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project Ô

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D7.5: Study of the current linear water economic model. Identification of weaknesses and opportunities in the water value chain

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Deliverable Review and Approval

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Deliverable Development and Review Process

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Executive summary

This document studies the current linear water economic models in the water value chain, identifying weaknesses and opportunities. It focuses on Project Ô demonstration sites, identifying how the project's approach and solutions could be beneficial for improving the efficiency of water systems and for enhancing circularity.

This deliverable will be the baseline for the later D7.6, which will develop circular economy business models for the demo cases, as well as conform the framework for the Users Collaborative Platform.

TABLE OF CONTENTS

1 Introduction

1.1 The objective of the deliverable

Project Ô aims to demonstrate that small loops of water management can play a role in alleviating the intense pressures on water resources. Key components of Project Ô include the testing of water treatment technologies for both technical and economic viability, the pulling together of all relevant stakeholders, and a focus on how the planning system and regulatory process can support the achievement of the objective of using small scale technologies to increase the circularity of water flows. The overarching output of the project will be to provide stakeholders with a toolkit that supports more effective planning and utilization of all water resources in a region. The benefits of this should be seen in both a reduction in water abstraction and in a reduction in waste water pollutants load, impacting not only on water resources but also leading to associated energy reductions from different treatment approaches.

Work Package 7 explores water and the circular economy. Task 7.3 in particular examines the transition from the linear to the circular economy and its relevance for water, looking at the current linear value chain and how it might transition to a system with more circular characteristics. Task 7.3 will:

- Analyse the implications of improvement and change from the current linear model at each step of the value chain;
- Document the key factors affecting efficiency of each step and the effectiveness of possible alternative measures;
- Develop a circular economy model which will set the framework to implement the user collaborative platform.

This Deliverable (D7.5) is a study of the current linear water economic model, identifying the weaknesses and opportunities in the water value chain. A later deliverable (D7.6) will build on this document for the creation of a circular economy framework for water treatment (with the inclusion of energy and materials). D7.5 therefore provides the baseline situation in terms of the current linear value chains and the business context within which these value chains have developed. It identifies the challenges of transitioning to a circular economy for the water sector and identifies opportunities that might exist to enable change of the current linear value chain. The document finally looks at circular economy frameworks that could be used to support the outputs of Project Ô.

1.2 The context of the current water system

Water availability is one of the biggest contemporary global issues. Goal 6 of the United Nations Sustainable Development Goals (SDGs), adopted in 2016, is to ensure availability and sustainable management of water and sanitation for all[1]. Adequate and safe water supplies are critical to attaining many of the other SDGs – food security, health, powering industry and creating jobs. The Sustainable Development Goals Report 2018 reviews the progress 3 years on from adoption and finds Goal 6 wanting. It states that, for Goal 6, 'water scarcity, flooding and lack of proper wastewater management also hinder social and economic development. Increasing water efficiency and improving water management are critical to balancing the competing and growing water demands from various sectors and users[2]'.

Water scarcity is linked to climate (for example in arid climates or as a result of drought events) and can be induced by human activity (for example as a result of landscape degradation or over abstraction to supply the needs of population, economic and agricultural pressures). As climate changes, water scarcity will become an ever more significant issue. In addition, water scarcity can be linked to pollution of otherwise useable water sources. For example, pesticide pollution accounts for 20% of well closures and nitrate pollution for 10% in Denmark, a Country characterized as having abundant water resources[3].

The scale of the water challenge – to provide enough water for the many competing needs - agriculture, household use, energy, industrial use and ecosystems - is significant. At the current time 2 billion people are living with the risk of reduced access to freshwater resources, and by 2050 at least one in four people is likely to live in a country affected by chronic or recurring shortages of fresh water. As human population is expected to increase to over 9 billion by 2050, demand for water is set to increase by 40-50% for the global food system, by 50-70% for the municipal and industrial sectors and by 85% for the energy sector[4]. By 2030 the world may face a 40% gap in water supply versus demand. The World Economic Forum (WEF) produce an annual Global Risks Report, and since 2013 'water crisis' has been in the top 5 global risks in terms of impact[5]. Under a business as usual scenario, such a gap presents significant challenges – economic, environmental, social and political, with conflict highlighted as a probable outcome.

Water scarcity may result in some regions not being able to reach their economic goals. The World Bank estimates that some regions could see their growth rates decline by as much as 6% of GDP by 2050 as a result of water related losses in agriculture, health, income and property, sending them into negative growth, although good water management practices could neutralize some of these impacts[6] (see Figure 1).

[1] UN SDGs
[2] The Sustainable Development Goals Report 2018, United Nations
[3] Water management in Europe: price and non-price approaches to water conservation (2018). European Environment Agency
[4] World Business Council for Sustainable Development - Food Land and Water programmes
[5] WEF Global Risks Report 2019
[6] High and Dry: climate change, water and the economy, (2016). World Bank

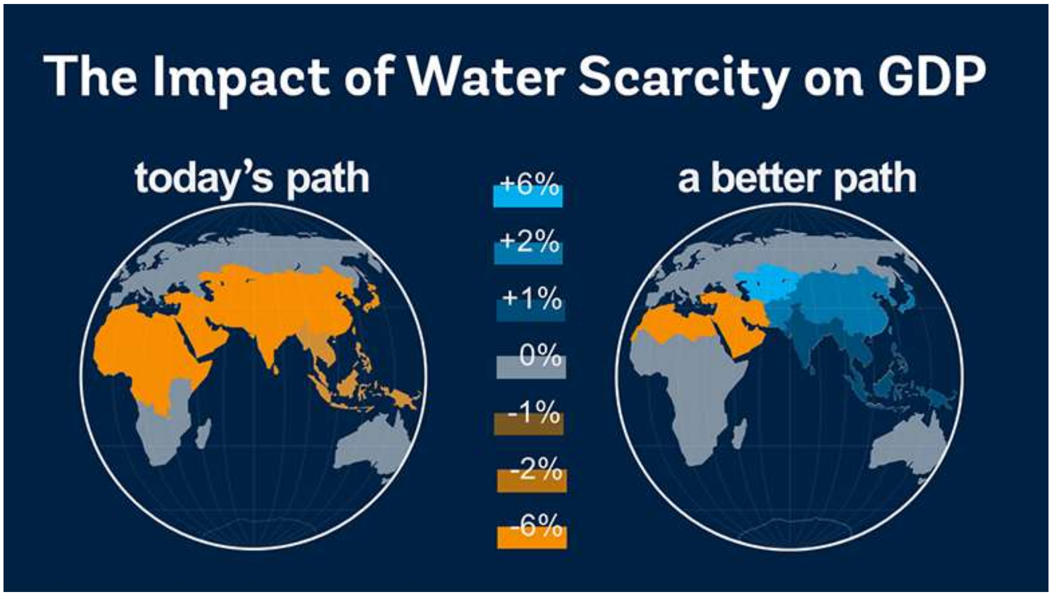

Figure 1: The estimated effects of water scarcity on GDP in year 2050 under 2 policy regimes: business as usual and efficient water policies (policy regimes that incentivizes more efficient allocation and use of water). Source: World Bank (2016)

In Europe, between 1990 and 2015, there was an estimated decrease in total water abstraction by 19% despite increases in the gross value added from all economic sectors, indicating a decoupling of water abstraction and economic growth. However, the impacts of water scarcity vary dramatically between regions. Around 30% of the total European population was exposed to water scarcity conditions in the summer of 2015 compared to 20% in 2014, primarily those living in densely populated European cities, agriculture-dominated areas of southern Europe and small Mediterranean islands[7]. Drought and water scarcity events are posing challenges in all Mediterranean countries, exacerbated by seasonal or geographic mismatches between water availability and demand, with water demand peaking along coasts during summer, typically the driest season. The Italian farmers association Coldiretti estimated that the agricultural sector in Italy had suffered losses of at least 2 billion euro as a result of the drought in the summer of 2017[8].

The mantra of reduce, reuse and recycle has been common for other resources – and is set to become more significant for water and wastewater. As with other resources, there will be a rethinking of waste water - seeing it as an expense that cannot be justified and seeing waste as a resource to be exploited. And so, with water and wastewater, this mindset, along with a much needed change in the economic and political context for water use, will give rise to new and different opportunities.

For business, this creates a new context: an end to free or cheap water? Increasing competition for limited water supplies? Changes in the way companies will have to measure and manage water? Step changes in the response to water risks and opportunities? Key to this is the rethinking of wastewater.

[7] Use of freshwater resources, European Environment Agency
[8] BBC World News, 2nd August 2017

2 Linear water use systems: weaknesses and opportunities

2.1 The linear value chains and their participants

In simple terms, the current and general linear value chain for water abstraction, treatment, use and disposal is shown in Figure 2.

A completely linear supply chain is not the reality in all cases, as there are many examples of water reuse within industry and in symbiosis between municipal wastewater outputs and agriculture, but it is fair to say that the linear model is currently the dominant model.

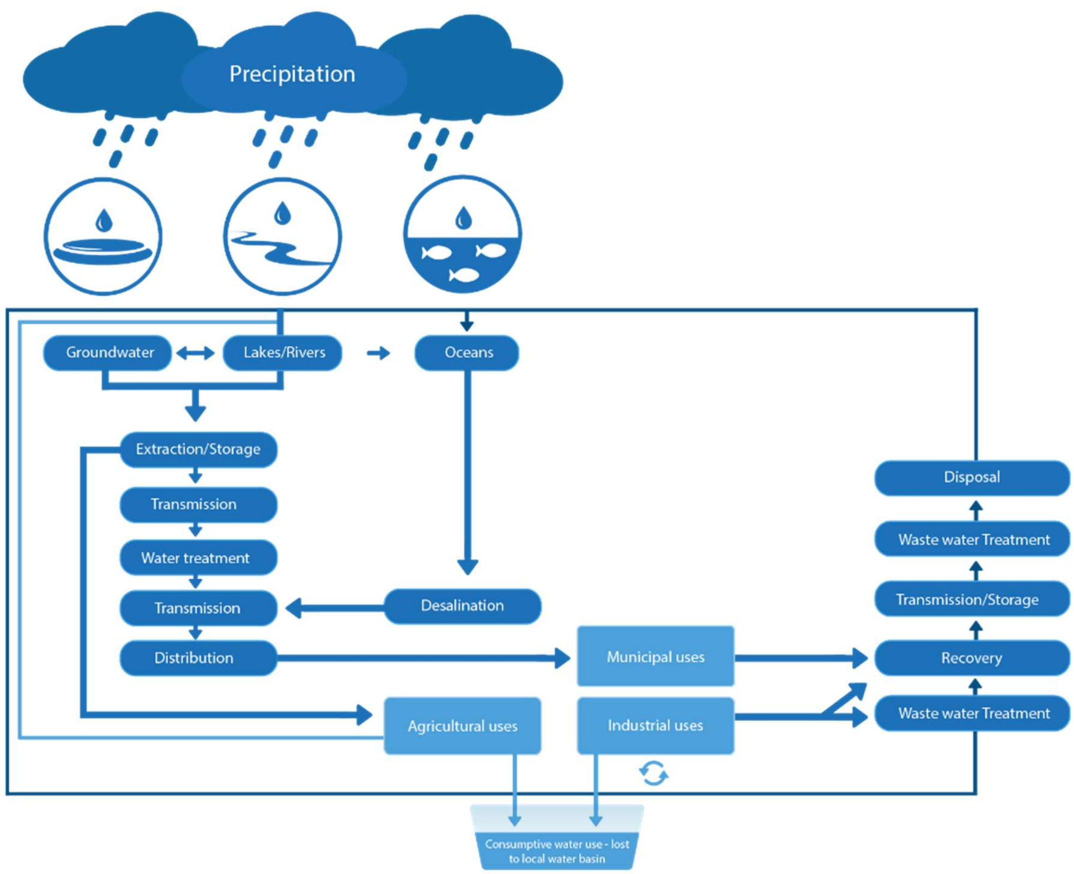

Figure 2: General water extraction and disposal value chain

Different water supply and waste water treatment scenarios will have distinct steps, processes and participants. Taking the general value chain structure fromFigure 2, for the purposes of the high-level description, certain stages in the value chain have been grouped (Figure 3) to provide a general overview of processes involved in water supply and wastewater treatment:

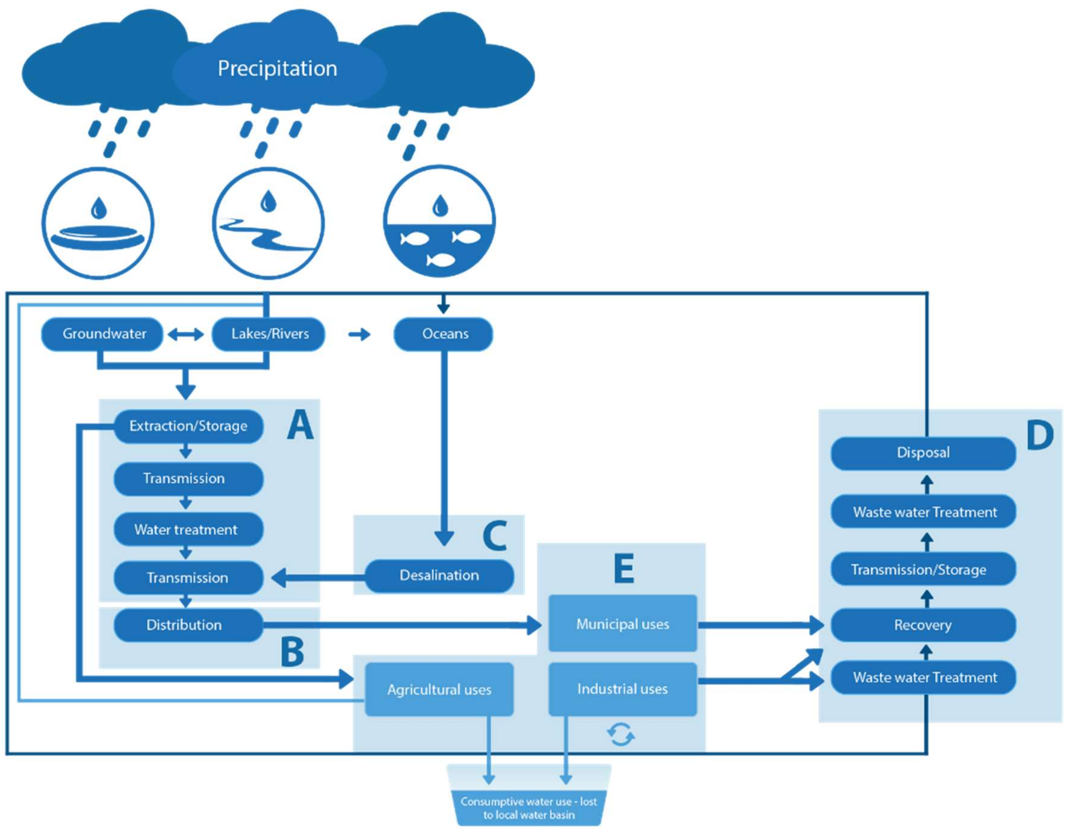

Figure 3: General value chain with groupings of processes

Extraction/transmission/water treatment (Group A in Figure 3)

Water abstraction is the process of taking water from a source. 'Raw water' is pumped from a number of different sources including groundwater via boreholes and surface water sources including rivers and reservoirs to treatment plants. Water from surface sources can be held in large open storage reservoirs. Storage has a number of advantages including mixing, and therefore, dilution of any contaminants with existing stored water, allowing the settling of debris and solids, the opportunity for sunlight to break down organic matter and for some bacteria to die off. It should be noted that dilution of contaminants does not mean they have a lesser effect, especially if they accumulate in organisms.

