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D7.6: Creation of a circular economy framework for water treatment with the inclusion of energy and materials

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Deliverable Review and Approval

The individuals listed below are not directly involved in the preparation of this deliverable and will review the present document.

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Deliverable Development and Review Process

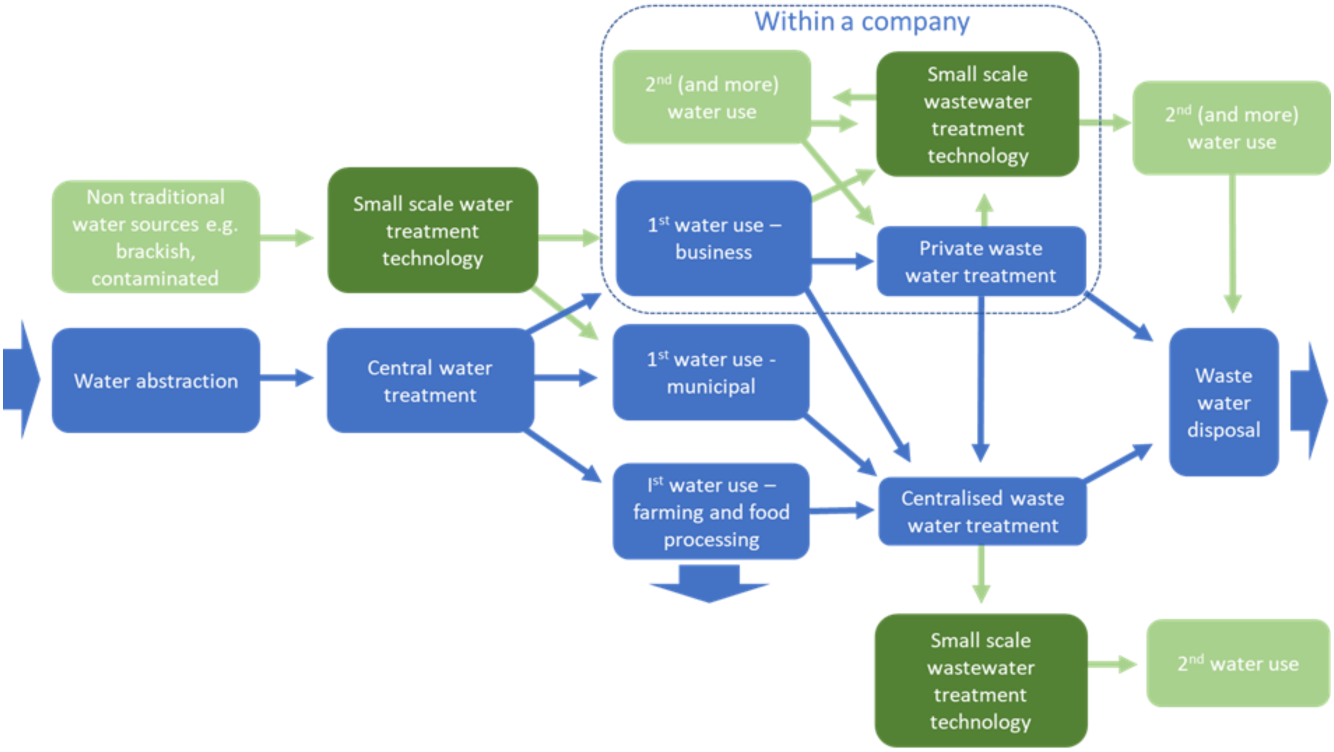
	Key Event	Deadline	Done by
1	Submission of Draft Deliverable to reviewers	*21.10.2019*	15.10.2019
2	Initial Review and Comments obtained	*31.10.2019*	18.10.2019
3	Uploading and submission of Final Deliverable on Participant Portal	*30.11.2019*	28.11.2019

Executive summary

This deliverable fulfils the requirements of Project Ô, task 7.3. Drawing from case studies in the literature and the Project Ô examples, the analysis looks at how value chains and business models can develop to benefit from greater circularity in water.

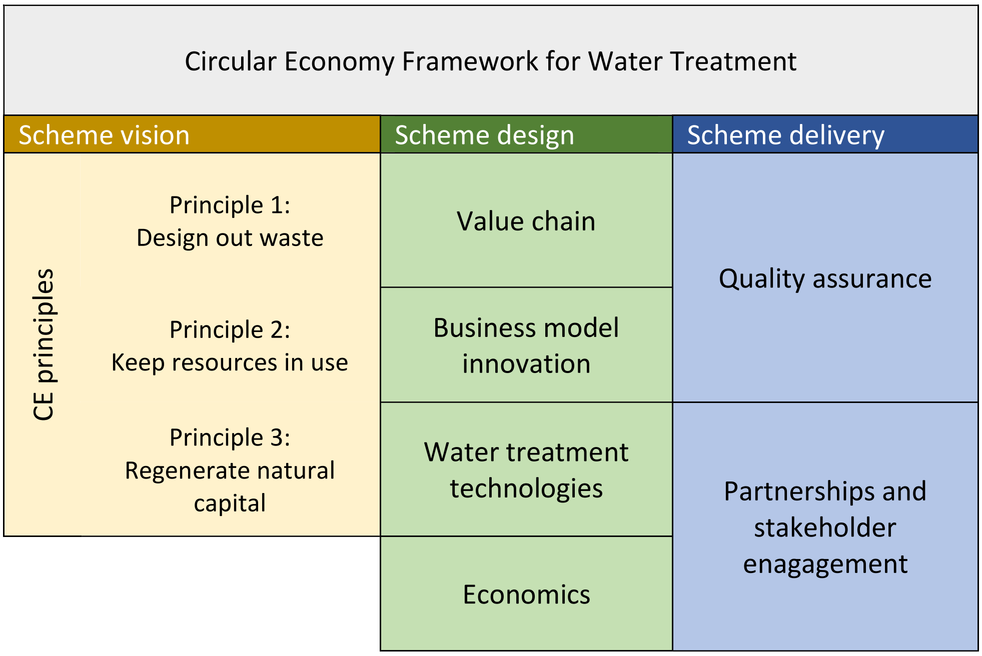
Drawing on frameworks for the circular economy identified in D7.5, this deliverable considers circular economy interventions that can be applied throughout the water value chain to design out waste, keep resources in use and regenerate natural capital.

Linear value chains dominate the economy, and this is also true for water, with only 2.4% of the EUs urban wastewater being reused. Described by the green boxes in the diagram below, Project Ô demonstrates low cost and energy efficient technologies that support the looping of water



These technologies have the potential to change the value chain – and open up the potential to develop different business models through creating value from secondary water or through exploiting otherwise unavailable water sources. Based on a literature review, published commercial case studies and the demonstrations themselves, changes in the value chain, and in the role stakeholders could take, are suggested. Opportunities arise for the reuse of secondary water and the exploitation of alternative water resources for both potable and of a lower than potable quality for appropriate applications, opening up the potential of both reducing stress on current water resources and of developing a resource with value rather than a cost to the system.

The concluding chapters present a circular economy framework for water treatment – a framework that sets out the need for both consideration of technical requirements but also the possible new business model opportunities to be considered and outlines the relationship between the framework and the multiuser platform to be developed within Project Ô. An overview of the framework is set out in the diagram below.



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1 Introduction

1.1 The objective of this deliverable

The objective of this deliverable is the creation of a circular economy framework to support the development of the business facing aspects of the users collaborative platform.

The field of water reuse and the technologies available is developing rapidly, driven substantially by the challenges of needing to supply water for human activities when water supplies are increasingly restricted. Project Ô seeks to test small, modular and energy efficient technologies that allow water reuse or enable use of alternative water sources within various contexts.

The framework suggested here encapsulates key aspects of such projects. It will be used within the development of the collaborative platform to support the flow of information required for successful projects using these small scale newly developing technologies.

The document follows these steps:

- Chapter 2: identifies changes in the value chain and possible different business models that can support more circular outcomes for water;
- Chapter 3: identifies examples from exiting projects and from Project Ô that demonstrate the factors underlying the efficiency of the business models (taken to mean the drivers and underlying requirements that make the examples work);
- Chapter 4: based on the analysis the development of a circular economy framework[1];
- Chapter 5: describes how the framework will be used within the multiuser collaborative platform.

1.2 Methodology

The following steps have been undertaken in the information gathering for this deliverable:

Analysis of circular value chains	Analysis of factors influencing change	Consideration of relevant business model options	Application of outputs
• Identification of relevant stakeholders in the value chain within a circular water treatment system • Identification of relevant circular economy objectives and key considerations for each step in the value chain • Reshaping the current value chain to make it more circular	• Identify and analysis of the implications of change to a more circular value chain • Key factors affecting the efficieny of each step and possible alternative measures • Gathering information from demonstartion sites, other studies and literature	• Identification of possible business models with examples • Identification of possible markets (B2B, B2C, C2B and G)	• Integration of business model thinking into the development to the User Collaborative Platform • Drafting of D7.6: *Creation of a circular economy framework for water treatment with the inclusion of energy and materials*

The information gathered and analysed here will be used in the development of the framework.

[1]A framework is 'an essential supporting or underlying structure': Concise Oxford English dictionary definition

2 Reshaping the value chain and new business models

Water reuse has been around for centuries – typically for crop irrigation, and in more recent decades to enable water reuse within businesses. However, only 2.4% of European urban wastewater is currently reused indicating a significant opportunity to access vital new water resources. In addition, the pollution of water resources causes both environmental degradation as well as exacerbating water security challenges.

2.1 Circular economy objectives along the value chain

D7.5, *Study of the current linear water economic model. Identification of weaknesses and opportunities in the water value chain*, provides an overview of water related challenges, outlines the case for taking a more sustainable approach to the management, use and reuse of water resources and provides an overview of current thinking regarding water and the circular economy.

The circular economy has 3 simple pillars as set out by the Ellen Macarthur Foundation:

- Design out waste and pollution
- Keep products and materials in use
- Regenerate natural systems

To apply these pillars to context of water and wastewater, the objectives of water management, taken from the analysis of frameworks undertaken in D7.5 are placed against the 3 high level principles (see Table 1).

Circular Economy Principles	Circular economy objectives/interventions
Principle 1: Design out waste	• Avoid water use
	• Reduce water use
	• Reduce water losses
	• Reduce energy use and shift to renewables
	• Find alternatives to difficult to remove substances that leading to down grading of water quality
Principle 2: Keep resources in use	• Maximise water reuse (no treatment) internally within the same process (closed loop) or other processes (open loop)
	• Maximise water reuse (no treatment) for external applications
	• Maximise water recycling (following treatment) for internal operations (closed loop or open loop)
	• Maximise water recycling (following treatment) for external applications
	• Extract resources (chemical, mineral, biological) from wastewater for further applications
Principle 3: Regenerate natural capital	• Use natural resources to the extent they can be regenerated
	• Return water of a specific quality from where it was taken from
	• Return biological resources to the biosphere

Table 1: Circular economy objectives aligned with the 3 principles of the circular economy

Figure 1 sets out theses interventions or objectives at different phases of the water value chain: (A)Extraction/transmission/water treatment (B) Distribution (C)Desalination (D)Wastewater treatment (E)Water users and waste water producers.

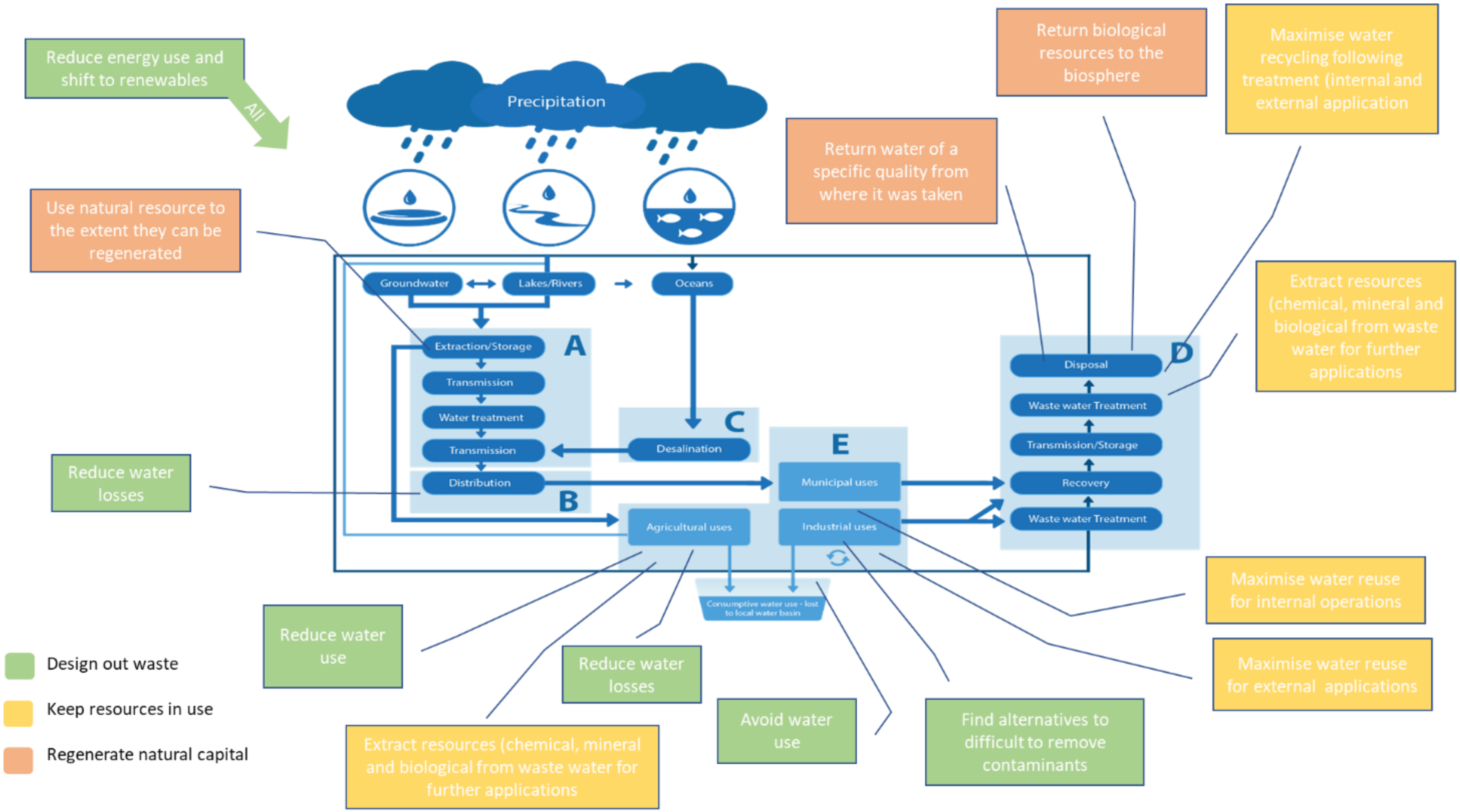


Figure 1: Interventions that support a circular value chain for water and water treatment

Project Ô aims to achieve some of these objectives with the demonstration projects. To do so requires a number of changes to the way in which traditional water and wastewater value chains and individual stakeholder within the value chain operate. These changes will be discussed below and, through a process of analysis of current examples of good practices, including project Ô demonstrators, key success factors will be identified and presented in a circular economy framework.

