

## Article

# An Integrated Assessment Framework for Transition to Water Circularity

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**Abstract:** Changing our unsustainable linear water management pattern is necessary to face growing global water challenges. This article proposes an integrated framework to analyse and understand the role of different contextual conditions in the possible transition towards water circularity. Our framework combines a systematic multi-level perspective to explore the water system and the institutional work theory for technology legitimation. The framework consists of the following stages: (1) describing and understanding the water context, (2) assessment of the selected technologies' circularity level, (3) assessment of the alternative circular technologies' legitimacy, and (4) identification of the legitimation actions to support the upscale of alternative circular technologies. The practical applicability of the integrated assessment framework and its four assessment stages was demonstrated in the exploration of circular water technologies for the horticulture sector in Westland, the Netherlands. The results revealed the conditions that hinder or enable the legitimation of the circular water technologies, such as political environmentalism, trust in water governing authorities, and technical, financial, and knowledge capabilities.

**Keywords:** sustainability transition; water circularity; circular economy; legitimation; multi-level perspective; technological innovation system; institutional work



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## 1. Introduction

Water is an essential resource for healthy societies, ecosystems, and biodiversity. In addition, it is vital for ensuring food security and, in most cases, energy production and industrial processes. However, the demand for water resources is growing due to high population growth, rapid urbanisation, rising income levels, high industrial growth, ageing infrastructure, the water–energy nexus, and the water–food nexus [1]. Furthermore, this increase in freshwater consumption will put even more pressure on water management by producing more wastewater that needs more energy and chemicals for its treatment [2]. Another critical factor exaggerating water supply uncertainty is climate change. Climate change is expected to disrupt the weather patterns leading to severe floods and droughts, shifts in precipitation patterns, and lower surface water quality due to higher temperatures and lower dissolved oxygen levels [3]. This disruption can impact the availability and the distribution of the current water resources as we know them extensively, further aggravating the competition needs for water resources among its users [1,2], and prompting action on climate change adaptation measures (e.g., green–blue solutions for reducing flood hazards in vegetated rivers [4]).

The increasing risk of water crises can hinder nations' sustainable socio-economic development goals, as water contributes to almost every sustainable development goal (SDG) [5]. Thus, there is a dire need to shift from the short-sighted and unsustainable linear management approach (take–use–discharge) to more circularity [1]. However, with all these threatening water challenges, the water sector still “sees few innovations” at a system level for different pragmatic, institutional, and financial reasons [6].

### 1.1. Circular Economy in the Water Sector

The circular economy (CE) has grabbed the attention of researchers, practitioners, and politicians. By addressing environmental, social, and economic sustainability jointly, CE is fully aligned with the UN 2030 Agenda [5]. CE was promoted because practitioners and scholars understand the high vulnerability of linear systems to lower availability of resource inputs, higher resource prices, and limited access to resources, and acknowledge the need for a model that separates development from resource consumption [7]. Many businesses, cities, and governments are moving towards a circular economy for its tremendous opportunity to realise greater social, environmental, and economic values [8]. Considerable work has been performed on CE in various sectors, such as the electronics industry, the construction sector, and the automotive sector. In addition, the circular economy in the water sector has been recently gaining more attention, as seen in the study conducted by Kakwani & Kalbar [9].

Applying the CE principles provides a systematic approach to solving water challenges and sustaining water services [5,10]. Water systems intersect with society, industries, and agriculture, and in these intersections lie the opportunities to create or unlock additional value for water by applying the CE principles [11]. Human actions, such as overexploitation of freshwater, inefficient water use, and water pollution result in social, environmental, and economic losses. CE provides the opportunity to eliminate these impacts by better aligning nature and human water cycles using the following measures: “Avoid, Reduce, Reuse, Recycle, Replenish, and Re-Optimize.” This alignment can help improve environmental quality while generating business opportunities [11]. Additionally, it can enhance social wellbeing by providing employment opportunities, improving health conditions, mitigating greenhouse gas emissions, and, most importantly, securing water [12–14]. In the CE, the water product can gain value by providing a service as water provision, as an energy source (carbon and thermal), and by acting as a carrier (e.g., of nutrients) [11].

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, and potential health and environmental risks [15–17]. Accordingly, adequate policy settings need to be readjusted to provide more robust policy measures that ensure higher protection levels for the environment and health [18], and social interventions are needed [2]. Applying CE principles to the water sector thus requires a holistic vision to pick the most circular solution [19]. Opportunities and risks can occur from the water sector transition to a circular economy, and there is a need to assess them on a case-by-case basis [20]. In addition, the contextual setting might need to change to allow the achievement of CE in the water sector. For example, the study by Eneng et al. highlighted the need to change the contextual setting to enable CE to address the present water challenges in Indonesia by changing regulations through “a new and revolutionary way of thinking, leaving the old linear thinking about resource use” [21] (p. 13).

Many alternative technologies can be classified as circular water technologies (CWT), such as water reuse, rainwater harvesting, energy and nutrients recovery from wastewater, etc. However, the selection and feasibility of the most appropriate solutions depend on the water system’s characteristics and embedded context [11]. As there is not a one-size-fits-all solution for all contexts, considering the context’s complexity and diversity—in terms of the natural and climatic context, prevailing problems, the land-use planning policies, regulations, and preferences—is a necessity for selecting suitable solutions [22,23]. Furthermore, different cultural, physical, regulatory, financial, and market contextual factors can act either as drivers or barriers to the shift from linear water management [2,14,24–27]. Accordingly, the circular water paradigm challenges the linear management approach with its current legal and social norms and practices. For this purpose, the proposed framework is focused on legitimising circular water technologies to overcome such challenges. Binz et al. [28] (p. 250) define the legitimation process as “the process where heterogeneous actor-networks fight over, construct and deconstruct alignments between a new technology and prevailing institutional contexts (widely held social norms, preferences and cognitive

associations)". According to Giezen [29], shifting towards circularity creates a dynamic in which actors can achieve transformative changes. Since this article focuses on the transition towards water circularity, understanding its institutional work is necessary.

