatment systems and the non-functioning of all existing treatment stations [31]. Treated wastewater reuse has not been used extensively so far. The responsible authorities for water-related fields and issues in Romania are very fragmented and include many national ministries, agencies, departments, and local authorities. Romania has also been the EU member country with the least emphasis on both centralised wastewater reuse application, and as for water reuse on a decentralized domestic scale, no related guidelines or regulations were found.

In the Netherlands, the amount of wastewater recycling and reuse is still small [22]. Currently, there are no standard requirements for the reuse of treated wastewater. There is also no regulation in place for small-scale applications. More Dutch municipalities are, however, subsidising the installation of a rainwater system. In addition to rain and greywater reuse systems, some examples of energy and nutrient recovery can be found in municipalities such as Groningen and Amsterdam [32].

Although water scarcity is still not an issue in Germany, it is considered a market leader for domestic decentralised water technologies [33]. Thirty-five per cent of new buildings built in Germany are equipped with a rainwater collection system. The German circular water solution systems industry is worth millions of Euros and creates a large number of jobs [34,35].

Table 1. Related European regulations for water in the CE.

Regulation	Aim	Possible Enabler or Barrier/Constraint for Circular Water Solutions
Urban Wastewater Treatment Directive (The Council Directive 91/271/EEC concerning the urban waste-water treatment of 21 May 1991)	To protect the environment from the adverse effects of urban wastewater discharges and discharges from certain industrial sectors (see Annex III of the Directive), concerning the collection, treatment, and discharge of domestic and industrial wastewater	It does not mention decentralised treatment and collection systems. Is mainly concerned with the environmental impact of wastewater rather than its reuse applications.
Sewage Sludge Directive 86/278/EEC	To promote the use of sewage sludge in agriculture and regulate its use to prevent harmful effects on soil, vegetation, animals, and people.	Sludge is one main by-product of treated wastewater that should be treated and disposed of properly. The directive objectives reflect core circular water practices. It does not mention decentralised treatment and collection systems. In some countries such as the Netherlands, the use of sludge in both agricultural application and landfilling is not legally possible.
Regulation (EU) 2020/741 on minimum requirements for water reuse	To harmonise minimum water quality requirements for the safe reuse of treated urban wastewaters in agricultural irrigation between EU countries;	There are concerns over the stricter water-quality requirements of the treatment process proposed by this regulation on the financial costs for some EU member countries. The regulation could encourage EU countries to increase their uptake of decentralised circular water solutions.
Regulation (EU) 2019/1009 Safe and effective fertilisers on the EU market	This regulation includes EU-wide end-of-waste criteria for compost, which can be used in organic fertilisers, soil improvers, and growing media.	The regulation is partially concerned with the protection of water quality and its suitability for circular application throughout its cycle.
Waste Framework Directive 2008/98/EC	The Waste Framework Directive lays down some basic waste-management principles. It explains when waste ceases to be waste and becomes a secondary raw material and how to distinguish between waste and by-products. The Directive also introduces the "polluter pays principle" and the "extended producer responsibility".	Most water utility companies in Europe enforce the polluter-pays principle for wastewater based on water consumption and not actual discharge. Therefore, domestic circular water solutions might impose some financial risk on these companies.
Industrial Emissions Directive 2010/75/EU (IED)	IED is the main EU instrument regulating pollutant emissions from industrial installations. The IED aims to achieve a high level of protection of human health and the environment taken by reducing harmful industrial emissions across the EU, through better application of Best Available Techniques (BAT) and permits approval.	Permits must consider the whole environmental performance of the plant, including water discharge. This might encourage manufacturers to apply decimalised circular water solutions within their plants/factories.
Energy Efficiency Directive 2012/27/EU	The directive established a set of binding measures to help the EU reach its 20% energy efficiency target by 2020.	One key element of the proposal is a specific requirement for the public sector to achieve an annual energy consumption reduction of 1.7% as part of the objective to enhance the exemplary role of the public sector across a wide range of activities including water. Circular water solutions present an opportunity for heat and energy recovery.

In Spain, water reuse is regulated by the Royal Decree 1620/2007, and the reuse of treated wastewater is already a reality in several Spanish regions on the centralised level. However, there are no regulations for circular water solutions on the decentralised or domestic levels [31]. On the other hand, the UK has no consistent or extensive pattern of treated wastewater reuse at the national or local government level. There is a guide for homeowners who wish to use rainwater harvesting or greywater systems in their homes, but it is not a legal or binding requirement.

Most innovative decentralised and circular water solutions in European countries are exemplar pilot and demonstrative projects [36], which rarely scale up to wider, mainstream applications. Innovative small- (domestic) to medium-scale decentralised projects that scale up pragmatically and economically are also scarce. The promising technological and sustainable potentials of decentralized and circular water solutions often fall short of market transformation [23]. This is despite more legislative and policy mechanisms introduced to serve as a starting point to implement such solutions. Therefore, these solutions should be evaluated under these frameworks at both EU and member states' levels. To analyse practical and legislative barriers and enablers, there is a need to understand to what extent local building regulations can help in their implementation.

3. Materials and Methods

This paper utilises the case study approach to explore the opportunities and barriers within national legislations, building regulations, and planning requirements for decentralised water solutions in EU counties. Secondary research methods were a literature and desktop review of building and planning regulations and circular water policies in Europe. Six demonstrator cases from six European countries were sampled (Table 2). Primary data were obtained through self-administered structured questionnaires to capture basic information about the cases, followed by in-depth open-ended interviews with seven projects' stakeholders and representing one from each sampled country and an additional case from Germany (Table 3), undertaking the demonstrating projects. Interview questions included both open-ended and closed-ended questions. Open-ended questions allowed the respondents to answer in their own words; thus, they provide richer and more valuable information. Closed-ended responses were analysed statistically, while open-ended questions were thematically analysed. Responses were analysed by going through all the open-ended responses and manually coding similar or related responses to generalise their responses and develop consensus and recommendations.

Table 2. Overview of the sampled NextGen case studies used in this paper.

	Case Type and Location	Available Circular Solutions	Key Figures	Relevant Sectors	Survey Respondent
1	Urban wastewater plant Germany)	Materials, Energy, Water	320,000 Population Equivalent, 30,000 m^2 of agriculture	Industry, Agriculture, Chemistry industry	Wastewater company
2	Housing scheme (UK)	Materials Energy Water	2675 homes, 2 nurseries, 3 schools, Multi-use commercial centre, New railway and urban, transport system	Urban services, Industry, Chemistry industry	Housing developer
3	Urban wastewater plant Timisoara, (Romania)	Materials, Energy, Water	2400 L/s Average secondary effluent flow rate, 38,000 tons/year Annual sludge production, 440,000 m^3/year Drinking water supply	Agriculture, Municipal sector, Water sector, Industry	Water and wastewater utilities

Table 2. *Cont.*

	Case Type and Location	Available Circular Solutions	Key Figures	Relevant Sectors	Survey Respondent
4	Urban Park (Greece)	Materials, Water, Energy	25 m^3/day autonomous and modular water system	Industry, Agriculture, Water sector, Domestic sector	Research project manager
5	Hotel (Spain)	Water, Materials	27 Municipalities in the area, 214 km of coast, 4,500,000 Tourists/year, 6,400,000 m^3/year of total water reused	Industry, Agriculture, Water sector, Tourist industry, Domestic sector	Water reuse technologies research centre
6	Urban water buffer (Netherlands)	Water, Energy	500,000 Households, 40,000 Industries	Horticulture, Heavy port industry, Chemistry industry, Domestic sector	Urban water research institute

Consent for participating and video-recording was obtained before the interviews. All interviews were conducted and transcribed in English. Each interview lasted for about 30 min. Efforts were made to keep the response time and effort as minimal as possible by providing flexible time and location options to meet and the opportunity to withdraw at any time. All participants were informed about the study's purpose, how they were expected to take part in it, how much time the experiment was expected to take, and the right of any participant not to answer any specific question and to withdraw from the study at any time. Participation in the study was entirely voluntary.