2.2 Applications for water reuse and new sources

Water reuse occurs in a number of different scenarios, each with its own legal, technological and social context – and at different scales. Typical scenarios for wastewater reuse or the treatment of alternative water sources are[2]:

Urban reuse	Use of reclaimed and alternative water sources for potable and non-potable applications in municipal settings. Different conditions may have to be met depending on whether public access may be restricted or unrestricted
Industrial reuse	The use of reclaimed and alternative water sources in industrial applications and facilities, power production and extraction of fossil fuels
Agricultural reuse	Use of reclaimed and alternative water sources to irrigate crops. Different conditions will have to be met dependant on whether crops are to be consumed by humans, whether crops are to be processed prior to consumption or no consumed by humans.
Environmental reuse	The use of reclaimed and alternative water sources for environmental purposes including augmenting water bodies.

The reclamation of water for potable uses either to augment drinking water sources (surface or ground water) or for introduction directly into a water treatment plant is not considered here as are not likely to be covered by the small-scale water treatment technologies being trialled by Project Ô.

Each scenario will have a different value chain. Project Ô is focused on small scale water reuse loops. In general, large systems have matured from smaller systems or 'backbone' facilities that were implemented to meet smaller demand in prior years. System size, defined by the capacity of the system[3]:

Large systems – over 10 mdg (440 L/s)

Medium systems – 1-10 mdg (44-440 L/s)

Small systems – 1,500 – 100,000 gpd (5.6 – 380 m^3/d)

Different applications of wastewater reuse will require different levels of treatment, with the distinction of the potential of coming into contact with humans as being a key aspect. The US

[2] Adapted from EPA 2012 Guidelines for water reuse
[3] EPA 2012 guidelines for water reuse

EPA suggest the following broad levels of treatment for general reuse applications – shown in Table 2. Specific treatment processes will also be needed to deal with specific contaminants.

Increasing Levels of Treatment; → **Increasing Acceptable Levels of Human Exposure**			
Primary treatment: *Primary decantation*	**Secondary treatment:** *Biological Oxidation, Disinfection*	**Tertiary / Advanced Treatment:** *Chemical Coagulation, Filtration, Disinfection*	
No uses recommended at this level	• Surface irrigation of orchards and vineyards • Non-food crop irrigation • Restricted landscape impoundments • Groundwater recharge of non-potable aquifer** • Wetlands, wildlife habitat, stream augmentation** • Industrial cooling processes**	• Landscape and golf course irrigation • Toilet flushing • Vehicle washing • Food crop irrigation • Unrestricted recreational impoundment	• Indirect potable reuse: Groundwater recharge of potable aquifer and surface water reservoir augmentation**

*Suggested uses are based on Guidelines for Water Reuse, developed by U.S. EPA.

*** Recommended level of treatment is site-specific.*

Table 2: Suggested wastewater treatment and uses. Source: US EPA[4]

2.3 Reshaping current value chains

Of course there is a long history of more circular concepts in the system, from the use of urine in the dyeing process of textiles to human waste as fertilizer – a practice still common in parts of the world where sewage and water infrastructures are less well developed. In regions where water is already a scarce resource and where water quality issues have been problematic, there are good examples of more circular approaches to water and wastewater management.

These are 4 common objectives of such projects:

- Use alternative, non-traditional water sources to relieve the demand of current water sources
- Reduce demand on water supply through water use reduction measures
- Treat used water to enable its use for other purposes thereby replacing fresh water supplies
- Improve the water quality in receiving waters

[4] US EPA website: water recycling

Using water once before treatment and disposal is typical of a linear approach, as set out in the schematic in Figure 2:

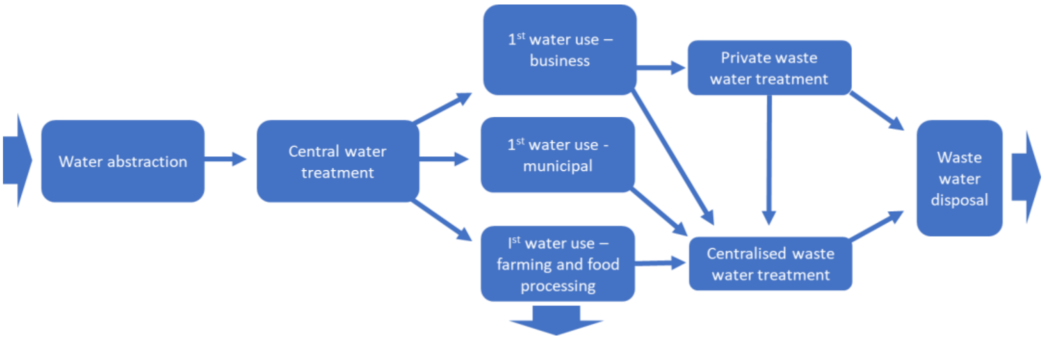


Figure 2: Schematic of the generalised linear water economy

Given the scale of modern-day demand and use of water, and the scale of the generation of wastewater the linear approach has provided the most effective and safe way for the provision of these services. There are many examples of the linear water use value chain.

The objective of the circular value chain for physical assets is to ensure that at all parts of the life of a product the highest value is achieved and that losses from the system are minimised. Within this system, jobs and the economy are supported through developing sustainable raw materials; designing products to support circular economy objectives; through accessing and using products in different ways that support product longevity and increased intensity of use; through the repair, remanufacturing and refurbishment of products; through extracting value from materials at the end of life for example through recovery and recycling.

2.4 Reshaping value chains in Project Ô

Figure 3 shows, in green, examples of interventions tested through Project Ô demonstrators, with arrows indicating water flows:

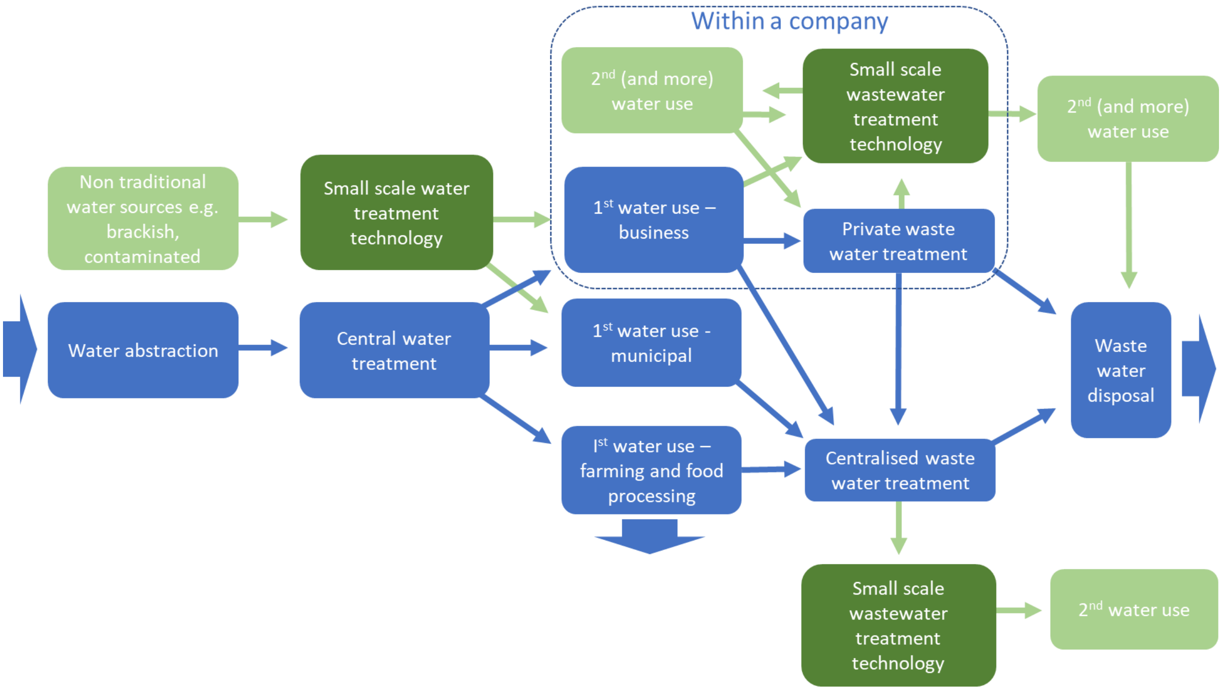


Figure 3: Schematic of Project Ô intervention types (in dark green)

Project O is focused on testing different water technologies – which in themselves offer great advances in the sustainable use of water. The development and sale of such technologies is an important contributor to sustainable, circular water management. The introduction of such technologies allows for reuse of water – and with it the creation of a valuable resource – and therefore the potential of new business models to operate. The value chains below present the existing baseline chains and the enhanced value chains as a result of the introduction of the new technologies. Alongside there are a representation of key players along the value chain, with suggestions as to how the introduction of the new technologies might offer opportunities for new business models. Whilst the potential for different stakeholders to test new circular business models is limited within Project O, the scenarios below suggest ways in which new/different value can be created.

2.4.1 Changing value chains: Demosite 1 – Acquedotto Pugliese, Italy

Figure 4 sets out the baseline value chain for Acquedotto Pugliese, demo site #1.

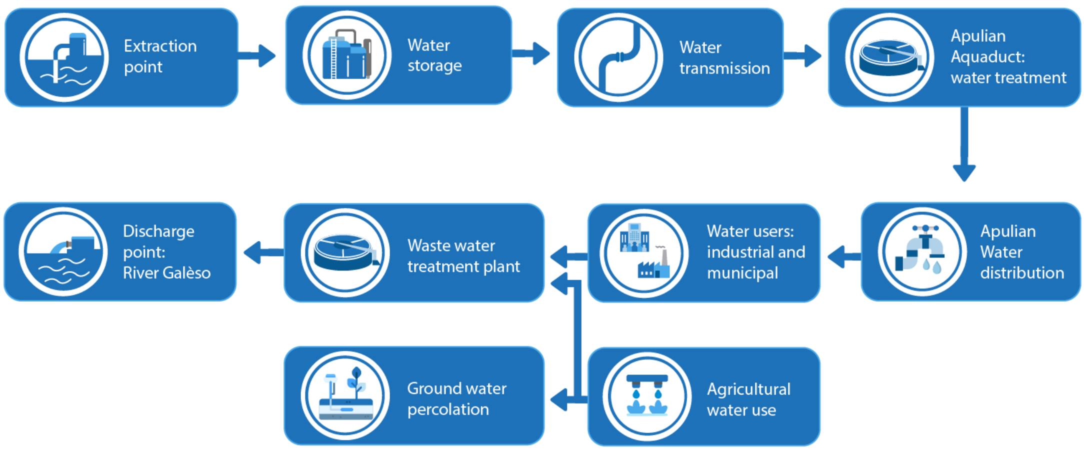


Figure 4: Baseline value chain for demo 1

The suggested user in this scenario is an agricultural user - however there may also be a wastewater stakeholder involved. This part of the value chain is not currently influenced by the new technology. Figure 5 outlines the key players and generalise roles in the baseline value chain. Other stakeholders, such as those organisations that set water price, are not include here:

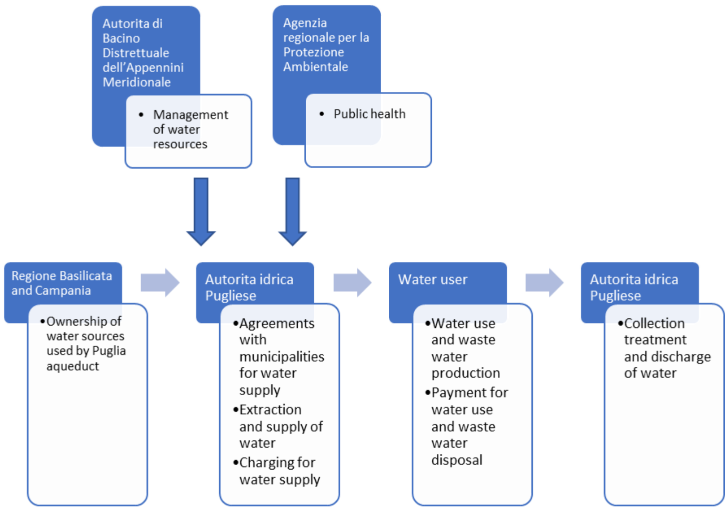


Figure 5: Key stakeholders and water related activities in the baseline value chain

Demo 1 introduces technologies that enable the treatment of water that is currently inaccessible for use in the regions' economic sector as shown in Figure 6.