Water treatment processes vary according to the type and quality of source water and aim to remove physical and microbial contaminants. Some or all the following steps can be undertaken for the treatment of water[9]:

- Screening – used mainly for surface waters, screening removes floating objects through water passing through metal grills and screens.
- Clarification – a chemical coagulant is added to the water which binds together fine suspended material such as silt and mud particles. The resulting 'floc' is then removed by settlement or floatation.
- Filtration – to remove suspended material from the water. Slow sand filters also have a biological action with micro-organisms in the sand breaking down organic compounds.

[9] Thames Water website: Drinking water treatment

- Aeration – to remove, reduce or oxidise unwanted compounds such as hydrogen sulphide and carbon dioxide and dissolved metals such as iron.
- Granular Activated Carbon (GAC) – water is passed through GAC vessels which contain porous carbon particles that remove pesticides, organic compounds and unpleasant taste and odours.
- Ozone dosing – ozone is injected into the water to breakdown pesticides and organic material and remove bacteria.
- Disinfection – chlorine is used as a disinfectant both for incoming raw water and at the end of treatment to destroy harmful micro-organisms.
- Ammoniation – ammonia can be dosed into the water following chlorination to form a longer lasting disinfectant.
- UV disinfection – use of UV light spectrum to kill or inactivate micro-organisms.

Water transmission is through large diameter pipes that take water from the treatment plant to the distribution systems.

Depending on the country, water abstraction and treatment within Europe is governed using four management models[10]:

- *Direct public management* under which the public entity is entirely responsible for service provision and management. This has, in the past, been the predominant model in Europe;
- *Delegated public management* under which a management entity is appointed by the public authority to execute the management tasks;
- *Delegated private management* where the public entity appoints a private company to management tasks on the basis of a time bound concession or lease contract. The ownership of the infrastructure remains in the hands of public authorities; and
- *Direct private management* under which all management tasks, responsibility and ownership of water and waste water treatment utilities is placed in the hands of private operators within regulatory boundaries.

Direct private management is found only in the Czech Republic and England and Wales. For example, in England and Wales, the provision of municipal water supplies is delivered only by private companies, some listed on the stock exchange and others privately owned. In the Netherlands, municipal water is delivered only by publicly owned authorities. Most European countries have a mix of both public and private ownership for 'public' water supplies. Approximately 20% of water abstraction across Europe supplies public water systems[11]. In relation to the demonstration sites the provision of water and wastewater supplies is as follows:

Demo site 1: Italy	• 50% of the population is serviced through delegated public management models • 36% public private partnerships • 5% concessions • 9% directly by municipalities

[10] The governance of water services in Europe (no date), The European Federation of National Associations of Water Services (EurEau)
[11] Towards efficient use of water resources in Europe (2012), EEA

Demo site 2: Israel	• National bulk water operator (Mekorot – responsible for potable water production and the national water conveyor) is a regulated public company[12]. • Municipal water and sanitation services provided by corporatized • regional utilities
Demo site 3: Spain	Water supply: • 10% of population direct public management • 56% delegated public management (34% being public companies and • 22% public/private companies) • 34% delegated private management Sewage • 43% of population served by private companies (delegated private management) • 56% delegated public management (both public companies and public/private companies) • 1% direct public management
Demo site 4: Croatia	Majority of water and waste water services are provided under the direct public management model (with the exception of Zagreb city where the WWTP is managed through delegated private management)

Water can also be self-supplied, for example, from private boreholes. In some countries, this can be a very significant proportion of total water abstraction and can, in particular, be a major source of water for the manufacturing sector. Germany, Poland, the Netherlands and Latvia have significantly more volumes of self-water supply rather than public water supply – in Poland, self and other water supplies are 34 times as high as that from public supply[13]. Whilst private abstraction is legal when licensed, there is also evidence for illegal abstraction of water in Europe, especially for agricultural purposes.

Distribution (Group B in Figure 3)

Water distribution systems carry treated water from centralized treatment plants to users to deliver water of the right quantity, quality and pressure. The systems consist of pipes, pumps, valves, storage tanks, meters, testing probes to measure pressure and water quality and other equipment.

The distribution system can be owned by public authorities or private enterprises.

[12] Water Management in Israel: Key innovations and lessons learned for water scarce countries (2017), The World Bank, report funded by the Government of Israel
[13] Eurostat data

Desalination (Group C in Figure 3)

Desalination has allowed non-traditional water resources to be tapped - produced using either brackish water (with a salt content of less than 10,000 mg/l) or seawater (salinity range of 30,000 – 44,000 mg/l). Currently, desalination provides around 1% of the worlds drinking water with capacity expected to double by 2030[14]. At the end of 2015 there were approximately 18,000 desalination plants worldwide with 44% of the plants located in the Middle East and north Africa. In Europe, Spain is the biggest user of desalination with capacity also in Italy, Cyprus, Greece and Turkey. In Israel, 85% of potable water comes from 5 desalination plants[15].

The 2 main technologies used are:

- Thermal evaporation; and
- Membrane separation using semi-permeable seawater reverse osmosis (SWRO) membranes

In comparison to freshwater supplies, the desalination process is expensive – both for building and operating plants. Technology advances, in particular more efficient desalination membranes, innovative thermal membranes or hybrid desalination technologies will lead to some cost reduction in the coming years. Concerns exist regarding the high energy intensity of desalination plants as well as other environmental impacts, such as the disposal of brine effluents and of waste including chemicals used during the pre-treatment and membrane cleaning of the desalination process. However, the fact that desalination is droughtproof and that the water supply is practically limitless gives it great advantages.

Companies building and running desalination plants are typically involved in other businesses – either water, waste and energy services (such as Veolia and Suez), infrastructure and power companies (such as Doosan Group and Fisia Italimpianti) and or other mixes of business (such as General Electric)[16]. Plants are typically built through public-private partnerships. In Israel, for example, some plants operate on a Build, Operate, Transfer (BOT) basis where the state owns the land, but the plant is run by a private company. Other projects use a Build, Operate, Own (BOO) structure where the entire operation is privately owned but the final desalinated water goes to the Israeli government[17]. One of the notable elements of the BOT schemes in Israel are the design of the contracts which have included government guarantees provided to private investors than is typical allowing Israel to get bid prices for desalinated water that are amongst the lowest in the world[18].

[14] Desalination – Past, present and future (2016), N. Voutchkov, Director of the International Desalination Association. *International Water Association*.

[15] Water Management in Israel: Key innovations and lessons learned for water scarce countries (2017), The World Bank, report funded by the Government of Israel

[16] Investing in desalination companies, Nanalyze

[17] Public-Private Partnerships recommended for desalination financing (2011), The University of Arazona, Water Resources Research Center

[18] Water Management in Israel: Key innovations and lessons learned for water scarce countries (2017), The World Bank, report funded by the Government of Israel

Wastewater treatment (Group D in Figure 3)

Wastewater treatment operations convert wastewater back into water that can be discharged into the environment or reused. There are a number of stages and different technical operations, however, the following steps are typical wastewater treatment stages for municipal waste water treatment[19]:

Primary treatment stage:

- Screening – removal of large items such as plastic, nappies, cans, etc.
- Primary settlement – use of sedimentation tanks that allow heavy particles of solid waste to sink and form a layer of sludge. This sludge is then taken away for treatment.
- Sludge treatment – the sludge is placed in large tanks (digesters) where bacteria break the sludge down and methane gas is released. The gas can be collected and used to generate electricity or heat to dry the sludge and produce fertiliser granules or can be incinerated or disposed of to landfill.

Secondary treatment stage:

- Biological treatment – the water component of the waste is held in large tanks and bacteria break the waste down into harmless substances. Air is continuously pumped through helping the bacteria to grow (activated sludge) and the water is passed over beds of special stones (filter beds) on which waste-eating bacteria live.
- Final settlement - the almost clean water is passed through humus tanks or reed beds to take out any remaining waste particles and to reduce nitrogen. Water can be returned to most environments at this point.

Tertiary treatment stage:

- Disinfection – disinfection aims to remove any remaining residual solids and to substantially reduce the number of microorganisms in water to be discharged back to the environment. Common methods of disinfection include ozone, chlorine or UV light treatment. Additional advanced disinfection steps can be undertaken if water is to be discharge is into sensitive environments or into an environment where algae can easily grow. In advanced treatment operations, nitrogen, phosphorus and other chemicals may also be removed at this stage.

In addition to municipal wastewater treatment operations, wastewater can also be treated on location at industrial sites, with technologies suited to the pollutants load particular to the operations of the industrial processes, and to other requirements such as odour control and licensing conditions for discharge to sewer or watercourse.

Similarly to water treatment, municipal sewage treatment can either be provided by private companies or by public organisations. Operators of wastewater treatment facilities obtain permits or licenses to operate the facilities. There is a trend towards higher proportions of the population being connected to urban waste water treatment plants, with above 80% of the population connected to at least secondary waste water treatment plants in the 15 EU member states for which information is available.

[19] The wastewater process, Southern Water

Sewage sludge is rich in nutrients but is often loaded with high concentrations of pollutants such as heavy metals. Typically, there are four different disposal routes for sewage sludge:

- *Fertilizer for agricultural use*: route for at least 70% of the total sewage sludge generated in Portugal, Ireland, the UK, Spain, Albania and Norway.
- *Composting*: accounting for 88% of sewage sludge in Estonia and 75% in Hungary
- *Incineration*: Netherlands, Germany, Slovenia, Austria and Switzerland reported incineration as their principal form of treatment for disposal.
- *Landfill*: Predominant treatment in Malta, Croatia, Romania, Italy, Serbia and Bosnia and Herzegovina.

Sludge disposal options vary significantly between EU member states as shown in Figure 4 (% data comes from different time periods between 2012 and 2015):

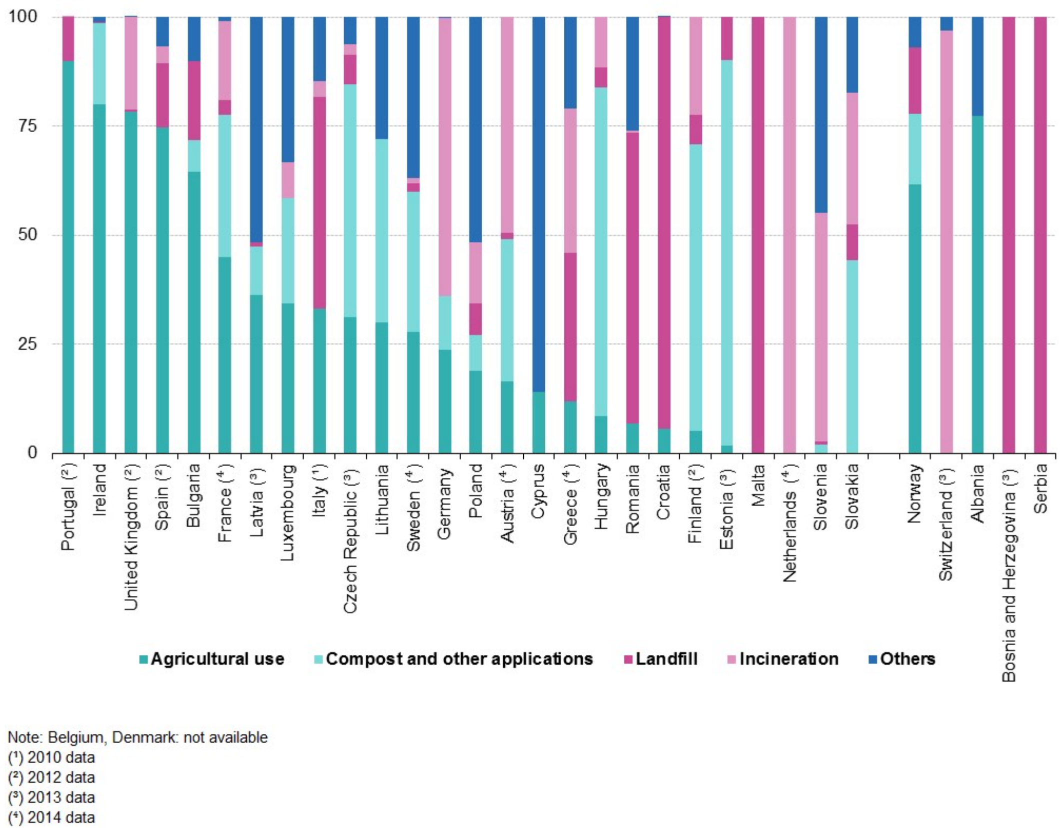

Figure 4: Sewage sludge disposal from urban wastewater treatment, by type of treatment, 2015 (% of total mass). Source: [Eurostat]

Water users and waste water producers (Group E in Figure 3):

Agriculture is a significant water user in Europe accounting for 33% of total water use, although this share can rise to as much as 80% in parts of southern Europe where the demand is much higher due to crop irrigation. The detrimental effects of excessive agricultural water use are exacerbated by relatively high consumptive use. Although some irrigation water is returned to groundwater, consumption via plant growth and evapotranspiration means that approximately

70% of water abstracted does not return to the water body from which it was abstracted[20]. The practice of reusing treated waste water for irrigating crops is growing within Europe and is particularly well established in Spain, Italy, Cyprus, Greece and Israel. The contribution of water recycling to meet agricultural demand can be substantial. In Gran Canaria, 20% of water used across all sectors is supplied from treated wastewater whilst in Cyprus targets for 2014 equate to about 28% of the agricultural water demand. The legislative aspects of water reuse are considered elsewhere in this document.

