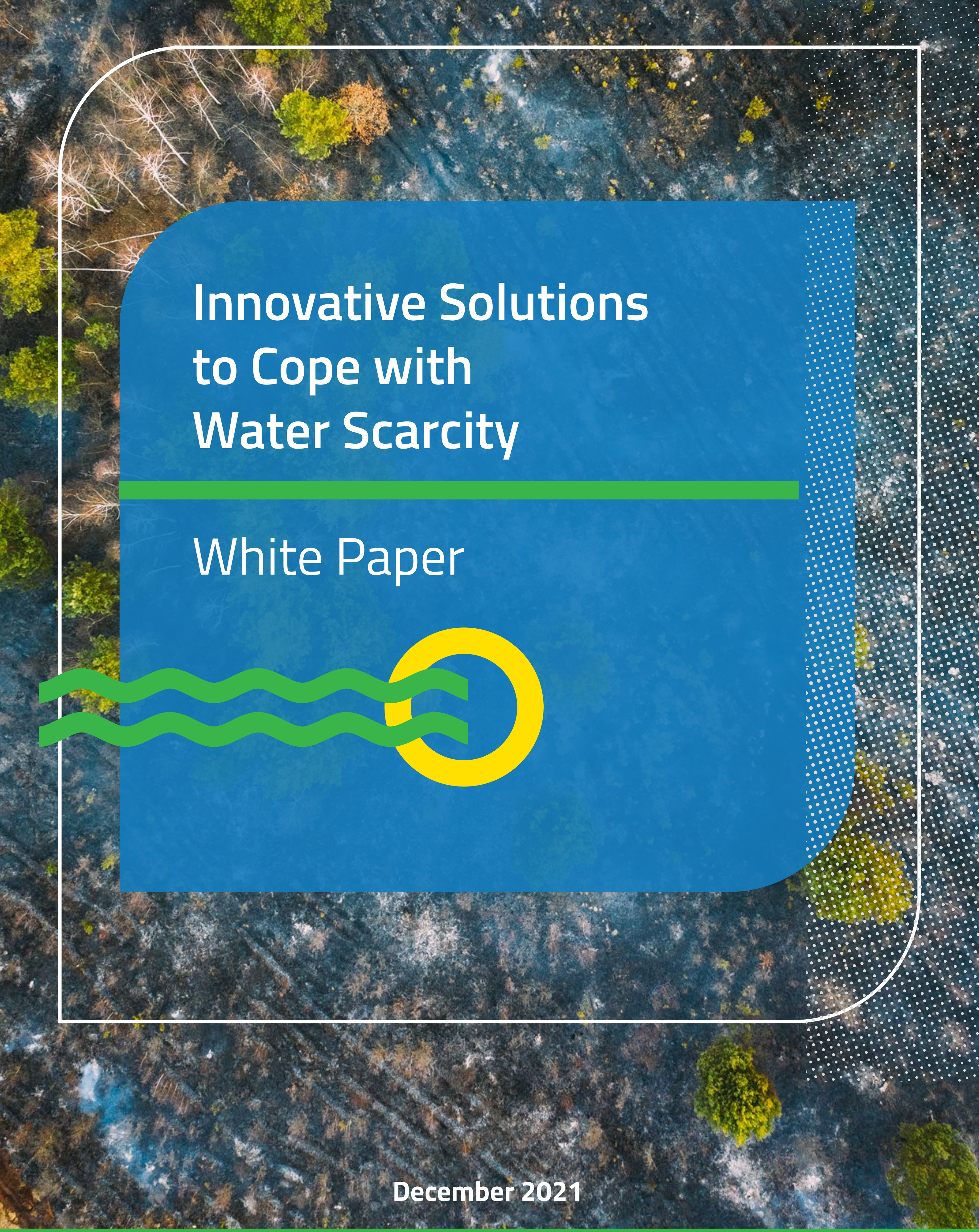

Innovative Solutions to Cope with Water Scarcity

White Paper

December 2021

EIT Water Scarcity

Funded by the European Union

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FOREWORD

Dear Reader,

Thinking over the past years: would you say your region is suffering from water scarcity? As a citizen, have you ever experienced limitations over water use for irrigating your garden? As a farmer, are you struggling to maintain production and income due to water shortages? Or maybe you are part of the water authority in the region, and you are in a delicate balance to allocate the available resources in the region for the different economic activities?

Water availability is a key challenge in Europe, especially in the Southern region although not limited to it. Millions of people are already affected, and much more will be in the following years as water scarcity is forecasted to increase, posing a risk to the socioeconomic development of the region.

It is time to act. The reallocation of water resources and limitation in its use for certain activities have not always been well received by different stakeholders. A holistic and dynamic approach to water resources' management must take into consideration all the stakeholders involved, from policy makers to farmers. And what is more, it must consider the full water cycle, from water extraction and allocation to its use, reclamation, reuse and discharge. This systemic change is needed to respond to the ever-evolving challenges posed not only by climate change, but also by the growing population and changes on socioeconomic dynamics.

Therefore, this paper is for you and for me: whatever we do and wherever we are. It is for water managers, water users, legislators, the scientific community, and our society in general. All stakeholders.

This paper aims at unlocking water governance in Europe. Innovative and effective water-related solutions are available to foster climate change readiness, including relevant services that can enable a more integrated water management planning across Europe. But their adoption must be on many occasions coupled with new and disruptive water governance schemes.

Here you will find a compilation of potential solutions to tackle the most acute challenges for Europe's stakeholders to create a water-saving and long-lasting sustainable economy. Of course, in an ever-evolving environment, solutions shall be adapted over time as new needs and new solutions arise. And that is why a systemic cross-cutting approach towards water scarcity is a must.

As a society, we do have the responsibility to share solutions and best practices for a more sustainable use of water-resources. Are you willing to contribute to the transformation?

Carmen Galindo,
Project Manager, EIT Food

EXECUTIVE SUMMARY

Water management solutions and technologies from the past no longer offer adequate solutions. Water scarcity has been exacerbated in the last decades because of increasing pressures such as unsustainable water abstraction, pollution of water bodies, the effects of climate change and inadequate water planning. Water crises are becoming more frequent and acute, and the risk is increasing affecting not only to traditional dry regions such as the Mediterranean but also to more water abundant regions. This new context requires an innovative approach built on existing knowledge and experiences.

The purpose of this White Paper is to propose innovative solutions to cope with water scarcity in southern Europe as a response to 5 main challenges, described in Chapter 2 as:

1. **Water pollution**
2. **Limited spread of circular economy options and practices**
3. **Restrained optimisation of water management through water-smart tools and solutions**
4. **Mismatch between water demand and supply**
5. **Suboptimal governance and financial schemes to tackle water scarcity**

In **Chapter 3** we present different solutions and technologies which have been applied in different contexts. These experiences are a collection of good practices to guide further implementation and include economic instruments, natural water retention and recharge measures, water reuse, water conservation measures in irrigation, use of alternative water sources, nature-based solutions, control of water abstraction, cap water rights and reduction of food waste.

All of the solutions proposed emphasise the role of good governance as an essential building block to ensure their success. Sound governance is crucial to adequately plan, efficiently implement, evaluate and monitor policy strategies and sustainable operations. Innovation oriented policies may provide incentives for companies, foster cooperation and knowledge sharing among innovators and help reduce market barriers.