3.1. Overview of the Cases

Table 2 provides an overview of the sampled demo cases. The first case is an urban park in Athens, Greece; an area in the process of redevelopment and regeneration to become the key metropolitan park of the capital. The area, which lies in the heart of Athens, is a mixed-use area, comprising urban green and urban agriculture spaces as well as administration and residential uses. The regeneration is an effort to boost both the local economy and improve the quality of life for the 4 million citizens of the Attica Region. The nursery comprises 4 ha of vegetation, supplies all urban parks and green spaces of Athens with plant material, and uses potable water from Athens's Water Supply and Sewerage Company (EYDAP) for its irrigation. This scheme fits the city's ambition to seek alternative water sources, leveraging circular economy solutions to achieve environmental, social, and financial benefits for the city.

The wastewater treatment plant (WWTP) in Romania is designed for a 440,000-population equivalent (PE) and an average flow of 250,000 m^3 per day. It is managed by Aquatim, a local water company, which operates 28 drinking water treatment plants and 22 WWTPs. The wastewater enters the treatment plant through four main sewers and goes through mechanical and advanced biological treatment facilities before being discharged into the Bega River. Today, the aerobically stabilized excess sludge is dewatered, solar-dried and landfilled. For future-proof sludge handling, more sustainable alternative solutions must be found.

The UK site is a former airfield being developed to provide housing and other mixed-use amenity schemes. The goal is for the development to serve as an attractive and sustainable area where people can live, learn, work, and prosper. A master plan has been approved, but further evolution of sustainable development ideas to implement is required. The construction started in 2018 and includes a strategic Surface Water System (SSW), ensuring reliable drainage and allowing local use of captured rainwater for reuse.

Table 3. Summary of survey results from the demo cases.

Case	Location	Year	Purpose	Types of Water Reuse Systems	Beneficiaries	Water Applications	ROI	Payback Period	Incentives	Required Permits
1	Athens, Greece	2019–2021	Urban irrigation	Blackwater, Nutrient recovery, Heat recovery	Local authority/municipality.	Garden and other irrigation uses	3.6–5.0%	More than 20 years	Direct financial subsidies/grant	Municipal permit.
2	Timisoara, Romania	2021	Mixed-use wastewater treatment scheme	Greywater, Rainwater, Blackwater	Local authority/municipality	Public parks and other irrigation use. Non-potable industrial use	2.0–3.5%	11–20 years	Subsidy from Horizon program at present.	Planning permit; Building regulations or compliance permit; Environmental permit; Health and safety permit; Wastewater-discharge permit; Municipal permit.
3	Bristol, UK	Ongoing	Mixed-use urban development	Rainwater, Blackwater, Greywater, Heat recovery, Nutrient recovery	Occupants/users of the project;	Non-potable domestic use; Outdoor communal purposes.	Unknown	Unknown	None were available/offered.	Building regulations or compliance permits; Planning permit.
4	Rotterdam, Netherlands	2018	Sports facility and stadium	Rainwater	Local authority/municipality; The managing company; and users of the project;	Football field and other irrigation	5.1–8.0%	11–20 years	Co-provided by the local municipality and Sparta football club initiative for water conservation.	Health and safety permit. Environmental permit. Municipal permit. Permits are necessary for water infiltration and extraction from the regional water authority.

Table 3. *Cont.*

Case	Location	Year	Purpose	Types of Water Reuse Systems	Beneficiaries	Water Applications	ROI	Payback Period	Incentives	Required Permits
5	Braunschweig Germany	2019	Agricultural	Blackwater, Nutrient recovery	Local authority/municipality; Farmers	Garden and other irrigation use; agricultural irrigation;	Unknown	Unknown	financed by wastewater fees;	Building regulations or compliance permits. Health and safety permit.
6	Hamburg, Germany	2013–2022	Residential scheme	Blackwater, Greywater, Rainwater	The managing company and residents of the project;	local discharge, irrigation, or commercial use;	Unknown	Unknown	Direct financial subsidies/grants;	Environmental permit; Waste-water discharge permit.
7	Lloret de Mar, Spain	Ongoing	Hospitality (Hotel)	Greywater	The managing company and users of the project.	Garden and other irrigation use.	Unknown	Unknown	Direct financial subsidies/grants	Health and safety permit; Municipal permit.

Westland (The Netherlands) is a dense region of urban and industrial areas (including Rotterdam harbour) and greenhouse complexes. The province of South Holland, cities, the water sector, industry, and agriculture are working towards a more circular use of water, resource recovery and renewable energy sources. Several initiatives are active, including excess rainwater falling on greenhouses being temporally stored in the subsurface and used for irrigation. Inside the greenhouses, water is recirculated, the evaporated water is condensed, and the emission of nutrients and pesticides is minimised. Advanced purification, green biogas production, and resource recovery are practised in several WWTPs and recovered materials are brokered to end-users through an innovative nationwide business model (by AquaMinerals). Horticulture companies are exploring collective purification and investment in High-Temperature Aquifer Thermal Energy Storage (HT-ATES). New communal efforts to better exploit this resource are underway: specifically, a "heat roundabout" is being constructed through which excess heat from the port of Rotterdam is transferred to the Westland Region and used by greenhouses.

In the Abwasserverband Braunschweig sewage treatment plant, a pre-treatment plant was taken with a mechanical and biological treatment in operation. This reduced the odour nuisance to a minimum. Until 1991, the expansion to a fully biological sewage treatment plant took place. In 2000, the sewage treatment plant was supplemented by sludge digestion. In 1990, the sewage fields were also converted into a biological post-treatment facility. In 1991, the "meander system" was introduced as a new cleaning process in the trickle operation. In 2007, the wastewater association built a biogas plant to convert the energy crops that grow in the rainwater area into biogas.

Costa Brava is a touristic region located on the Mediterranean east coast of Spain, characterized by high seasonal demand and frequent water scarcity episodes, which cause saltwater intrusion. It is one of the first areas in the uptake of water reuse in Europe with 14 full-scale tertiary treatments for agricultural irrigation, environmental uses, non-potable urban uses, and, recently, indirect potable reuse. This demo case is aimed at implementing and piloting greywater harvesting solutions in the hospitality sector and increasing public acceptance toward such decreolized systems.

The scope and interest of this research were limited to a careful sampling of demonstrator cases and countries necessary to address the project aim without compromising the depth of understanding and analysis. The findings presented in this paper provide a useful baseline and an appropriate method than can be repeated and duplicated by other researchers in future expansive studies.

3.2. Data Collection

The case study approach included a self-administered structured questionnaire to capture basic information about the cases, followed by in-depth, open-ended, semi-structured interviews with project partners undertaking the demonstrating projects. Interview questions included both open-ended and closed-ended questions. Open-ended questions allow the respondents to answer in their own words; thus, they provide richer and more valuable information. The data collection phase was kickstarted by sending personalised emails to the sampled demo-cases project leaders, inviting them to participate in the interview process. After the initial approval was obtained, another personalised email was sent containing details of the interview process, topics, and length. The emails also contained a consent form and the self-administrated questionnaire that was required to be filled out and sent back before the interview (Appendix A).