Approximately 20% of water abstraction across Europe supplies *public water systems*. The relative share of municipal and industrial use varies considerably between countries. Figure 5 shows water use split between municipal and industrial use in EU states of public water supplies. As noted above, private water supplies are much more significant for industrial uses in many countries (these are not shown on this graph).

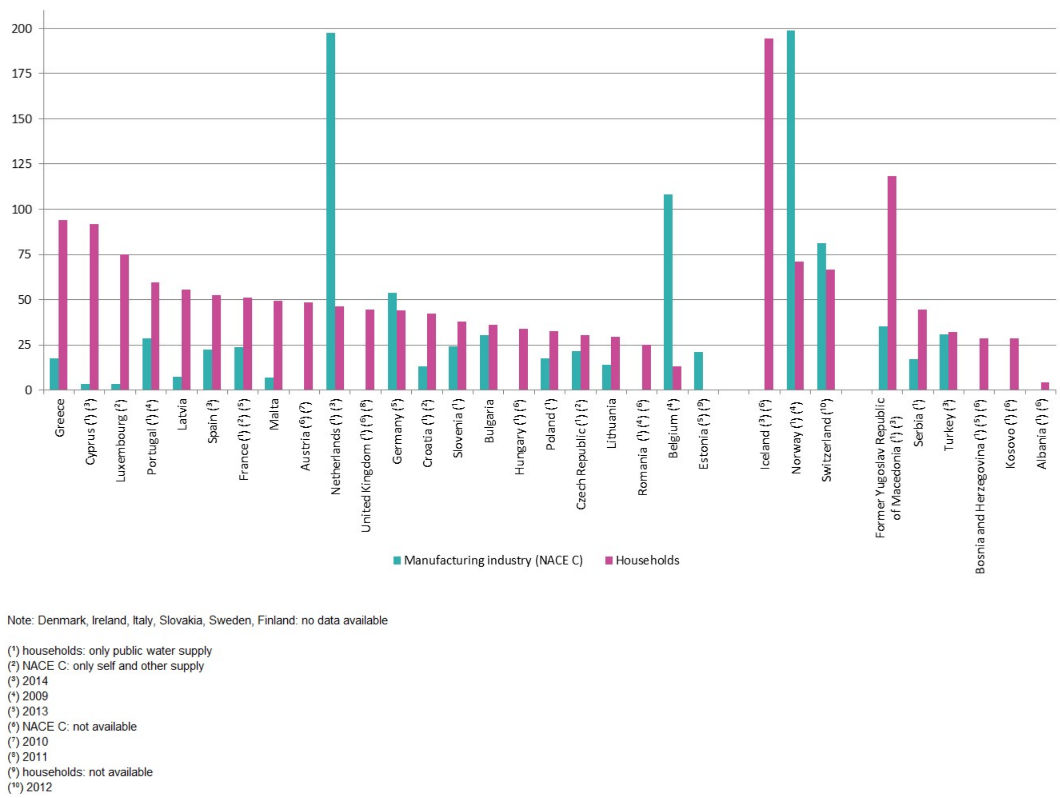

Figure 5: Water use by households and the manufacturing industry for public water supply and self and other supply, 2015 (m^3 per inhabitant). Source: Eurostat

Key drivers influencing public water demand are population and household size, income, consumer behaviour and tourist activities. Technological developments including water saving devices, reuse of greywater or rainwater harvesting and measures to address leakage in public water supply systems also currently play a role in meeting demand.

[20] Towards efficient use of water resources in Europe (2012), EEA

Industry is one of the main water users in Europe accounting for about 40% of total water abstractions[21]. Energy production and distribution dominates in terms of water use accounting for anywhere up to 99% in Cyprus[22], although cooling water is significant in this data. The links between water use and energy are highly relevant in water scarcity (the 'water – energy nexus') with significant variation in the water intensity of different forms of energy production. Energy depends on water – for hydroelectric power, the extraction, transport and processing of fossil fuels, cooling of power plants and the irrigation of biofuel crops. Wind and solar PV require very little water use per kWh produced compared to other power generation sources[23].

Aside from energy production, Figure 6 shows how water is used in other industries within Europe.

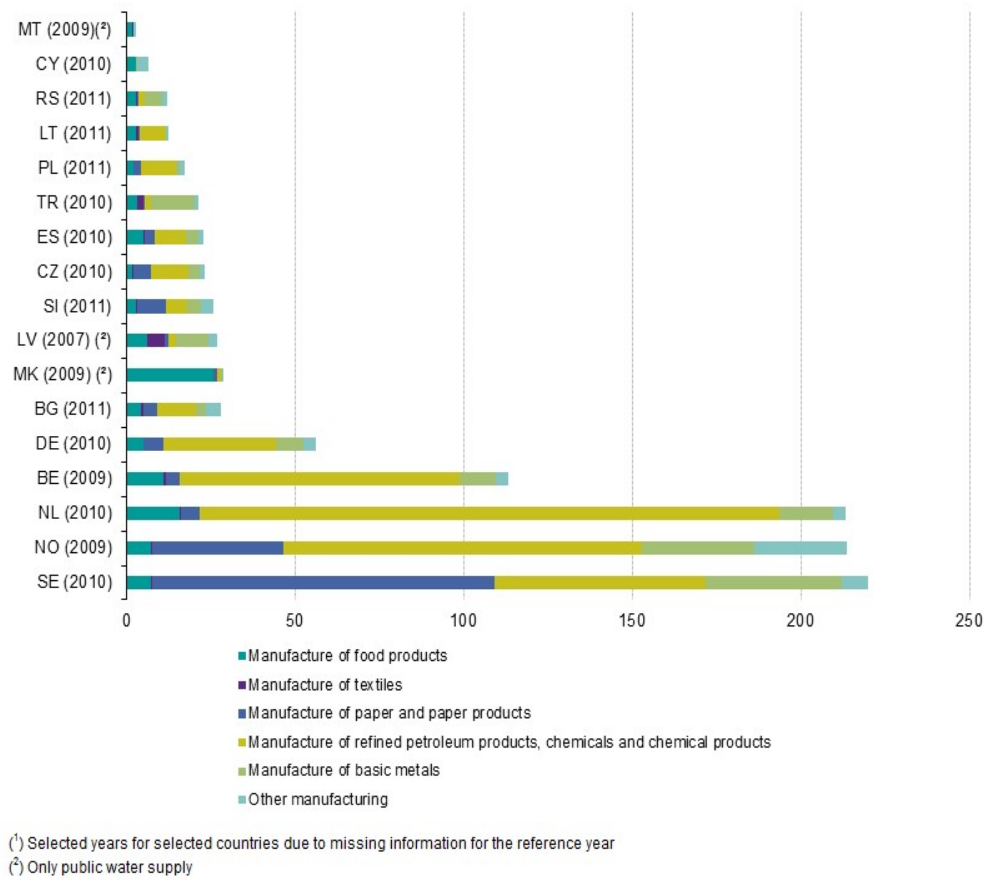

Figure 6: Water use in the manufacturing industry by activity, 2011 (m3 per inhabitant). Source: Eurostat

[21] Eurostat: Water use in industry, 2014
[22] Source: Eurostat (2010 data)
[23] Sizing up electricity's water footprint (2018). Water footprint Calculator

2.2 Stakeholders in the water and waste water sector

In addition to direct participants noted above, there are a number of stakeholders involved in the supply of water and treatment of wastewater, and those stakeholders will differ depending on the political, regulatory and institutional context of the system. The World Bank defines stakeholders as 'people or organizations who either (a) stand to be affected by the project or (b) could 'make or break' the project's success. They may be winners or losers; be included or excluded from decision-making; be the users of results; or participants in the process[24]'. There are also strong arguments that non-humans can be stakeholders, in particular the environment and other species. These stakeholders may be represented by human stakeholder groups.

The range of stakeholders involved are noted here for the wider consideration of any likely impacts of value chain changes arising from Project Ô. The list of stakeholders might well be long and will vary depending on the geographic context or the activity for which the stakeholders are being identified. In the context of water abstraction, use, treatment and disposal, typical stakeholders would include:

Stakeholder Group	Examples of stakeholders
International actors	• European Commission DG Environment Directorate D: Water, Chemicals and Cohesion • European Environment Agency • European Topic Centre on Water • International Development Banks • World Health Organisation
Political actors	• National political parties • National government departments • Local politicians • Local government and local authorities
Public sector agencies	• Water regulators and watchdogs • Environmental regulators • Planning authorities • Public health regulators
Water and waste water treatment companies – 'the water industry'	• Private companies – water and sewerage • Public sector water and sewerage organisations • National water associations • European Union of National Associations of Water Suppliers and Waste Water Services (EUREAU)
Interest Groups and civil society	• Environmental NGOs • Community Groups • The Media • Consumer organisations • Citizens associations • Other NGOs and lobbying groups

[24] Guidelines for Concept note: Stakeholder Analysis, World Bank

Business Community	• Business that use water and water technologies • Employees of businesses • Investors • Contractors and suppliers • Water technology and equipment providers
Non-business customers	• Residents within the municipality • Tourists/visitors
Researchers and data provision	• Academic researchers • Water industry researchers • Data providers • Water metering services
Non-human stakeholders	• The environment

Further details regarding stakeholders are covered Deliverable D8.1 in Project Ô.

2.3 Problems and challenges of the linear model

For solid resources, the linear flow of materials is obvious in the current 'take, make and dispose' economic model, clearly seen by the scale of imports of virgin materials and the products made from them, and the generation of vast volumes of waste. For water, the linear flow is not always so obvious to see, except through reductions in surface water stores. However, in the abstraction, use and disposal of water, similar patterns emerge to those seen for solid resources:

- levels of abstraction leading to scarcity and other environmental damage;
- use not considering efficiency and reuse; and
- disposal at the end of useful life in a way that make resources unavailable to replenish stocks or for reuse. In the case of water into rivers and oceans that take the water away from the water basin from which it was abstracted, or through making water unusable by increasing pollutant loads.

In its most simplistic and linear model, raw water is taken, used once, treated to minimize damage to the environment (typically this is the case within Europe) and disposed of. Water becomes more polluted as it moves through the system rendering it useless and an expense to treat. Wastewater streams may be mixed together making end of pipe treatment expensive for users and for society in general.

Water is critical to people and businesses. With global population growth and the drive to improve living standards through growth in GDP, abstraction of water is undertaken in such volumes that in many parts of the world the current rates of abstraction are unsustainable. Most water resources are renewable (with the exception of fossil aquifers created under pre-existing climatic conditions), but the rate at which they are being used exceeds the rate at which they are naturally replenished within the water basin. This has lead, and is leading, to water scarcity.

Water scarcity challenges our current linear model of water use, including the underlying reasons or historical contexts within which the linear model has developed, and creates a different context in which business has to relate to water.

2.4 Key factors driving the linear model

It is worth considering the key factors that have driven the linear model of over consumption and pollution of water. In doing this we can understand what might need to change and what barriers might exist limiting the move to circular approaches to water management.

Water supply and demand are not coupled: Water scarcity is a human made problem, defined by the European Commission as 'a recurrent imbalance that arises from an overuse of water resources, caused by consumption being significantly higher that the natural renewable availability'. Demand has increased due to population growth, increased industrial activities and land use changes, for example the huge expansion in the land area under irrigation. Water scarcity is aggravated by water pollution, during drought episodes and through climate change[25]. In Israel, there is a strong control and enforcement of water allocations with state organisations having the authority to regulate and allocate consumption for alternative uses, supported where necessary with enforcement sanctions[26].

The challenges of measurement: Whilst improving now, the ability to understand and measure water availability and water scarcity has been a key challenge. A large number of indicators have been developed, but the spatial and temporal characteristics, as well as respective methods of calculation make interpretation difficult. Inconsistencies in spatial measurement, recording procedures and accuracy can impact accurate measurements and therefore can impact water planning. The Water Exploitation Index (WEI) used by the European Environment Agency, for example has its challenges, the consequences of which is an inability to identify the volumes of water that can be mobilized at one point and place in time[27]. In addition, the use of fixed volumetric or percentage flow allocations in water planning belies the complexity of hydro-climatic variability and uncertain human demands[28] that can defy accurate prediction. Great efforts have been put into improving the monitoring and evidence base on the status of water bodies in the EU and for River Basin Management Planning and this has assisted in recent years in taking actions that have improved the status of many European water bodies.

Lack of ecosystem services thinking in business (and therefore a loss of ecosystems services): Ecosystem services are the goods (such as food, wood, water) and services (such as natural filtration of water and flood protection through water percolation) provided by nature. These services have been free in many cases – but when impacted can lead to risks for businesses. Ecosystems services have not traditionally been considered due to a lack of understanding, a lack of interest by key business stakeholders and an inability to account for the value provided. The ecosystem costs are often external to business operations, to the remit of decision makers or are not identified and valued ('externalities'). Often the negative impacts can impact the least well represented groups of people. This has resulted in degrading of the natural environment and a reduction in the services provided, for example clean water availability.