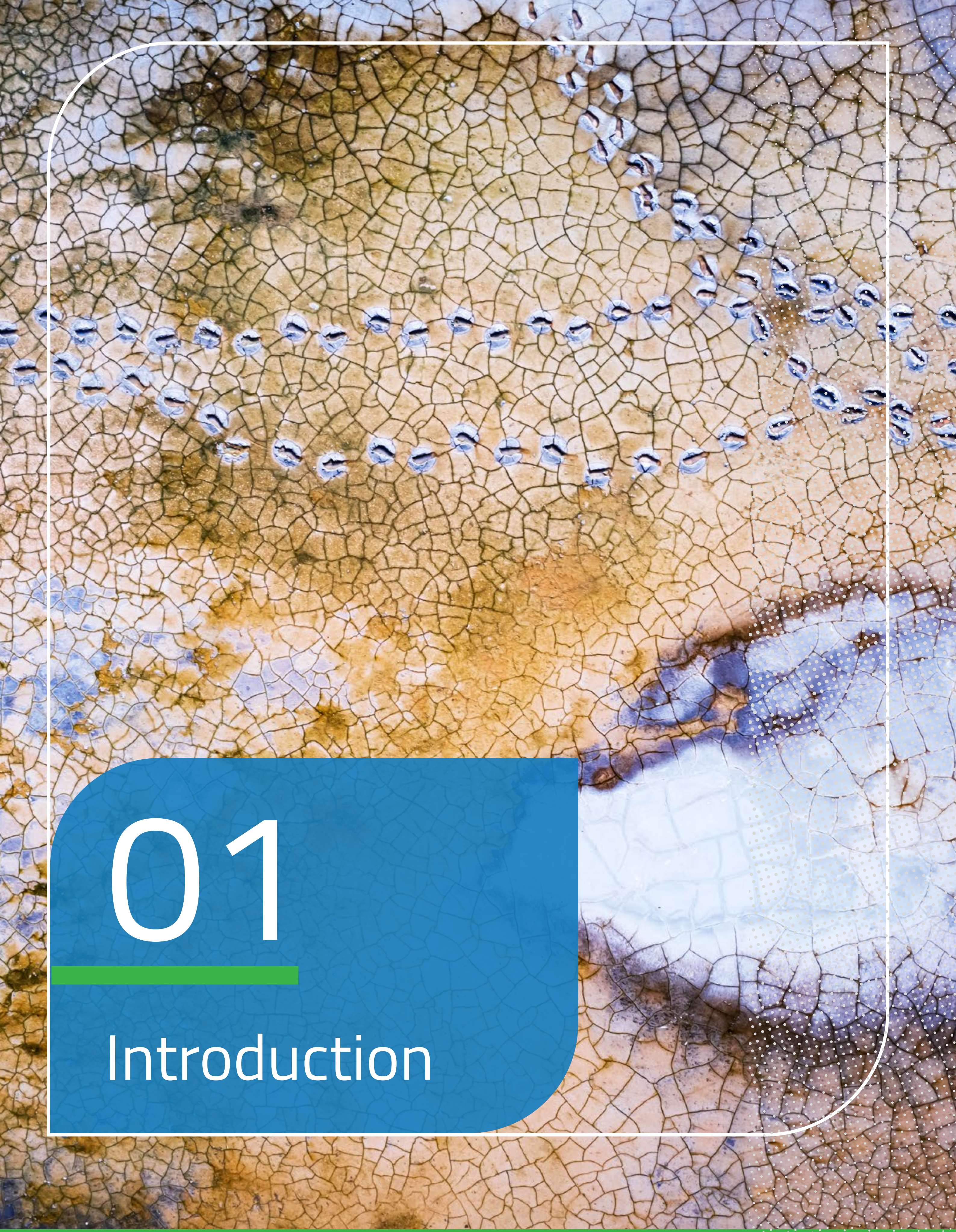
Chapter 4 includes a set of recommendations with practical proposals oriented to facilitate the implementation of the different solutions described in the previous chapter. These recommendations intend to also serve to support the implementation of European Union Directives and Regulations which require further policy development by Member States.

Chapter 5 returns back to the Challenges and analyses potential long-term impacts of solving these challenges with their environmental and socio-economic implications.

Water scarcity can be alleviated by the reduction of water pollution, the reuse of water in irrigation advancing towards a more circular economy, the improvement of the profitability of investments in water technology, or by the reduction of food waste, allowing to reach the targets of EU policies.

Water resource management can benefit from the use of new monitoring technologies to reduce waste and to mitigate the gap between water demand and availability allowing the re-design of farm processes with greater involvement of interested parties. This would allow the combination of water supply and demand to adapt to seasonal and structural imbalances, implementing innovative protocols and using international regulatory tools for the integrated planning of water resources. Governance and financial schemes can effectively address water scarcity by implementing control over water abstraction, increasing lawful uses of water, and investing in metering, monitoring and control devices.

Our White Paper confirms that water scarcity is a complex challenge with no silver bullet solutions. However, we aim to contribute with our selection of solutions to the design of complex and systemic solutions are needed with multistakeholder collaborations and the integration of adequate governance and financial schemes that complement EU policy framework.



01

Introduction

PURPOSE OF THE WHITE PAPER

The White Paper aims to share today's understanding, innovations, experiences and knowledge in addressing water scarcity in southern Europe with water managers, water users, stakeholders and legislators.

Water scarcity is dynamic: it has been exacerbated in southern Europe and is extending towards a broader area and for a longer duration, due to ever-increasing water consumption, changing societal values and climate change.

Consequently, the solutions must be different. 50 years ago, water scarcity was addressed by building new dams or an inter- basin water transfer, increasing water supply. Today, solutions to increase the water supply – such as the reuse of treated wastewater, managed aquifer recharge and desalinisation - are more costly and complex. In addition, actions to increase the control of water use, improve efficiency and cost recovery and others have emerged over the past years.

The work reported therein is the result of the [Finding innovative solutions for water scarcity in Southern Europe programme] led by EIT Food, with the collaboration of EIT Climate-KIC, EIT Manufacturing, EIT Digital, Bioazul and Athena Research Centre. The objective of this programme is to enhance knowledge and overcome current barriers to tackle water scarcity in Southern Europe through innovation, entrepreneurship, education, and communication. In 2020 the programme established the Body of Knowledge (BoK) expert group comprising of renowned experts across Europe specialising in water scarcity from governance, technology, and financial perspectives. In 2021 the BoK was tasked with delivering a White Paper and a Mapping of Financial Tools to tackle water scarcity. This White Paper describes the main challenges (2- Challenges) in tackling water scarcity identified by the BoK, describing the main causes, data, impacts, focus areas, knowledge gaps and priorities. It also presents innovative solutions, assessing their strengths, weaknesses, lessons learned from case studies and the need to rely on a robust policy framework, including governance.