### 1.2. Aim of the Study

Moving to a circular water system shows promising prospects in creating the needed changes to meet future water demands and withstand the expected climate change impacts [11]. However, as noted from the literature, there is a lack of understanding on how this sectoral shift towards more water circularity will occur. Fidélis et al. [30] have emphasised that anticipating different paths is necessary for the EU member states while exploring CE in water to understand and disseminate the CE concept adequately in national contexts. Yet, no studies were conducted explicitly to anticipate contextual factors' role in selecting the appropriate CWT and upscaling them to achieve more circular water management.

This article refers to the research on the sustainability transition depending on spatial and historical contextual conditions. There are mainly two streams to analyse the different dimensions that affect the processes of innovation development and transition: technological transition and technological innovations, both of which apply the emerging technology perspective and the transition perspective [31]. Furthermore, both streams use the socio-technical systematic view to analyse innovation/transition dynamics. However, few studies applying those frameworks in analysing the transition of the water sector to new paradigms are available [32]. For example, Quezada et al. [32] analysed Australia's context to understand how adopting decentralised water systems could occur using the socio-technical transition perspective. Another study conducted by Binz et al. [28] explored the upscale of innovations in the water sector, taking the success story of water reuse in California, through understanding the processes of how actors created legitimacy for the new technology, which is a key function in the technological innovation system [28].

No studies were found explicitly for *circular* water transitions built on these transition and innovation frameworks. To fill the gap, this article introduces a combined framework applying concepts and related methodologies that can be used to access the upscale of circular water technologies and ultimately transition towards a circular water system. This shall be accomplished by defining the factors to be analysed while shaping transition pathways towards circularity in the water sector. Using an empirical case study, we present a novel approach consisting of transition and technology legitimisation frameworks to endorse the upscaling and transition of circular water solutions. More background information on those frameworks will be provided in the theory section.

The paper is structured as follows: the next section introduces the methods used to develop the framework. Section 3 presents an overview of the key theoretical and conceptual sustainability transition frameworks. Section 4 combines these into an integrated framework and discusses its elements in more detail. Section 5 applies the developed framework to a case study, providing a partial empirical application of the framework. Section 6 discusses the framework application implications at the case study level and regarding more general insights outlining its pros and cons. The lessons learned are presented in the final conclusion in Section 7.

## 2. Materials and Methods

This section explains the methods used to identify the concepts needed to assess the transition towards water circularity. First, a thorough literature review was conducted on the usual frameworks used in the sustainability transition. Those frameworks were analysed in terms of how they can explore the overall transition and upscale of circular water technologies. Secondly, the study assessed how these socio-technical transition concepts could be applied in a real-life case study: circular water technologies in the horticulture companies of the Westland region in the Netherlands. This case study is one of the demonstration cases of the EU H2020-project NextGen on circular water solutions.

The literature review and assessment combined insights from two widely used frameworks: the multi-level perspective framework and the technological innovation system framework [31,33]. In addition, as building legitimacy for the circular water technologies is required, insights from the technology legitimation using the institutional work analytical framework of Binz et al. [28] were also drawn from. Furthermore, a recent World Bank framework called Water in Circular Economy and Resilience (WICER) is applied to assess whether the proposed circular water technologies meet circularity criteria [5].

The first point was to understand the existing external pressures and systematic configuration to describe the potential transition pathways. The socio-technical system analysis was conducted during the first phase of the research by applying the systematic perspective lens to the defined case study. This step is necessary to understand the confining and nonconfining nature of the contextual factors, which will lay and sketch the boundaries for possible circular water solutions. This step is an essential building block for developing the circular water transition pathway. The resulting understanding will reveal the stabilising or destabilising impact of the regime's external and internal pressures and how niche (and regime) actors can take advantage of such pressures.

Thus, the aim is to explain how those frameworks were combined and adapted to a real-life case. The research used a qualitative research design with a case study approach to describe how the context affects the adoption of the new CWT. Interviews were used to collect data on how the water is managed in the horticulture sector in Westland and what could ease or hinder the adoption of new CWT by horticulture companies. Conducting interviews is the most familiar way to collect empirical data in explorative qualitative studies [34]. The format of semi-structured interviews allowed the researcher to ask additional questions to understand better when needed. The main actor groups for interviews were defined after conducting a literature review on water management in the horticulture sector in Westland and a discussion with the project team leader. This sampling method is referred to as strategic sampling, and it helps maintain the research's validity [34].

A 16 question, semi-structured interview guide was used to interview four high-level representors of the main actors in the horticulture sector in Westland: (1) South Holland Province, the provincial government, (2) Delfland Water Board, the regional water authority, (3) Glastuinbouw NL, the entrepreneurial network in the Dutch greenhouse horticulture sector, and (4) KWR water research institute, a researcher involved in implementing the CWT in Westland. The interviews were transcribed and then analysed using MAXQDA software through a coding scheme based on theoretical frameworks. Data analysis consisted of applying a categorising strategy through coding, widely used in analysing narrative data in qualitative studies [35]. The authors have followed the multi-step approach, where the findings of one stage feed into the next one.

### 3. Frameworks for Sustainability Transition

Research on sustainability transition has expanded dramatically during the last twenty years, driven by the motivation to recognise the societal challenges encompassing existing environmental problems [36]. Those societal challenges are caused by unsustainable consumption patterns and the unsustainable production of goods and services. In addition, technical fixes or gradual improvements cannot resolve those challenges. Instead, they need radical shifts towards new sustainable socio-technical systems that fulfil the societal needs, the "sustainability transition" [36–38].

Two principal streams analysed the transformation processes: the technology and transition perspectives. While the former focused on examining the dynamics of a specific innovation by identifying its potential drivers and barriers to its diffusion, the latter examined the factors pushing for transition at a higher level [31]. As a result, those two streams resulted in different theoretical frameworks for understanding sustainability transition studies. Out of which, the authors have selected the multi-level perspective (MLP) and the technological innovation system approach (TIS), both of which address

the two perspectives [31]. In addition, both use the systems perspective to analyse the co-evolutionary transition processes, explain path dependencies, and conceptualise non-linear change dynamics [36].

The authors have picked the MLP for its empirical features in describing and analysing socio-technical systems and ongoing processes. In addition, applying the MLP can help identify barriers and indicate possible pathways for innovations. However, the MLP cannot produce instructive insights that allow the transition stakeholders to engage in the change processes [39] proactively and strategically. For that reason, the authors have complemented the MLP with the analytical framework of Binz et al. [28], which focuses on legitimacy dynamics and legitimation strategies for technology to thrive in the system.