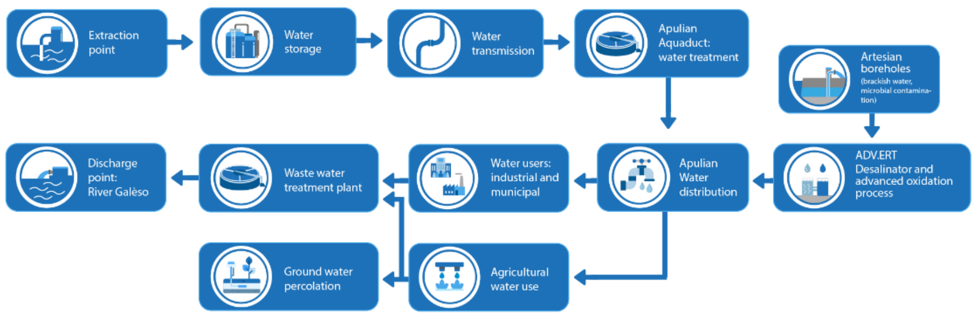


Figure 6: Project O value chain for demo 1

The key players[5] in the new value chain are shown below – in two different scenarios. Scenario one in licensee or owner of ADV.ERT, with a permit for extraction, supplies water to the existing water company, Acquedotto Pugliese.

[5] Key stakeholders are taken from D8.1, V2, June 2019

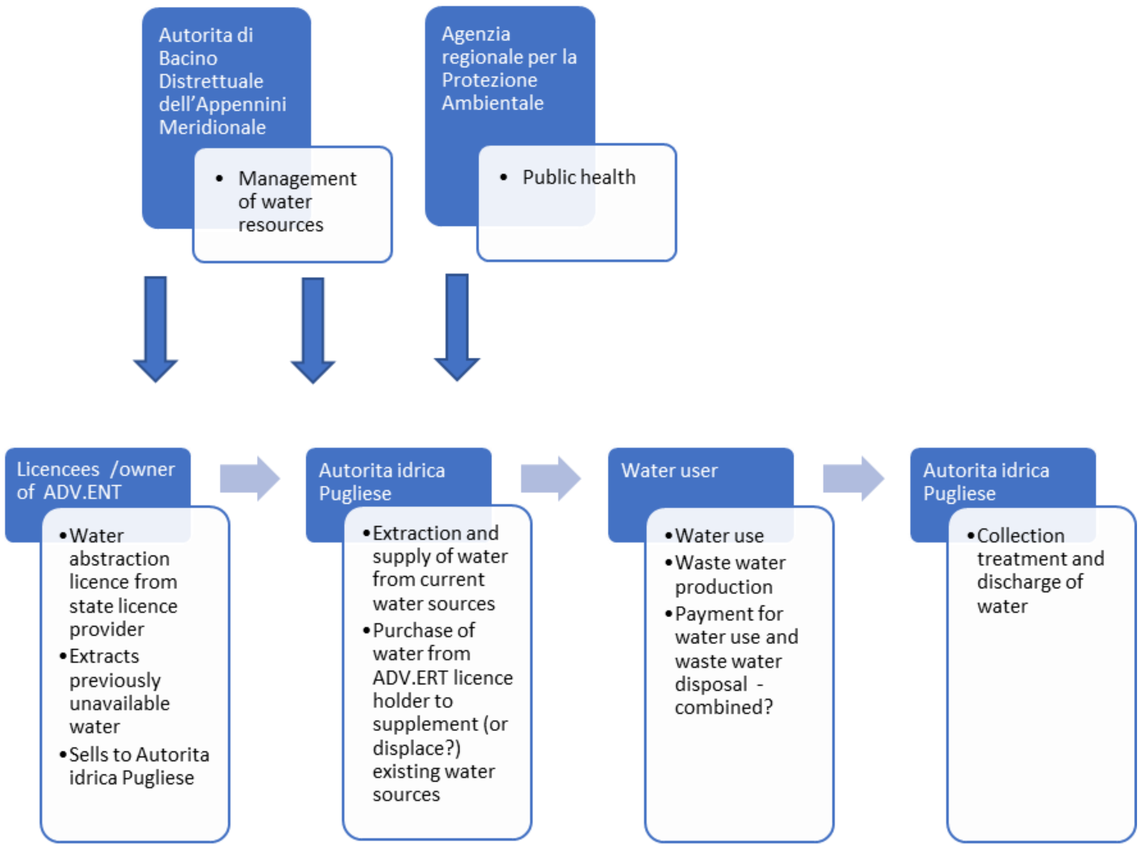


Figure 7: Key stakeholders and water related activities in demo 1, scenario 1

Scenario 2 enables the permit holder to supply water directly to a water user. Acuedotto Pugliese may still be involved with regard to pricing structures, water resource planning and licencing, but there would be direct contact between the new water supplier and the customer.

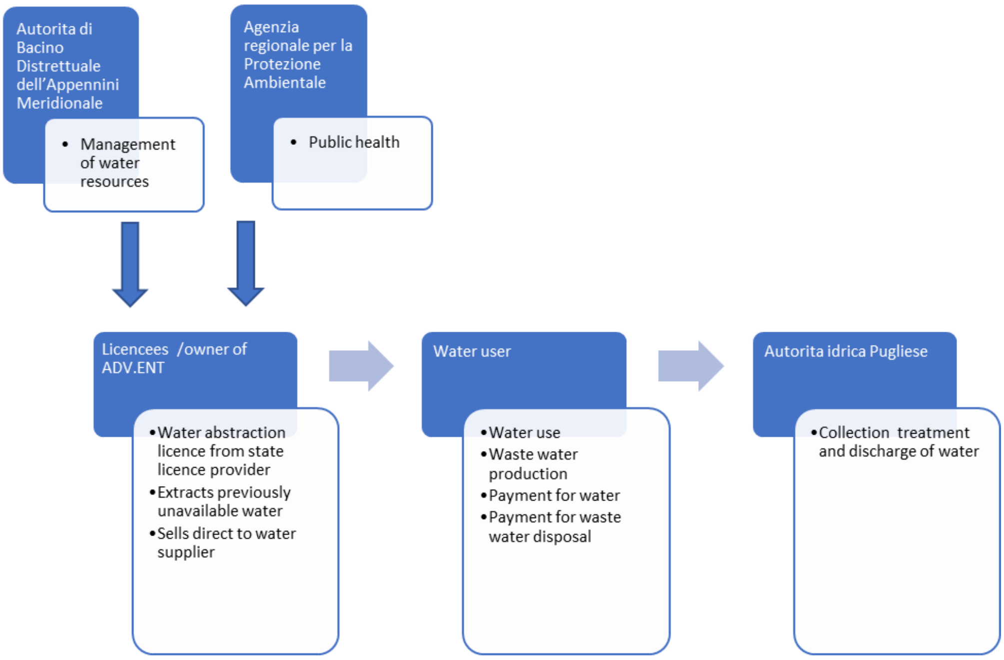


Figure 8: Key stakeholders and water related activities in demo 1, scenario 2

2.4.2 Changing value chains: Demosite 2 – National Centre for Mariculture, Israel

Figure 9 sets out the baseline value chain for the National Centre for Mariculture, demo site #2:

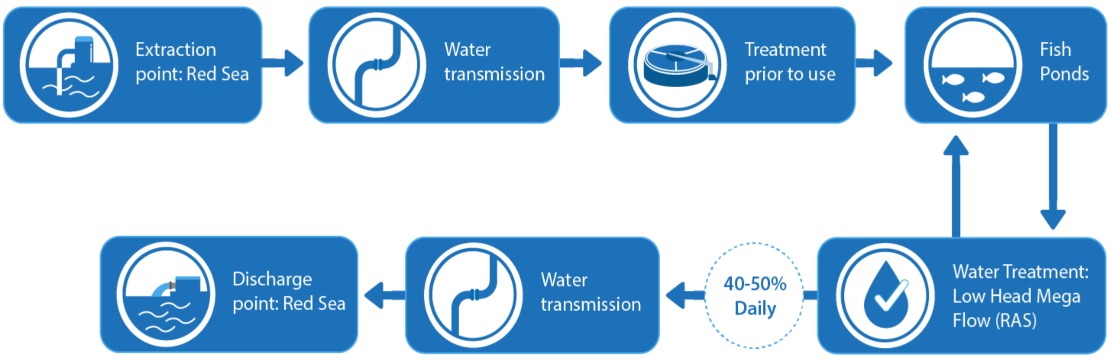


Figure 9: Baseline value chain for demo 2

Key players in this baseline value chain are limited in this example as water is abstracted from the Red Sea for a specific use, by the user - see. Any contacting out of pumping and other supply of sea water is not included in this value chain:

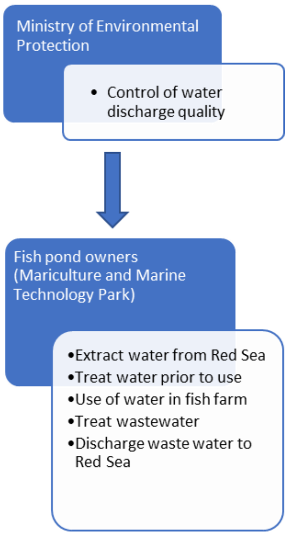


Figure 10: Key stakeholders for demo 2

The technologies being tested at the National Centre for Mariculture aim to treat wastewater from the fish ponds with the result of either an ability to reuse the water for irrigation purposes, or to use the biological processes of algae to clean the water to a quality sufficient for reuse in the fish ponds as shown in the value chain of Figure 11.

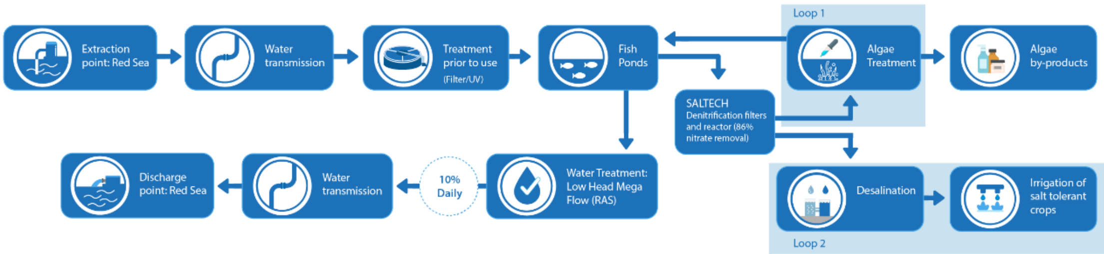


Figure 11: Project O value chain for demo 2

In this scenario, the different participants could own a stake and gain value from the reuse of water. A scenario is shown in Figure 12.