PROBLEM DEFINITION

Water scarcity is the scenario where the water demand is higher than available supply. This scenario may cause overexploitation meaning more water is used than what is available. Many regions in Southern European countries are already suffering from it, and the risk of occurrence is increasing and extending to more water abundant regions. Scarcity is defined by long term planning (multiyear) and is different from drought which is a seasonal or multiyear underaverage precipitation. However, during drought periods, water availability is reduced, and often the water scarcity increases, when water uses remain stable or even increase.

Scarcity is therefore driven by the existing and unsatisfied freshwater extraction for economic uses such as agriculture (by far the main user of freshwater resources), industry and urban supply, as well as by increasing societal environmental concerns, given there are higher amounts of water being allocated to preserve ecosystems. The pressure on water resources is further exacerbated by climate change and urbanisation.

While there are solutions to reduce pressure on water resources, current fragmented water governance is a major barrier for wide application of available solutions. Water scarcity is a result of poor governance.

This report has been prepared with reference to relevant EU regulation and policies, including the European Green Deal and the EU Biodiversity Strategy for 2030, the Zero Pollution Action Plan and the Climate Adaptation Strategy, as well as the Water Framework Directive (WFD) and its conceptual DPSIR approach (Drivers-Pressures-Status-Impact-Response). Furthermore, it considers the 2030 Agenda for Sustainable Development, adopted by all United Nations Member States in 2015 and its Sustainable Development Goals (SDGs; sdgs.un.org/goals) whenever relevant.

OUR APPROACH

This report is divided into four main chapters.

2- Challenges chapter provides an overview of the water scarcity challenges Southern European face, looking into the reasons why water scarcity has not been tackled yet. In this report we will refer to water pollution; limited spread of circular economy options and practices; restrained optimisation of water management through smart tools; mismatch between water demand and supply and suboptimal governance and financial schemes.

3. Solutions chapter presents a selection of innovative solutions to tackle water scarcity that are particularly well fitted for Southern Europe. In this report we consider full cost recovery implementation; nature-based solutions and Hybrid Grey-Green infrastructure; water reuse implementation; water conservation measures in irrigation; innovative alternative water sources; control and enforcement of water abstraction; cap water rights in overexploited basins and aquifers; global view - Reduce food waste. For each of these solutions you will find a concise definition and an analysis of strengths, weaknesses, lessons learned and policy frame.

4- Policy recommendations chapter presents short policy briefs for each of the solutions described in the previous section, offering concrete policy recommendations to enable the successful implementation of the solutions proposed in this White Paper.

5. Potential impact chapter highlights the positive outcomes we envisage the solutions can have in terms of alleviating the challenges identified in this paper.

02

Challenges

Water covers almost 70% of our planet but freshwater represents only 3% of the overall amount of aquatic resources available (Shiklomanov, 1993). Not surprisingly, water scarcity is present in all continents and poses a number of water stress challenges to (i) the scientific community as knowledge and innovation providers; (ii) policy makers, responsible for the implementation of best available measures, especially in emergency conditions; (iii) economic actors, as the main beneficiaries of water for different uses (for example agriculture, industry, tourism); and, (iv) society in general, which must adapt the use of water resources to existing circumstances.

This chapter gives an insight into the main water scarcity challenges in southern Europe. Challenges are defined in this context as any force leading to a situation of water scarcity (or even water scarcity aggravation). The challenges considered in this chapter were identified by members of the BoK on the basis of their knowledge and hands-on experience in the region.

Water scarcity is driven by four main factors:

1. climate and its seasonal variability;

2. water dewmand, largely driven by population growth/ population density and water use for different economic uses, for example agriculture, tourism;

3. the poor implementation of sustainable water management plans/ strategies; and

4. water quality conditions, as barriers to water consumption for different uses.

All the challenges described below result from the complex interaction of these factors and call for technological, institutional and educational solutions that consider the needs and preferences of local stakeholders. Such solutions are thoroughly described in the following chapter.

THE **FIVE MAIN WATER SCARCITY CHALLENGES** IN THE SOUTHERN REGION IDENTIFIED BY THE BOK ARE:

1. Water pollution, caused by the accumulation of contaminants from agricultural, urban, industrial and mining activities in both surface and groundwater and the limited treatment of wastewater

2. Limited spread of circular economy options and practices, which offer possibilities for the treatment, recycling and reuse of water and water-associated resources for different usages

3. Restrained optimisation of water management through water-smart tools and solutions despite the technological breakthroughs achieved over the last few decades

4. Mismatch between water demand and supply, which not only causes the insufficient availability of water resources for specific uses but also potential conflicts between economic sectors or social communities

5. Suboptimal governance and financial schemes to tackle water scarcity

For the sake of clarity, the description of all these challenges has been structured similarly. As depicted in Figure 1, the information given in the following lines will provide a good understanding of the current state of southern European waters in relation to each of the challenges selected, drivers or causes of each challenge, and the main environmental and socioeconomic impacts.

To illustrate the current situation in certain southern European areas, a few examples (case-studies) are included. A final section focuses on the actions already taken, or potentially available, for addressing each of the challenges specific scientific issues that should be tackled in the future through Research, Development and Innovation (RDI) activities to revert the current situation.

Why this challenge?	▪ Outline of the main causes triggering each challenge and for which quic actions are needed in order to reduce the risk of water scarcity exacerbation.
What is the current state?	▪ Description of the context. ▪ Provision of data (qualitative or quantitative)
Who is mainly impacted?	▪ Analysis of the main environmental and socioeconomic impacts as a result of existing challenges.
Where are challenges taking place?	▪ Examples of areas where challenges are of special magnitude and where specific solutions have been applied.
How can challenges be overcome?	▪ Knowledge gaps/ priorities that should be addressed in the future in order to overcome this challenge

Figure 1: Questions addressed by the Challenges chapter

Although all these challenges have their own specificities in terms of incidence and impacts across southern European regions, all of them have a common feature – the role of good governance in their proper management and in the implementation of solutions.

For the purpose of this paper, and building on the work of the Organisation for Economic Co-operation and Development (OECD) and the United Nations Development Programme, the BoK describes water governance as a concept that refers to the political, social, economic and administrative systems that determine the use and management of water. Thus, good governance is a global concept that encompasses:

1. the clear definition of roles and responsibilities of all actors in charge of, or affected by, water management plans
2. policy coherence so that different sectoral policies go in the same direction and commonly seek water protection and restoration
3. the existence of regulatory frameworks and financing tools for the funding and long - term financial sustainability of solutions
4. the availability of data and information, as enablers of water strategic decisions
5. social participation to ensure the involvement of stakeholders in the co-design and adoption of best available solutions/ water management plans
6. capacity building/ capacity development to enable all actors to become engaged in water management and/ or improve their management capacities through, for instance, the adoption of innovative supporting tools, enhanced education, and knowledge and technology transfer

Given the importance of good governance in water management in general, and water scarcity in particular, the following section focuses on specific governance issues that need to be addressed to combat and adapt to water scarcity in southern Europe more efficiently. Subsequent pages describe in detail the five main challenges identified by the BoK.

THE ROLE OF GOVERNANCE IN MANAGING WATER SCARCITY IN SOUTHERN EUROPE

Water scarcity is not just a physical phenomenon. It is mainly a governance issue (OECD, 2008). It requires all actors participating in water management to adequately plan, efficiently implement, evaluate and monitor policy strategies and sustainable operations. Sound governance is essential not only in water scarcity management, but in attaining the SDGs. The following paragraphs describe specific areas where further progress is needed in order to improve the governance of water in southern Europe. Many of the areas are not specific to idiosyncrasies of southern Europe, which also make them applicable to northern Europe.