[25] Water Scarcity and Drought Gap Analysis (2018), EEA

[26] Water Management in Israel: Key innovations and lessons learned for water scarce countries (2017), The World Bank, report funded by the Government of Israel

[27] Water Scarcity and Drought Gap Analysis (2018), EEA

[28] Irrigations efficiency and water policy implications for river basin resilience (2014) Scott, S., Vicuna, S., Blanco-Gutierre, Meza, F., Varela-Ortega C., *Hydrological and Earth System Sciences, 18*

Alteration of hydromorphological features: the EUs River Basin Monitoring Programmes (RBMPs) have shown that the most commonly occurring pressures on surface water bodies are hydromorphological, affecting 40% of such bodies[29]. This impacts on water flow as well as quality. Examples include removing or changing characteristics that would naturally support water retention and ground water replenishment. Examples include building on flood plains; removing woodlands; diverting surface water to storage reservoirs which would otherwise percolate into ground water; and adding characteristics that speed up water movement such as surface water feature straightening and channelization.

Ineffective water pricing: In Europe the regulatory principles for water pricing, set out in the Water Framework Directive (WFD) are clear – that water prices must allow for the cost recovery of water services, that the main water users should contribute to the recovery of costs proportional to their contributions to the pressures imposed and that water pricing policies must provide adequate incentives for users to use water efficiently. However, setting a price that reflects the true value and costs of water is a complex task. Significant social and political pressures need to be considered, as well as the objective of the sustainable management of water resources. As an example, agriculture is the biggest consumer and largest polluter of water, but it is difficult to ask farmers to pay the true price when profits are low and the price of food is such a critical social and political issue. How the objectives of pricing as set out in the WFD are implemented in Member States is therefore not always clear. The European Environment Agency states that 'there are questions concerning the extent to which current economic instruments applied to water contribute (if at all) to the achievement of the environmental objectives of the Water Framework Directive[30]. Approaches to calculating charges for water vary enormously between and even with countries. In Spain, the most frequently applied tariff model is the 2-part tariff structure composed of a fixed fee and a variable fee, although there is much variation amongst municipalities such as the ratio between fixed and variable fees, the number of blocks of variable fee and the upper and lower boundaries of the blocks and the unit price of each block. Water meters are a well-established method of billing users consumption in Spain. Analysis shows that the cost recovery level in Spain varies enormously from 33% to 95% of cost. This is made more complex by the fact that the costs of water provision vary considerably from region to region, but also when abstraction, transport and storage are financed by the public budget, only part of the total costs are charged to the end user[31]. Pricing is important not just to ensure sufficient money can be reinvest in adequate infrastructure, but also as an indicator of the value of water, therefore as part of the management of consumption. The case studies examined by the EEA show that pricing does affect water consumption, so that it is important, although the impact of price on consumption varies.

[29] European waters – Assessment of status and pressures (2018), EEA
[30] Assessment of cost recovery through water pricing (2013), EEA Technical report No16/2013
[31] Urban water tariffs in Spain: what needs to be done (2015), Garcia-Rubio, M, Ruiz-Villaverde A., Gonzalez-Gomez F., Water 7(4)

Charging systems and average prices for the pilot study countries are shown here[32]:

	Water tariff setting	Average price for water
Demo site 1: Italy	Tariff for water services is proposed by the local regulator (or directly from the water company is the local regulator does not act) and approved by the national regulator.	€1.5 /m^3
Demo site 2: Israel[33]	National water regulator sets tariffs for all water and sanitation services. A uniform tariff structure exists with all potable water and sanitation customers paying the same price.	Average: NIS 8.92/m^3 (2017) (€2.18 /m^3) Tariff for up to 3.5m^3 per capita per month NIS 6.56/m^3 (€1.16/m^3) Over 3.5m^3 per capita per month charged at NIS 10.56/m^3 (€2.58 euro)
Demo site 3: Spain	The most common forms of tariff approval are joint actions by municipalities and price commissions or through regional public bodies and regional governments.	€1.78 /m^3
Demo site 4: Croatia	Water service operators propose tariffs that are approved by the local government The government determines the lowest price base for water services and the types of costs covered by water tariffs. Water tariffs are made up of fixed (covering costs associated with connection to the municipal water network) and variable (based on water consumption) parts.	€1.98 /m^3 (2013 data)

The table shows that costs are considerably higher in Israel, where prices have increased in recent years as a strategy to recover costs as well as to influence consumption. In Israel, reforms have put Israeli water sector on a course towards financial viability based on the principles of full cost recovery through tariffs. This sends a strong signal to users that water is precious. However the system is not perfect as it is noted that within Israel the use of uniform water tariffs nationwide both for municipal and agricultural consumers has introduced economic inefficiencies in the allocation of water resources (in particular related to the density of population and need to transport water longer distanced – and therefore with greater cost - in some parts of the country).

Approaches to charging for effluent treatment and the allocations of responsibilities for authorisation and control of water pollution vary significantly for member states. In the

[32] The governance of water services in Europe (no date)
[33] Water Management in Israel: Key innovations and lessons learned for water scarce countries (2017), The World Bank, report funded by the Government of Israel

Netherlands and Germany, the charges are relatively high and thus deter water pollution. In Denmark the charging system motivates reduction in nitrogen and phosphorus but not biological oxygen demand. In Germany effluent charges are reduced if quantity and toxicity of an effluent meet minimum requirements[34]. In the UK the Mogden formula is used which takes into account costs for collection, primary and biological treatment, treatment and disposal to sea, biological oxidation of settled sewage and treatment and disposal of primary sludge. This means that a customer pays less for wastewater that is cleaner and easier to treat[35]. The Water Framework Directive requires that environmental and resource costs are taken into account, however there is no agreement on best practice and no standards to follow for understanding and calculating these costs – so it is not certain if effluent charges always provide effective internalisation of these costs.

Failure of the water market (linked to ineffective water pricing): There is no clear market for water in much of Europe. Combined with the requirement of effective pricing to allow for the recovery of supply costs, consumers do not have complete information on the service provided and its real costs. In many Countries, consumers are not yet aware of how much they are paying for water, and nor is there a principle of 'service of supply' – how much will a consumer pay for one additional unit of water - which depends on geography, distances and the needs for treatment before supply[36]. Attempts to rectify this have included the introduction of more widespread metering.

Poor governance in both private and public water companies: the privatization of water provision can bring advantages, but also challenges. A focus on profitability, treating water as a commodity, can lead to lack of investment in the infrastructure needed to deal with the longer-term challenges of water scarcity. As an example, the new chief executive of the UK water regulator OFWAT has highlighted a UK water company that had high levels of debt, engineered high returns and routed the resulting dividends through tax havens[37]. She has spoken about the need to change the philosophy, so water companies "curate the natural capital on which they depend". The UK National Infrastructure Commission has calculated the cost of running emergency water supplies in 2050 to be £40billion a year given the likely impact of climate change on industry – so thinking of the longer term is critical for the ongoing sustainability of water supplies. The European Environment Agency notes that the water and sanitation sector is, in places, characterized by weak regulatory oversight and weak governance. Conflicts of interest could occur, for example local regulators holding shares in utility companies, or the conflict of rules set at the national level (following EU frameworks) or being set at lower levels of governance (such as municipalities and water boards) then being followed by local or municipal governments who are themselves at the core of providing water services. In Spain, tariff revisions are usually conducted annually. Local governments in their role as supervisors of water prices have mainly been concerned with ensuring prices do not increase at a faster rate than the consumer price index. Water tariff increased above inflation are more frequent when urban water management is privatised. However, the licence fee paid by private operators is not often ring fenced for reuse within the water management system – but is used for other

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[34] Effluent Charging Systems in the EU member States: working paper (2001), European Parliament
[35] OFWAT website
[36] Assessment of cost recovery through water pricing (2013). EEA Technical report No16/2013
[37] 'It's essential to life': Ofwat's Rachel Fletcher sets a new course for water' Interview in The Guardian, December 2018

municipal purposes[38]. Combined with low levels of cost recovery this can lead to under investment in adequate infrastructure.

Low levels of wastewater reuse: about 1 billion m^3 of treated urban waste water is reused annually, accounting for approximately 2.4% of the treated urban wastewater effluents and less than 0.5% of annual EU freshwater withdrawals. Levels of water reuse vary considerably between countries. Cyprus and Malta already reuse more than 90% and 60% of their wastewater respectively, while Greece, Italy and Spain only reuse between 5 and 12%, indicating a huge potential for further uptake[39]. Croatia has low levels of reuse, with the market for secondary water reuse described as in its 'initial phases', with the need for goals to be adopted in this area[40]. Conversely, in Israel 87% of treated wastewater effluents are reused in agriculture. Despite both the benefits to water supply in areas of water scarcity and the lower energy requirements when compared to alternative supply options, water reuse is limited in the EU. The causes of this include inconsistent legal frameworks across member States, a limited public awareness about risks and benefits and a general distrust from the public, and potential obstacles to the free movement of agricultural products irrigated with reused water. The risks to businesses may be significant – whether real or perceived. As an example, the outbreak of E. coli in Europe that was incorrectly blamed on the contamination of cucumbers from manure, still cost Spanish exporters $200million a week[41]. In addition to the issues of public acceptance, there have also been a lack of clarity, information and case studies regarding the methods for assessing economic feasibility of water reuse. Market based information is needed to assess the benefits of using waste water for irrigation (e.g how will it increase crop yields), whilst indirect methods (about which there is little agreement) must be applied to assess the non-use benefits (such as recreational and environmental benefits). A lack of market-based information for environmental benefits might lead to inaccurate estimation[42]. Costs vary depending on the treatment costs in relation to the incoming effluent quality standard, the scale of the plant, transportation costs to the site of use and of storing and pressurizing the water for use – and benefits vary depending on the use of the reclaimed water.

The efficiency paradox: this explains the paradox that tighter (re)cycling of water can in fact increase total water use. Water 'saved' through increased efficiency, for example, will be used to expand areas under irrigation – thereby not supporting absolute water use reductions'[43]. Where river basin management is centred on recapture of 'losses' through efficiency, water may simply be redirected to other sectorial uses, thereby not solving the issue of water scarcity. Any increase in supply will also lead to an increase in demand unless a ceiling on water consumption is enforced.

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[38] Urban water tariffs in Spain: what needs to be done (2015), Garcia-Rubio, M, Ruiz-Villaverde A., Gonzalez-Gomez F., Water 7(4)

[39] Proposal for a regulation in minimum requirements for water reuse (2018). Europa website

[40] Eco-innovation in Croatia: EIO country profile 2014-15 (no date), The Eco-Innovation Observatory, European Commission

[41] E.coli cucumber scare: cases likely to increase, BBC World News 31 May 2011

[42] Cos-benefit analysis of wastewater reuse in Puglia, Southern Italy (2017) Arborea, S., Giannoccaro G., de Gennaro B., Iacobellis, V., Piccinni A., Water

[43] Irrigations efficiency and water policy implications for river basin resilience (2014). Scott, S., Vicuna, S., Blanco-Gutierre, Meza, F., Varela-Ortega C., *Hydrological and Earth System Sciences, 18*.

Policies that encourage behaviours that conflict with good water management: the production-based subsidies from the Common Agricultural Policy (CAP) encouraged the expansion of irrigated areas favouring the production of high-yielding, water intensive cereals such as maize, barley, rice and wheat. Recent CAP policy reforms have decoupled subsidies from production, encouraging the production of high value crops with lower water requirements such as vineyards, olive trees, fruit trees (e.g. peach and plum) and vegetables (e.g. tomatoes and melons)[44].

Understanding the true cost of water and a failure to invest in new technologies: the current balance of low prices for water and high infrastructure costs make it difficult to achieve the return on investment related to water saving or reuse projects and therefore to win CAPEX approval. This will be exacerbated by a lack of knowledge or ability to account for the true costs of water within businesses. Examples of the full costs of water are shown in Figure 7. Failure to invest might also be caused by a lack of awareness with businesses not considering the issue of water reduction and reuse, and therefore opportunities might be missed.

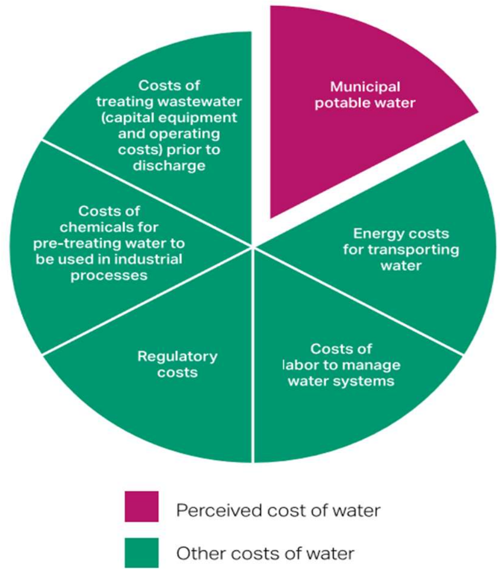

Figure 7: Perceived and actual full costs of water. Source: WBCSD

Lack of sufficient corporate action: a recent report by the Carbon Disclosure Project (CDP), which asks corporates to report on water, noted that corporate action was insufficient to achieve SDG6 and deliver a water secure future[45]. Presenting responses from a sample of 783 of the world's largest publicly listed companies, 77% of the companies report exposure to substantial water risks. However only 29% set targets and goals at multiple levels of the business, only 59% regularly monitor and manage water aspects across facilities and only 40% engage value chains on water issues. The report concludes that the pace and scale of change seen in the corporate world is insufficient to meet the challenge. Whilst compared to 2015 more companies were reporting risks and setting targets to reduce water withdrawal, there was an almost 50% increase in the number of companies reporting higher water withdrawals. Whilst explanations included improved metering and monitoring, a rise in water withdrawals was also cause by increased production, the opening of new operating plants and the need for increased irrigation due to extreme weather events. There are corporate examples of good practices, such as AstraZeneca who have a global strategy to cap water use at 2015 levels while doubling revenue and Sony Corporation who aim to develop new technologies to improve productivity and reduce environmental impact. The report notes the significance of embedding water into corporate governance – through strategic decisions made by the CEO and board – as critical to transforming outcomes.