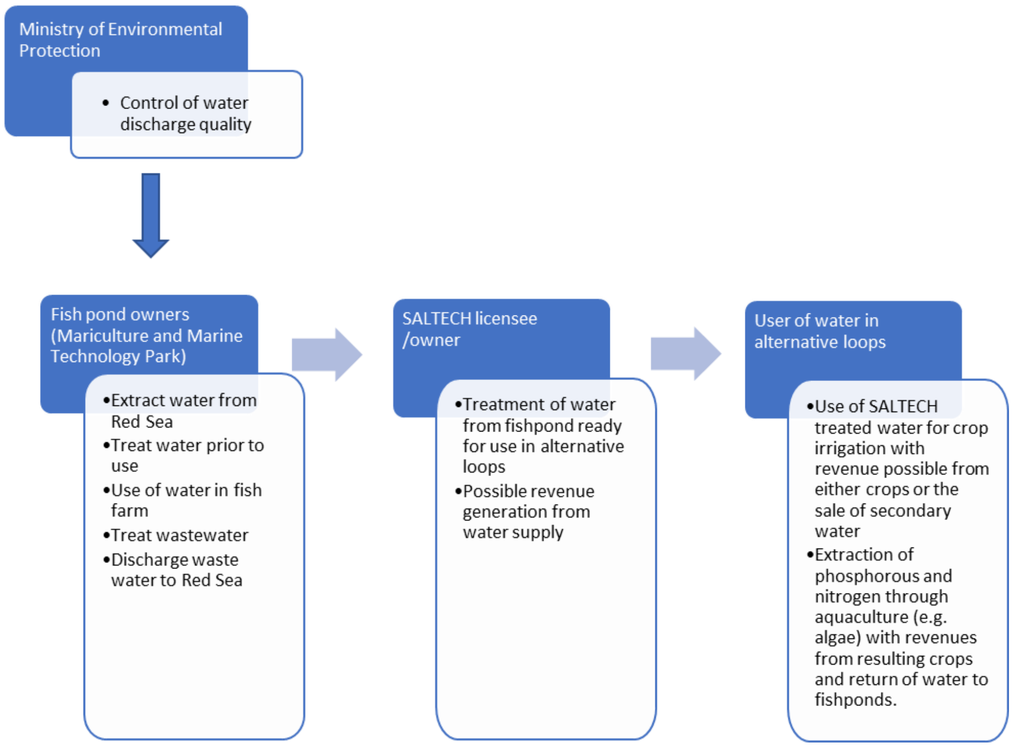


Figure 12: Key stakeholders and water related activities in demo 2

2.4.3 Changing value chains: Demosite 3 - Almendralejo WWTP, Spain

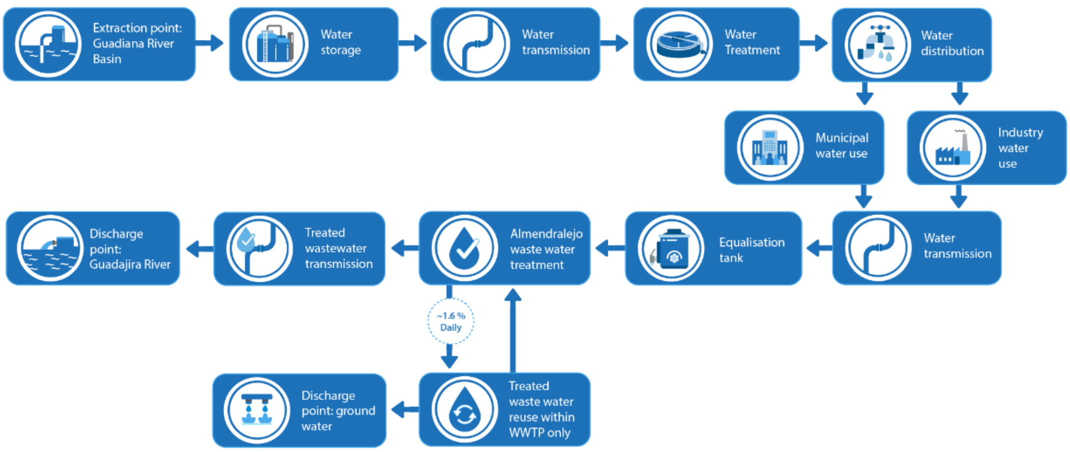


Figure 13: Baseline value chain for demo 3

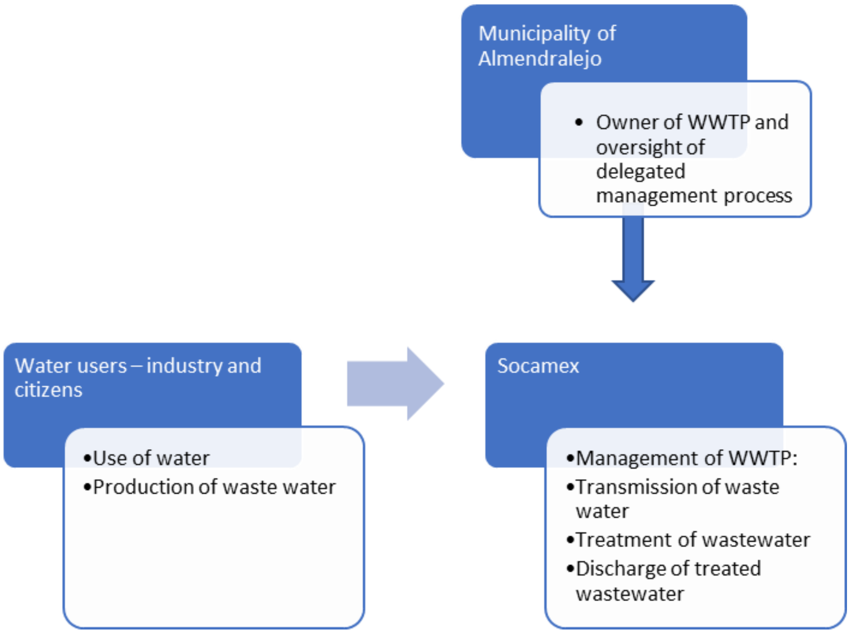


Figure 14:Key stakeholders and water related activities for demo 3

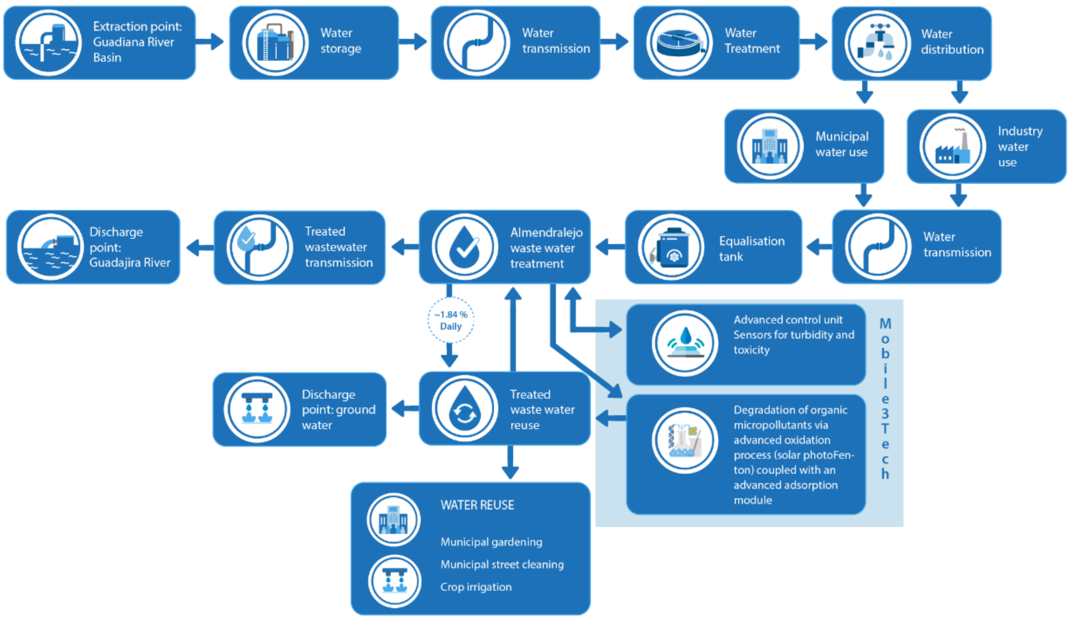


Figure 15: Project O value chain for demo 3

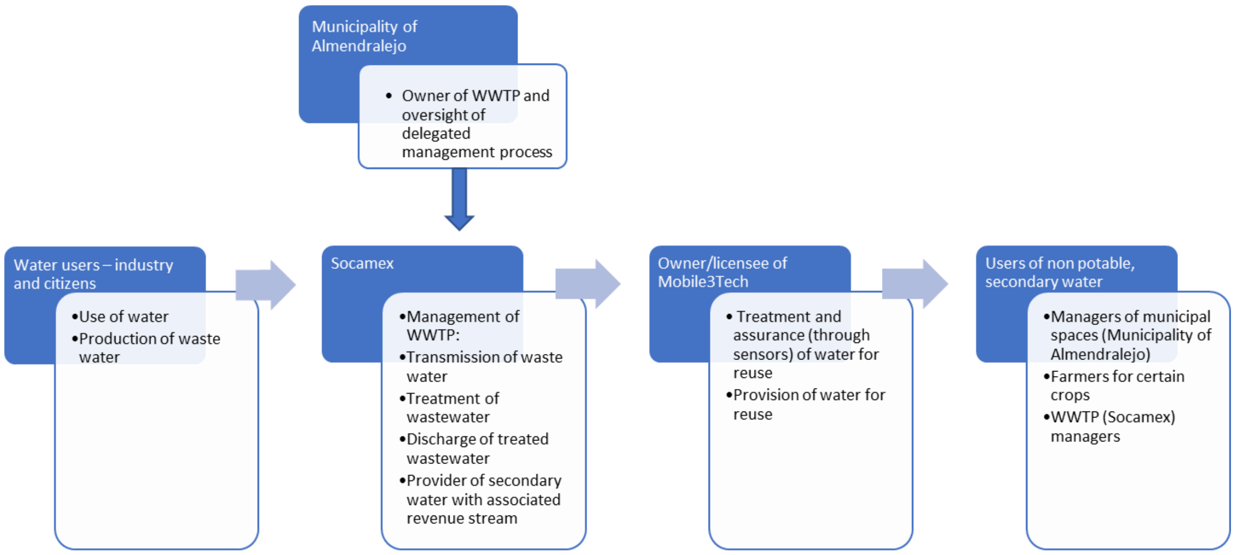


Figure 16: Key stakeholders and water related activities for Project O scenario in demo 3

2.4.4 Changing value chains: Demosite 4 - Omis WWTP, Croatia

The baseline value chain for Galeb, a textile company from Omis, is shown in Figure 17.

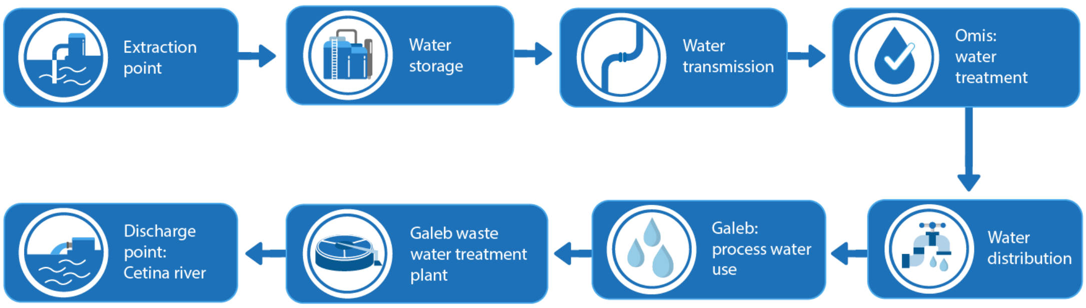


Figure 17: Baseline value chain for demo 4

Key stakeholders and their activities related to the project are shown in Figure 18.

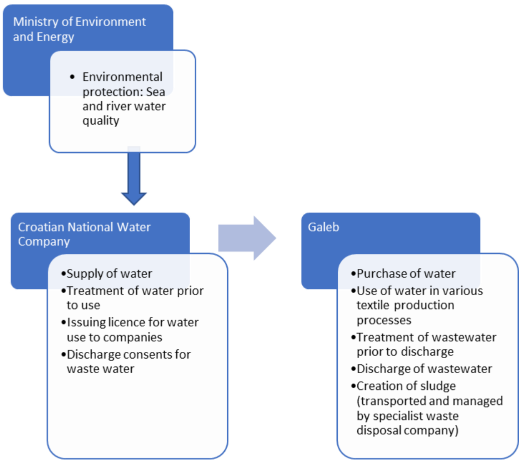


Figure 18: Key stakeholders and water related activities in the baseline value chain

Project Ô provides a technology that removes non-biological contamination (residual dyes and detergents) to enable reuse of water and utilises the heat within the wastewater. The technology is an extension of the internal water management system of Galeb.

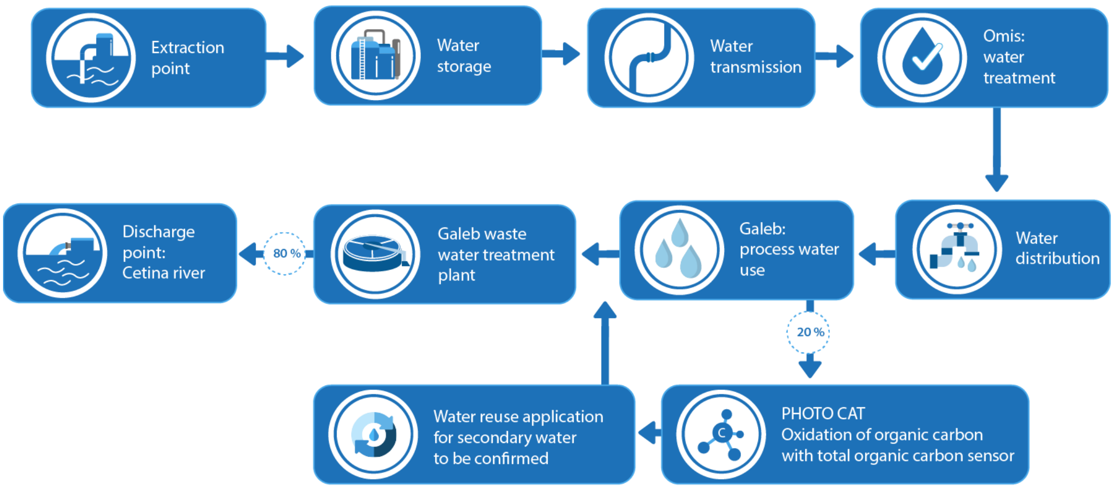


Figure 19: Project O value chain for demo 4

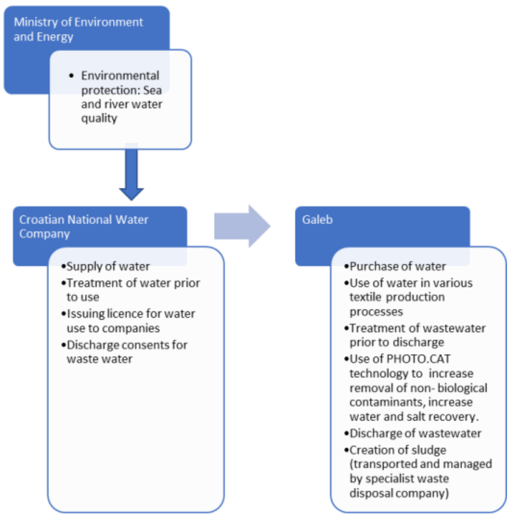


Figure 20: Key stakeholders in the Project O value chain for demo 4

Project O for Galeb is an internal project, and therefore there is no reshaping of the value chain in this example, except possibly the addition of a new water treatment technology provider.