The WFD is Europe's forefront legislative instrument for the protection of European waters. Evidence shows that, even though much progress has been made in improving water quality all over European river basins, EU Member States have failed to achieve WFD's objectives because of, amongst other issues, implementation challenges.

Good governance is driven by the clear definition of the roles and responsibilities of different authorities in water management. Each Member State must ensure appropriate administrative arrangements, including the appointment of competent authorities, whilst promoting cooperation and shared responsibilities in planning, risk assessment and the management of conflicts of interest (Green et al., 2013). Inputs from the European Commission reveal that the administrative and territorial reforms in southern

European countries (for example France and Italy) over the last few years have resulted in the creation of new authorities, leading in some cases to legal uncertainty, the loss of administrative know-how and the poorer implementation of the WFD (European Commission, 2017a). The decentralised nature of the WFD implementation allows Member States flexibility in developing scale -specific water management strategies, which calls, at the same time, for stronger coordination at river basin scale.

Coordination at the international scale is lacking as well. Despite the existence of international coordination mechanisms, only a few Member States have reported using them in transboundary river basins. Water-oriented Living Labs (WOLLs) enable the testing and validation of water management options and solutions through the involvement of stakeholders. Further deployment of WOLLs would allow a better understanding of responses of aquatic ecosystems to different policy options[1].

The WFD institutionalises participatory processes in river basin planning across the European Union. Projects involving participatory approaches have revealed that participation facilitates raising awareness around the state of water and water solutions, resolving conflicts and enabling policy results. However, studies report that the success of participatory approaches in water management is determined by the level of ownership of the process by stakeholders and the clear articulation of social interests. Participatory approaches are therefore more efficient if i) stakeholders are fully engaged, and ii) individual interests are substituted by commonly agreed interests defined by all stakeholders concerned. Social science research suggest that these two conditions are usually not met in southern Europe (Kallis et al.,2006).

Other than human consumption, water offers a wide variety of uses for different sectors ranging from irrigation, hydropower, leisure activities, biodiversity maintenance, to industrial production. Water is thus within the scope and competences of many policies. Policy coherence and alignment is needed as policy decisions made in one sector can have significant impacts on other sectors.

Policy coherence is particularly required between the WFD and the following pieces of legislation/ EU strategies: Common Agricultural Policy (CAP), the European Green Deal, the Circular Economy Strategy, the Climate Change Policy, and the Rural Policy. **Such coherence is also needed at the implementation phase, which has proved relatively weaker at national, regional and local levels. This has led to conflicts in policy implementation both vertically between different administrative levels and horizontally between sectors.** Greater policy coherence can only be built if policy inconsistencies are remov ed and relationships between different actors across sectors and levels of governance are developed.

A specific example of policy incoherence is that of Regulation (EU) No 1307/2013 on greening measures, which does not directly address water issues. Another relevant example is the Spatial Planning Policy. The EU has no jurisdiction over this matter. It belongs, in most cases, to the regional or local authorities. Too often, these authorities decide to install tourism or other enterprises with a relevant demand for water in areas where it is scarce, causing a serious deficit of the resource, especially during vacation times and in the summer.

In addition to regulatory measures enabling compliance with environmental standards for water quality and quantity, **regulatory frameworks are as well required for untapping the potential of European innovation in the water market.**

1 For more information see: https://watereurope.eu/water-oriented-living-labs/

EU innovative water solutions often fail to reach their full economic potential because of limited access to appropriate forms of finance, or the lack of frameworks for the protection of the economic and intellectual value of European innovations. Similarly, the market uptake of innovations is usually hampered by limitations in education and communication/ dissemination. As described under Challenge 3, the adoption of digital innovations struggles to find real applications and market uptake in southern Europe. his results in low productivity growth and inefficient management (Schivardi and Schmitz, 2019).

In this context, the BoK recommends future water rese arch and innovation programmes to:

1. **explore regulatory, administrative, organisational, education and management conditions that better contribute to removing barriers to innovation and to strengthening the competitiveness of European innovation hubs;**
2. **develop approaches to reduce the time between the initial demonstration of innovations and their real market uptake;**
3. **favour knowledge transfer to enable the diffusion of key lessons and practices in the marketing and commercialisation of products; and,**
4. **identify opportunities for the creation of new financial mechanisms for an innovative water sector.**

A final issue to consider is the availability of data and integrated systems for the monitoring, evaluation and forecasting of water systems. Integrated systems, such as Decision Support Systems (DSS), have proved useful in guiding decision making by providing a good understanding of impacts following the implementation of different types of measures. Different tools are currently available for data collection including satellite observation, sampling or the analysis of historical databases. However, citizen science has acquired a prominent role in the compilation of data. Citizen science not only enables the acquisition of data that might not be amassed through other instruments, but it also facilitates the public acceptance of proposed measures.

The functionalities offered by artificial intelligence and data networks should be further unlocked whilst improvements are still required in the fields of **standardisation, interoperability as well as the free and open access to data.** Finally, the opportunities provided by water related research infrastructures and networks of infrastructures should be further seized.

The description above shows that governance is not only about policy conception and evaluation. It is also about the participation of and sharing of responsibilities across actors, policy coherence across sectors, data availability. **The analysis of literature reveals that southern European countries need to make a special effort in the implementation of regulatory frameworks enabling the adoption and widespread use of innovations, the participation of citizens in policy processes and the clear definition of roles and responsibilities in water management.**

Setting the context: current state

The protection of water resources has been a priority for European countries, and southern European countries in particular, since the late 1970s ("Water JPI SRIA 2.0," 2016). Concerted actions resulted in the adoption of the Water Framework Directive (WFD 2000/60/EC), which is the main policy framework for the protection of water resources, the Urban Waste Water Directive (91/271/EC) and the Nitrates Directive (91/676/EEC).

As illustrated in **Figure 2**, the WFD requires Member States to achieve a good ecological and chemical status for surface water bodies and the good chemical and quantitative status for groundwater. A first target was set for 2015 and further deadlines are fixed for 2021 and 2027. The **ecological status assessment** looks at the quality of the structure and functioning of surface water ecosystems (EEA, 2018a) whereas the **chemical status assessment** analyses if the concentration of specific pollutants is exceeded beyond quality standards.