### 3.1. Multi-Level Perspective Framework

The multi-level perspective (MLP) is a prominent approach taken in transition studies [40,41]. The MLP framework examines the regime transformation and present socio-technical regimes [31]. The framework is an abstract analytical framework that incorporates the socio-technical systematic perspective and combines evolutionary economics, technology sociology, and institutional theory [42,43]. The selection of this framework was first guided by the fact that it is widely used in examining transitions in different areas, including water supply and sanitation, making it one of the key frameworks in the sustainability transitions field of research [36]. Secondly, by its purpose, the multi-level perspective is a framework applied to analyse complex and multi-layered systems to understand the socio-technical transitions. Finally, its socio-technical systematic perspective provides a comprehensive view of understanding and interpreting the complex problems resulting from unsustainability [44,45].

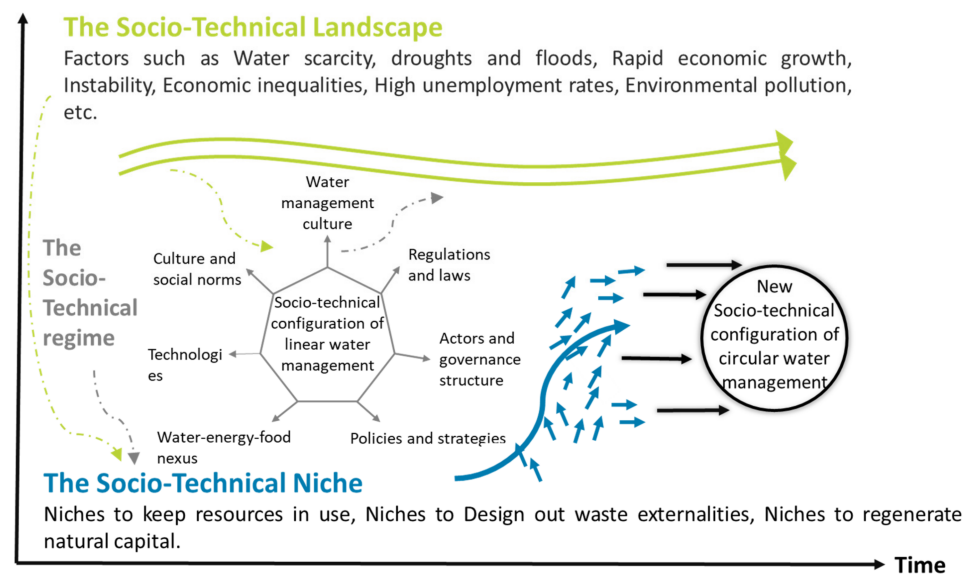
Geels [33] defines technological transition as a transformation in how societal functions are fulfilled after introducing new technologies and changing other technology-related elements, such as infrastructure, user practices, regulations, skills, behaviours, etc. Even if a new technology offers promising features for society and the environment, it cannot solely assure a successful adoption by society. That is because a specific socio-technical configuration already exists and is aligned with the existing technologies, presented by a set of heterogeneous social and technical elements linked together [33]. The relationship between the socio-technical aspects can be characterised as lock-in when that systematic arrangement stabilises over time, hindering the upscale of new, favourable, and more sustainable technologies or any attempt to change the configuration [46]. Thus, for new technologies to break through, they need to overcome this socio-technical configuration. Still, the question is how, which Geels [33] tries to address with the MLP framework. Geels [33] revealed that the idea behind using different levels is to help understand the complex dynamics of the socio-technical change. The characteristics of those three levels are summarised as follows:

1. Macro-level (Socio-technical Landscape): It includes changes in politics, social culture, worldviews, paradigms, and macroeconomic aspects. Those changes are called landscape developments, and their characteristics are as follows [1]: they are relatively slow, create undercurrents, and influence niche and regime levels. Social groups, scientists, firms, and entrepreneurs have a significant role in defining the landscape developments perceived by regime actors as pressures that can create opportunities for novelties [33,47].
2. Meso-level (Socio-technical Regime): The socio-technical regime performs its intended function and is stable through the continuous interaction of its subsystems. However, this stability has a dynamic feature, as it allows innovation to occur at a gradual pace [33]. At this meso-level, existing actors, institutions, and networks of actors adhere to the current rules, standards, methods, and interests set in the technical system [47]. Thus, the embeddedness of a technological regime is a function of cognitive routines [48], rules and standards [49], lifestyle adjustment according to the technical system, high infrastructure, and investment costs [50,51]. This configuration

complicates the inclusion of new technological innovations and stabilises certain technologies [33].

3. Micro-level (Niche-innovations): At this level, dedicated individuals or a network of actors develop unstable socio-technical innovations. Those individuals take the first steps toward possible transition by improving their learning processes and eventually creating new practices or behaviour [47]. This level is vital to allow change, as it comprises the space needed to develop deviating methods and technologies [33].

Based on Geels MLP approach [33], Figure 1 illustrates the multi-level perspective on circular water transitions for linear water systems. The ongoing incremental processes among the three levels are represented with dashed arrows. The regime elements often resist landscape and niche-level influences. Niche innovations can stabilise into a dominant configuration, represented by a new water system setup, if the niche actors take advantage of the window of opportunities. This MLP representation shows the complexity and uncertainty of transition initiatives [44].



**Figure 1.** A multi-level perspective on the transition toward circular water systems.

### 3.2. Institutional Work for Technology Legitimation

The second framework selected for this study is the legitimation framework developed by Binz et al. [28]. They elaborated their framework components from the technological innovation system (TIS) framework and the institutional work (IW) framework. It was developed to understand the legitimation process of technology concerning the actions implemented by the actors during the legitimation process. Binz et al. [28] (p. 250) define the legitimation process as “the process where heterogeneous actor-networks fight over, construct and deconstruct alignments between a new technology and prevailing institutional contexts (widely held social norms, preferences and cognitive associations)”. Binz et al.’s [28] framework focused solely on the legitimacy creation function mentioned in the TIS Framework. This focus is because although legitimacy plays a crucial role in the technology’s success or failure, Binz et al. [28], (p. 250) criticised the innovation studies that were applying the TIS approach on treating legitimacy as an “aggregate state variable” rather than focusing on the process of how legitimacy is built up. Furthermore, both the MLP and the TIS framework were criticised for the unclear conception of agency [30,42,52]. Thus, Binz et al. [28] aimed to provide a more accurate description of the regime actors’ actions to legitimate technologies for the transition.