The technology to be trialled at Galeb leads to significant cost benefits for the company, as outlined below:

- Savings from reduced water consumption through reuse (current cost of supply and discharge of water is about €3.5/m3[6])
- Savings of €40,000/year in discharge costs (less water discharged and lower contaminant levels).
- Savings from reduced natural gas use for water heating required for the process (recycled water has a temperature of 25-35ºC, network water has a temperature of 15ºC, working temperature needed is 20-98 ºC, depending on the production process)
- Some reduction (minimal) in raw material input through the reuse of salts - but amount depends on how much salt will be in the purified water and in which process the water is reused as each requires a different concentration of salt.
- Helps maintain and satisfy the criteria of discharge wastewater needed to maintain the water permit.

In the future, consideration could be given to the reuse of secondary water from Galeb by other local users (for example by a local aluminium casting company). This potential will not be considered further within Project O.

2.5 New business models

There are many water related challenges for organisations. A summary of some of the key impacts for organisations are shown in Figure 21:

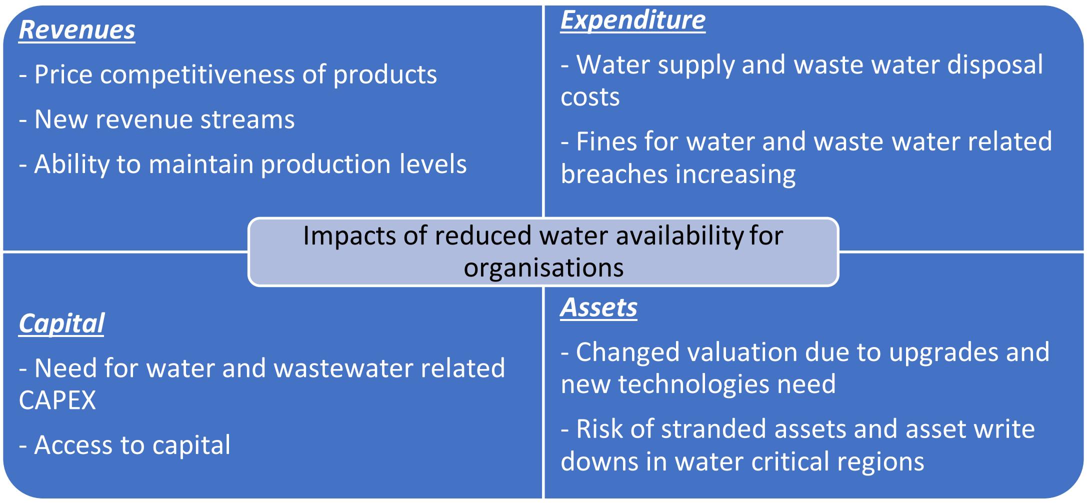


Figure 21: Summary of key water related impacts for businesses

Further elaboration of the drivers and related impacts is included in Annex 1.

[6] €1.8/m3 for supply of water and a yearly fee of circa €50-60k

There are a number of fixes to these challenges including changing behaviour and new technologies. New business models also offer solutions – finding ways to reduce negative impacts, and even positively regenerate natural capital by working in different ways.

The concept of different business models has been a strong feature of moving to a circular economy, as the solutions are limited and even blocked by traditional linear economic patterns (take, make, use, dispose).

Increasing the circularity of resources within the economy requires a number of different actions: reducing resources use and waste; requiring reuse and prolonging product use; ensuring biological resources are returned to natural cycles; recovering and recycling of non-biological materials. Enabling these activities and having them as the foundations of our economies requires changes to occur within our products and how money is made.

The linear economy is well established. Traditional business models have not typically found value in circular approaches – but the legal, social and business context is changing. The need to manage risks and the potential to create economic gain in other ways will challenge the linear economy – although the speed of change might be challenged.

DaSilva and Trkman[7] describe how a firm is a bundle of resources and capabilities with value generated through the transactions made with the use of these resources. Resources and capabilities might include assets, workforce skills, relationships with suppliers, leadership, etc. A business model represents a specific combination of resources through which transactions generate value for both the customers and the organization. A business model describes how a company generates value at a given time.

Business models within a circular economy can mean a number of changes to businesses and products compared to traditional linear business models, for example:

Traditional approaches		***Circular economy approaches***
Silo thinking with end of pipe solutions prevalent	→	Creative partnerships and creative ways of financing innovative, green actions that are more cost effective than traditional solutions (e.g. paying farmers to reduced nitrogen runoff rather than building denitrification plants – Payments for Ecosystems services)
Lack of common sustainability goals resulting in limited interaction and trust between stakeholder groups	→	Partnering with different organizations (companies, NGOs or academic organizations) to provide complementary capabilities
Owning products and equipment resulting in low product utilization	→	Exploiting commercial opportunities of different ownership patterns e.g. sharing and product as a service that benefit from long life products and higher utilization rates

[7] The definitions and discussions here are taken from - Business Model: What it is and what it is not, DaSilva, C., and Trkman, P., (2014), *Long Range Planning, 47*, including some of the references referred to in this journal article.

Short product lifespans with continual replacement supports key economic model	→	Maximizing value through the whole life of assets through repair, refurbishment and remanufacturing
Disposal of product at end of life resulting in removal of resources from the economy	→	Exploiting waste as a resource by identifying opportunities to extract value
Limited materials and other product information.	→	Availability of information for decision making to support reuse, repair, recycling, remanufacturing, etc.
Water and wastewater treatment to potable standard	→	Design of facilities according to specific needs avoiding high investment when not needed

Underpinning these approaches for organisations are new technologies and digital infrastructures, changing customer behaviours and demands, different business risks and opportunities, cash flows and revenue streams.

A number of business models types have become associated with the move away from linear patterns. Examples are described in Figure 22.

Business model type	***Definition***
Circular supply chains	Use of renewable energy, biobased or potentially completely recyclable materials
Optimise use e.g. sharing platforms	Increase usage rates through collaborative models for usage, access or ownership (reduces the demand on new products and materials)
Product as a service	Offering products for use with retention of product ownership (which incentivises resource productivity)
Product life extension	Extension of life cycle through repair, maintenance, upgrading, resale and remanufacturing (reduces the demand on new products and resources)
Recovery and recycling	Recover value through usable resources, energy production and by-products
Enabling decision making	This is not often included as a business model type – but enabling decisions to be made that support the circular economy will require new and different trading systems, assurance and other information to be available and useable.

Figure 22: Examples of circular economy business models

How could this look, for water, in terms of typical business models?

Consideration of different approaches, based on different transactional parties, is provided here:

Business to Business (B2B) refers to the process of selling products and services between businesses. In the context of water, examples might be:

- The costs of water treatment being reconsidered through (water companies?) funding interventions (by farmers or companies for example?) that tackle the causes of pollution rather than investing increasing and significant amounts in end of pipe solutions. Wessex water in the UK is a good example of creative, new business models to find solutions to some of their water quality problems. Through an online market, Entrade[8], farmers bid for funding for resources to deliver environmental outcomes (such as funding cover crops, undersowing maize and installing buffer strips). The initiative is rooted in an approach started in 2016 to engage farmers in reducing nitrogen loading in agricultural runoff, rather than investing in new CAPEX as an end of pipe solution.

- Selling technologies that enable water reuse, reduction and higher quality treatment water treatment
- Industrial symbiosis, a form of exchange between businesses of one businesses waste or by-products as the raw material – or energy - for the another. The concept of industrial symbiosis has been around since the 1960s. One of the longest established examples is Kalundborg[9] in Denmark, with symbiotic partnerships between 9 public and private companies for raw materials, wastewater and energy production (including in pharmaceuticals, energy production, plaster board production). In Europe these situations have developed organically, although public support and vision often underpins the functioning of the system[10] to enable markets, contracts and information and technical advice to facilitate the process.
- Trading waste from one business to another for use as a raw material is also increasing common and profitable. Could the trading of reclaimed water and associated by-products also become more common?

Business to Customer (B2C) refers to the process of selling products and services between businesses and end users – possibly one of the most common forms of business transaction in the linear model. Examples in the context of small closed loop systems for water and wastewater might include:

- The sale of reclaimed water back to customers as potable water supply (e.g. NEWater, Singapore) or for domestic irrigation (e.g St Petersburg, USA).
- Selling compost back to the public made from organic matter collected through kerbside waste collection systems might be an equivalent example.

Customer to business (C2B) refers to the process of selling products and services from customers (individuals) to business. Typical examples include consumer reviews or product ideas. The development of the internet and the relationship with bloggers or internet forums has enabled this relationship to develop through product promotion by individuals paid for by business. Considering examples within the utilities sector, in the UK government backed scheme for homeowners to sell energy produced from their solar panels to energy companies was initiated by the government through support on tariffs[11]. In 2019 a private energy company E.ON instigated a scheme called 'Solar Reward' to pay customers for energy exported back to the grid[12]. Traditionally removal of wastewater from a customer is a paid for service. Could the retrofitting of greywater systems or new technologies ever change this relationship?

[8] Wessex Water: Entrade website
[9] Kalundborg website
[10] For example the Industrial Biotechnology Innovation Centre (IBioIC) in Scotland
[11] OFGEM website with details of the Feed In Tariff (FIT) scheme
[12] Solar Reward scheme - E.ON's website

Government (G) has a key role in supporting small closed loops for water management with aspects including the public procurement standards, setting levels of fiscal incentive e.g. pricing of water or taxes, support to innovation, and provision of education and information. As governments (directly or through licenses to private companies) currently manage water and wastewater – they would seem to be in a good position to exploit technologies, find new revenue streams and reuse water. Relationships of G2B and G2G are the most obvious connections.

2.6 Changing roles of stakeholders

With changing objectives with water management and the potential of exploiting different business models, the roles and relationships between stakeholders within the water sector will change. Table 3 describes how the roles of stakeholders within the water sector might change with a shift to a circular economy. The term reclaimed water here is taken to mean both reused wastewater streams and non-conventional water sources.

One key aspect of a more circular approach to water use is a shift from traditional, centralized water supply and wastewater treatment to localised alternatives – and with it a shift in resources and styles of water service delivery. This means that stakeholders that were traditionally water users might become water suppliers.

Stakeholder	Traditional role/interest in linear economy for water	Potential role/interest in circular economy for water
Government (National and/or regional)	• Environmental protection • Setting framework for water and wastewater management • Establishing compliance regime and oversight structures	• Establishing standards and a regulatory framework for water reclamation and reuse • Education programs to support increased water reuse • Setting pricing model that encourages reuse • Creating a political context that rewards the use of recycled water • Working in co-creation models with water users to generate ideas and innovation relevant to specific applications
Water companies (Government owned or private)	• To provide potable standard water • Protection of national water resources conflicts with need to supply increasing demands • Establish and maintain water distribution network	• Include reclaimed water as an integral part of a sustainable water management programme (Recovery of used water as one source of water supply). • Setting pricing and other terms suitable for reclaimed water users • Identifying users and uses that would benefit from reclaimed water • Water companies could be seen as the 'representative' of its customers for the protection of water resources – a stronger regulatory role for managing user demands? • Structuring financing for non- traditional solutions to water challenges that would traditionally have required and financing to water related challenges (eg Entrade)
Wastewater companies	• Transport and treatment of wastewater	• Seller of reclaimed water (or partnership with organizations able to do this). Will waste water treatment companies become known as water recycling companies? • Provider of distribution networks that allow non-linear water flows • Partner to technology providers who can deliver reclaimed water systems • Establish and maintain reclaimed water distribution network • Quality assurer for reclaimed water use • Provider (manager?) of the supply of water reuse services. • Owner of a resource with value – extracting and selling by-products (or partnering with organizations to enable this) – WWTPs become biorefineries

Businesses	• Users of potable water provided by water company • User of private borehole water • Some examples of water reuse within business • Water considered as a resource to be used once	• Business innovation substituting persistent pollutants from business activities that limit reuse of wastewater streams • Seller of reclaimed water - either treated on site, or in agreement with customer • Seller of by-products extracted from waste streams • User of locally produced energy as a by-product from wastewater treatment • Buyer of reclaimed water • Use of water is either closed loop or enabling continual recycling • Working in co-creation models with governments, water related businesses and other water users to generate ideas and innovation relevant to specific applications
Farmers	• User of potable water • User of private borehole water	• Users of reclaimed water for irrigation • Working in co-creation models with other stakeholders to generate ideas and innovation relevant to specific applications
Citizens	• Users of potable water	• Users of reclaimed water for watering gardens • Acceptance of reclaimed water for municipal uses • Working in co-creation models with other stakeholders to generate ideas and innovation relevant to specific applications
Town governments	• Users of potable water	• User of reclaimed water for municipal purposes • Educators of citizens regarding reclaimed water • Working in co-creation models with other stakeholders to generate ideas and innovation relevant to specific applications
Wastewater technology providers	• Provider of water treatment technologies and associated supplies	• Providers of technologies for treatment of wastewater to agreed standards for reuse (cheaper water for clients) • Providers of equipment (pipes, valves etc) for reclaimed water networks • Providers of technologies to extract by-products (including energy) from wastewater • Providers of equipment and data on water quality • Payment for performance delivered (service provision) rather selling of equipment (e.g. payment per m^3 water recycled) potentially encouraging designing in increased repairability and remanufacturing potential of the equipment. • Partner for wastewater companies to extract value from wastewater streams • Provision of new trading platforms for selling recycled water, by-products and energy

Information technology companies	• Internal information provision • IoT	• Provision of sharing platforms to enable increased utilization of water through reuse – sharing information to facilitate new models • Gathering, analysis and sharing of information
Business Associations	• Promotion of water conservation practices	• Promotion of best practices for water reclamation and reuse
Academic and research organisations	• Research into traditional wastewater treatment	• Research into water reclamation and system recharging technologies and systems • Research into good practices and quality issues
Investors	• Provision of financing for water treatment facilities	• Provision of financing for water reclamation and reuse facilities

Table 3: Suggested changes to stakeholder roles within more circular water value chains

3 Learnings from Project Ô and from other studies

To support the analysis of how the current value chain might be reshaped, and for the development of the collaborative platform, examples of other water use and wastewater related examples that demonstrate circular economy principles along the value chain of water have been identified. The Project Ô demonstration projects are also included.