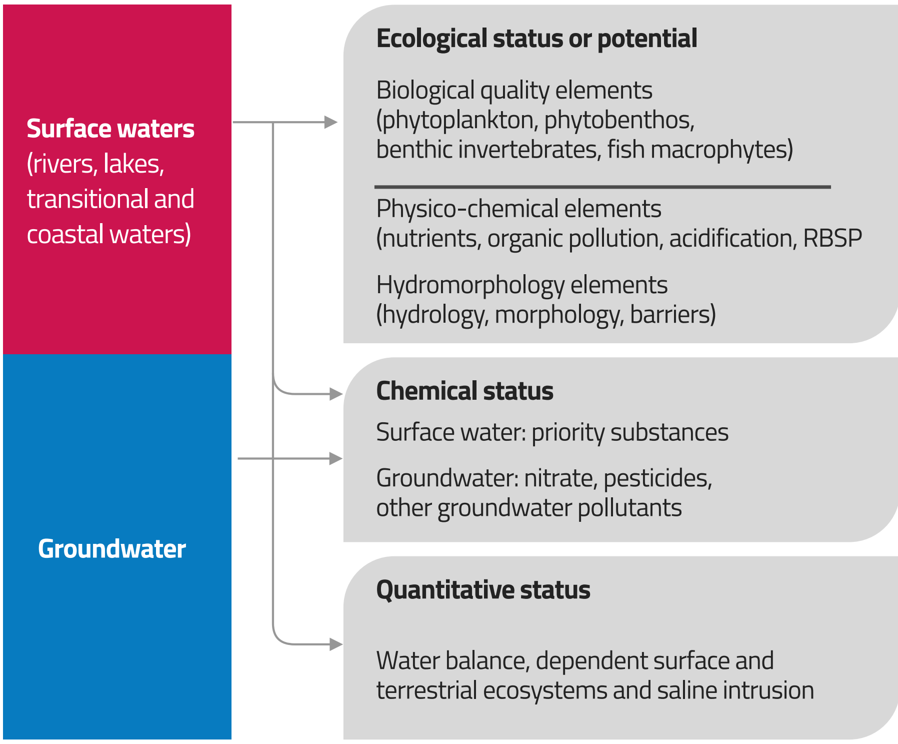
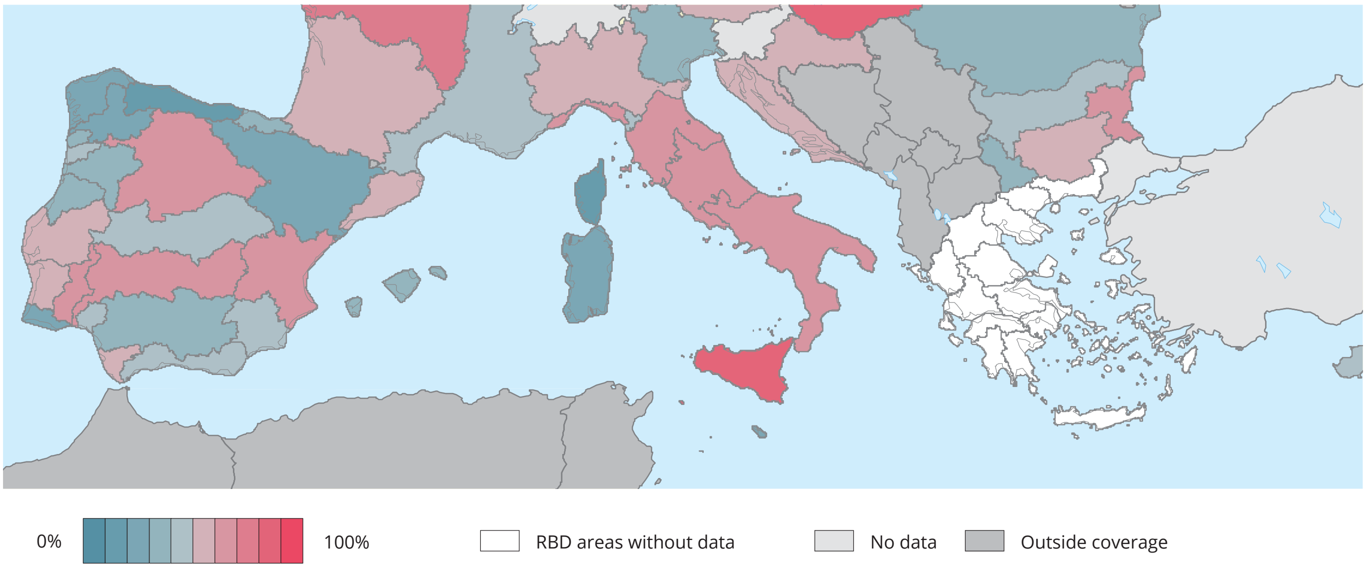


Figure 2: WFD criteria for water quality assessment, Source: (EEA, 2018a, p. 13)

Quality of surface waters in southern Europe

As shown in Figure 3, the percentage of surface water bodies not in good ecological status is above 50 per cent in river basins from Southern Portugal, Central Spain, Southwest France, Italy, Croatia and Bosnia Herzegovina.



Map 1: Percentage of water bodies not in good ecological status or potential per river basin district (RBD) in second River Basin Management Plans (RBMPs), Adapted from (EEA, 2018a, p. 26)

Data from the review of the second RBMPs indicate that progress has been made in improving the **chemical status of surface water bodies in southern Europe (Figure 4).**

It is still a major concern in Malta and Slovenia (with reservations with Portugal and Italy, as the lack of data does not allow the drawing of clear conclusions).

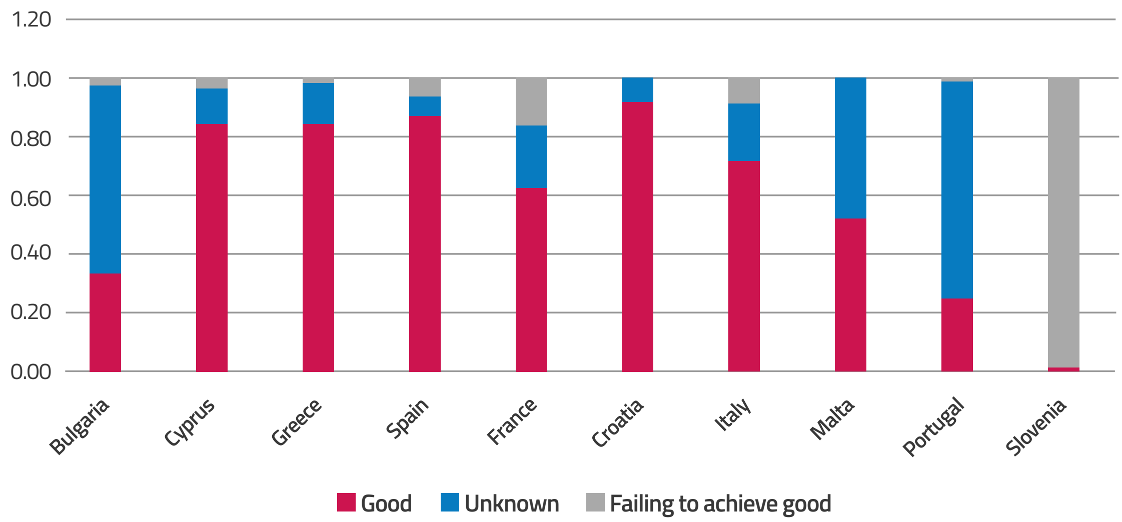
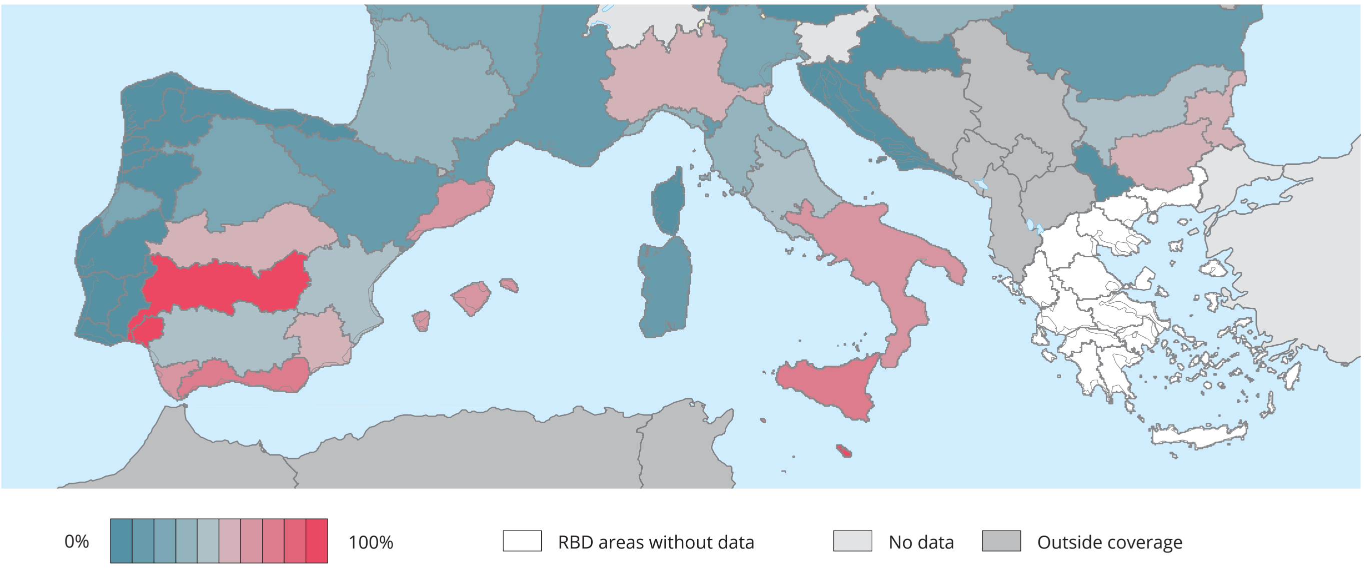