Legitimation is one of the main functions in the TIS framework necessary to support a new or emerging innovation system. It is “formed through actions by various organisations and individuals in a dynamic process [ . . . ], which eventually may help the new technology

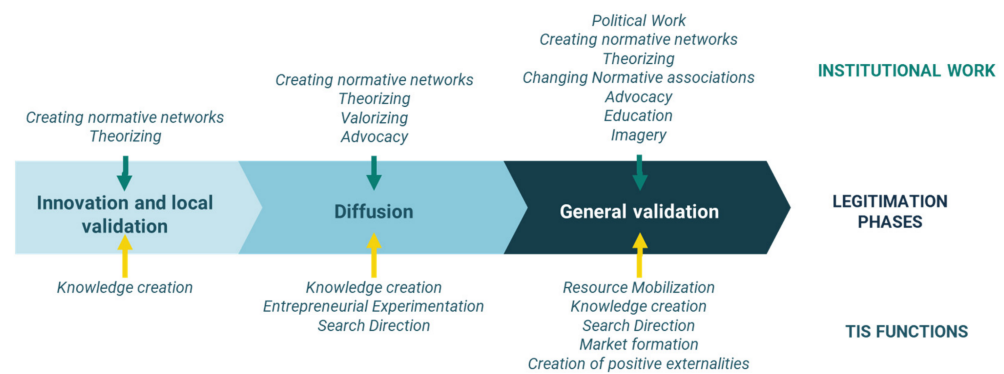
overcome its “liability of newness” [53] (p. 407)”. However, Binz et al. [28] criticised how empirical TIS studies treated legitimacy. Accordingly, they called for a close-up on the micro-level actions that lead to successful technology legitimization. To do so, they relied on the literature on institutional work. Before defining the institutional actions that take place in the legitimacy function, Binz et al. [28] have referred to the classification of the key legitimacy dimensions provided by Harris-Lovett et al. [54], Scott [55], and Suchman [56]:

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

Many institutional studies recognised the significant role of actors in creating, maintaining, and disrupting institutions [57,58]. Hence, the institutional work framework describes the different actions to create, disrupt, or maintain institutions. The core idea behind that framework is that actors embedded within a specific social structure unconsciously align their actions to the existing institutions. However, different activities can allow the actors to change, maintain, or create institutions that better serve their needs, which means that institutions are dynamic and not static [29]. Binz et al. [28] have referred to a list of institutional actions implemented in earlier studies that assessed the process of technology legitimization:

- Advocacy: Actors using direct social persuasion techniques and organising direct networks to mobilise support at the political and regulatory levels.
- Political work: Via political power to directly attain precise goals.
- Changing normative associations: Actors altering the connections between practices and their moral and cultural foundations.
- Constructing normative networks: Construct connections between different organisations to sanction some practices normatively and form the relevant peer group responsible for monitoring and evaluation.
- Mimicry: Link new practices with prevailing technologies, social and legal rules, and taken-for-granted practices.
- Theorising: Develop and stipulate specific abstract categories and explain cause and effect chains.
- Educating: Improve actors’ skills and knowledge that are necessary for supporting new institutions.
- Valorising and demonising: Provide positive or negative examples that show the institution’ normative foundation, such as awards.
- Mythologising: Keeping the institution’s normative foundations by making and maintaining myths about its history.
- Imagery: Use images that create fear, anxiety, joy, or comfort.

The framework conducted by Binz et al. [28] also tries to envisage how legitimization and the other system built-up processes interact overtime during the legitimacy stages defined by Geels & Deuten [59] and Johnson et al. [60]: innovation and local validation; diffusion; and general validation. Each specific phase includes characteristic institutional work. Binz et al. [28] reconstructed how each legitimacy phase interrelates with the six remaining TIS building functions to build the general legitimacy for the technology, as shown in Figure 2. At that moment, other alternatives do not easily replace the technology, and it becomes part of the socio-technical regime.



**Figure 2.** TIS formation functions and institutional legitimation work along the legitimation phase.

### 3.3. WICER Framework Circularity Assessment

According to the context, there is a research gap in identifying the appropriate circular water solutions. Using the MLP framework will help the researcher determine and scope those contextual factors that can create opportunities or risks for proposed circular water technologies. The next step is to assess whether the proposed circular water technologies meet circularity criteria. For this purpose, the Water in Circular Economy and Resilience Framework (WICER) is selected [2]. This analysis can help the researcher determine how to increase the selected technologies' legitimacy in water circularity.

Water in Circular Economy and Resilience (WICER) Framework is a product of the World Bank Global Water Practice initiative that promotes a paradigm shift towards a more circular and resilient water sector. The WICER framework is divided into three primary outcomes with corresponding actions [2]:

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.

## 4. An Integrated Framework to Access the Transition towards a Circular Water Economy

By combining existing concepts and methodologies to transition, technology legitimation and circularity assessment, we have developed a new overall framework to access the upscaling of circular water technologies and transition towards a circular water system (see Figure 3).