The interviews were set on a date and a time that was suitable for the participants and project leaders. The interview was held using MS Teams. The interview guide started by explaining the research premises and its objectives and what the interviews would be about. After that, the participants were asked to introduce themselves and provide a summary of their experience, work background, and current role in the demo-case project. (Appendix B). The interview questions addressed the following points:

- The project, water application; building, urban, irrigation, etc.
- Characteristic of the circular water solutions available in the project.
- The motivations which led to the use of circular water solutions in the project.
- The evaluation of the project: does it meet one or more set objective (s)? Other purposes? . . . If it does not work, what are the barriers?
- The operation of the system and its cost.
- The maintenance of the system.

3.3. Data Analysis

Data analysis was guided by thematic analysis or qualitative content analysis [37]. Closed-ended responses were analysed statistically, while open-ended questions were thematically analysed. Responses were analysed by going through all the open-ended responses and manually coding similar or related responses to generalise their responses and develop suggestions and recommendations. To analyse the interviews, first, all data (including data from the self-administered questionnaire and the transcript of the interview) were thematically analysed for recurring patterns and issues and were written in the form of a scientific report alongside analysed and collected data from other documentary and literature sources. Thematic results were backed with results from the Likert scale obtained from the self-administered questionnaire to relate them to the questions of interest.

4. Results

Table 3 summarises findings from the surveys. Most of these projects are demonstration cases to showcase the potential and success of wide-scale implications. It was found that most EU countries do not include domestic or decentralised water solutions in their water and building-related legislations. Therefore, the process of obtaining permits and authorisation for most of these projects was usually lengthy and complicated. In most cases, multiple permits such as health, water, municipality, and safety were required in addition to standard building requirements. Furthermore, only a few of these cases received direct governmental financial subsidies which reflect a larger picture regarding incentives directed toward decentralised circular water solutions. In most of these projects, the local government was the main beneficiary of these projects. It is also noted that payback periods for these projects are quite long, up to 20 years.

Table 4 summarises the state-of-the-art review of regulatory and legal frameworks for circular water solutions for the studied EU countries. It focuses on the current regulations for water reuse, domestic circular water solutions, building and planning, permit and authorization, and financing incentives. The countries in the case study do not have specific regulations for circular water solutions at the decentralised level. Local authorities do not enforce any circular water solutions except for water-saving measures and equipment, such as in the case of Greece and Spain. Instead, circular-water-related regulations and requirements are fragmented among various national and local authorities. Different types of building regulations exist within one country, and obtaining permits requires implementing any solutions that are spread across various health and water authorities. Most member states only have provisions for the installation of water-saving equipment in new houses. In other regions, circular water solutions are encouraged but not required.

The primary data were compiled from questions with predefined possible answers/ratings, and these questions were asked to gather information related to the respondent's attitudes (e.g., reactions to the concept of greywater reuse, risk perception, and confidence in a greywater reuse system) to provide an overview of the case. The thematic findings are summarily discussed in the following sections.

Table 4. State-of-the-art regulatory and legal framework for circular water solutions in case study EU countries.

Country	Policy Framework	Building and Planning Framework	Circular Water Legislation	Wastewater	Rainwater	Greywater	Governmental Subsidies	Approval Process	Water Discharge Fee
Greece	The Joint Ministerial Decree (JMD) 145116/11, and JMD 5673/400/1997	The General Construction Code (Γενικός Οικοδομικός Κανονισμός, or ΓΟΚ), and the Greek urban planning legislation regarding land use mention circular solutions that are required or suggested. In particular, the use of greywater in the buildings is encouraged, as well as the reduction in water consumption by using alternative resources of water, e.g., rainwater, wastewater, etc.	The EU directive on Water Reuse (2019). (JMD) 145116/11, and JMD 5673/400/1997 set minimum requirements for water treatment and reuse in agriculture	Irrigated Agriculture	Non-potable purposes	Non-potable purposes	Non-available	Through local municipality and its sub-divisions (e.g., Health, energy, water) where required or applicable	Unknown
Romania	Environmental Protection Law and Law No. 107/1996—the Waters Law	Law No. 197/2016 on the authorisation of construction works ("Construction Law") and Law No. 350/2001 on Territorial and Urban Planning ("Urban Planning Law")	The EU directive on Water Reuse (2019) and Law No. 107/1996	No use	No use	No use	Non-available	Unknown	Unknown
UK	The water Act (2014) and its implementation. The Environment Act (1995), Environmental Permitting (England and Wales) Regulations (EPR)	BS 8525-1:2010 Greywater a code of practice (BS 8525). BS 8515:2009 Rainwater Harvesting Systems—Code of Practice (BS 8515). The Environment Agency information guide on rainwater and greywater harvesting for more guidance.	BS EN 16941-1:2018 and the EU directive on Water Reuse (2019)	No use	Non-potable purposes	Non-potable purposes	Non-available	The local water authority notified	None
The Netherlands	The Council Directive 91/271/EEC concerning urban wastewater treatment	No local or national building and planning regulation exists for circular or decentralised water solutions	The EU directive on Water Reuse (2019)	Irrigated Agriculture	Non-potable purposes	Football field and other irrigation	Available for RWH in some cities	Unknown	None
Germany	Non-available on a national level	Varies by city and state The DIN 1989-1 and DIN 4045 work as a recommendation text and guideline for those who wish to use such systems.	The EU directive toward water reuse of 2019, DIN 1989-1 DIN 4045	No use	Non-potable purposes	Garden and other irrigation use; agricultural irrigation;	Available for RWH in some states	Not required	In some regions
Spain	The Royal Decree 1620/2007	The Spanish decree for building construction does not specify any requirements for circular water solutions	BS EN 16941-1:2018 and the EU directive on Water Reuse (2019)	Irrigated Agriculture	Non-potable purposes	local discharge, irrigation, or commercial use;	Non-available	Through local municipality	In some regions

4.1. Barriers and Challenges

Figure 2 illustrates participants' views on the issues related to circular water solutions in their projects. As seen from the figure, participants ranked design and technology limitations as the least important barriers to implementing circular water solutions. This highlights that increasing CE for water uptake is not related to the availability of these technologies or their effectiveness. On the other hand, issues related to initial costs, permits, authorisation, and the absence of supportive financial and legislation tools were ranked as the highest barriers. Furthermore, there appears to be a disagreement among participants on the role that end-users play in implementing these systems. Based on the questionnaire results and interview discussions, the following barriers and challenges for implementing and increasing decentralised circular water solutions uptake were identified.