Figure 3: Percentage of water bodies not in good ecological status or potential per river basin district (RBD) in second River Basin Management Plans (RBMPs) considering all priority substances, Adapted from: (EEA, 2018a, p. 42)

Quality of groundwater in southern Europe

Groundwater chemical status is better in general terms than that of surface waters. However, poor chemical status is reported in a number of areas in Spain, France and Italy (Figure 5). It should be noted the unavailability of data from numerous areas in Eastern European countries.

As regards the quantitative status, the proportion of groundwater hydrogeological units reaching good quantitative status is less than 50 per cent in Cyprus and Malta. This figure is between 75 and 100 per cent in Croatia, Portugal, France, Spain and Italy.



Map 2: Percentage of area of groundwater bodies not in good chemical status per river basin district (RBD) in second River Basin Management Plans (RBMPs), Source: (EEA, 2018a, p. 51)

Why is water pollution a real challenge in southern European countries? Analysis of causes

Water quality is influenced by direct point sources (for example wastewater treatment, industrial discharge) and diffuse pollution (for example agriculture, atmospheric depositions, industrial emissions). Key pollutants from both sources include nutrients, pesticides, sediment and faecal microbes and hazardous chemicals (EEA, 2018a). Recent assessments of the European Environment Agency (EEA) reveal that agriculture exerts the most significant pressure on Southern European surface water bodies and groundwater (EEA, 2018a). Advances in precision agriculture allows more efficient fertilising of irrigated areas, which account for a high proportion of agricultural production value in several countries (although area occupied by irrigation is lesser than rain fed). Breakthroughs are still needed in the control of chemical inputs in rainfed areas and, to a lesser extent, in irrigated land.

A second driver of water pollution in southern European countries is excessive water abstraction for different uses (e.g. agriculture, industry, energy production, tourism, households), which can greatly exacerbate the impacts of water scarcity. Abstraction can worsen water quality by reducing the capacity of water bodies to dilute pollutants. Similarly, water abstraction from coastal aquifers can generate the intrusion of saline water and soil sealing, in turn responsible for the washing of pollutants to nearby water bodies during episodes of heavy storms (EEA, 2009). Wetlands or wet ecosystems are also damaged by uncontrolled water abstraction, resulting in the lowering of the water table.

The dilution capacity of water bodies is also impacted by the effects of climate change, which has so far translated into more frequent and longer drought periods.

The proportion of the population connected to urban wastewater treatment in southern Europe is still relatively low compared to central and northern Europe (EEA,2017). The absence of urban wastewater treatment systems results in the presence of pollutants in water bodies, putting both human and ecosystems health at risk.

Addressing the strong nexus between water, climate, energy and food is essential to reduce water pollution and achieve the objectives of the European Green Deal, the Water Framework Directive and the Sustainable Development Goals (SDG6, in particular).

Impacts of water pollution

Impacts from water pollution are many and diverse including the deterioration in the ecological quality of aquatic ecosystems, threats to human health, high water treatment costs, and lower availability of water resources for human consumption or agriculture use. High concentrations of nutrients (nitrates and phosphates), organic matter and heavy metals constitute a real challenge that Member States have to face through pollution control at source and enhanced water treatment capabilities. Moreover, the presence of emerging pollutants, for example nano plastics and pharmaceutical products, pose new questions to the scientific and policy communities, water utilities and industries.

New economic developments, for example tourism intensification in certain areas or the establishment of new pharmaceutical industries, are expected to exacerbate water pollution through, for example, the accumulation of phosphates or the higher accumulation of antibiotics in water systems.

Water pollution affects all groups of society although water for human consumption and agricultural production will be more likely impacted. Indeed, stringent regulations exert a strong control on quality parameters for drinking water and food quality.

A CASE-STUDY OF WATER POLLUTION:
MALTA (NEW WATER PROJECT)

Malta's groundwater and surface water are some of the EU's most polluted by nitrates, according to data from the European Commission (European Commission, 2018). In Zebbug (Gozo), nitrate levels are more than six times the acceptable levels. The situation is similar in Xaghra and in the coastal area of Pwales. Longstanding efforts have been made by the Maltese authorities to rectify the problem. National measures, such as balanced fertilisation and sustainable manure management, continue to improve , but in sectors like horticultural production the use of nitrogen-based fertilisers is still high. Likewise, the biogas industry and the intensification of livestock production constitute real threats to water pollution in Malta.

The tertiary and quaternary treatment process – Membrane Filtration (Removal of Bacteria and Solid-Associated Contaminants), Reverse Osmosis (Removal of Dissolved Contaminants) and Advanced Adsorption or Oxidation (Removal of Remaining Pollutants) – as well as Nature-based Solutions (NBS) offer clear possibilities for water pollution reduction, wastewater reuse and groundwater recharge for which case -by-case sustainability should be evaluated.