### 4.1. Framework Overview

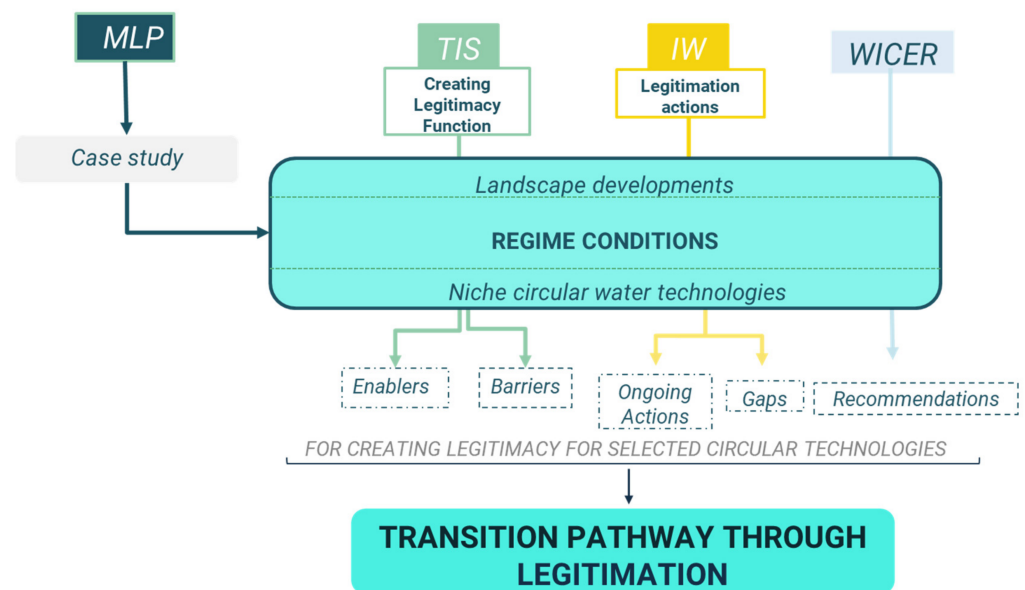
This framework targets researchers, practitioners, and decision-makers interested in readily adopting new circular water technologies or practices to allow the transition toward a circular water system. Similarly, with our focus on the legitimation processes, we shed light on the agency of the possible change actors. The framework does not aim to specify needed actions to upscale technologies as it does not cover the full functions of the technology innovation system. Instead, it seeks to act as the first step to testing the suitability and legitimacy of any circular water technology according to the context.

The overarching analysis is structured along the three levels of the socio-technical system: regime, niche, and landscape. The aim is to explore the extent of favourable and hindering conditions for existing unsustainable and new circular water technologies. This can be summarized by the critical guiding research question: "How do different contextual conditions affect the adoption of circular water technologies in the water sector?"



To address this question, we propose an integrated assessment framework that consists of four connected stages:

1. An analysis of the water sector's socio-technical system produces information on the context-specific climatic, social, economic, and environmental conditions;
2. The selected technologies' circularity level is assessed according to the identified contextual conditions;
3. An assessment of the circular technologies' legitimacy according to the identified contextual conditions;
4. The identification of legitimation actions to support the adoption of alternative circular technologies.



**Figure 3.** Integrated framework to assess circular water technology transition.

#### 4.2. Description of Stages

##### 4.2.1. Stage 1: Describing and Understanding the Water Context

The MLP framework helps to understand the context of water management to identify the “game changers” for the system reconfiguration. Defining the socio-technical regimes is conducted at the sectoral (e.g., water sector) or sub-sectoral level (e.g., agriculture water sector). Markard and Truffer [31] have concluded from several articles that describing actors, institutions (formal and informal), and existing technologies are essential to the regime description. The analysis of such components is not spatially constrained to the spatial boundaries of the case study, as some actors and institutions from provincial, national, regional, transnational, and international levels play a significant role in regime (de)stabilisation.

To understand the context and represent the water system's status quo, the MLP categorisation of the regime, landscape, and niche is to be applied. In addition, the MLP analysis includes reviewing and examining the existing contextual condition to understand why particular technologies are prevalent and why specific user preferences are developed.

The framework advises using qualitative methods to explore the complex water system, such as interviews, workshops, questionnaires, literature reviews, national and international reports, etc. It is also helpful to involve relevant stakeholders in group discussions to reach a shared understanding of the favouring and hindering conditions. Therefore, in the ideal form, stakeholder mapping should first be conducted to identify stakeholders, such as policymakers, technology experts, water users, and thematic academic experts. Then, those actors should be brought together in workshops to collaboratively represent the system conditions and identify their positive, negative, or neutral effects on changing the status quo. In our case study, we conducted a literature review and interviews

with key stakeholders and applied the community-of-practice approach [61,62]. After identifying the main actor groups and actors with institutional power, the next step is to recognize their preferences, norms, and values. Related data regarding certain technological or institutional concepts can then be collected from sources other than the existing literature, such as interviews with those actors, actors' statements recorded in the newspapers, social media accounts, magazines, etc.

Firstly, describing the regime includes describing the involved public and private parties in water management, the existing water problems, policies directly or indirectly related to water management, existing rules and regulations, the water-related technologies and their impact on the environment, and lastly, the norms, practices, and preferences of water users and regulators established around those technologies. Secondly, the MLP framework emphasises the role of the external factors, "the landscape developments", which can stabilise, destabilise, and create pressures on the niche and regime. Therefore, the second step to describe the context is to gather the external factors that affect water management. External factors could be categorised into social, environmental, economic, and environmental groups. Examples of such factors include scientific findings, political directions, and social movements at national, regional, and international levels that play a role in decisions related to the water sector. Upon identifying those external factors, their impacts on favouring or disfavouring the existing unsustainable technologies and alternative circular technologies should be assessed. The idea is not to quantify their effects but to capture the fuller context's complete picture. Thirdly, describing the niche level includes identifying the potential of the proposed technologies in terms of their readiness level, environmental impacts, economic, legal, and infrastructural considerations, expertise requirements, etc.

A catalogue of possible analytical questions that can provide a comprehensive perspective of how the water system is functioning is provided in Appendix A.

#### 4.2.2. Stage 2: Assessment of the Selected Technologies' Circularity Level

The second stage assesses the circularity level of the suggested technologies based on the information obtained from Stage 1. The circularity level of the technologies is to be evaluated using the WICER framework. According to the context, the WICER framework reveals actions that increase the circularity of suggested practices, i.e., delivering resilient and inclusive services, designing out waste and pollution, and preserving and regenerating natural systems. Therefore, the outputs of this evaluation shall act as recommendations to ensure a higher circularity level of the technologies and indicate which of the alternative technologies can better suit the existing context. As a result, the pragmatic legitimacy of the alternative circular technologies with lower circularity levels is reduced as a possible solution for more water circularity.