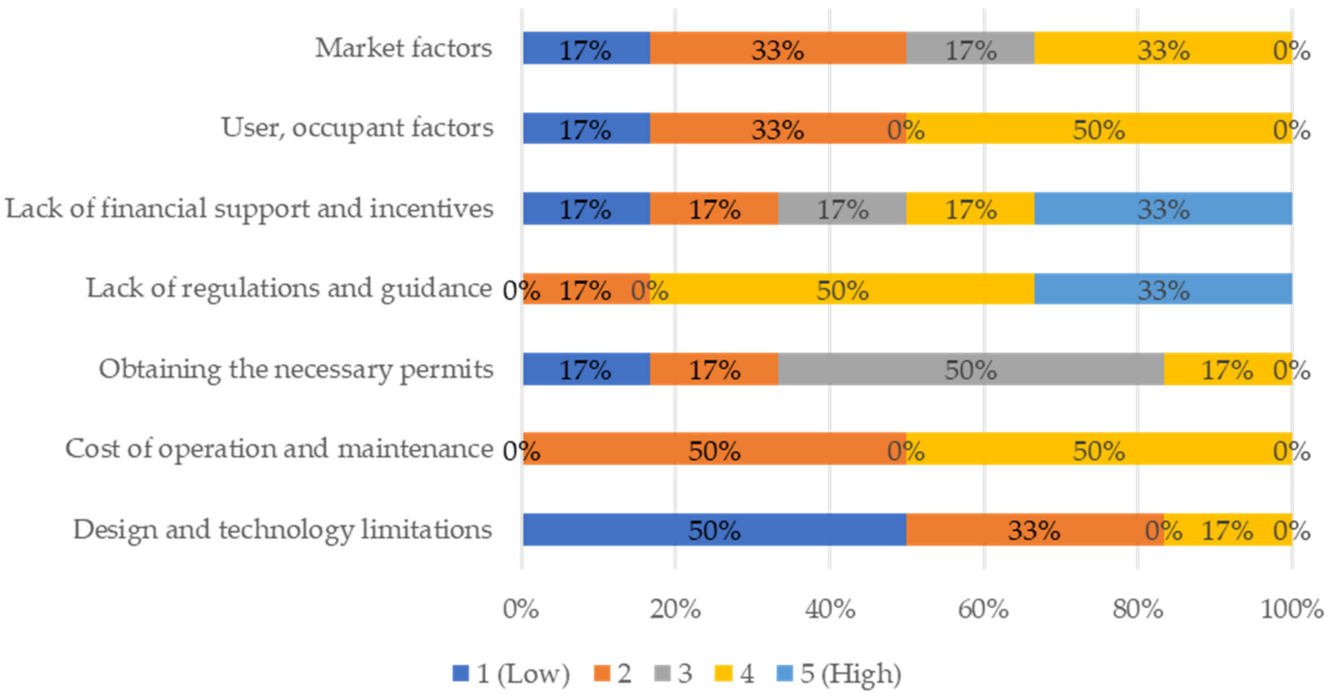

Figure 2. Participants' rankings of the barriers to implementing the circular water/water reuse solutions in the project.

4.1.1. Policy and Regulations

Apart from the proposed EU Regulation 2020/741 on the minimum requirements for water reuse due to become automatically binding on 26 June 2023, there appears to be no new building/planning or circular water reuse solutions regulations that are due to be active in any of these countries. There are no indications that a similar regulation will also apply in the UK post-exiting the European Union. Therefore, the current regulatory framework and building codes in many of the demo-case countries do not currently encourage developers to use circular water and energy solutions. Only general provisions for water management and water-saving solutions are included in the building code of Greece, the UK, Germany, and Romania.

Although current building regulations might not be limiting for circular solutions, they are also not encouraging. Disparate rules and requirements are often required at different levels of government, by different government departments and across different municipalities and regions. The planning and building regulations are not often up to date and circularity as a concept has not been yet integrated. Nevertheless, in domestic projects, water reuse solutions can be implemented as they mostly refer to greywater reuse and/or rainwater harvesting systems. Depending on the design they can be profitable and innovative, e.g., using also subsurface water solutions.

4.1.2. Cost and Incentives

Except for the Rotterdam-Netherlands and Hamburg-Germany projects, no other demo case has received a direct governmental financial incentive. Some of the case study participants highlighted that the local authorities usually do not have the required legislative and financial tools to impose innovation and circular water solutions and they remain cautious in imposing them unless there are scarcity issues with water supply. Most local authorities (except the cities seen as innovative) are reluctant to enforce circular water requirements as these can be seen as investment repellent and they cannot be seen denying investment over such technicalities.

There was also a prevailing perception that large housing developers and builders would not be interested in installing decentralized circular water solutions unless forced through legislation as there is no direct commercial incentive. Perceived benefits only to the end-users rather than the developers or investors can discourage implementation. Local authorities currently do not have enough legal and legislative tools to influence developers towards using circular water reuse solutions, as they are sometimes not even familiar with these systems. There is no cost-benefit to developers, and while they can be innovative regarding designing and implementing circular water solutions, it could impact their profit margins.

4.1.3. Permit and Authorisation

From discussions with the leaders of the project, it was clear that due to the rather innovative nature of the water solutions available in these projects, there was hardly any regulation in place for small-scale applications leading to potential inaction by local authorities to adopt these solutions. Furthermore, all the projects reported that there was no one specific local law or regulation concerning water reuse in their cities or regions related to urban planning and housing. This is more apparent on a domestic level where these cities are still debating the type of regulations and measures required for the use of circular solutions. Figure 3 illustrates responders' views toward factors associated with securing the right permits for the scheme.

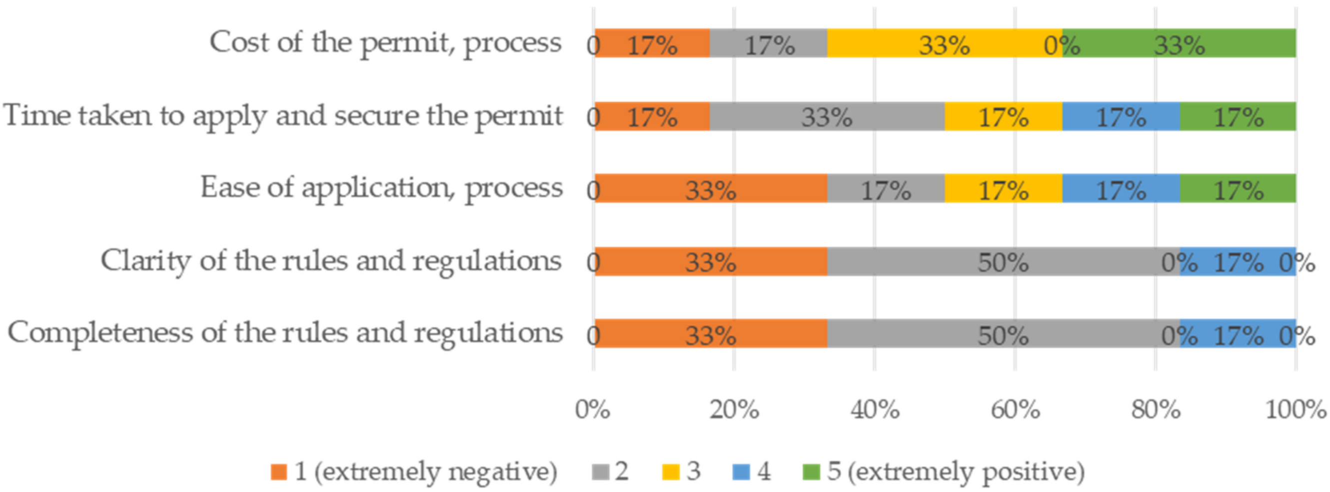

Figure 3. Participants' ranking of the factors associated with securing the right permits for the scheme.

In most of the demo cases, the permits and regulations followed in the planning and installing circular water solutions were more related to the general construction, building, and other approvals that all projects must follow. This includes safety requirements, fire prevention, state-of-the-art technologies, and public health. Therefore, the building codes were not a particular barrier. However, when asked to rank the barriers and forces associated with planning circular water solutions, participants' rankings of the clarity and availability of building rules and regulations were the lowest (Figure 3). This indicates a bureaucratic barrier due to the absence of clear regulations, so these authorities are very reserved when it comes to circular water solutions. Furthermore, the customers and users of the reclaimed and treated water are sceptical and must be convinced of the quality of the reclaimed water also due partly to the vacuum of a dedicated building and planning-related regulation. In Germany and the UK, the DIN and the BSI standards for reused water are only cited for reference and guidance rather than as legal statutes.