The purpose of providing these examples is to:

- support the development of the circular economy framework through exploring real examples;
- draw out factors that underpin the delivery of different business models – meaning those factors that have enabled the circular actions and associated business models to develop; and
- provide insight that would support the development of the multi-user platform for Project Ô.

Details of the case studies themselves are include in Annex 2: Summary of information from examples. Key factors affecting the efficiency and effectiveness of projects are drawn out from the literature. Key points from the case studies reviewed, background reading and Project O demonstrators are presented in Figure 23 as a mind map.

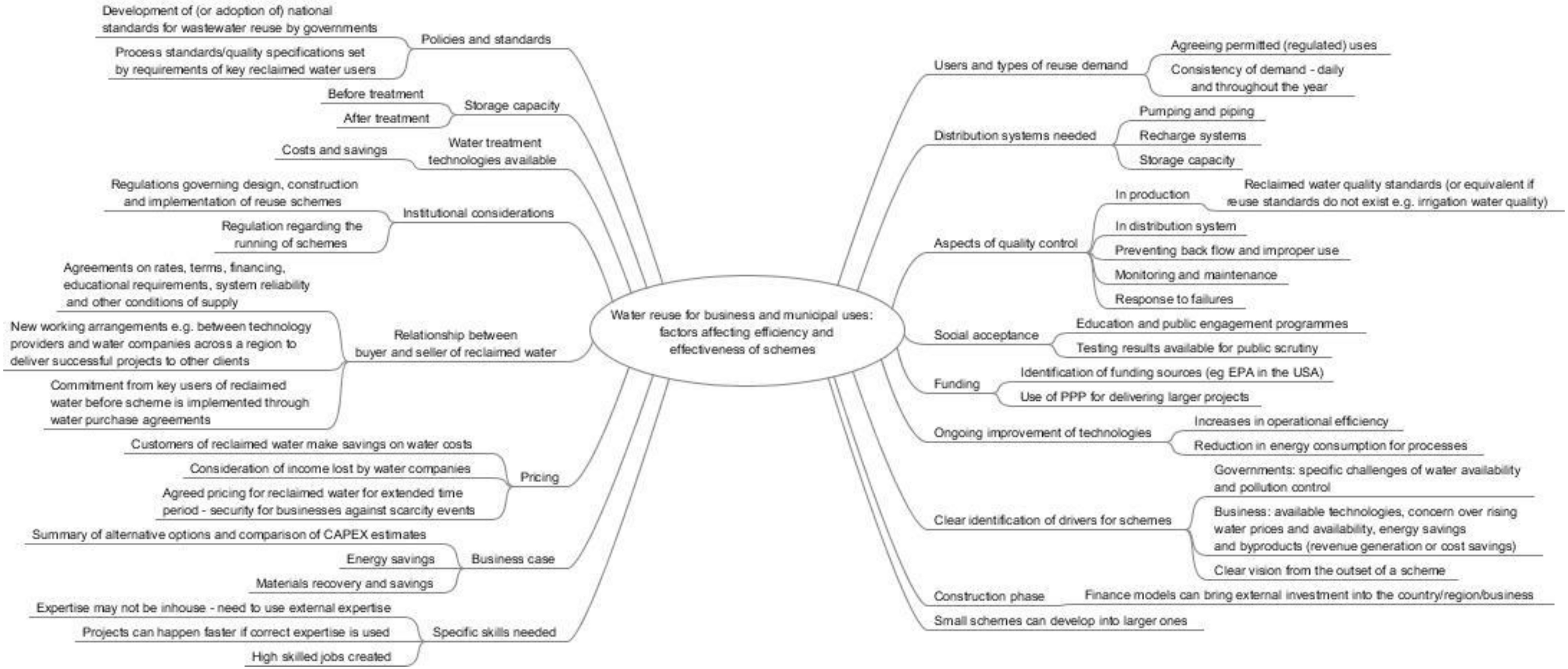


Figure 23: Factors affecting the success of water reuse projects

4 Circular economy framework for water treatment with the inclusion of energy and materials

4.1 Purpose

The circular economy framework for water treatment sets out a systematic approach to identifying the opportunities and key considerations of small-scale loop water projects.

Within Project O this framework will be used to provide the structure for the multi-use collaborative platform. The framework is related to the deployment of small-scale technologies as demonstrated through Project Ô, not large scale reuse projects.

4.2 Overarching conditions

For the successful delivery of water reuse projects, certain conditions ideally need to exist for success and widespread uptake:

- Adoption of policies and standards to support water reclamation and reuse from non-traditional sources. (These might include changes in other sectors such as building codes that require the inclusion of grey water plumbing systems.)
- Water pricing structures that support reuse
- Framework conditions that build trust between key players (e.g. regulations and oversight)
- Support in developing the infrastructure for the use of reclaimed water
- Promotion of the use of reclaimed water as a key tool in integrated water management
- Foster trust and acceptance between stakeholders surrounding water reuse projects

4.3 Outcome of small closed loop water systems

Large infrastructure projects will be critical in progressing with increased water reclamation – but small-scale projects can equally play their part. Small scale projects can be more accessible and achievable in a shorter timescale – not requiring complex funding arrangements and planning challenges. In addition, they offer opportunities for many in a circular economy – cost saving, jobs and environmental improvements. Appropriate technologies play a critical part in supporting such projects. Figure 24 identifies outcomes that can arise from small-scale closed loop water projects:

Figure 24:Outcomes from small-scale closed loop water projects

4.4 Elements of the framework

The CE framework for water treatment provides an approach to supporting circular economy considerations related to water challenges through the use of small-scale technologies and solutions. The framework offers key considerations and steps.

Circular Economy Framework for Water Treatment			
Scheme vision		Scheme design	Scheme delivery
CE principles	Principle 1: Design out waste	Value chain	Quality assurance
	Principle 2: Keep resources in use	Business model innovation	
	Principle 3: Regenerate natural capital	Water treatment technologies	Partnerships and stakeholder engagement
		Economics	

Figure 25: Circular Economy Framework for water treatment

The various aspects of the framework are described below. Whilst each of the aspects stands alone, the process of identifying the most appropriate solution to the challenge is likely to be an iterative process between each of the steps:

	Framework aspect	Description of aspect	Key steps
The vision	*The circular economy principles*	Development of a vision for water based on the principles of the circular economy with associate objectives (see Table 1)	• Characterization of the problem including business risks • Consideration of solutions based on the CE principles and associated objectives • Identification of success criteria for the scheme
Scheme design	*Value chain*	Map other stakeholders in the value chain including those that can influence the problem being solved	• Consider all value chain stakeholders up and down stream • Consider their role within the value chain • Identify key partners critical to the delivery of the project
	Business model innovation	Consider how alternative business models can be used to solve the problem	• Consider examples from within and outside the sector to explore other non-traditional approaches to solving the problem
	Water treatment technologies	Identification of possible small-scale water treatment technologies and systems suitable for achieving the schemes objectives	• Characterization of the wastewater or alternative water sources (chemical and biological quality) • Characterization of the needs of the (re)use application (fitness for purpose) • Identification of suitable water technology modules
	Economics	Analysis of the costs, savings and revenues earned from developing the options	• Identification of the running costs of the technologies • Identification of cost savings • Identification of new revenue streams
Scheme delivery	Quality assurance	Ensuring trust in the scheme through governance and process management structures	• Establishing standards and procedures that support agreed quality criteria (including for incidents and emergencies) • Establishing management practices and infrastructure to meet required standards • Ensure monitoring and governance oversight to provide assurance
	Partnerships and stakeholder engagement	Identification of stakeholders that influence the project and the type of engagement with the project.	• Identification of key partners in the project and key aspects of the relationships • Consider issues of social acceptability and how to manage public perceptions

5 Relationship of the framework to the multiuser collaborative platform within Project Ô

The use of shared platforms has been a significant part of the progression of the circular economy. They allow transparency of information enabling those other than the manufacturer of products to enable second and end of life aspects, such as in new developments of materials passports for buildings[13], and the creation of new marketplaces, for example secondary materials exchange sites[14].

The Multi-User Collaborative Platform within Project Ô has 2 elements:

- Decision Analytic Platform (DAP) – this provides support to water regulators and municipal water providers to support water resource management and the exploration and management of differing objectives and trade-offs; and
- Circular Economy Collaborative Platform (CEP) – a business facing platform that allows the selection of the best technology to match water requirements and to enable the exchange of water, sub-products and other resources between different partners – including with the involvement of water regulators to support the achievement of regional water management objectives. The CEP will have 2 main modules (a) the *Tech-Solution Toolbox* (CEP1) which will allow for the selection of the best technology solution or system of solutions and (b) the *Users Collaborative Platform* (CEP2) to improve the circularity of resource between different partners in the water treatment value chain.

Figure 26 provides the circular economy framework for water treatment with the inclusion of energy and materials, overlaid with the 2 elements of the multiuse collaborative platform

[13] For example Madaster
[14] For example the Excess Materials Exchange and Veolia's Bio trading website

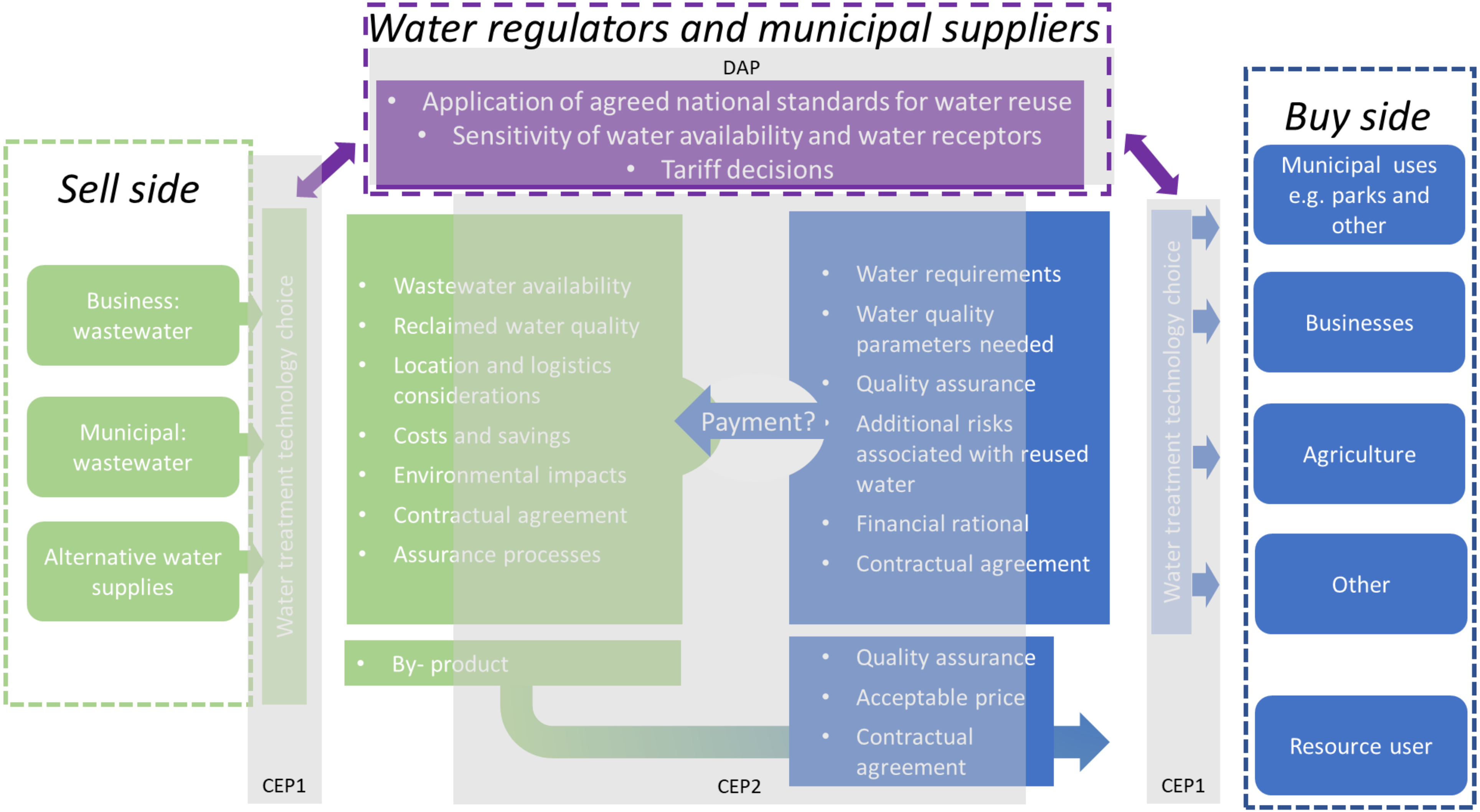


Figure 26: Overlay of the multiuser collaborative platform structure

Annex 1: Business related risks and opportunities related to water

A world with water scarcity will impact business – through the need to take actions, or through the consequences of not taking action. In addition, there is undoubtedly a growing demand for businesses to be accountable for, and identify related risks, regarding the impact of water on business operations. Examples of business-related risks and opportunities are set out below.