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[44] Irrigations efficiency and water policy implications for river basin resilience (2014) Scott, S., Vicuna, S., Blanco-Gutierre, Meza, F., Varela-Ortega C., *Hydrological and Earth System Sciences, 18*.
[45] Treading water: Corporate Responses to Rising Water Challenges (2018), CPD

2.5 Opportunities for improvement

Water is the most important shared resource across all supply chains and waste water is an under-exploited waste category. Taking a circular economy philosophy for water shines a spotlight in the dysfunction of a system that takes a valuable resource, and within a quick timescale renders it not only useless, but a cost to society.

A circular economy approach for water requires that water should retain its highest value after each use and that irreversible contamination that renders it useless for further use should be stopped. This is a radical change requiring changing mindsets, the instigation of new technologies, of a revaluing of water and of changes in the political and legal frameworks. Water has already been included within the discussions on the circular economy, with particular focus on:

- Reducing pollution at source
- Exploiting new water sources especially through water reuse and desalination
- Identifying exploitable byproducts from the wastewater treatment process

At the European level, the EU Action plan for the Circular Economy[46] makes two significant proposals in this respect:

- A proposal to revise the EU regulation on fertilisers to facilitate the circulation of fertilisers based on recycled materials within the EU. The movement of such fertilisers is currently hampered by different rules, quality and environmental standards across member states. The objective of the revisions will be to facilitate the EU wide recognition of organic and waste-based fertilisers and stimulate an EU wide market.

- The promotion of the reuse of treated wastewater in safe and cost-effective conditions to increase water supply and alleviate pressures on over exploited water resources. The paper notes that water reuse in agriculture contributes to nutrients recycling by substitution of solid fertilisers. It proposed to take actions to promote reuse including legislation on minimum requirements for reused water. A proposal for a regulation on minimum requirements for water reuse was issued in May 2018.

The EUs proposal for a revision to the directive on the quality of drinking water intended for human consumption[47] also notes the link to the circular economy as it will help Member States manage drinking water in a resource efficient and sustainable manner helping to reduce energy use and unnecessary water loss, as well as increasing people confidence in tap water thereby reducing plastic bottle use.

The proposal for a regulation on water reuse in Europe comes amidst a widespread acknowledgement of the benefit that can arise from a greater uptake of water reuse. In Spain for example, where practically all surface water resources are already stored in reservoirs and in many cases groundwater resources are over exploited, there are no significant conventional

[46] Closing the loop - An EU action plan for the Circular Economy (2015) European Commission COM (2015) 614 Final

[47] Proposal for a Directive of the European Parliament and of the Council on the quality of water intended for human consumption (2018), European Commission

sources of water to exploit to meet future demand, so alternative water sources including desalination and water reuse will play a key role[48]. Criteria for water reuse has been developed in Cyprus, France, Greece, Italy, Portugal and Spain – although there is little harmony amongst the standards. Although reuse levels are currently low, in Spain there is an established legal framework, Royal Decree 1620/2007 (RDR) which sets out the legal standards for the reuse of reclaimed water, establishing rigorous criteria based on maximum permissible value and stipulating numerous water quality analysis. Reused water is currently used for a number of functions:

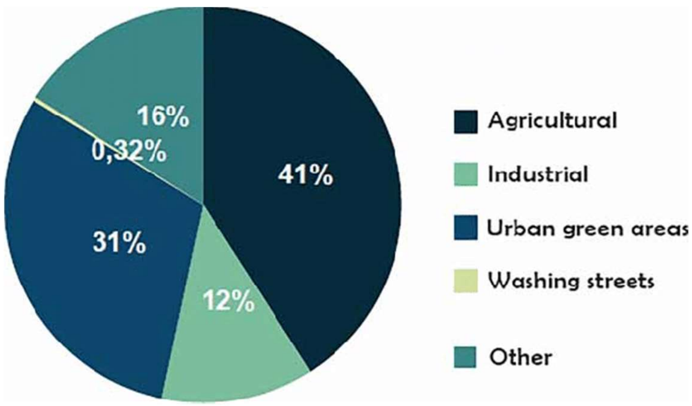

Figure 8: Uses of reclaimed water in Spain (2014). Source: AEAS

The Spanish law (RDR, Annex 1.A) permits use of reclaimed water for the following uses:

Urban	• Residential – watering gardens and discharge from sanitary applications • Services – irrigating urbane green areas, washing streets, fire-fighting, industrial vehicle washing
Agricultural	• Irrigation of crops (with various conditions), pastures and aquaculture • Irrigation of ornamental flowers • Irrigation of industrial (non-food) crops
Industrial	• Water for processing and cleaning and other industrial uses • Cooling tower and evaporative condensers
Recreational	• Irrigation of golf courses • Ornamental ponds, bodies of water and flowing water features • Aquifer recharge by local percolation through the ground • Aquifer recharge by direct injection
Environmental	• Irrigation of woodland, green areas and other spaces • Silviculture • Other uses e.g. maintenance of wetlands, minimum stream flows

[48] Taken from Water reuse and desalination in Spain – challenges and opportunities (2018) Navarro, T. Journal of water reuse and desalination.

Exploitation of wastewater requires the development of technologies – a key element of Project Ô. However, the economics of water reuse technologies still need to be demonstrated. This is made complex through the current under-pricing of water services, of a failure to capture the environmental costs of water scarcity, of the challenges of private costs (i.e. the farmer pays) for public goods (i.e. environmental improvements) and of the difficulties in finding a common methodology to assess the economic viability of water reuse. The economic justifications for widespread adoption of water reuse technologies will depend very much on local scenarios. Comments in the literature bear this out. In one example, a comparative analysis of desalinating seawater, importing water and reclaiming wastewater on the Aegean islands, concluded that the latter imposes the lowest cost and energy requirements. Reclaiming wastewater was recommended as part of a long-term strategy for managing water resources sustainably across the islands and has various potential uses, including agricultural irrigation[49]. However, costs might still be higher than the market will currently withstand in some countries without a changed perception of the value of water. In Israel, 87% of treated wastewater effluent is reused for agriculture representing half of all irrigation water nationwide. For Israel, it is noted that this process is costly, and still needs public subsidies. Even with the subsidies, farmers pay significant prices for reclaimed water (well above what farmers pay in most other countries), in particular to cover the costs of conveying treated wastewater effluents to irrigated areas, subsidies concentrated on the treatment of waste water and storage of recycled water [50].

In Israel market drivers through pricing differentials are used to encourage the uptake of different water streams for irrigation through water pricing[51]:

- Freshwater between NIS 1.6/m^3 – 2.6 /m^3 (euro 0.39 – 0.64/m^3).
- Brackish water depending on salinity NIS 0.9-NIS 1.6/m^3 (euro 0.22 – 0.36/m^3)
- Treated waste water NIS 0.8 – 1.25/m^3 (euro 0.20 – 0.31/m^3)

Possibly opportunities could be explored based on the learnings and similarities with the commoditization of resources through the Payments for Ecosystems Services (PES). PES is an economic tool used to value the benefits of natural capital – ecosystem services provided. PES schemes encourage landowners to adopt practices that are privately unprofitable but are either socially desirable or desirable for other businesses by agreeing and making payments for specific actions. When the services in question relate to water, the term payments for watershed services (PWS) is often used. As an example, if in a water catchment with limited water availability agricultural water users had to forgo profit to ensure that municipal water supplies were protected, agricultural users would be compensated for their lost profits due to their role in regulating water quantities[52]. This concept might be used when considering approaches to sharing the costs of waste water treatment for reuse when private costs prohibit the use of technologies to the detriment of societal/public benefit.

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[49] Towards efficient use of water (2012), EEA

[50] Water Management in Israel: Key innovations and lessons learned for water scarce countries (2017), The World Bank, report funded by the Government of Israel

[51] Water Management in Israel: Key innovations and lessons learned for water scarce countries (2017), The World Bank, report funded by the Government of Israel

[52] Determining payments for watershed services by hydro-economic modelling for optimal water allocation between agricultural and municipal water use (2018) Haavisto R., and Perrels A., *Water Resources and Economics.*

A UN report[53] identified the following technical aspects as opportunities in the wastewater management cycle:

- *Prevention or reduction of pollution at source:* prioritizing approaches to water pollution control that focus on wastewater prevention and minimisation over end of pipe treatments.
- *Wastewater collection and treatment:* both centralized waste disposal or on-site systems. The report notes the trend globally towards decentralized waste water treatment systems serving small groups of properties. These systems allow for the recovery of nutrients and energy, save fresh water and help secure access to water in times of scarcity. It has been estimated that the investment costs of these facilities represent only 20-50% of conventional treatment plants, with even lower operational and maintenance costs (in the range of 2-25% of conventional activated sludge treatment plants). The use of ecosystems to provide economical waste water treatment services is also noted.
- *Using wastewater as an alternative source of water*: The use of untreated or diluted wastewater for irrigation has taken place for centuries. Reclaimed water can provide opportunities for a sustainable and reliable water supply for industries and municipalities. In general water reuse becomes economically feasible if the point of reuse is close to the point of production. Treating wastewater to water quality standards acceptable by a user (i.e. 'fit for purpose' treatment) increases the potential of cost recovery. Wastewater reuse becomes all the more competitive when freshwater process reflects the opportunity cost of using fresh water and pollution charges reflect the cost of removing pollutants from wastewater flows.
- *The recovery of useful by-products*: the potential of wastewater as a source of resource, in particular energy and nutrients, remains underexploited.

Many reports clearly identify the potential benefit from focusing on the reuse of wastewater in particular. The WBCSD report identifies several uses for this water:

- Cooling system make up, process water, washdown water and miscellaneous uses such as site irrigation, fire protection, road cleaning, dust suppression, construction aggregates, beautification.
- Agricultural irrigation (industrial crops, fodder and seed crops, orchards, forests, food crops).
- Indirect potable reuse (aquifer recharge, reservoir replenishment) portable reuse (extensive advanced treatment of municipal wastewater beyond conventional secondary and tertiary treatment directly into a water distribution system).

In addition, there are a number of examples of by-products identified in the literature including (not an exhaustive list):

Energy: technologies exist for on-site energy recovery (biogas) through sludge/biosolids treatment processes integrated into wastewater treatment plants allowing the plants to achieve energy neutrality or even become net energy producers. Energy recovery can reduce operational costs, carbon footprint and increase revenue streams through the sale of electricity. Off-site energy recovery involves sludge incineration through thermal treatment processes.

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[53] Wastewater: the untapped resource (2017), The UN World Water Development Report

Nutrient recovery: particularly nitrogen and phosphorus from sewage or sewage sludge is technically possible and financially feasible through the sale of the resulting mineral fertilizers. Faecal sludge presents a relatively lower risk for chemical contamination compared to sewerage biosolids. It is likely that urine collection and use will become an increasingly important component of ecological wastewater as it contains 88% of nitrogen and 66% of phosphorus found in human waste. With extractable mineral phosphorus resource limited, recovery from waste water could be a viable alternative.

Metals and chemicals including biopolymers: Investigations have demonstrated that sewage sludge can contain a range of metals. These include heavy metals (aluminium, arsenic, cobalt, chromium, iron, mercury, nickel, lead, magnesium and zinc), noble metals (silver, gold and platinum) and other chemicals with potential commercial value (e.g. potassium, magnesium sodium and silicon)[54]. Examples of biopolymers found in sewage sludge include polyhydroxyalkanoate (PHA), a biopolymer stored inside certain bacterial as granular carbon and energy reserves. Whilst commercialization may still be a challenge, these biopolymers can be extracted to produce biodegradable thermoplastics (polyesters) with possible applications in packaging, agricultural, plastics and medical industries[55].

There are many areas where opportunities for greater circularity can be found. Project Ô is demonstrating water reuse, and in the example aquaculture demonstration moving much closer towards closed loop operations, through testing water reuse in 3 different scenarios within a municipal WWTP, a textile factory and onshore fish farming and of exploiting new sources through the use of small-scale desalination technologies.

[54] Precious metals in sewage sludge (2018), Hamood, A., in Water and Wastewater Treatment.
[55] Resource recovery potential of wastewater treatment: biopolymers, Sing-Key, J., Imperial College London summary paper.

3 Current value chains of the demonstration sites

Project Ô has 4 demonstration sites at which to explore the effectiveness of small-scale waste treatment/water looping technologies, summarised in Table 1:

	Demo site	Existing facilities	Tech implemented	Platform/Tools
1	**Acquedotto Pugliese** Puglia Region (*Italy*) N 41°7' E 16°52'	Groundwater extraction facilities; system-wide sensors and controls	Advanced Oxidation Process and advanced filtration for treating contaminated brackish groundwater	DAP; integration of water resource planning with spatial planning
2	**National Centre for Mariculture** Eilat (*Israel*) N 38°41' O 6°22'	Salt water fish farms with small algae plant	Polishing algae plant + innovative desalination and disinfection (Capacitive deionization + Microwave enhanced catalytic degradation)	**UCP**; integration of water resource planning with spatial planning
3	**Almendralejo WWTP** Almendralejo (*Spain*) N 29°33' E 34°58'	WWTP with lamellar deposit, 2 stage biological treatment and 2 stage decantation	Mobile Advanced Absorption and Solar Photo Fenton with advanced control unit	DAP (light version); integration of water resource planning with spatial planning
4	**Omis WWTP** Omis (*Croatia*) N 43°44' E 16°69'	WWTP, egalization, flocculation with coagulation ($HCL+CaCO_3$), deposition and drying of sludge in dry fields	Photocatalytic module	**UCP**; integration of water resource planning with spatial planning (*to be confirmed*)

Table 1: Summary of demonstration site activities

The next sections set out the context of the water scenario in each of the geographies, the current value chains for each demonstration site and a brief overview of the objectives of the demonstration activities.