In the Rotterdam demo case, a handbook was drafted by the applied research institute of the regional water authorities and province to tackle the regulation vacuum in support for the competent authority. This guide provided a supportive framework for technical and legal aspects of risk assessments of smaller-scale applications of circular water solutions for non-potable applications. It has played an important role in enhancing decision-making for adopting water solutions in Rotterdam. This illustrates the importance and power of suitable regulations in the uptake of domestic circular water solutions.

4.1.4. Overlapping Spheres of Influence

In addition to the absence of clear and enforcing legislation, regulations and permit requirements in most of the European countries are still vague and overlapping when it comes to circular and decentralised water solutions. This is most obvious in housing, where multiple permits such as water authority, safety, health, and municipality are required in many cases. Many projects are being undertaken throughout Europe; therefore, the need to update regulations when it comes to acquiring permits to reutilize the different material flows (service water, nutrients) is becoming more and more essential. The current lack of a regulatory framework is the main barrier. However, with the implementation of the new EU regulation, similar circular water initiatives in Europe will have a continuous legal basis with which to operate until more suitable legislation is adopted in their regions.

4.1.5. Users and Customers' Appreciation

Another limitation regarding implementing decentralised and circular water solutions comes from the fact that the main benefactors of circular water solutions are usually the end-users, who still undervalue such solutions. Customers remain sceptical and suspicious of their quality and must be convinced of the quality of the reclaimed and harvested water. To improve the uptake of water circular solutions, the users should be more informed and the technologies made attractive and efficient. In some cases, sustainable and circular solutions are only good for marketing and not for the actual housing values. Furthermore, grey and wastewater are less attractive for developers and users than, for example, rainwater, which can reduce the possibilities of their uptake in future projects. Therefore, mortgage lenders in the UK do not value innovation in circular and sustainable housing solutions and would not finance them unless forced by law or other drivers applied. Individual property owners and landlords are also unlikely to value water reuse systems unless they derive a direct benefit.

In most European countries with little water stress, water prices are still very cheap to justify using such domestic solutions. In the case of Hamburg, Germany, the beneficiaries of the water reuse scheme are the users of the water because it is available in a greater amounts than groundwater and as a result much cheaper and more environmentally appropriate. The water has a better quality after the treatment, and the WWTP saves treatment costs, which are passed on to the end-users as they pay reduced water tariffs. This is a win-win scenario for all stakeholders. The wastewater fees, by which the wastewater treatment is financed, are proportional to the consumption of freshwater. At the end of the water reuse scheme, the plants from the irrigated fields are used to produce bioenergy. The public corporation intends to finance wastewater treatment and keep the wastewater fees for the citizens low. However, the leaders of this project expressed their concern that the new EU regulation on minimum requirements for water reuse can cause some financial worries because a further treatment step is needed to fulfil the statutory provisions.

4.1.6. Possible Harm to Water Companies

Some water companies in member states charge based on the water consumption (both for water supply and for sewage discharge). However, water discharge in many regions is based on the amount of water consumption and not discharge. Applying circular water solutions might lead to lower water demand while keeping the water discharge level the same if not increasing them, such as in the case of using rainwater harvesting. This would lead to significant revenue loss for these companies. Therefore, circular solutions can reduce income, drive an increase in water prices, and harm local water companies financially unless the charging model is changed or a new service model is proposed. However, large-scale circular water reuse solutions may minimise financial harm to the water companies as the company might benefit from a reduction of costs by not treating the extracted sewage that is treated locally.

4.2. Opportunities

The sampled projects were part of initiatives to use reclaimed and recycled water that benefits the local authorities rather than the residents and users of the project. Therefore, financial costs were not comprehensible or quantifiable. Additionally, as a public institution, paid by taxes, their focus is more on the environment and demo case testing rather than profits. However, there are still some unique opportunities that exist in the field of decentralised water solutions that can increase both the public and developers' interest in the topic and raise the uptake of such decentralised water projects required to combat water shortage and climate change. These include

- Opportunities to optimise rather than create new legislations: There already exist some water-saving requirements in most building codes and legislations that can be altered and tweaked to include compulsory circular water solutions. This is appropriate if suitable financing options and incentives were provided to increase the uptake of these solutions.
- CE for water can support flooding and other climate-resilience strategies: Local government and water authorities/companies are open to the idea of reusing water, as there is likely a need for major investments in the centralised water infrastructure if the system has not been modernised. A circular solution for water on housing and local street levels can help fix existing issues with sewage and storm drainage, which can directly benefit local municipal and water authorities. In addition, green spaces, soft landscapes, and water features require a significant amount of water to maintain, which drives the need for communal circular solutions. Most participants have reported that due to increasing water stress, especially in the summertime, there might be a rethinking of water reuse policy, which could bring circular water solutions more into focus. However, they all agree there is much work to be done on a political level to promote water reuse in Europe.
- Early-stage integration in large-scale housing and urban schemes: High-density and mixed-use developments provide both economic advantages and better chances to deliver circular solutions in design and urban planning. New housing developments provide good opportunities to implement and drive circular innovation solutions. Housing developers in many EU countries already usually install rainwater butts and rainwater control measures on plots as they are required by most planning frameworks. These can be made to be retrofitted or upgraded in the future for rainwater harvesting. Similarly, new mixed-use housing developments could be built with a dual piping system (one for greywater and one for blackwater) in a way that allows future house owners to install greywater treatment and heat-recovery systems. There is also still a possibility of implementing circular regulations on ongoing projects if the timing is right.
- Demonstrator projects help to raise awareness, explore, and enhance financial and non-financial value of CE for water solutions: The cost-benefit analysis of schemes should include other value metrics such as water-saving requirements and environmental

beliefs. Innovative circular water solutions combined with good marketing strategy make schemes more attractive and competitive for investment. It was demonstrated that successful demo case projects can drive and encourage local and national legislation. First, it is important to have pilot projects as demonstration/reference points of innovative circular technologies. Then, it is important to train, educate, and sensitise the local authorities to be able to support the operation of such configurations and technologies. This should be done in a well-structured manner through a dedicated piece of legislation. This kind of activity can be implemented through a top-down approach as first the decision of the planning is down to a high level and then the implementation part is performed by a user/technician.

- Maximise existing opportunities for decentralised treatment and reuse: Current circular-water technologies allow water to be extracted from sewers and treated locally in space-limited units for reuse at the point of demand. What is left is the optimisation of the configuration in terms of efficiency and cost-benefit balance for developers and users.
- Lastly, an opportunity for European countries lies in the implementation of the new EU regulation on minimum requirements for water reuse, which will provide the legal baseline for water reuse for agriculture and encourages local authorities to adopt suitable regulations in the future for urban reuse as well.

5. Discussion

This study found inconsistencies in the policy aspects of circular water solutions across various European countries and member states. For instance, some countries allow indoor non-potable reuse of treated grey- and rainwater, and some do not include greywater in regulations. Regulatory frameworks for water reuse (where they exist) vary significantly between countries (Summary in Table 4). Some EU member states and the UK have implemented water-reuse regulations based on water-quality requirements, but mechanisms and experiences of implementation have varied significantly. Some standards have been proposed in several European Union countries focusing on the optional domestic uses of rainwater. There is much interest in water reuse and nutrient recovery in many European countries, including Germany, Spain, and the United Kingdom. In Spain, there is the Royal Decree 1620/2007, which establishes quality standards for possible uses of recycled water; in France, there is the Décret du 2 Juillet 2008; and the United Kingdom, there is the BS 815, 2009.