How to deal with water pollution

Reducing water pollution has been a key objective for numerous EU research and innovation projects. Recent projects have focused on pollutants of emerging concern (monitoring, removal, upstream management). Amongst others, we should consider the SOLUTIONS Project and the MARS Project. Results from both projects have resulted in the elaboration of numerous policy briefs and guidance documents, and they have allowed the development of a better understanding of the behaviour of emerging pollutants and multiple stressors, respectively.

Aquatic pollution has also been the object of two Water JPI calls in 2013 (first call) and in 2020.

Despite the efforts made by previous interventions, the analysis of water pollution data and drivers in southern Europe highlights some specific scientific, policy and management knowledge and practice gaps that should be addressed in the future before the scale of water pollution aggravates, including:

- Enhancing monitoring and understanding of pollution sources, processes and fate in order to attenuate the impact of anthropogenic activities on water resources. The development and implementation of smart water quality monitoring tools should be promoted by seizing the opportunities provided by digital technologies, artificial intelligence, Earth observation and innovative visualisation tools.

- Enlarging wastewater treatment and reduce pollutants' discharge to surface water bodies. More cost-effective, less energy dependent and low-carbon footprint technologies are needed to ensure the rapid reduction and control of pollutants (including AMR products). NBS for the control of pollutants of emerging concern (CEC) should be further promoted and deployed.

- Widening the adoption and deployment of approaches, methods and tools enabling the protection and/ or restoration of water, aquatic ecosystems (and ecosystem services) at large scale, and filling the information gap between problem holders and solution providers. From a land-to-sea perspective, the impacts of anthropogenic activities on coastal and transitional water and ecosystems need to be further considered, for example saltwater intrusion.

- Exploring hotspots and possible mitigation options for water pollution by implementing Life Cycle Assessment (LCA) analysis in line with International Organization for Standardization standards.

- Developing tools for better estimating and predicting the environmental impact connected to water pollution in real time.

- Strengthening the implementation of national and international regulations to better protect downstream countries and their ecosystems from upstream induced pollution. Water challenges in transboundary water management should be better understood and cooperation opportunities should be further exploited.

- Progressing in the acceptability of reclaimed water reuse for different purposes.

- Aligning EU water policies to international and regional efforts (Mediterranean) for sustainable resource use (SDGs and the UN Agenda to 2030).

CHALLENGE 2: LIMITED SPREAD OF CIRCULAR ECONOMY OPTIONS AND PRACTICES

Setting the context: current state

In 2017 the UN World Water Development Report was entitled 'Wastewater: The Untapped Resource' demonstrating how improved wastewater management generates social, environmental and economic benefits essential for sustainable development and to achieving the 2030 Agenda for Sustainable Development.

In 2019 the relationship between principles of circular economy (1- Designing out waste externalities; 2- Keep resources in use; 3- Regenerate natural capital) and sustainable water management was explored by the 'Water and Circular Economy: A White Paper' by professionals from industry, academia and water utilities (Tahir et al., 2018). Here, the dimensions of water as: service (consumptive use, production use, process use); carrier (nutrients, chemicals, minerals) and source of energy (kinetic, thermal and bio-thermal) were considered in human- and nature-managed systems, while the water system is a sub-system of a 'System of Systems', which includes the environmental systems, agricultural systems, industrial systems and municipal systems. To demonstrate the maturity of the possible solutions, eight featured case studies have been reported, while phase 2 of this work (future) includes consolidated framework activities to go from niche to widespread application and market uptake. However, to date, circular economy principles in water scarce areas are not properly addressed or focused. In general, arid lower plains are associated with ecosystem services having potentially high value. Here water reuse would be a key measure and solutions that provide alternative water sources would be suitable for specific cases to be singularly analysed at local, regional and catchment scale.

Safe and secure access to water, while exploiting and preserving its full value, has an increasingly fundamental role as a way to a resilient and sustainable circular society (drafted by value in Water Vision Leadership Team, Water Europe, 2021), particularly in water scarce and water stressed regions.

However, water systems are still widely managed by the Take- Use-Discharge approach, against the Circular Economy Principles of (1) Design out waste externalities; (2) Keep Resources in Use; (3) Regenerate Natural Capital (Tahir et al., 2018).

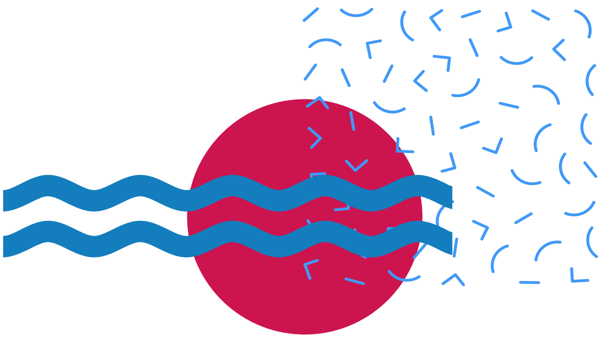
The value in water should be consolidated and promoted through its efficient use and safe reuse. This approach can also recover and valorise energy and materials embedded in raw and used water streams. It is important to bear in mind the role of digital tools and nature -based solutions to achieve circular objectives and monitor key performance indicators. In addition, many water utilities are considering circular economy as a main pillar of their sustainability strategy.