Details of the technologies used are included in D2.1.

3.1 Demosite 1: Acquedotto Pugliese (Italy)

3.1.1 Context of the demonstration activities

The context of demonstration site 1 is the River Galèso, a short river (900 meters) that discharges into the Mar Piccolo (Little Sea), a bay near Taranto, in Apulia, Southern Italy. Mar Piccolo is a part of the Taranto Sea, the other part of which is called the Mar Grande. Mar Piccolo is an inner basin connected to the Mar Grande which is directly connected to the open sea. Tidal exchanges are important as far as water exchange between the Mar Grand and Mar Piccolo which are connected by two channels along the island of the old town of Taranto. The Mar Piccolo is one of the most intensive mussel farming areas in Italy, enabled by the presence of submarine fresh water springs.[56]

[56] Mass exchange systems in the Taranto Sea (2007), Umgiesser G., Scroccaro I., and Alabiso G. Transitional Waters Bulletin, Volume 1 issue 2.

The regions climate is distinguished by a rainy winter and a dry summer period. Temperatures range from 9°C in January to 25°C in July – although average highs of nearly 30°C are recorded in June and July with higher temperatures of over 40°C possible. Rainfall amounts to around 490 mm per year with very low precipitation levels in the summer and with pronounced annual variations in rainfall. Accordingly, maximum discharges of the Galèso river were in the spring (April – May) and minimum discharges in spring (July – August). The amount of rainfall in the region influences the discharge of the submarine freshwater springs and hence the salinity of the Mar Piccolo. The 2007 report noted here highlighted poor data regarding measurement of discharges from the freshwater springs.

The water system is within the Apulia region is karst (limestone) leading to its distinctive hydrological characteristics – and the distinct water resourcing issues. Karstic aquifers and environments are highly vulnerable to contamination and to anthropogenic modifications. Particular issues are: thin soils, especially if they are affected by soil erosion leading to the loss of protective topsoil, leading to bare karst slopes and changes to infiltration rates; and point rather than diffuse recharge of the system due to features such as dolines (sink holes), shafts and swallow holes, which leads to rapid flow rates and high percolation rates. Because of the thin soil and underground features, groundwater is often the only freshwater source and water moves relatively fast through the system. This is the case in the Apulia region where groundwater is more than double that of surface runoff[57]. Apulia hosts a large number of coastal karstic aquifers that form the main regional water source. These are often affected by degradation in quality due to seawater intrusion. Apulian karstic aquifers are highly permeable due to fracturing and dissolution well below the current sea level where groundwater flow mainly happens.

3.1.2 The current value chain

The Galèso water system comprises 9 wells and was used as an alternative source of water during droughts. The water was always mixed with water from other sources mainly due to its saline content, its hardness and the presence of contaminants. The Galèso wells are no longer used due to the degradation of the Apulian karstic aquifer and its vulnerability to seawater intrusion. In testing undertaken as part of Project O (and described in D2.1), issues of microbial contamination, high levels of salinity, and levels of arsenic and cadmium that exceed safe drinking water limits need to be treated. Water is supplied to the region via the Apulian aqueduct – the public water supply. The aqueduct network stretches for 22,500 km and is the biggest aqueduct in Europe. In addition, there are just over 10,000km of sewage networks and 182 treatment plants. Large reservoirs have been built to capture and store water. Reuse and water efficiency are key priorities for the region[58].

[57] Karstic aquifer vulnerability assessment methods and results at a test site (Apulia, Southern Italy) (2009) Polemion M., Casarano D., Limoni P., Natural Hazards and Earth System Sciences, 9
[58] WssTP: Puglia-region the European Water Platform

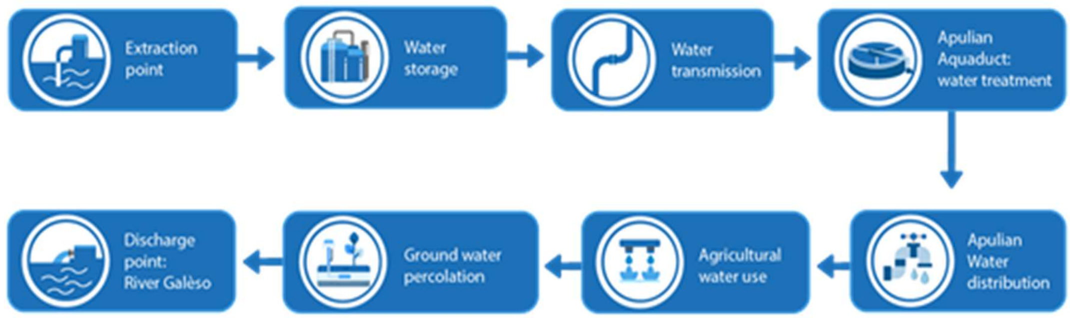

Figure 9: Demonstration site 1: current value chain

The demo will add to the current Apulian Aqueduct water supply.

3.1.3 The objective of the demonstration activities

The objective of this demonstration is to exploit artesian wells bored in the karstic aquifer as sources of safe drinking water and/or water for irrigation. This approach would locally ease pressures on the aqueduct providing high quality water from alternative sources. The pilot will allow for the treatment of 20m^3/day, with the final scenario reaching a flow rate of 200 l/s.

The module developed is for onsite treatment of water and would ensure low investment and operational costs and low environmental impacts. The module will be compact and compatible with off-grid application, favouring solutions that do not require chemical reagents to operate. The technology consists of a tertiary treatment system that combines membrane filtration that could be used for desalination where required and with control of ionic pollutants and an advanced oxidation process (AOP) (to deal with the microbial contamination and persistent pollutants made of large molecules). The technologies to be trialled are nanofiltration (NF) (by partner Aalborg University) and high voltage nanosecond pulsed electrical field (HVNSPEF) (by IRIS) integrated with contributions from EKSO who will implement un-intrusive infrastructure recovery techniques. Data will be collected by EKSO.

To minimise impacts, the distance of the demo site to the main water treatment plant will be considered and the demonstration will aim to keep the dimensions of the plant relatively small, the power consumption as low as possible and avoid using consumables.

The water quality requirements to be met are set by the Italian reference standard of drinking water.

3.2 Demosite 2: National Centre for Mariculture (Israel)

3.2.1 Context of the demonstration activities

The National Centre for Mariculture in Israel is focused on developing environmentally friendly land-based systems for rearing fish in land-based seawater ponds using recirculating aquaculture systems (RAS). Aquaculture systems provide 47% of global human fish consumption with output set to increase by a further 60-100% over the next 20-30 years. Water recirculation is a key aspect of improving the sustainability of these systems by reducing discharge of aquaculture effluents into the environment. In addition, water recirculation allows for aquaculture ponds to be located away from coastal areas therefore relieving stress to these areas (already 40% of the world's population live within 100km of the coast), as well as enabling the production of fish closer to consumers[59].

Nitrogen, phosphorus and organic matter are key components of waste from fish farming, levels of which need to be controlled for successful mariculture. A number of physical, chemical and biological methods are used in wastewater management of aquaculture systems. These include:

- Physical processes such as solids removal by sedimentation, sand or mechanical filtration. Newly produced sludge from aquaculture is considered a good 'slow release' fertilizer in agriculture, but organic waste can also be composted or used in vermiculture;
- Biological processes such as biofilters, trickling filters and fluidized bed reactors are employed for the oxidation of organic matter, nitrification or denitrification. Rotating microscreens are commonly used in land-based intensive fish farms;
- Wetland systems to remove solids, organic matter, nitrogen, phosphorus, trace elements and microorganisms;
- Improved feeding formulations to reduce loss through runoff and reduce fish excreta, and the inclusion of dietary binders to fish feed to enhance the stability of fish faeces thereby improving settling efficiency and mechanical removal;
- Control of nutrient load through temperature adjustment;
- Integrated intensive aquaculture where fish are cultured with plants and other animals which are used as biofilters (including shellfish, seaweed and vegetables) and can use nutrient discharges for growth. The plants can also provide and revenue stream; and
- Constructed wetlands including examples using salt tolerant plants.

RAS recycles water through running the water through waste treatment systems to remove fish waste and food before recirculated back into the tanks. This both saves water and provides a waste stream that can be used as compost or fertiliser. Optimised RAS can be combined with biofiltering organisms such as plants and algae. The level of waste treatment and water reuse depends largely on the requirements of the fish, environmental regulations and standards and the technology available.

3.2.2 Current value chain

The National Centre for Mariculture is developing novel approaches to aquaculture using marine and brackish water. The current challenges in RAS are the increased requirements for removal of total water nitrogenous effluent loads to meet environmental legislation, and to enable near 100% closed loop reuse of water.

The current scenario uses seawater from the Red Sea with daily water exchanges of 40-50% of the systems total volume (1200m^3). Water is circulated between the fishponds and the treatment unit. The treatment unit is a Low-Head Mega Flow RAS including a solid filter and a

[59] Sustainable Treatment of Aquaculture Effluents – what can we learn from the past for the future? (2014) Turcios, A., and Papenbrock J,. Sustainability 6

submerged moving bead nitrification biofilter. The pump has low energy requirements and includes an innovative air-lift system for aeration and massive water flow.

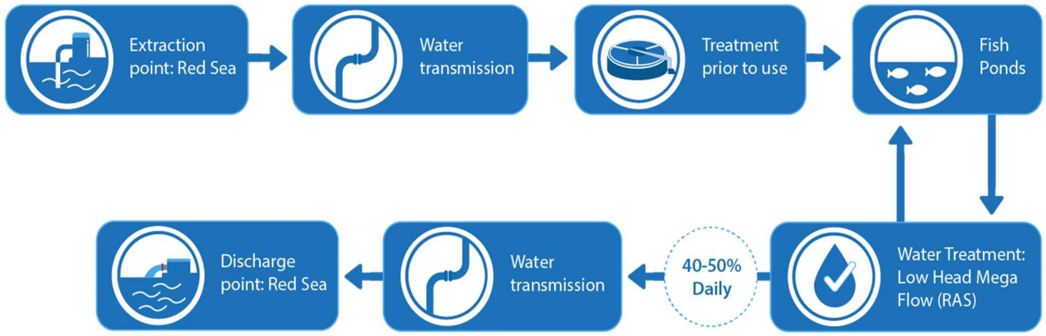

Figure 10: Demonstration site 2: current value chain

3.2.3 Objectives of the demonstration activities

Recent environmental regulations issued by the Israeli Ministry of Environment (as set out in D2.1) require an increased removal rate of nutrients that would not be possible with the current treatment process. Based on a relatively high fish stocking density, the demonstration project has shown a reduction in water exchange to about 10% through high removal efficiencies of nitrogen, phosphate and total suspended solids, enabling effluent to meet the rigorous standards for effluents discharged into the Red Sea

The demonstration site tests the possibilities of increasing water reuse volumes both within the fishponds and externally. The demonstration site will take water from the fish ponds, pass it through the denitrification reactors then send it through 2 separate test processes:

- Water loop #1: an algae plant (by IOLR) allowing the reuse of seawater in fish ponds, and;
- Water loop #2: desalination through capacitive deionization (by NanoQ) and membrane distillation using a molecular separation membrane (by AAU) to produce water for the irrigation of salt tolerant crops.

Data will be collected by IOLR.

The benefits arising from this pilot are therefore:

- improved water effluent standards;
- increased water reuse - including the associated energy costs from pumping;
- benefits to increased fish yield through better temperature control and more efficient disease control;
- further consideration of water for irrigation as a saleable product; and
- algae production for use sa food, animal feed, biofuels, green chemistry etc.

3.3 Demosite 3: Almendralejo WWTP (Spain)

3.3.1 Context of the demonstration activities

Almendralejo WWTP is located in the city of Badajoz, situated close to the Portuguese border on the left bank of the river Guadiana. Badajoz is the capital of the province with the same name. Summer temperatures average at around 25°C but with temperatures above 30°C common. Cooler winter months average under 10°C with little likelihood of temperatures falling below 0°C. Average annual rainfall in Badajoz is 523mm with summer rainfall a few mm in a month and winter rainfall of over 70mm possible[60]. However, there are extreme variations in rainfall season to season and year to year. Potential evapotranspiration within the Guadiana River basin will greatly exceed rainfall with the basin defined as semi-arid.

The Guadiana river basin is one of 5 main river basins shared with Portugal. The Albufeira Convention was agreed in 1998 between Spain and Portugal and is cited as an example of good practice in negotiating and sharing the benefits of the water resource between the nations and to balance environmental protection with sustainable use of the water resources [61]. Spanish territory is upstream and accounts for 83% of the land area. Irrigation is a highly consumptive use and is the main source of demand in the region accounting for 90% of all water consumption compared with 7% for domestic use and 3% for industry[62]. Seasonality is important at this site due to higher abstraction rates for agricultural needs and different wastewaters derived for the processing of seasonal produce. Low water pricing has resulted in over exploitation, with the traditional focus for solving water scarcity and allocation challenges being the construction of dams and large-scale water transfers from wetter to drier regions – an option now no longer available. In addition, annual precipitation has decreased by up to 90mm per decade in the Iberian Peninsula since 1960[63].

The Almendralejo WWTP treats over 2.5million m^3/year of wastewater from the 35,000 citizens of Almendralejo together with the food industries surrounding the city (olives, olive oil, wine, vegetable canneries, processors and packaging). Seasonality is important at this site due to higher abstraction rates for agricultural needs and different waste waters derived for the processing of seasonal produce.

More than 28 businesses operate in the olive sector (oil and table olives). Wastewaters from olive processing in particular have resulted in high values of total organic carbon (TOC), together with high concentrations of macronutrients and polyphenols. The difficult waste streams are caused by the treatment of olives in caustic soda and the disposal of brine used for olive preservation. The WWTP has a lamination deposit (an equalization tank) where industrial effluent is retained if necessary. Some of the contaminants are too toxic for biological treatment with bacteria and can therefore damage the WWTP and end up untreated in the environment.