Currently, only a few countries have compulsory standards on water reuse enforced through specific water-reuse legislation (e.g., Spain, France, Greece). However, these standards are mainly geared toward agricultural irrigations and centralised wastewater treatment plants. Only the UK, Germany, and Belgium have presented guidelines and standards for decentralised circular water solutions mainly geared toward non-potable purposes. These inconsistencies and variations are mainly due to the differences in water consumption and stress situations between European countries. Most northern European countries have abundant water resources, and they all give priority to the protection of water quality. However, in southern European countries, water reuse takes a different form and is geared toward providing additional resources to counter the water stress issue [22]. Homogenised best practices and guidelines should bring consistency and homogeneity among all EU member states [22,38,39]. These barriers are consistent with gaps found by other researchers. For example, Cipolletta et al., concluded that current EU legislative frameworks do not provide proper guidelines or provide institutional support or financing schemes for small decentralized systems [23]. Maniam et al., concluded that changes in policy and regulation at the local government scale were necessary for the implementation of the decentralized water systems [40]. However, neither explored which of these regulations need changes or in which ways, and neither researched regulations and policies on building and planning levels.

Building and planning regulations have a major influence on the feasibility, implementation, and operation of circular-water solutions, especially at the smaller, decentralised scale. It was also found that there is a need to include water reuse in broader water supply and urban/neighbourhood planning legislations and requirements. A clear definition of realistic building- and planning-specific standards and guidelines for the credible operation and monitoring of small-scale systems by the public and commercial stakeholders is necessary. This will in turn increase the confidence to invest. The legal and financial position of the company's developers offering circular water solutions is severely compromised in the absence of clear and binding regulations which aim to protect public health and ensure the safe operation of water reuse schemes. This is relevant for new innovations to which the regulatory framework needs to relate.

In most of the reviewed countries, planning and designing a water reuse scheme is informed by risk and environmental assessment frameworks in order to identify the potential benefits and any potential drawbacks and risks to public health and the environment. Therefore, it is worth noting that many benefits and risks found will be specific to local circumstances and, therefore, need to be determined on a case-by-case basis. In some cases, there are urban planning and building regulation and code vacuums related to implementing circular water solutions, especially at the communal or the small, decentralised housing scale. The absence of adequate regulation can lead to health risks and poor public perception of the use of circular water solutions. It can also remove policy support for circular water technologies. Mianjy [32] discussed a pilot project for greywater reuse in the Netherlands that went very wrong. After a few years, it was discovered that approximately 10% of the piping connections from the main supply pipeline to household distribution were made the wrong way. People were drinking greywater and washing their cars and flushing their toilets using clean drinking water. The project was stopped, and subsidies for domestic greywater reuse have halted since then.

Due to such health concerns, France's legislation, for example, is very cautious and strict regarding circular water solutions, resulting in significant financial and bureaucratic burdens for those that choose to adopt them. While many participants from demo case studies argue that the lack of such criteria has been the main barrier to growth in the reuse sector, it has also been recognised that legislated quality criteria can actively hinder reuse schemes if they impose overly burdensome treatment and/or monitoring requirements. The challenge is to compromise between excessive precaution and insufficient safety in developing regulations. Appropriate water reuse regulation can raise awareness and trust among the general population and encourage uptake of decentralised water systems.

There is fear among some interview participants that the adoption of the EU Commission Regulation 2020/741 on water reuse might lead to stricter water quality. This is most notable in regions where water reuse has been established for years, such as Spain, Greece, and the Braunschweig region of Germany. Stricter water quality might increase water reuse prices and jeopardise the success of these projects. Therefore, some allowances should be made to negotiate the minimum requirements in countries with well-established and successful local policy protocols for water reuse.

Regarding permits and the authorisation process, each country has its own set of permits, risks assessments, and authorisation requirements and protocols for circular water solutions. Participants in interviews and surveys repeatedly mentioned this as a potential barrier to adoption. The EU Regulation 2020/741 addresses the quality aspects of permits with the minimum quality requirements specified; however, it does not set a unified permit or authorisation process. With 17 specified additional pieces of legislation in Regulation 2020/741, water reuse schemes are subject to numerous water quality requirements in addition to those explicitly described in the regulation. The findings show that the policy and regulatory requirements covering circular-economy technologies and their products are split between many different directives, and alignment between them is still poor. In the case of potential conflict, there is little or no 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. With less than two years before the regulation comes into effect, identifying the responsible parties/agencies that should oversee water reuse permit allocation is of the highest priority. This must be done to ensure that questions can be answered before the law comes into effect on 26 June 2023.

To make use of experiences among member states and the UK, documents on learning and experiences could be made publicly available for parties interested in developing reuse schemes. As the transparency provisions specified in Regulation 2020/741 require that information on water reuse is made publicly available, this is a logical first step in raising awareness and disseminating accurate information. Confusion or uncertainty could be circumvented by the creation of a master list of water quality parameters (e.g., chemicals and pathogens) to help in the drafting of the Water Reuse Risk Management Plans (WR-RMP). Such a list could be made freely available for all parties interested in pursuing water reuse in general, as Regulation 2020/741 also encourages industrial reuse and reuse for amenity-related and environmental purposes. This would be helpful since some parties or member states interested in water reuse may be lacking technical or practical knowledge and experience in implementing reuse schemes. A database with acceptable risk levels or water quality for different reuse purposes, as well as relevant preventive measures, would facilitate the implementation of the proposed regulations [41]. In addition, referencing practical case studies (not only limited to agricultural reuse) would provide insight into which monitoring is practical, feasible, and meaningful for the reuse operators and others involved in creating the WRRMP to further specify site-specific monitoring requirements.

A list of technical specifications would also be helpful. Identifying which disinfection processes (e.g., UV disinfection, ozonation, chlorine, etc.) are suitable and which are not would be helpful to spread experience among member states [42]. Allowing more treatment processes to be included in a reuse scheme, depending on the desired removal of chemicals, could increase the uptake of reuse. Regulation 2020/741 currently does not discuss options for water storage, which could discourage some potential water-reuse schemes and rather increase the de facto reuse if required monitoring is too expensive (for the AWT) or there is a lack of expertise on either side (AWT or water users).

6. Conclusions and Recommendations

Laws and government policy are vital for driving the adoption and uptake of CE for water [43,44], as well as for implementing socially and ecologically responsible practices, such as rainwater- and grey-harvesting systems. Local governments' laws and policies are vital for driving the adoption and uptake of decentralised circular water solutions, as well as for implementing socially and ecologically responsible practices, such as rainwater- and grey -harvesting systems. This paper investigated the current European policies to improve uptake and promote a new circular economy for water-delivery models. It was found that each country has its set of permits, risk assessments, and authorisation requirements and protocols for circular-water solutions. Further, some EU countries recognise the principle of fit-for-purpose for water use, where uses do not require high-quality treated water, whilst others apply environmental principles to promote water reuse. Where circular economy (CE) water is permitted, diverse regulations for implementation exist, and applications, monitoring, and enforcement measures vary according to the existing policy and water priorities of member states. It was also found that implementing CE for water continues to be hampered by the cost-benefit gap for those investing in systems. Other challenges include the disparate approaches to incentives, the complexity and bureaucracy of permits, disparate technical standards, technical competencies, lack of knowledge about CE, and how to best implement it within the business and financial models. It was, however, accepted that the EU Regulation 2020/741 for water reuse will address some of these challenges. Meanwhile, other gaps remain, notably in housing regulations specific to smaller-scale installations.