Policy risks and legal enforcement

EU water related policies have been developing over the last 50 years. Key directive are shown in Figure 27: Key water related EU DirectivesFigure 27.

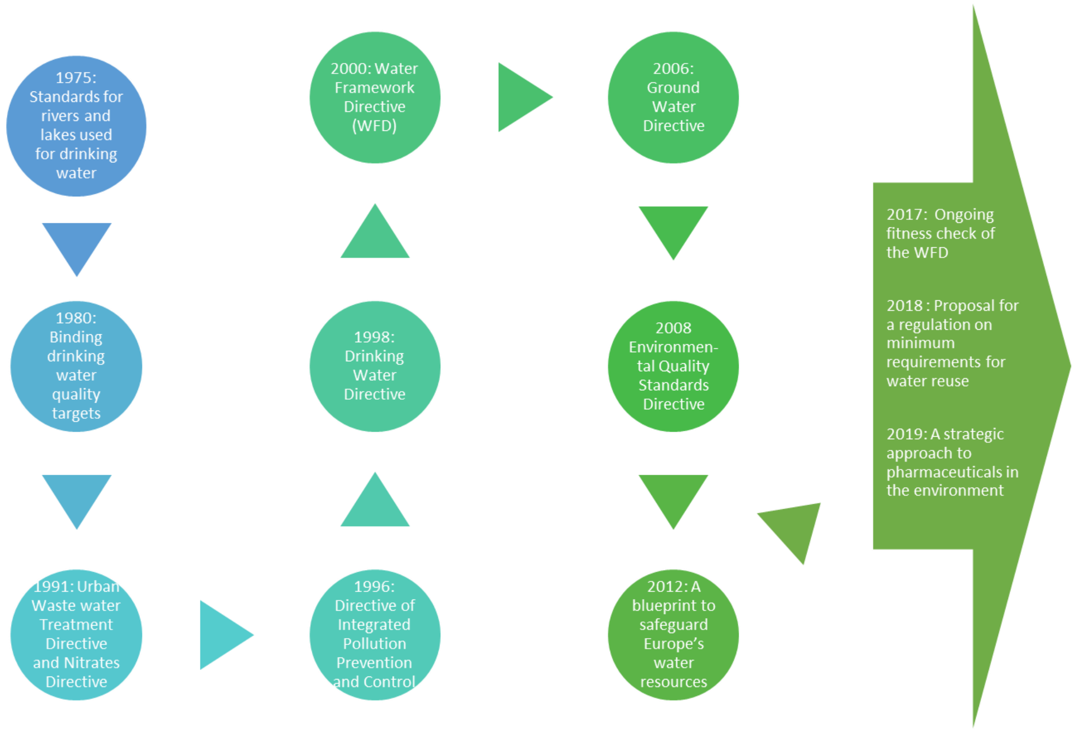


Figure 27: Key water related EU Directives

The combined implications of the Directives have impacted water body quality, water discharge, abstraction limits and pricing mechanisms – as well as developing the information needed and governance structures for water basin management.

For business, the tightening water policies are indicative of a trend in a greater understanding of and responsibility for human impacts on water resources – hence a trend towards greater disclosure of water use and management by corporates, and of national and regional policies and regulations that have imposed constraints on and initiated encouraging activities related to water consumption and wastewater discharge. This has led to a need for investment in new technologies to manage wastewater quality and in some places to pay higher water bills. In addition the risk of litigation and resulting fines, as well as the value of loss and damages has been growing – for businesses.

The nature and timing of policy changes will differ between geographies, but the trends related to increasing visibility of and need for clearer pricing for water, of tighter wastewater discharge requirements, and of new measures related to pharmaceutical contaminants and water reuse are clear.

Technology risk

In industries where water use is significant (e.g. chemicals, textiles, paper and energy) the role of technology to remain competitive will be significant. This will include technologies that reduce water use, are low carbon, recover or reduce chemical use and do not result in waste streams that are expensive or difficult to dispose of.

Reputation risk

In regions with significant water availability challenges, businesses that do not take the issue of water seriously risk reputational damage if excessive use is detrimental to other water users. On the flip side, proactive action can support a positive reputation where other corporate responsibility performance is positive.

Water availability risks

There are a combination of causes for observed changes in water availability - climate change, pollution and increased demand from population and industrial growth. These factors indicate a greater likelihood of extreme events, as well as longer term shifts in water availability, quality, sourcing. This will inevitably result in financial impacts for companies, either directly or through their supply chains.

Cost saving opportunities

Companies taking steps to identify, management and reduce water consumption will benefit from long term cost savings. As technologies develop, it is hoped that the return on investment of new technologies can reduce. Where limited focus has been given to water, there may be low or no cost water reduction steps that can be undertaken. When looking at the whole life costing of water use, savings do not just arise from reducing potable water bills, but from the costs of treating water (chemical, equipment and energy), the cost of labour to manage water systems, regulatory costs and energy costs for transporting water. In case studies of wastewater reuse the water is often cheaper than the potable water alternative. In addition, using by-products from other businesses or finding users of waste products can offer financially positive outcomes.

New revenue stream opportunities

By-products – either directly from the treatment of wastewater or using resources to create products – can create new revenue streams.

Water efficiency products and services

Organisations will innovate and develop new low/no water use products and services to grow business and opportunities as customer pressure increases.

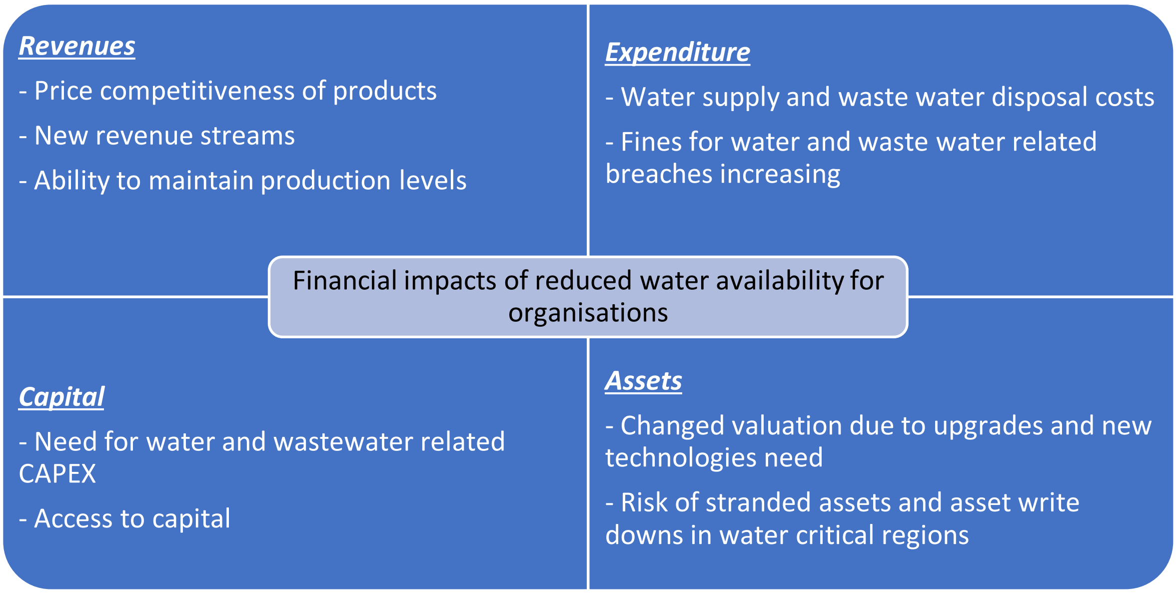
Access to finance

Fair to say that water risks can be under the radar for investors – primary focus in on climate. Growing understanding that the 2 are linked and that water risk need to be considered. But there are indications of changes. If water becomes a factor critical to a business, it could become a feature in considering access to capital. Equally new streams of capital could become available to those businesses responding innovatively to the water related challenges arising. For example there has been a huge increase in the use of green bonds (USD 117.8bn in the first half of 2019, up 48% on the first half of 2018[15]), primarily to invest in lower carbon projects. Could there be a move towards green bonds incorporating sustainable water related investments in the coming years?

Long term resilience

Considering trends in water availability, taking moves that adapt to a world of lower water availability will increase business resilience. The term ‘stranded assets’ is used where the value of a companies assets have had to undergo premature write downs, dramatic devaluation or even conversion to liabilities. Changes due to climate change, both physical and social, have resulted in stranded assets related to fossil fuel investments for example. Without appropriate action, similar issues could arise for other corporate assets reliant on regular water supplies.

A summary of possible financial impacts for organisations, based on the points above are shown below:



[15] Climate Bonds Initiative [Green bonds market summary H1 2019]

Annex 2: Summary of information from examples

Urban reuse

St Petersburg, Florida, USA

The business case: Drivers for the system were low available rainfall, flat geography (resulting in limited water containment opportunity) and coastal situation (saline intrusion) lead to water supply challenges in a densely populated part of the USA. In 1972 legislation was enacted requiring discharge into Tamper Bay to cease or be subjected to advanced wastewater treatment.

The system: The system is a water reuse and deep well injection programme that result in zero discharge to surface waters. It was the first built in the US (the initial retrofit system went into operation in 1977 but the system has grown since then) and still the largest reclaimed water system in the world. Initial reclaimed water distribution system was limited to serving irrigation water to golf courses, parks and school grounds and large commercial areas. Currently there are 3 reclaimed water facilities providing 37 million gallons of reclaimed water per day to more than 10,000 active customers. 290 miles of reclaimed water pipelines. Used for irrigation and fire hydrants. 9 monitoring wells exist throughout the city at major irrigation areas with water quality samples routinely obtained.

Limitations of the system: The use of reclaimed water for irrigation displaces the use of potable water. In St. Petersburg, the average household discharges 5,000 gallons of wastewater per month to the sewer system. However, it takes the discharge from six wastewater customers to produce enough reclaimed water to supply one residence with irrigation water. As a result, it is not possible at this time to supply all residences in St. Petersburg with reclaimed water. The typical residential lawn can require up to 30,000 gallons of irrigation water per month, especially during the dry spring and winter seasons.

Funding and pricing structure: Funding of the extension of the system into residential areas was through a grant from the EPA as water quality in those areas was too poor for irrigation. The system includes both city owned and private pump and booster pump stations. Reclaimed water lines into residential areas are voluntary and brought into an area when 50% of residents in that area petition or service and agree to connect to the system and pay for extending the distribution lines and other installation requirements. Payment is made on an Equivalent Residential Unit (ERU) basis – related to the size of the property rather than volume used.

References:

- St Petersburg reclaimed water website
- Crook, J *St. Petersburg, Florida, Dual water system: a case study* in Water conservation, reuse and recycling: Proceedings of an Iranian-American Workshop (2005)
- St Pete Beach reclaimed water website

NEWater Singapore

The business case: The Public Utilities Board (PUB) in Singapore explored the feasibility of producing drinking water from treated used water since the 1970's. It wasn't until the early 2000's that the technologies had matured, and the production cost reduced significantly.

The first 2 NEWater plant were built and operated by PUB. The other 2 plants adopted a PPP approach in which the private sector arranged the financing, designed, built, own and operate the plants and supply the water to PUB. The agreement is the provision of NEWater to PUB over a 20 year period for one plant and a 25 year period for the other. PUB pays for the distribution and customer services costs.

PUB has been working with industry partners to develop new membrane technologies that can increase operational efficiency and reduce energy consumption during the production process.

The system: Singapore has a water supply system called the 'four national taps' – water from the local catchment, imported water, desalinated water and NEWater.

NEWater is high grade reclaimed water. The first plant was opened in 2003 and there are now 4 plants. A 3-stage process is used:

- Microfiltration (filtering out solids and particles)
- Reverse osmosis (filtering out bacteria, viruses, heavy metals and dissolved salts)
- UV disinfection (inactivating all organisms)
-

The NEWater plants meet up to 40% of the nations current water needs, and by 2060 is expected to meet up to 55% of demand. Mainly used for industrial and air-cooling purposes. Small amounts are used during summer months for indirect potable use by topping up reservoirs. Biggest industrial uses are wafer fabrication plants that require stringent water quality standards. It is also used for electronics production, power generation and commercial air conditioning cooling.

Public acceptance and confidence: was key to the success of the project. There was a public engagement campaign before the launch of NEWater to educate the public on the stringent production process. They engaged stakeholders such as grass roots leader, businesses, water experts, schools and the general public. A visitor's centre has been created to maintain this process. The water has been well tested and is within WHO guidelines

References:

- Singapore's National Water Agency website
- Fact sheet NEWater in Singapore

Industrial reuse

Industrial reuse includes on-site water and graywater reuse systems, but also, maybe of more interest in terms of the circular economy of expanding reuse opportunities between industries or from wastewater treatment to industry reuse.

Dow and Evides Water Co

The initiative: Public private partnership between chemical facility of Dow and Evides Water Co. Started in the late '90s when water availability restricted production expansion plans. Dow uses wastewater from the city of Terneuzen, purified by Evides Water Co, to generate steam used in its manufacturing plants. After the steam is used in the production process the water is used in the cooling towers where it evaporates.