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[60] climatedata.org

[61] Water for life: Spanish-Portuguese Albufeira Convention (2013), United Nations Department of Economic and Social Affairs

[62] Irrigations efficiency and water policy implications for river basin resilience (2014) Scott, S., Vicuna, S., Blanco-Gutierre, Meza, F., Varela-Ortega C., Hydrological and Earth System Sciences, 18.

[63] Urban water tariffs in Spain: what needs to be done (2015), Garcia-Rubio, M, Ruiz-Villaverde A., Gonzalez-Gomez F., Water 7(4)

The Almendralejo WWTP regenerates some water (estimated at around 120m^3/day), used only for the internal processes of the WWTP including facilities cleaning, road watering and drip irrigation.

3.3.2 Current value chain

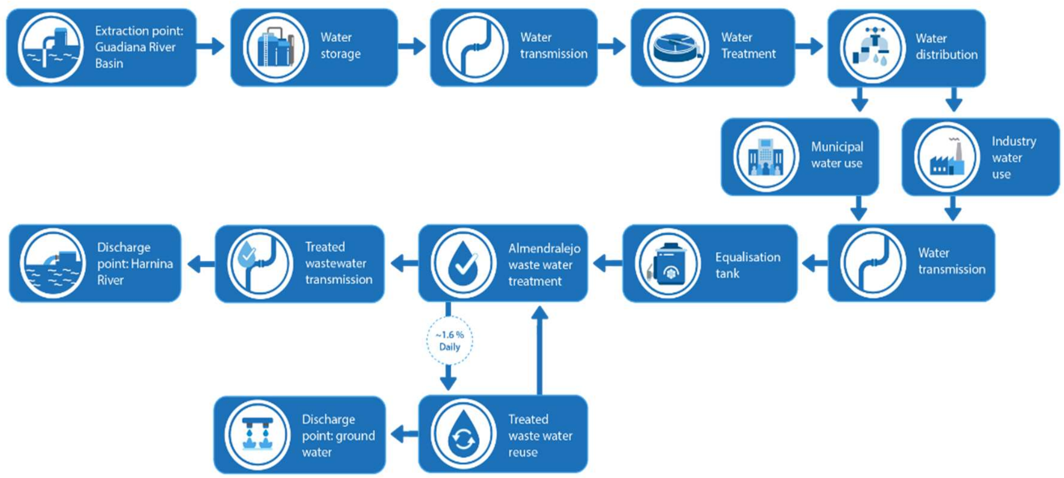

Figure 11: Demonstration site 3- current value chain

3.3.3 Objectives of the demonstration sites

Current wastewater quality requirements are set to change due to:

- Pioneer legislation in Switzerland and Denmark to develop national strategies to prevent micropollutants getting into surface waters with calls for a European wide policy on micropollutants;
- Controls introduced in Denmark on pharmaceuticals in effluent of waste waters. that would require an additional step at WWTPs for which technologies are limited[64]; and
- the EU regulation on water reuse to enter into force soon including water quality limits.

Demo site 3 will test the continuous monitoring of water that has already gone through the WWTP in order to perform the final elimination of particular micro-nutrients. The system will be connected to the equalization tank so that accidental spills can be detected in a timely manner and treated properly. Research carried out on the pollutants affecting the waters in Almendralejo WWTP have identified terbuthylazine (a herbicide), pharmacological products and disinfection by-products as needing to be monitored.

More regenerated water will be made available for use from 1.6% (20m^3/day) of total amount of water entering the WWTP to 1.84% (138 m3/day) for the pilot demonstration. This will be used for purposes including garden watering, street watering, the irrigation of certain crops in the municipality, and to be filtered into the sanitation system at the park (water loops #5 to #8

[64] IFAT 2018: Call on EU to develop standards for micropollutants in wastewater (2018) Dutch Water Sector Magazine.

as described in D2.5). The final scenario will seek to reuse up to 90% of the totality of waste water treated. The ecological impacts of this on the river will be take into account.

The technology to be tested at this site is solar photo-Fenton (by UPV), advanced adsorption technology (by CNRS), bacterial stress based closed loop control (by Technion). Data will be collected by SOCAMEX.

Demo site 3 is also to test the advanced closed loop control unit based on bacteria stress sensors in the activated sludge facility.

3.4 Demo site 4: Omis WWTP (Croatia)

3.4.1 Context of the demonstration activities

The demonstration site is the factory of a textile company called Galeb d.d based in Omis, Croatia. Omis is located at the mouth of the Cetina river. Its climate is classified as warm and temperate. Summer temperatures average at 25ºC in July but can reach over 30ºC and in January average at 7.5ºC. July is the driest month with an average of 35mm of rain, with November experiencing the most rain with an average of 119mm.

According to Eurostat, Croatia recorded the highest volume of freshwater resources within Europe (27,339 m^3 per inhabitant), more even than Finland and Sweden[65]. Tourism is a key pillar of the Croatian economy, and the quality of the Adriatic Sea coastal waters is critical. Hrvatske vode (Croatian Waters) is the main institutional player in the provision and management of wastewater services in Croatia.

Galeb d.d is constructing a new WWTP. Galeb has 3 brands:

- Galeb: primarily classic underwear and nightwear mostly made from cotton knitted fabrics.
- Adriatic: includes underwear and outerwear with products include elastane fibres and /or viscose fibres as well as knitted fabrics.
- GLB: including underwear, outerwear and nightwear made from knitted fabric enriched with new fibre types such as micro modal, Lycra and viscose.

The textile industry is water intensive, with water used for cleaning raw materials and within the dying process. Wastewater is a major environmental challenge for the textile industry. Textile production uses many kinds of substance in the process including synthetic dyes, solvents, resins, caustic soda and bleach which can end up in the wastewater streams. Different water treatment techniques are needed depending on the quality of wastewater and the type of contaminant. If discharged, it can affect aquatic life due to low light penetration and oxygen consumption. Component metals and chlorine present in synthetic dyes can also have negative consequences for marine life[66].

[65] Croatia leads on freshwater resources per inhabitant (2017), Eurostat

[66] A critical review on textile wastewater treatments: Possible approaches (2016) Holkar et al. *Journal of Environmental management, Volume 182*

3.4.2 Current value chain

The site is currently under construction – so technically there is no value chain at this point. Figure 12 has been drawn with an assumption that some operation already exists on the site, but without the WWTP.

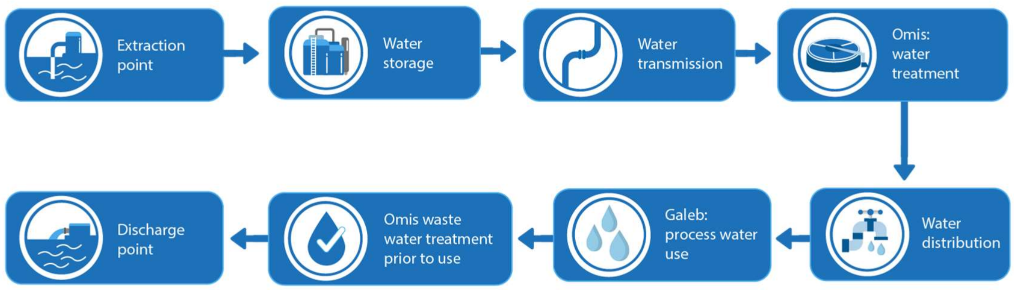

Figure 12: Demonstration site 4: current value chain

3.4.3 Objectives of the demonstration sites

The new plant will reuse wastewater in the bleaching and dyeing process depending on the properties of the treated water.

The technology to be tested at this site is photocatalysis (by UNITO). Data will be collected by Galeb.

4 Principles of the circular economy

4.1 Background to the circular economy

The concept of the circular economy has developed as a result of the increasingly obvious negative impacts of unfettered human demand and use of the planets resources. This has led to impacts that change the conditions needed to both regulate the Earth's system at the planetary level, and to impacts that lead to more local degradation of natural systems and ecologies. From an anthropocentric perspective, our societies and in particular our economies are supported by the complex processes operating within these natural systems (for example climate regulation, water provision, maintenance of ocean pH levels) and have been based on levels of resource use that are not renewable within human scale timeframes. The linear model of 'take, make, dispose' has driven this with resource use expected to reach nearly 90 billion tonnes in 2017[67], with municipal waste volumes of over 2 billion tonnes a year[68] and 3 billion tonnes of construction and demolition waste globally[69]. Both resource use and waste volumes are predicted to grow. Freshwater withdrawals have tripled in the last 50 years with demand for freshwater increasing by 64 billion m^3 a year – 70% used for agriculture, 20% for industry and 10% for domestic use[70] with an estimated 80% of waste water globally discharged without treatment[71].

Within this bleak summary there have been moves to regulate the damage of unrestrained economic growth. Environmental laws and regulations, the use of fiscal instruments to drive change (for example the emissions trading scheme and payments for ecosystems services), the gathering of data and monitoring and development of more efficient technologies for example. The evolving philosophy of 'sustainable development' has changed and matured since the 1980's. The last few decades have seen a growing awareness of the challenges demonstrated through ambitions of improved resource efficiency, of measurement and transparency and latterly of the articulation of the need to decouple economic growth from environmental resource use. But, whilst great strides have been made, the continual pressure of population growth and economic development has meant that in 2019 there remain very serious environmental challenges to tackle, with terms like 'crisis' being commonly used.

4.2 Objectives of the circular economy

The concept of the circular economy is seen as one approach to managing the environmental challenges of modern society, whilst still enabling economic prosperity and growth. 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

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67 Assessing global resource use (2017), International Resource Panel, UNEP

68 What a waste 2.0: A global snapshot of solid waste management to 2050 (2018), World Bank Group

69 Construction and demolition waste generation and properties of recycled aggregate concrete a global perspective, (2018) Akhtar, A., and Sarmah, A., Journal of Cleaner Production, Volume 186

70 Worldometers: information on water

7171 Waste water the untapped resource (2017) The united Nations World Water Development Report

The benefits of adopting a circular economy approach for Europe have been estimated at Euro1.8 trillion by 2030, a halving of CO_2 emissions by 2030 and a drop in primary material consumption by 32% by 2030[72]. The EU[73] identifies benefits including boosting EU competitiveness by protecting businesses against resource scarcity and volatile prices, helping to create new business opportunities and more efficient ways of producing and consuming.

For the economy to be circular there must be a move away from finite resources to renewable and recycled resources, and within use resources should be maintained at the highest value through product strategies such as life extension, reuse, repair, refurbishment and remanufacture. Design is a critical part of the circular economy, as these objectives must be at the forefront of product design to enable them to happen. In addition, these objectives can best be met through changes in the way businesses operate (different business models), through ensuring that customer behaviour enables the objectives to be met and that the economic, policy and legislative environment supports circular behaviours, technologies and markets.

The circular economy is also seen as beneficial in the consideration of water resources, although the principles might not always be as obvious for the water sector.

The EU circular economy paper identifies some tangible actions in addition to current water efficiency measures, specifically the critical role of the reuse of treated wastewater in safe and cost-effective conditions. It identifies relevant areas of focus as the reuse of water in agriculture contributing to nutrients recycling and by substitution of solid fertilisers. Actions were promised specifically to:

- address the challenges of the circulation of fertilizers based on recycled nutrients, currently hampered by differing quality and environmental standards across different member states; and
- promote the reuse of treated wastewater, including legislation on minimum requirements for reused water.

A feature of the circular economy is the consideration of different business models – new ways of thinking about how the economy operates. These include in particular the concepts of:

- products (through design) having retained value in the materials at the end of life, and therefore businesses finding ways to recapture the products.
- businesses not selling products at all, but services, thereby retaining ownership of physical assets e.g. through leasing, sharing, pay per use or pay for functional results (eg a good night sleep or lighting).

Taking these different business models makes it necessary to think differently, for example to:

- reconsider product design to both enable longer life and to ensure there is maximum value at the end of a products life;
- to reconsider cash flow and what this might mean for investors into businesses; and

[72] A circular economy vision for a competitive Europe (2015), Ellen Macarthur Foundation
[73] Closing the loop - An EU action plan for the Circular Economy (2015), Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee the Committee of the Regions, 2.12.2015.

- to consider how customers might behave and how the behaviours that support more circular products can be incentivised.

This comes from the fundamental challenge of the circular economy which can defy 'traditional' business models. How do you create wealth by making things last? How do you balance using more labour but fewer resources, as is required for approaches such as remanufacturing, refurbishment and repair? Can selling services rather than goods become mainstream[74]?

Some of these challenges and new ways of doing business can be applied to the water and wastewater industries. The following points may challenge traditional approaches to business:

- Is it possible to sell performance not water, for example through different levels of pricing and convenience to encourage reduced use, to sell water saved 'back' to network?
- Can wastewater move from being a cost to a revenue stream? Can organic nutrient cycles and other by-products be monetized?
- Can full-life costing and the broader economic benefits that can come from better water management within businesses be realized – where can savings be made and who can do this and who benefits from them?
- Are new partnerships needed – the users of new by-products, the scientific community to research opportunities, equipment manufacturers and joint ventures. Do water companies become mining companies?
- Are water companies able to offer broader expertise regarding new technologies and championing the opportunities that come with energy production – are they the right organisations to move quickly and maximise the benefits? Is there a need for different expertise?
- Who will create and manage the local organic nutrient cycles of the future? Can the challenges of contaminated waste streams be solved to find solutions for the agricultural sector that is looking for new sources of nutrients?
- Should there be a move towards standardization and the promotion of best practice. Can the EUs Best Available Technique Reference Documents (BREFs) that Member States have to reflect when issuing permit requirements for industrial installations and promoting best practices be adapted to promote better water management
- Is there a need to share good practice and strengthen capacity within the sector to ensure learnings and change can be rapidly rolled out and shared?

[74] *The circular economy* (2016), Stahel, W., Nature, Vol 531.