The findings show that the policy and regulatory requirements covering circular economy technologies and their products are split between many different directives, and alignment between them is still poor. CE for water implementation is hampered by a lack of knowledge on how to implement it in business models. The barriers also show inadequate awareness, understanding, and insight into CE, especially within the built environment [45]. Participants in interviews and surveys repeatedly mentioned this as a potential barrier to adoption. In the case of potential conflict, there is little or no 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. With less than two years before the regulation comes into effect, identifying the responsible parties/agencies who should oversee water reuse permit allocation is of the highest priority. This must be accomplished to ensure that questions can be answered before the law comes into effect on 26 June 2023.

To tackle these issues and to increase the uptake of circular water solutions, the paper recommends a five-point route map for new and revised policies and regulations targeting improved uptake of circular water technologies in Europe as follows:

1. Adopt the fit-for-purpose water principle: In addition to reducing the unnecessary water abstraction and treatment processes and streamlining 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 lifecycle use.
2. It is a matter of scale: Policy, guidelines, processes, and protocols for circular water reuse should reflect the context, application (quality), and scale (system). Permit processes for small-scale domestic schemes and prosumers should be streamlined and accessible and should not be as complex as those of urban-scale, public-oriented systems.
3. Mitigate cost and financial risks by allocating investments and incentives along with three deployment scales: capture and treatment, distribution, and use. Rainwater, greywater, and nutrient recovery can operate at centralised, satellite, and local scales. This means that life-cycle cost-benefits and risks should be assessed, and incentives should be targeted at those more capable to provide the necessary infrastructure and upscaling but least likely to directly benefit from such investment. This will address the value disparity in water processes, e.g., industry pay per water discharged, end-user pays per water used, or new versus retrofit projects. Studies have shown that incentives at the bottom—end-use scale—are minimal considering the already low cost of water, whereas direct costs to companies and industry are more significant as projects could be high-risk, high-cost, and high-uncertainty. Therefore, the key driver should be ensuring that the correct systems are installed, serviced, and maintained at scale to maximise updates and make circular water solutions more widely used.
4. Address the process, performance, and route-to-market gaps: In the cases studied, one to more than six permits could be required for projects by different regulatory bodies or authorities. The complexity of bureaucratic processes and durations for obtaining permits also varies. This can be particularly burdensome for those proposing small-scale systems or solutions, who may also lack the technical and administrative expertise to navigate the various rules and requirements. In addition, once permits are issued, quality and other maintenance requirements may be too burdensome and bureaucratic to make endeavours profitable. These rules are also less likely to be monitored or enforced. Therefore, permits should be designed based on scale, application (fit-for-purpose principle), and risks. Reporting and monitoring processes ranging from self-reporting and certification to approved certifiers should be considered.
5. Improve knowledge and awareness across all sectors and user groups: The sustainability basis for circular water technologies relies on a coherent justification of the environmental, economic, and social benefits and impact. Social impacts include maintaining the health and wellbeing of people. This includes overcoming perceptions of health risks of decentralised water sources. Therefore, in addition to points 1–4 above, improving access to information and technical support; commissioning, publicising, and making more demonstration projects available for visits,

question, and answer sessions; and offering training and certifications for policymakers and skilled professionals would collectively raise awareness and improve the positive uptake of decentralised water solutions.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study prior to their participation. Data collected from the participants in the form of audio recording were stored securely on the University of Bath server. No names were collected during the study process.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A. Project's Leader Interview Guide

Participant (Title and Name):
Interviewer:
Purpose of the interview

This study is part of the NextGen project, which is funded by the European Union's 2020 research and innovation program. For further information please go to the website https://nextgenwater.eu/, accessed on 18 June 2022. This interview aims to examine legislative urban development and planning frameworks, as well as relevant building and construction regulations, and consider their implications for new housing and commercial developments that incorporate more decentralised circular solutions.

You have been invited to this interview because you have been identified as someone who has a great deal to share about circular water solutions in residential projects. The project you worked on will be one of several case studies around Europe. These case studies will enable us to reveal and overcome technological and regulatory issues to increase the uptake of circular water solutions for future residential projects.

Interview protocol

This interview is planned to last no longer than half an hour. During this time, we have several questions that we would like to cover. If time begins to run short, it may be necessary to interrupt you to push ahead and complete this line of questioning. The Interviewer will sometimes ask a follow-up question to the original points being discussed to ensure that all points were covered during the interview.

To facilitate our notetaking, please note that this interview will be video recorded. Only researchers on the project will have access to the recording which will be eventually destroyed after they are transcribed.

Ethics and confidentiality

All data will be handled in accordance with the Data Protection Act (1998), and the General Data Protection Regulation (GDPR, 2018). Participation in this study is entirely voluntary. Data related to this interview including the video recording will be stored on a password—secured computer. You may choose not to participate or withdraw at any point during the interview. Your identity as a participant in this research study will remain confidential with respect to any publications of the results of this study. There will be no reimbursement for participation in the study.

Interview guide

You have been selected to speak with us today because you have been identified as someone who has a great deal to share about circular water solutions in residential projects. The project was selected as a case study within your regions.

Our research project as a whole focuses on the improvement of teaching and learning activity, with a particular interest in understanding how faculty in academic programs are engaged in this activity, how they assess student learning, and whether we can begin to share what we know about making a difference in undergraduate education. Our study does not aim to evaluate your techniques or experiences. Rather, we are trying to learn more about teaching and learning, and hopefully learn about faculty practices that help improve student learning on campus

1. Would you please introduce yourself?
    a. What is your current job title/position?
    b. How many years of experience do you have in your current role?
    c. What do you consider your main area of expertise?
    d. In which ways? Can you please elaborate?
    e. Can you please describe your responsibilities and your role within this project?
2. What circular water solution does the project utilise?
    a. What was the main motive and reason for implementing these circular solutions in the project? (e.g., sale, environmental, or regional authorisation)
    b. Did the project achieve those goals? If yes, how? If not, why?
    c. Do developers in your region prefers one type of circular water solution over the other? Which one is more prevalent? Why?
    d. In addition to these circular solutions what other water-related design and specifications were required by local or national building code? (e.g., reduction of water consumption or wastewater discharge requirements)
3. Did the installation of circular water/water reuse solutions in your project required any prior authorisation or planning permits?
    a. If no, why? If yes, who required the approval/permit?
    b. Can you describe the process required to get the permit? How long did it take? Do you think the regulation requirements are reasonable?
    c. Did you or the developer/owner of the projects face any issues while planning, designing, or acquiring authorisation for the circular water/water reuse solutions in this project?
    d. If Yes, what were they? (e.g., permit-related, technical, bureaucratic)
    e. If no, are you aware of any common regulatory or planning issues that similar projects face in your country/region? What are they? Why?
    f. Do these issues reoccur with each project? Why? Were they solved? Why? How could they be avoided?
4. What were the main building codes and regulations that applied to the project including the design, planning, operation, and maintenance phases?
    a. What are the requirements? What conditions apply?
    b. What would you consider to be the positive and negative aspects of these planning codes, regulations and planning requirements?
    c. What are the challenges to compliance and implementation?
    d. Do you have any concerns about legislations? What are they? Why?
5. Are there planning rules and requirements that apply to the implementation of circular water technologies and solutions to buildings?
    a. What are the requirements? What conditions apply?

   b. What are the challenges to compliance and implementation?
   c. What would you consider to be the positive and negative aspects of these codes and regulation requirements?
   d. Do you have any concerns about the legislations concerning the use of circular water technologies in buildings? e.g., Technical, procedural (time, cost), financial (general/overall costs), water quality requirements, capacity to implement etc.
   e. Did these codes and regulations include incentives including tax, financial support?
   f. If yes, was this project eligible? In what way or form?
   g. What were the criteria required to get the funding/to subsidise? Can you describe the application process? How long did it take?