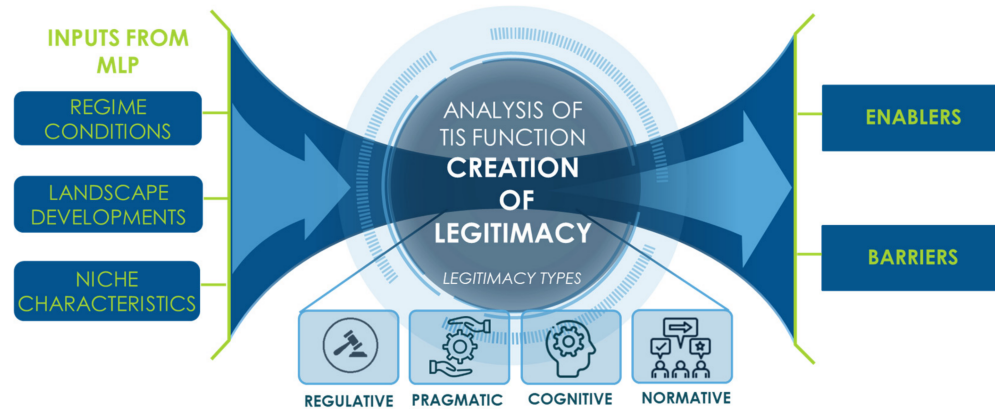
#### 4.2.3. Stage 3: Assessment of the Alternative Circular Technologies' Legitimacy

According to Binz et al.'s [28] framework, for the innovations to diffuse, they need to become locally legitimate either through being compliant with the existing institutional settings [63] or by being not too challenging [60]. This phase is significant to succeed if the aim is to diffuse and upscale the innovations [60]. So, to ensure that technologies are legitimate enough to be adopted in the regime, one should first understand barriers and enablers for creating legitimacy for such technologies.

The third stage involves assessing the legitimacy of the proposed circular water technologies in their four forms: regulative, cognitive, normative, and pragmatic. Figure 4 describes the assessment approach, where the content of the regime and landscape analysis was cross-checked and synthesised from the perspective of TIS. This has resulted in categorising the findings into factors that can reduce or increase the legitimacy of the circular water technologies alternatives. Those factors are then further classified as barriers or enablers for adopting the new alternative circular technologies as follows:

1. Regulative barriers concerning legal frameworks and regulations;

2. Normative barriers concerning norms and values;
3. Cognitive barriers concerning knowledge and capabilities;
4. Pragmatic barriers concerning social, economic, and environmental benefits.



**Figure 4.** Legitimacy assessment of circular water technologies.

This assessment and categorisation of barriers and enablers for creating legitimacy are subjective to the researcher's interpretations of the information obtained from Stages 1 & 2. In addition, the researcher can enrich the analysis of these barriers through consultation meetings with relevant stakeholders, which can be held in the context of a community of practice meeting [62]. This exercise could also identify the technologies with various barriers, indicating their unsuitability for the context. Categorising the contextual settings in this way can help decision-makers identify which technology better fits the context and point to the areas where the selected technologies' legitimacies need enhancement.

#### 4.2.4. Stage 4: Identify Legitimation Actions to Support the Upscale of Alternative Circular Technologies

The first set of legitimation actions is to push the regime to reach a certain tipping point. This point is required to disentangle the identified barriers, create windows of opportunities, and trigger a regime change towards another system [44]. In addition, this set of actions aims to reduce the legitimacy of the existing "unsustainable" technologies. These actions include the steps that need to be conducted to translate the identified landscape developments into pressures challenging the regime's status quo and reducing the regulative, normative, cognitive, or pragmatic legitimacy of existing technologies.

The second set of legitimation actions aims to remove the identified barriers and feed into creating legitimacy for new alternative circular technologies. So, upon distinguishing the barriers and enablers for the suggested circular technologies, it is crucial to identify what the main actors could do to alleviate the obstacles or benefit from the enablers. According to the framework proposed by Binz et al. [28], relevant legitimation actions can be selected, such as advocacy, theorising, constructing normative networks, etc. These actions persist during the different legitimacy stages defined by Geels & Deuten [59] and Johnson et al. [60]: innovation and local validation, diffusion, and general validation. Thus, after identifying at which legitimacy stage each of the alternative circular technologies occurs, its characteristic institutional work is known. From the interviews conducted with the main actors, their organisation's efforts to those conditions are to be identified. Combining the analysis results on the institutional settings and the ongoing legitimation actions can reveal the legitimation pathway of the alternative circular technologies.

## 5. Application of the Framework in a Real-Life Case

This section presents the results of applying our overall framework to access the upscaling and transition of circular water technologies in the horticulture sector of Westland. The Westland region in the Netherlands is well known for its greenhouse horticulture.

Mainly vegetables (tomatoes, peppers, cucumbers, etc., mostly on hydroponics), flowers, and potted plants are grown there. Horticulture uses rainwater (collected in shallow basins) for irrigation, which is supplemented with desalinated groundwater in times of shortages. In the transition towards a more circular water system in the region, alternative water sources for the horticulture sector are of interest. Therefore, two alternative circular water technologies are considered and assessed in our framework: (1) reuse of municipal wastewater treatment plant effluent, and (2) region-wide rainwater storage and reuse using large-scale aquifer storage and recovery (ASR) systems.

### *5.1. Stage 1: Describing and Understanding the Water Context*

Using the MLP framework, the analysis of how the water is being managed in the horticulture sector in Westland revealed the underlying institutions regulating it. Moreover, it explained the contextual factors that organise the water system in Westland.

Regarding the current water supply technologies, the horticulture sector depends on rainwater and uses groundwater desalination to augment its water needs during water shortages. The horticulture sector is already advanced in its water circularity as it treats and reuses its irrigation wastewater. However, groundwater desalination is not environmentally sustainable, as it produces brine, which is later discharged deeper into aquifers, causing groundwater salinisation.

Regarding formal institutions, current circular initiatives have a narrow focus on the water sector. There are no adequate legal frameworks for water reuse and aquifer storage and recovery, and the environmental policy in the Netherlands has issues in terms of its consistency and continuity (see, e.g., [64]). Regarding informal institutions, collaborative water management exists to jointly manage the competing water issues in Westland. Additionally, solid political environmentalism is presented by the political emphasis on addressing low surface water quality. Lastly, Westland's horticultural sector is a leader in innovation and proactive decision-making.

In brief, the MLP assessment showed that water shortages prompted the horticulture companies to make significant investments in groundwater desalination. Dutch policy allowed them to use groundwater and discharge the resulting brine into deeper groundwater levels. Accordingly, groundwater desalination stabilised the horticulture water system to complement the rainwater harvesting. However, currently, due to the increased problems with brine pressure, it is necessary to destabilise those desalination practices by either reducing their use and/or seeking alternative water sources.