Dow uses a similar model in its Freeport, Texas facility using wastewater from the city of Lake Jackson to produce steam.

Environmental impacts: Reduction of fresh-water use – Dow uses 10,000m^3 of municipal household wastewater, purified by Evides Water Co per day. Water is used twice by Dow (so 3 times all together). Reduction in energy use through an energy efficient purification system – cutting CO_2 emissions by 60,000 tonnes each year

Financial impacts: Cost of system not known but savings of $1.5million annually compared to next best option. Dow saves money on electricity and water costs. Compared to energy cost for conventional seawater desalination - 95% reduction in energy use. 90% of this reduction is through the use of membrane separation rather than thermal desalination. Another 50% reduction by using municipal effluent instead of sea water. Using municipal effluent instead of sea water has lower salt constituents requiring less pump pressure to remove the salt and lower usage and cost for chemical treatment of membrane systems (50% less).

Further opportunities: Dow Benelux is developing robust water systems with a large number of industrial, urban and rural partners in the Netherlands. Dow provides stakeholders with access to water at an affordable cost through developing low-cost applications that can utilise local raw water for reuse purposes that do not need fresh water.

References:

- Environmental Leader article

Water recycling for industrial use, Durban, South Africa

The initiative: Development of a sewage to clean water recycling plant. The first private water recycling plant in South Africa. Treats 47.5million litres of domestic and industrial wastewater per day to a near potable standards for sale to industrial customers for direct use in their processes. Largest customers are the Mondi Paper Mill in Merebank and the SAPREF refinery owned by Shell and BP

The business case for the water company: Water use is an important issue as South Africa is a water scarce country. There was industry concern over raising water prices. There were sewage capacity constraints in Durban, with the costs of construction of a new marine outflow to increase capacity high. Using a PPP, the project delayed capital investments need by EWS and transferred the risks associated with the recycling plant. For the region it delayed new investment for additional sewage treatment and potable water production works. A long term revenue stream from a levy raised on the production of recycled water was created thereby reducing the cost of water services to Durban citizens. Having a vision at the outset was significant. Direct foreign investment and the latest technologies brought to South Africa through the involvement of companies from France, the US, and Japan in DWR

Financing and getting the project going: The technology was proven, but funding was the initial barrier. Treating sewage for industrial reuse was not seen as a core function of the local authority. Due to costs, technical complexity and risk, the water service provider, eThekwini Water Services (EWS) decided a PPP would be the best approach.

A public private partnership was commissioned in 2001. Build, Own, Operate and Transfer (BOOT) with a 20-year concession to treat 10% of the city's wastewater. The concession contract is between Durban Metro and Durban Water Recycling (DWR). Funding was provided by the Development Bank of South Africa, the Rand Merchant Bank and DWR shareholders. DWR is a consortium of local and international companies – the main shareholder being OVT France (a subsidiary of Veolia). DWR pays Durban Metro Water Services an annual management fee, a fee for the lease of the land of which the plant is constructed and a fee of R 0.24/m3 as payment for the loss of cross subsidisation income from participating industries. There are restrictions on PPP's (e.g. that a PPP cannot collect revenue that the public sector should collect can restrict their use). However in this case the DWR provides a service to a client based on a raw material that Durban Metro provides for free

Mondi Paper had already approached EWS, and so was envisaged as the major customer. Water purchase agreements are in place with Mondi and Sapref.

Professional team from Durban Metro and the other companies enabled the agreement to be processed in a short time.

Once the project was underway, several other industrial companies expressed interest in participating in the project leading to further demand for recycled water.

Key partners:

- Veolia Water (was Vivendi Water) – a major stakeholder (provided finance and technical solutions)
- Mondi's endorsement through committing paper production at its Merebank Mill to recycled water was significant for the go ahead from the project. Water is used in the production of fine paper – a process sensitive to water quality due to its impact on paper brightness. For Merebank Mill 'second class water' makes up 94% of all water used in the mill.

Water specifications: The specialised water treatment process is specifically tailored to meet the requirements of DWRs main client, Mondi Paper. The water specification includes 32 contractually specified parameters (set by Mondi). These include 23 parameters that are measured in the South African potable water standard (SABS 241:1999). Mondi's specification meets or exceeds the potable standard or 77% of the parameters for class 1 potable water. The standard is guaranteed continuously and reliably.

The system: process used for wastewater recycling includes technologies developed by Veolia Water technologies South Africa. Key aspects of the design – reliability, compactness, cost-efficiency, safety and reliability of supply to the customer are the main priorities. Best available technologies were used with the exception of desalination technology which was incompatible with the target water prices. Potable water back up can be added to the storage and distribution system to correct any temporary quality problems. The water treatment technologies implemented for the project are standard but the innovation combination of the different steps makes the project unique and ensures that the recycle water meets the quality standards of the industrial clients.

Environmental benefits: Reduced demand for potable water - frees up sufficient drinking water for approx. 300,000 people. Reduced quantity of effluent discharged to the ocean

Business case for industry partners: Reduced costs for business as they obtain a water supply cheaper than potable water (30% cheaper) – allowing companies to be more competitive. R2.8/m3 rather than R5.4/m3 for potable water. An agreed price of water for the next 20 years and higher security in case of scarcity events - reduce risks related to water availability for industrial client. A broad range of stakeholders are interested in Merebank Mill and the environmental performance is significance.

Other benefits: High skilled jobs created. DWR bursary programme adds a social element to allow 3 individuals from local disadvantaged areas to obtain training at this and other sites

References:

- An overview of the scheme: Government of Durban, South Africa
- Mondi South Africa Division, Merebank Mill Operaion Socio-economic assessment toolbox report (SEAT), 2015, Mondi group website
- Durban eThekwini Water Services South Africa Case Study, Veolia Water technologies website
- Summary of information about the wastewater reuse project, IRC WASH (Water, sanitation and hygiene)
- Wastewater: From Waste to resource – the Case of Durban, South Africa, World Bank case study
- Durban Water recycling project, Water Research Commission, Bhagwan J, 2012

Agricultural reuse

Wastewater reuse in Souss-Massa, Morocco

The challenge: There is a water deficiency in the region. Over-pumping of groundwater has lowered the water table leading to increasing pumping cots and groundwater salination due to sea water intrusion. The region is significant for horticultural products especially for export. Agriculture consumes about (90% of the water resources). The potential of 50 Mm^3/year of treated wastewater. The contribution of wastewater reuse is a key solution in the protection of water sources, in turn a priority concern of development programs. Inclusion of wastewater reuse in Morocco's National Water Strategy since 2000 – signals a high priority for water reuse

The initiative: Wastewater treatment and reuse for irrigation for agricultural irrigation (cereals, vegetables to be cooked, fodder crops, fruit trees) and high value crops (alfalfa and olive trees).

Benefits for the farmers: Fertilizing nutrients within the wastewater reduced operating costs of farmers by minimizing chemical fertilizers and increasing crop yields. Drip irrigation systems used by most farmers due to water quality and low volumes available. Farmers organised into agricultural irrigation associations to facilitate awareness programmes on the best practices for reusing treated wastewater

Financing: The cost of the plant, pumping and irrigation network was paid for through public funding.

Governance: Governance through the creation of a monitoring committee and well-defined responsibilities. Agreement between all stakeholders (including health department)

References:

- Wastewater treatment and reuse for irrigation as alternative resource for water safeguarding in Souss-Massa region, Morocco, European Water 59: 365-371, 2017
- Some information from: Feasibility of Using Desalination for Irrigation in the Souss Massa Region in the South of Morocco, Hirich, A., Choukr-Allah, R., Rami, A., El-Otmani, in Recent Progress in Desalination, Environmental and Marine Outfall Systems, Springer International Publishing (2015)

Environmental reuse

Reuse for environmental restoration covers a number of applications including aquifer and other groundwater recharge, stream augmentation and wetland support. Pretreatment requirements for groundwater recharge vary considerably depending upon the purpose of groundwater recharge, sources of recycled wastewater, recharge methods and location (i.e. the hydrogeology, topography, hydrology and land uses). In general poor quality source water will require a higher level of pre-treatment before use[16]. This is especially the case where the receiving environment already contains high quality water and where the water will be recovered for higher value uses such as drinking, or where there is a potential for clogging (e.g. in fine -grained aquifers).

Examples of approaches to recharge include[17]:

- Aquifer storage and recovery
- Aquifer storage, transfer and recovery
- Infiltration pond
- Dune filtration
- Local rainwater harvesting
- Sand dam

Details of individual projects are not included here. These schemes are very much part of integrated water management considerations, but are not relevant to the activities of Project Ô, or the target of the collaborative platform.

[16] Page D et al (2018) *Managed Aquifer recharge (MAR) in sustainable urban water management*, in Water 2018, 10, 239

[17] Murray R (2017) *Managed Aquifer Recharge: an introductory guide for the SADC Groundwater Management Institute including the Windhoek Case Study*, Groundwater Africa

Alternative water sources

Desalination for irrigation, Souss Massa Region, Morocco

The challenge: Over-pumping of groundwater has lowered the water table leading to increasing pumping costs and groundwater salination due to sea water intrusion. The region is significant for horticultural products especially for export. Agriculture consumes about (90% of the water resources). There is a water deficit in the region 90Millm3/year pumped with recharge of 30million m3/year

The initiative: the development of a desalination plant. Construction of plant, 44km of pipes, drinking water tank, high voltage power lines, pumping stations, loading tanks

Funding: Euro 345million - Funding through national office of Electricity and Drinking water (ONEE) and BMCE Bank.   French engineering firm BRL Ingenierie and Moroccan partner Agro Concept established a public private partnership (PPP)

Business case for the farmers: The PPP demonstrated to farmers that what was considered a free resource (ie current ground water) actually cost 3.5 dirhams/m3 (the drilling instillation, maintenance and electricity to operate), and would increase in price as ground water level decreased. They negotiated a saltwater supply tariffs of 5 dirhams/m3 and groundwater quotas (with accepted field controls).   Farmers are contributing Euro 1000 per each hectare – to be collected on accomplishment of the desalination plant in 2020 - in exchange for a discounted price on future desalinated water.

Community involvement: Communication with farmers important – a website allows farmers to identify themselves and subscribe directly to the project (farmers take ownership of the project)

References:

- Feasibility of Using Desalination for Irrigation in the Souss Massa Region in the South of Morocco, Hirich, A., Choukr-Allah, R., Rami, A., El-Otmani,in Recent Progress in Desalination, Environmental and Marine Outfall Systems, Springer International Publishing (2015)
- World largest seawater desalination plant to be built in Agadir, Morrocan World News, 2017
- Africas largest desalination plant be built Morocco, Smart Water magazine, July 2019
- Souss region farmers contribute building worlds biggest water desalination plant, The North Africa Post, Dec 2017
- Morocco seawater desalination in Chtouka financed by PPP model has been launched, Afrik 21, 2018

Creation of by products

Biogas production:

For example: Del Monte Philippines Inc and Global Water Engineering (GWE)

Initiative: Example of anaerobic technologies successfully deployed on organic agribusiness waste streams. Wastewater treatment plant achieving 93% removal of organic material (COD) in anaerobic reactors to meet effluent quality targets. Methane rich biogas produced to power two 1.4MW generating electrical power generator units (gensets)

Environmental benefits: 13,000 m^3 treated per day. Improved COD levels of 83% removal in final effluent

Financial aspects Energy generation, waste heat from gensets used to heat up boiler feed water. ROI in 2-5 years

Reference: [Article regarding Del Monte Inc]

Cellulose from waste toilet paper:

The first production facility to extract sewage-based cellulose was opened in 2017 by CirTec[18] and KNN Cellulose BV, recovering 400kg of cellulose a day from sewage as part of the H202 SMART-Plant project[19]. The raw material was incorporated into a cycle path and as a raw material for biocomposite. In addition to the raw material produced, the process reduces COD and TSS, produces less sludge leading to reduction in dewatering and disposal costs. There are also savings in terms of maintenance costs and technical life of equipment. Further

Fertilizer from wastewater:

There are commercial operations already existing to produce fertilizer from wastewater, for example the Milwaukee Metropolitan Sewage District producing Milorganite, a nitrogen fertliser based on the microbes used in the wastewater treatment process[20]. In addition, there are innovation projects, for example those being developed through the EUs SMART-plant innovation.

Decision making tools

Green Infrastructure support tool (GIST)

This example is included for interest due to the use of the tool to support decision making relate to hydrological features.

Circular economy business model type	Enabling decision making
Description of the initiative	The outputs from GIST answer questions regarding the most effective green solutions based on water and cost to ensure water security for a region. The project has developed an easy to use, map-based app which can be interrogated by decision makers in companies. It allows the comparison of

[18] CirTec website article
[19] SMART-plant EU
[20] Milorganite website

	different options for wetland development ('natures reservoirs') as a means for providing sufficient water to a business. The outputs provide, for example: • Hydrological comparisons; • Output costs (restoration and annual maintenance costs); and • Financial measures (value of water quality increase, NPV, IRR, ROI and a comparison of costs avoided compared to the alternative). Sitting behind the interface are complex data sets and scientific modelling that enable the interrogation and interpretation of the data sets within the business context. Public and private data sets include drought intensity, watershed boundaries, critical habitats, population.
Environmental gains	Enables companies to easily explore the financial and water-based consequence of implementing green infrastructure projects rather than grey alternatives.
Financial implications	The objective is to provide quality data at low cost and raise the value of the data through the use of the tools within which it is used. The platform allows for easy access to the data and tools.
Reference	Earth Genome project website