6. To what extent does the planning and building regulations impact on decisions to implement circular water/water reuse solutions in your scheme?
   a. Do you think the current regulatory framework and building code encourage developers to use circular water and energy solutions? If no, why? If yes, how?
   b. What barriers did you experience? How can they be avoided?
   c. Are you aware of any new building/planning or circular water/water reuse solutions regulations that are due to be active soon? What are they? How are they different?
   d. What are the challenges?
   e. How do you think these can be addressed?
7. Who were the beneficiaries of the scheme?
   a. How do they benefit?
   b. Were they and other stakeholders consulted? During which stages of the project?
   c. Are there any stakeholders not benefiting or being affected negatively by the use of circular solutions in the project? Who are they? How? How could this be fixed?
   d. Some water companies and authorities' price water and tax sewage based on consumption alone and not discharge, is that is the case in your region? If this is the case, would large scale domestic circular water/water reuse solutions harm water companies financially? Why? How? What can be done?
   e. Did the use of circular solutions for water impact the unit' value, sale, lease of the building or property? If so, How?
   f. Who is responsible for maintaining the system and paying the energy bill? What is the current arrangement?
   g. In your opinion are the circular water/water reuse solutions valued, effectively utilised by end-users?
   h. Was the use of circular water/water reuse solutions profitable? For whom, the provider or the end-user? Why? What are the main issues? What could be done?
8. In your opinion, do current planning and building regulations drive innovation in practices toward circular water/water reuse solutions in housing projects?
   a. Why? How? What barriers did you experience/exist? How can it be improved?
   b. Can most developers be innovative when it comes to circular water/water reuse solutions in domestic projects? Can they be innovative and profitable? Why? How?
   c. Do local authorities currently have enough legal and legislative tools to influence developers towards using circular water/water reuse solutions? How? Why?
   d. What innovative planning policies and regulations do you think are needed? What legislations are missing?
   e. Should they be implemented top-down or bottom-up? Why? How?
   f. How can these be adopted and implemented? Where are the bottlenecks?

   g. Is the developer interested in using circular solutions in future projects? Why? What are their concerns? How to overcome it? What would your future advice be? Why?
   h. What else can be done to improve the uptake of domestic water circular solution?
9. What other factors inform your decisions to implement circular water technologies
10. Any other comments, observations?

Thank you for your time.

Appendix B. Case Study Survey Form

This study is part of the NextGen project, which is funded by the European Union's Horizon 2020 research and innovation programme under grant agreement no. 776541. Our study aims to examine legislative urban development and planning frameworks, as well as relevant building and construction regulations, and consider their implications for new housing and commercial developments that incorporate more decentralized circular solutions. For further information please go to the website https://nextgenwater.eu/), accessed on 18 June 2022.

This survey aims to collect general data and information about building projects that have implemented circular water technologies across Europe to gain insight and create collective learning opportunities to accelerate the uptake of circular water solutions in residential projects.

*All data will be handled in accordance with the Data Protection Act (1998), and the General Data Protection Regulation (GDPR, 2018). Participation in this study is entirely voluntary. You may choose not to participate or withdraw at any point up until the completion of the survey by simply exiting the browser page, and all the files will be destroyed. Your identity as a participant in this research study will remain confidential with respect to any publications of the results of this study. There will be no reimbursement for the participation in the study.

Thank you.

1. Project's name:
2. Location (City, Country):
3. Year constructed or installed:
4. The main use/purpose of the project:
   a. Residential
   b. Non-residential
   c. Mixed-use
   d. Agricultural
   e. Other:
5. If it is residential, what types are available (please select all that apply):
   a. Detached Houses
   b. Semi-Detached Houses
   c. Terraced Housing
   d. Flats/apartments
   e. Non-applicable
   f. Other:
6. The approximate number of units:
7. The approximate number of occupants/users:
8. What types of water reuse systems were implemented in the project? (Please select all that apply)
   a. Rainwater harvesting
   b. Greywater recycling
   c. Black (waste) water recycling

   d. Nutrition recovery
   e. Wastewater Heat recovery
   f. Other:

9. Who were the main beneficiaries of the circular water/water reuse solutions? (Please select all that apply)
   a. The owner/developer of the scheme
   b. Occupants/users of the project
   c. The managing companies
   d. Local authority/municipality
   e. Other:
10. What are the main applications for the recycled or reclaimed water or energy? (Please select all that apply)
   a. Non-potable domestic use e.g., toilet flushing, cleaning
   b. Non-potable industrial use e.g., cooling systems
   c. Garden and other irrigation uses
   d. Outdoor communal purposes only e.g., Vehicle washing
   e. Water and/or space heating
   f. Other:
11. If known, what was the approximate cost of the system?
12. Was the answer for the previous question (Q.12) per:
   a. Unit installation
   b. Scheme
   c. Other
13. What was the expected rate of return on investment (ROI) for the circular water/water reuse solutions?
   a. Less than 2.0%
   b. 2.0–3.5%
   c. 3.6–5.0%
   d. 5.1–8.0%
   e. More than 8.0%
14. What is the expected Payback Period for the circular water/water reuse solutions?
   a. Less than 12 months
   b. 1–2 years
   c. 2–5 years
   d. 5–10 years
   e. 11–20 years
   f. More than 20 years
15. What types of incentives/subsidies were available for the project? (Please select all that apply)
   a. None were available/offered.
   b. Direct financial subsidies/grant
   c. Indirect financial subsidies (e.g., Tax breaks)
   d. Logistic aid and planning/design
   e. Special building permit authorization
   f. Other:
16. Who provided the incentive?
   a. Transnational government (e.g., EU)
   b. Central government
   c. Municipal, Local government
   d. Private financial institution
   e. Other governmental agency

f. No incentives were received
g. Other:

17. What type of permit(s) were required for the installation? (Please select all that apply)

a. None required
b. Planning permit
c. Building regulations or compliance permit
d. Environmental permit
e. Health and safety permit
f. Water abstraction/authority permit
g. Waste-water discharge permit
h. Municipal permit
i. Other:

18. Please rate the following factors associated with securing the right permits for the scheme? (1 = extremely negative, 5 = extremely positive)

	1 (Extremely Negative)	**2**	**3**	**4**	**5 (Extremely Positive)**
Completeness of the rules and regulations					
Clarity of the rules and regulations					
Ease of application, process					
Time taken to apply and secure the permit					
Cost of the permit, process					

19. Please rank the drivers for implementing the circular water/water reuse solutions in the project? (1 = low, 5 = high)

	1 (Low)	**2**	**3**	**4**	**5 (High)**
Environmental benefit					
Social benefit					
Financial benefit					
Corporate image, reputation					
Competitiveness e.g., more sales, share value, increase in market share.					
Green building rating and certification purposes					

20. Please rank the barriers to implementing the circular water/water reuse solutions in the project? (1 = low, 5 = high)

	1 (Low)	**2**	**3**	**4**	**5 (High)**
Design and technology limitations					
Cost of operation and maintenance					
Obtaining the necessary permits					
Lack of regulations and guidance					
Lack of financial support and incentives					
User, occupant factors					
Market factors					

21. Any other comments. Thank you for participating

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