### *5.2. Stage 2: Assessment of the Selected Technologies' Circularity Level*

The selected technologies were evaluated through the lens of the WICER framework, using the contextual information obtained from the MLP analysis.

The water reuse solution can increase water circularity in recovering treated wastewater and ensure its usage instead of discharging it into the sea. It can also improve the water system's resilience to possible shocks. However, the WICER framework indicates the factors leading to lower circularity because water reuse does not maximise existing infrastructure use. If water reuse is adopted, infrastructure built for groundwater desalination would no longer be used. Horticulture companies require very high-quality water of low nitrogen, pathogen, and micropollutant levels to ensure their contribution to the zero-emission target. This means treating effluent to that level would consume large amounts of energy and chemicals. In addition, the distribution infrastructure for transporting the effluent from the municipal wastewater treatment plant to the horticulture companies over a long distance will need massive material and energy resources. That also should be evaluated against the horticulture expected water demand.

The ASR solution scores better on the WICER circularity criteria, which might indicate that this solution is more appropriate for the Westland case study. ASR will lessen the drought impacts by ensuring another diversified, sustainable water source. ASR will help recharge and restore the aquifer, thus reducing its salinity and soil subsidence. In

addition, applying the ASR system still requires desalination post-treatment; thus, it would maximize the use of the existing desalination infrastructure. ASR can also lead to more energy efficiency, since rainwater infiltration will enhance the quality of the saline water, leading to energy savings for the energy-intensive, post-treatment requirements.

### *5.3. Stage 3: Assessment of the Alternative Circular Technologies' Legitimacy*

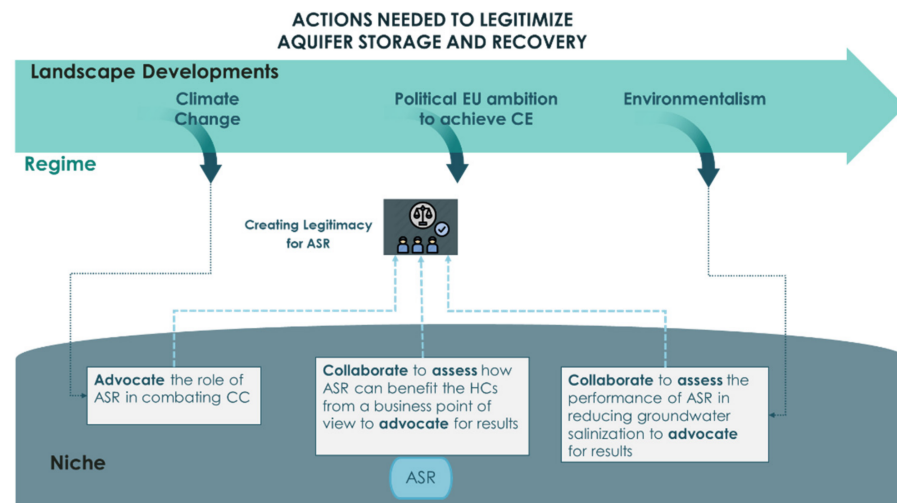
The findings from the MLP analysis are then categorised into barriers or enablers for the suggested technologies. For water reuse, regulative barriers included lack of regulations and guidelines, lack of environmental policy consistency and continuity, and CE actions plans and policies that have limited focus on the water sector, limiting its potential in transition. On the other hand, new EU water reuse regulations are issued, and at the same time, the Dutch government shows its commitment to the EU's targets and ambitions. In addition, the horticulture sector shows high adaptability to comply with strict laws. On the other hand, different barriers were also found, reducing the pragmatic legitimacy of reuse. Such as the vast investments in groundwater desalination technologies, the high-quality water requirement for horticulture, the low market price for groundwater, and the lack of acute water scarcity, the water quantity is not (yet) a primary concern in the horticulture industry's operation.

For Aquifer Storage and Recovery, contextual factors increasing its legitimacy are: (a) the preference for horticulture companies for rainwater, (b) its ability to reduce groundwater salinisation, and (c) it complements groundwater desalination technologies. On the other hand, its legitimacy is constrained by a relatively low recovery efficiency in the Westland region; thus, more experimentation is needed. ASR systems can gain regulative legitimacy by reducing groundwater salinity, thus complying with the government's decision to limit groundwater salinisation. However, if exemptions are made to brine emissions and the government does not take strict and affirmative actions against them, this would also lessen the need to invest in ASR.

### *5.4. Stage 4: Identify Legitimation Actions to Support the Upscale of Alternative Circular Technologies*

The results obtained from the interviews show the dominance of advocacy and theorising, followed by the construction of normative networks efforts by the key actors in the horticulture water system. However, some gaps were also identified, such as the need for theorising efforts to develop the circular water concept and quantify brine emissions' effects on groundwater salinisation. For example, regarding ASR application in the Netherlands, efforts are still needed to demonstrate its long-term viability, analyse its impacts on surrounding hydrological settings, and enhance its construction and operation knowledge [65]. At the same time, more advocacy efforts are still needed to convince and collaborate with the horticulture companies on the need for such circular water technologies and convince the politicians to provide more comprehensive regulatory frameworks for the selected circular water technologies.

For Aquifer Storage and Recovery systems, a transition pathway could be drafted based on the legitimation actions (see Figure 5) that aim to increase the economic, social, and environmental incentives for ASR by: (a) advocating its role in combating climate change, (b) evaluating its performance from an economic point of view, (c) assessing its performance to reduce groundwater salinization (d) maximizing collaborating efforts to ensure optimal tasks distribution. For water reuse, no transition pathway was drafted, since legitimacy analysis findings indicate a high level of uncertainty if reuse would succeed in replacing the old technologies.