4.3 Frameworks to help understand the circular economy

Taking these broad objectives of the circular economy and water and translating them into a usable framework, the following examples of CE frameworks can be used to support thinking in developing the structure to be used in the collaborative platform for Project Ô.

4.3.1 World Business Council for Sustainable Development (WBCSD)

The WBCSD use the 5Rs in its Business Guide to Circular Water Management[75]:

1) Reduce: reduce water losses and boost water efficiency;
2) Reuse: reuse water, with minimal or no treatment, within and outside the fence for the same or different processes;
3) Recycle: recycle resources and wastewater (treated by membrane or reverse osmosis to a very high quality) within and outside the fence;
4) Restore: return water of a specific quality to where it was taken from; and
5) Recover: take resources (other than water) out of the waste water and put them to use.

4.3.2 ReSOLVE framework

The Ellen Macarthur foundation presented the ReSOLVE framework in 2015, describing 6 action areas:

Regenerate	• Shift to renewable energy and materials • Reclaim, retain, and restore health of ecosystems • Return recovered biological resources to the biosphere
Share	• Share assets (e.g. cars, rooms, appliances) • Reuse/second hand • Prolong life through maintenance, design for durability, upgradability etc
Optimise	• Increase performance/efficient of product • Remove waste in production and supply chain • Leverage big data, automation, remote sensing and steering
Loop	• Remanufacturing products or components • Recycled materials • Digest anaerobically • Extract biochemicals from organic waste
Virtualise	• Dematerialise directly (e.g. books, CDs, DVDs, travel) • Dematerialise indirectly (e.g. online shopping)
Exchange	• Replace old with advanced no-renewable materials • Apply new technologies (e.g. 3D printing) • Choose new product/service (e.g. multimodal transport)

[75] Business Guide to Circular Water Management: spotlight on reduce, reuse and recycle (2017), WBCSD

4.3.3 Circular economy and water, Ellen MacArthur[76]

The Ellen Macarthur foundation considered the following objectives of water systems against the principles of the circular economy:

Circular Economy Principles (Ellen MacArthur Foundation)	Water Systems management
Principle 1: Design out waste	• Optimise the amount of energy, minerals and chemicals use in operation of water systems in concert with other systems • Optimize consumptive use of water within sub-basin in relation adjacent sub basins (e.g. us in agriculture or evaporative cooling) • Use measures or solutions which deliver the same outcome without suing water
Principle 2: Keep resources in use	• Optimize resource yields (water use & reuse, energy, minerals and chemicals) within water systems • Optimize energy or resource extraction from the water system and maximize their reuse • Optimize value generated in the interface of water systems and other systems
Principle 3: Regenerate natural capital	• Maximise environmental flows by reducing consumptive and non-consumptive uses of water • Preserve and enhance the natural capital (e.g. river restoration, pollution prevention, quality of effluent etc) • Ensure minimum disruption to natural water systems from human interactions and use

In addition, the Ellen MacArthur foundation identifies the opportunity for the ‘human water cycle’ to better align with the ‘natural water cycle’ through the following measures:

Avoid use: through rethinking products and services and eliminating ineffective actions

Reduce use: driving continuous improvements through water use efficiency and better resource allocation and management

Reuse: pursuing any and all opportunities to reuse water within an operation (closed loop) and for eternal applications within the surrounding vicinity or community

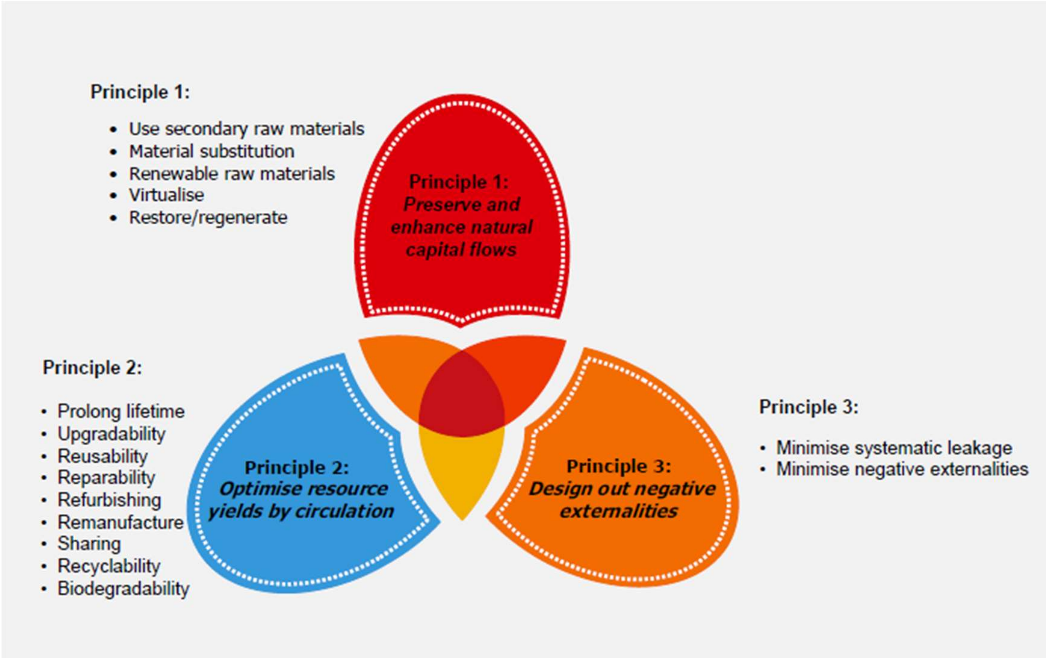
Recycle: within internal operations and /or for external applications

Replenish: efficiently and effectively returning water to the basin

4.3.4 Framework developed for ECOBULK

On another H2020 funded project, Ecobulk (GA number 730456) regarding the circular economy and composite materials (as yet unpublished[77]), the team has used the following structure to consider the objectives of the circular economy when thinking of product design and related business models:

[76] Water and Circular Economy White paper (2018), Ellen Macarthur
[77] ECOBULK



Some of these aspects may be applicable to the considerations with circularity of water and wastewater

4.3.5 Durable and consumable water from McKinsey

A McKinsey paper notes that the objectives of the circular economy rest on 3 beliefs[78]:

- All durables, which are products with a long or infinite life span, must retain their value and be reused, but never discarded or down cycled (broke down into parts and repurposed into new products of lesser value);
- All consumables, which are products with a short life span, should be used as often as possible before safely returning to the biosphere;
- Natural resources may only be used to the extent that they can be regenerated.

Water could be considered differently depending on whether it was viewed as durable or consumable:

- *Considering water as a durable:* kept in a closed loop under zero liquid discharge conditions and reused as much as possible. Major goal not to keep free of contaminants but to manage the integrity of the closed loop. This suits scenarios where the pollutant has value e.g. water born solvents, electro plating baths and alkaline solutions.
- *Water as a consumable*: must be kept pure and any matter added should be easy or profitable to extract. All water should be cascaded into other uses. Energy and nutrients extracted.

[78] Rethinking the water cycle (2015), Martin Stuchtey, McKinsey

4.3.6 Strategies for slowing, narrowing and closing loops[79]

The consideration of strategies for minimising of waste, emissions and energy leakage through slowing, closing and narrowing material and energy loops:

Slowing strategies	*Increasing the length of tie between a product entering and leaving the use phase*
Product longevity	• Durability • Product upgrade/modularity • Repair • Reuse (product/component) • Remanufacture

Closing strategies	*Turning waste material and energy flow into useful inputs (and moving up the waste hierarchy)*
Turning waste into resources	• Recycling – end of life products • Recycling – manufacturing scrap • Waste energy recovery • Industrial symbiosis
Tightening loops	• Reuse (product/component) • Remanufacture • Recycling

Narrowing strategies	*Providing the same service using less energy and/or material inputs (or more service from the same energy and/or material inputs)*
Same service, less energy/resources	• Reducing manufacturing yield losses • Servitisation • More efficient production processes (new or improved) • Product light-weighting • More intense use • Digitisation • Reduced energy/resource consumption in use

[79] The Circular Economy—A new sustainability paradigm? (2017) Geissdoerfer, M.; Savaget, P.; Bocken, N.M.P.; Hultink, E.J. J. Clean. Prod. 2017, 143, 757–768

5 Conclusions and next steps

The circular economy can provide a structure that contributes clear objectives for the water and wastewater sector, and which can challenge traditional views. It builds on the thinking about sustainability and water that has occurred over recent years, but as with solid resources, it can establish clear positions rather than the 'business as usual but with increased efficiency' that much recent sustainability thinking has focused on. Some of these can be challenging – for example how can the value of water as a resource be maintained for recirculation in the economy if it is contaminated in a manner that allows for no further use.

The circular economy can provide new opportunities for different players in the value chain – water providers and waste water treatment operators, technology providers, water users and new players that can exploit opportunities brought about by the changing regulatory environment, changing demands of those tasked with managing water resources, changing water user demands and evolving technologies.

Project Ô is demonstrating technologies that, in themselves are not the solution to circularity – but can play a significant part in the overall objectives of circular water cycles. The objectives of the demonstration projects within the context of the circular cycle of water is shown in Figure 13:

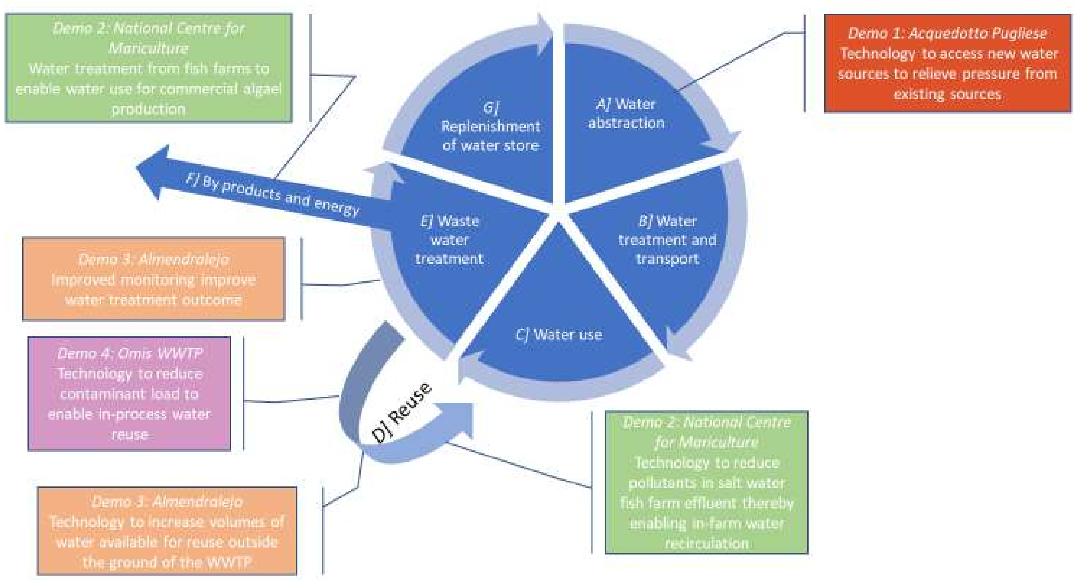


Figure 13: Circular cycle of water and the demos of project Ô

When considering what might be relevant as a circular economy framework for Project Ô, the following might be useful, drawn from the research, examples and frameworks presented within this document (linked to the phases within the circular cycle above):

Stage of cycle	Points for consideration	CE Principle alignment
A] Water abstraction	• Link project water outputs to water basin targets to support overall reductions in water abstraction • Clarity around the natural capital consequences and costs of water over abstraction, such as impacts on tourism, to support the business case for reuse/desalination	Regenerate natural systems
B] Water treatment and transport	• Consideration of the relationships/commercial contracts between the new 'providers of water' (e.g. from waste water sources) and traditional water providers • Transparency/full costs of raw water treatment and distribution needed to make water reuse competitive • Transparency of other non-financial indicators (e.g. carbon intensity) to enable comparison and choice	Design out waste and pollution
C] Water use	• Prevention of contamination through processes improvements and developing closed loop systems (link back to the full cost of water and to R&D to innovate in wastewater pollution) • Consider treating specific contaminant streams at source prior to inclusion in mixed waste water streams • Very clear charging differentials to prohibit problem contaminants (private benefit) entering municipal waste water streams (public cost) • Link to established good practices (e.g. in Best Available Techniques (BAT) Reference Documents (BREFS)) to establish the best water use and waste water treatment outcomes • Consideration of whether water use is a consumable (will be reused and so needs to be kept pure or be able to have impurities extracted at a profit) or durable (will be contaminated and so needs to be closed loop)	Design out waste and pollution Keep products and materials in use
D] Reuse	• Get product (reclaimed water) pricing correct to encourage uptake (link to true costing of alternative water supplies) • Ensure legal standards and actual reclaimed water quality standards are clear – assurance provided • Provide assurances to users regarding consistency of supply – a critical benefit of reclaimed water • Clarity of the offer to the user • Consideration of the development and product longevity of water technology equipment (reuse, repair, refurbishment, remanufacturing etc)	Keep products and materials in use

E] Wastewater treatment	• Establish links/processes to enable the financing of new and innovative water supply technologies • Consider whether value is lost by mixing different waste streams	Keep products and materials in use
F] By products and energy	• Provide information needed to further support the development of capacity and partnerships with R&D organisations to bring opportunities of new by products to the point of commercial exploitation (e.g. the data needed to support exploitation of wastewater) • Identify those players best able to exploit the resources within waste water	Keep products and materials in use Regenerate natural systems
G] Replenishment of water store	• If no further reuse options are available, prioritize best environmental option (e.g. returning water abstracted from the water basin to aquifers; supporting river flow; maintaining surface water features) to ensure availability for further use or for ecological benefit.	Regenerate natural systems

The next step for WP7 is the development of a suitable framework that will provide the structure for the user collaborative platform for Project Ô. Elements identified through this deliverable will be taken forward into the design of this platform and for specific engagement with the demonstration sites and other partners within Project Ô.