**Figure 5.** Legitimation actions for ASR in the socio-technical horticulture water system in Westland.

## 6. Discussion

In this study, the authors have chosen multiple frameworks used in the transition literature to find a framework that can analyse what is needed to achieve the transition towards a circular water economy. First, the authors used the socio-technical perspective from the MLP framework to examine the current water supply system and analyse the role of regime conditions on the potential transition. Secondly, the framework developed by Binz et al. [28] was used to understand how increasing the technologies' legitimacy can improve the potential of circular technologies (niche development) to crack the socio-technical regime and stabilise within. Accordingly, the paper contributes to the transition literature both theoretically and empirically. Theoretically, it aims to offer a socio-technical transition perspective for understanding the role of regime conditions in enabling transitions towards a circular water system by conceptualising the complex contextual factors. The paper empirically seeks to verify the concepts and arguments developed from an integrated assessment framework through the case study of Westland, the Netherlands.

This developed framework can analyse the different conditions and their role in the potential transition. This is useful since socio-technical water management regimes differ widely in norms and values, regulatory environments, governance practices, and institutional settings [21,23]. Therefore, using this integrated assessment framework can allow the researchers to understand how existing conditions are interacting to either keep the system as is and reduce the potential of it restructuring or challenge its status quo. Furthermore, it indicated the factors limiting the transformational ability of interventions aiming for the transition towards sustainability. The authors, however, need to ensure data validity, as for the different stages in the framework, data is needed from various sources.

One of the main cons of the developed framework is the sole focus on the technologies' legitimacy. However, creating legitimacy for technologies does not exclusively guarantee the upscale and achievement of the intended change momentum [59,60]. Thus, future adaptations of this framework should assess all functions of the TIS, such as market formation and resource mobilisation, to give a more holistic understanding of what is needed for those technologies to thrive. Moreover, a collaborative, multi-stakeholder and inclusive innovation process will be needed for successful technology uptake [66]. However, the developed framework reached its aim in pointing to technologies that are more fit to the context, which might allow a quicker transition towards water circularity.

## 7. Conclusions

Including the CE paradigm in water sector management can allow it to grasp more efficiency-oriented technological innovations [8]. This article aims to understand how to change the linear paradigm that has long permeated water governance by integrating

different frameworks to analyse the contextual factors hindering or enabling the upscale of new technologies and applying them to Westland's horticulture sector. Using this integrated framework has provided a way to zoom out away from the sector and technology alone and has shown how the horticulture water system transition happens in Westland. This finding corresponds with Giezen [29], who highlighted the potential of combining institutional work with MLP to find how actors can enable or hinder societal transformation on a larger scale.

Many lessons were learned from applying the integrated assessment framework to the Westland case study. It helped to point out the economic, legal, and regulatory barriers that might slow down the change. First, there is a lack of a suitable legal framework for water reuse in terms of the legal-regulatory obstacles. Yet, the Dutch institutional setting is organised to positively react to the EU review of the water directives that published new guidelines and regulations for water reuse. Secondly, in terms of economic barriers, the lifespan of the existing groundwater desalination and the large investments by the horticulture companies can reduce the legitimacy for new water solutions. At the same time, the analysis of the ongoing actions to increase the legitimacy of new water solutions revealed that the main actors in the horticulture water regime were found to coordinate, collaborate, theorise, and advocate for finding solutions to the groundwater salinisation problem. However, more efforts are necessary to focus on the negative impacts of brine emissions on the environment. In addition, the effects of groundwater salinisation on the horticulture companies' business revenues and the economic feasibility of the new suggested technologies need to be evaluated. Such theorising efforts are necessary to change the horticulture companies' perceptions of existing practices and legitimise the policy's intention to impose strict brine emission regulations.

Future research should apply this framework to developing contexts, as its existing conditions highly differ from developed contexts, especially since there is a narrow focus on the sustainability transition knowledge field in developing countries [67,68]. Such analysis can lead to designing better interventions that are more suitable to that context rather than copying the success stories of the developed contexts. In addition, since this framework aims to identify the most legitimate solution according to the context, future research should also consider analysing the remaining functions of the TIS analysis for that technology. Such an analysis would be necessary to define other actions needed to successfully upscale the technology and increase the circularity of the water sector.

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## Appendix A

A catalogue of analytical questions that can provide a comprehensive perspective of how the water system is functioning is provided in Table A1.

**Table A1.** Analysis levels and analytical questions.

Level	Examples of Analytical Questions
Landscape	<ul style="list-style-type: none"> <li>Which political, economic, environmental, social, institutional conditions external to the water sector affect the decision of regime actors to engage with new water technologies?</li> <li>Which external political, economic, environmental, social, and institutional factors influence water decisions?</li> <li>Which megatrends affect water governance, such as climate change, urban growth, etc.?</li> </ul>
	Infrastructural <ul style="list-style-type: none"> <li>How does the water flow from sources to users and back?</li> <li>Which infrastructure systems and technologies have negative environmental impacts?</li> </ul>
	Actors and network of actors <ul style="list-style-type: none"> <li>Who are the main stakeholders in water governance, how do they interact, and how rules and responsibilities are distributed?</li> <li>Who are the primary water users?</li> <li>What are their preferences concerning water quality and quantity?</li> <li>What are their norms and values concerning water use, environmental awareness and innovation?</li> </ul>
Regime	Environmental <ul style="list-style-type: none"> <li>What are the major water problems in the region?</li> <li>How do the existing technologies interact with those problems?</li> <li>What are the climatic regional conditions of the case study?</li> </ul>
	Legal <ul style="list-style-type: none"> <li>What are the existing water policies, and how do they respond to the current water problems?</li> <li>How do they address the existing unsustainable technologies?</li> <li>How far do they support alternative circular water technologies?</li> <li>What are the policies in other sectors that can affect the water sector?</li> <li>How strong are the synergies between them?</li> <li>How do they support existing unsustainable technologies or alternative circular technologies?</li> <li>How are water policies put in place, and how efficiently are they implemented?</li> <li>How clear and consistent are those policies and their implementation, and how do they affect the existing and proposed technologies?</li> <li>What are the existing regulations and laws that govern current unsustainable technologies or alternative circular technologies?</li> <li>Which regulations are lacking or insufficient? What are the reasons behind that?</li> </ul>
	<ul style="list-style-type: none"> <li>What is the technological readiness level of the alternative circular technologies already introduced to the expected users?</li> <li>What are the technical capabilities of the technologies?</li> <li>What are the technologies requirements regarding technical knowledge for operation and maintenance, infrastructure, costs of purchase, use, and maintenance?</li> <li>What are their intended effects on protecting the environment and solving the existing water problems?</li> </ul>
Niche	

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