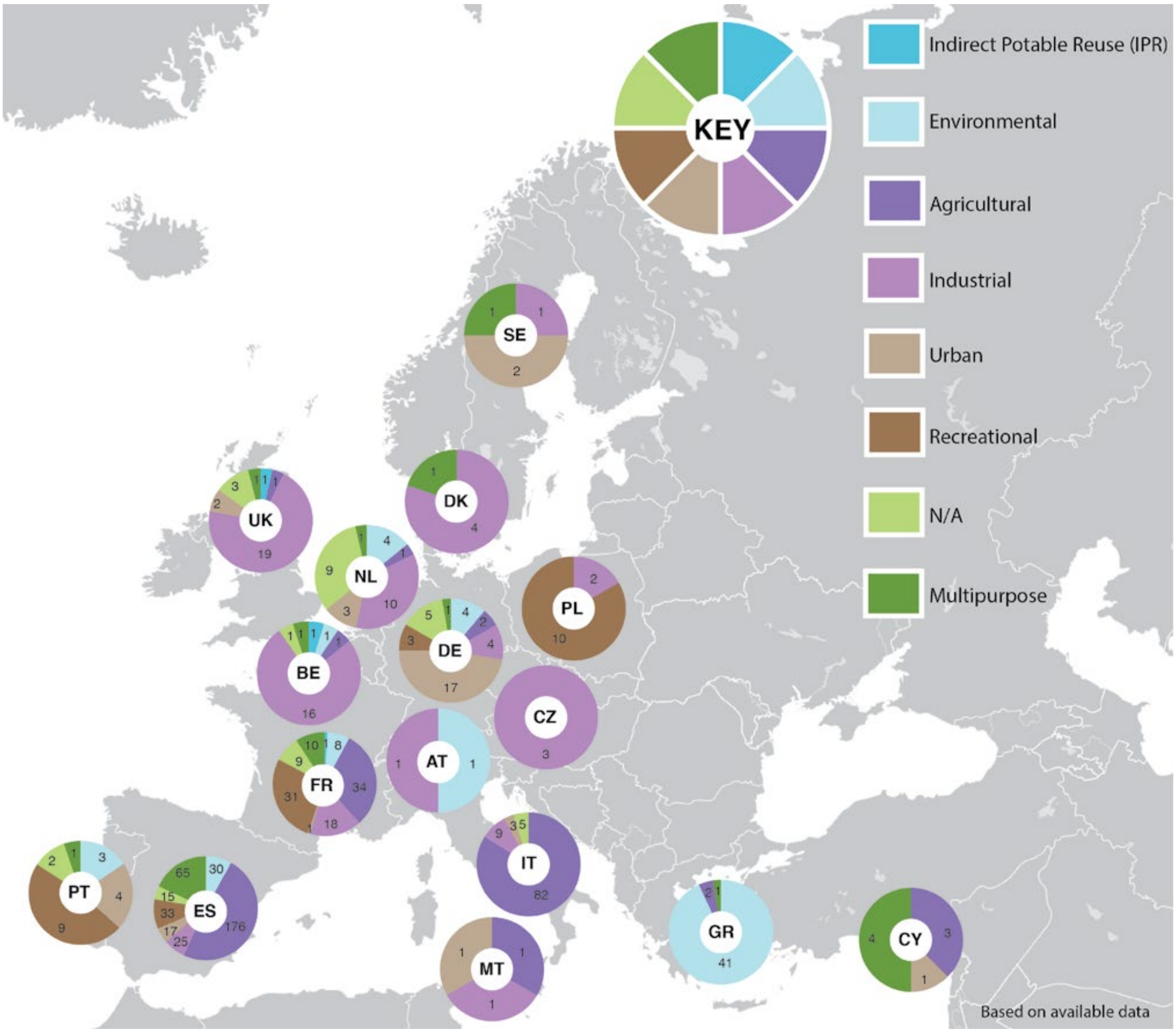
The Mediterranean area is one of the world's most vulnerable areas for environmental stress (Malagó et al., 2021) . The construction of circular economy scenarios through specific territorial contexts and resource flows, considering the Water–Energy–Food-Ecosystem (WEFE) nexus in a place-based approach, may provide practical pathways toward the desired future of Europe's circular economy and bioeconomy. In fact, the use of circular economy in water systems intrinsically calls for WEFE nexus approach, linking the nexus components (water, land & soil, energy, food, climate, ecosystems, waste). For example, food waste **(estimated in 20% for EU) implies wasted resources (land, water, inputs) contributing to resource depletion and climatic change.** By reducing food waste, water scarcity will then be reduced. Communities which have established critical interdependencies and developed partnerships between the water-related sectors are more resilient and better equipped to respond to, and recover from, water resource crises. The Water-Energy-Food-Ecosystem (WEFE) Nexus concept is critical for achieving adequate resource security for all while preserving the natural environment (Bidoglio et al., 2019).

Finally, in new concepts of circular cities and regions the wastewater treatment plants are considered water resource recovery facilities which can become circularity hubs, integrated in water and bio-based materials value chains (for example CircularAmsterdam).

According to Water Reuse Europe, the global market for water reuse solutions has grown significantly since the early 90s, when less than 1 million m^3/d of reuse plant was installed annually, to 7 million m^3/d installed capacity during 2017. Development is projected to continue to expand to over 10 million m^3/d by 2022. Industrial use followed by irrigation (for agriculture and landscape) are still the largest global markets. Although Europe is experiencing increasing water scarcity, it represents only a small percentage of the global reuse ma rket (best available data 2.6 million m^3/day total installed capacity to 2006 compared to 30 million m^3/day globally and lags far behind the Americas and Asia Pacific in implementing reuse solutions (Water Reuse Europe, 2020).

Through a review of the sector performed in 2017 by Water Reuse Europe, 787 schemes practicing reuse were identified, distributed across 16 countries, 437 more than identified by a previous review of the water reuse sector in Europe performed in 2006. Overall, agricultural reuse remains the most common water reuse application in Europe (39% of the schemes) followed by industrial reuse (15%) and reuse for recreational purposes (11%). The majority of the schemes classified as industrial (68%) are located in northern Europe.





Map 3: Water reuse state of the sector (Source: Water Reuse Europe, 2020)

Why does the limited spread of circular economy practice present a real challenge in southern European countries? Analysis of causes

Over the last 5-10 years global and European initiatives (listed below) have been looking at the water cycle through a circular economy lens. However, water is still not central in the European plan of actions for circular economy. **In March 2020 the new EU Circular Economy Action Plan marginally considered water systems, with the focus mainly on integrated nutrient management and sewage sludge, and water reuse already considered in the previous CEAP in 2015. Water is therefore transversal but not central in the circular economy scenario.**

In addition, while the new Water Reuse Regulation paves the way for reclaimed water reuse in many sectors, there is still a lack of relevant criteria from policy and regulations to support technology providers.

The Mediterranean agricultural sector already has problems related to water scarcity and it is expected that climate change will further reduce water availability. Therefore, alternative water resources have to be considered, including reuse of treated waste water. Although indirect reuse of treated wastewater might be significant but difficult to be accounted, direct reuse of reclaimed water depends on many factors, not only related to technology implementation, but also to health, regulatory, governance socioeconomic and legal aspects (Foglia et al., 2021).

The new EU Regulation 2020/741 on 'Minimum requirements for water reuse' establishes limits on contaminant concentrations and defines risk management strategies to identify, characterise, minimise and monitor risks. The water reuse risk management plan will be based on all key elements of risk management (described in Annex II of the new EU Regulation).

Risk management will comprise of identifying and managing risks in a proactive way to ensure that reclaimed water is safely used and managed and that there is no risk to the environment or to human or animal health. However, current regulations, as well as other guidelines such as DEMOWARE's project deliverable, WHO's manuals for Sanitation Safety Planning, WHO's manual for Quantitative Microbiological Risk Assessment (QMRA) and Water Safety Planning and WHO's Guidelines for the safe use of wastewater, excreta and greywater, currently provide only general approaches, which need to be adapted to the specific case -study.

Conditions relating to the additional requirements, depending on the outcome of the risk assessment, may concern in particular: (a) heavy metals; (b) pesticides; (c) disinfection by - products; (d) pharmaceuticals; (e) other substances of emerging concern, including micro pollutants and microplastics;(f)anti-microbial resistance.In2017-2018 theEUInnovation Deal on Water Reuse considered the fragmentation of water reuse legislation in Europe, even concerning the approach to toxic and emerging contaminants.

Furthermore, risk management strategies have still to be managed case by case. There is a need for the harmonisation of guidelines for water reuse risk management plans at European and Mediterranean level (including quantitative methods). In addition, emerging contaminants should be prioritised in monitoring strategies, considering a sound risk-based approach addressing public-health and environment. Prioritisation and monitoring strategies should consider techno-economic sustainability, which is also linked to the scale of the reuse district . Small and decentralised systems can close the loop in water scarce areas in the Mediterranean basin, but they face policy and legislative barriers (Cipolletta et al., 2021).

Impacts of the limited spread of circular economy Case-studies

Full scale case studies of sustainable wastewater treatment and reuse are in place in the Southern European Union: for example, Valencia and Murcia Region in Spain; Forcatella Lake, ARETUSA, Milano and Puglia Region in Italy.

1

In Valencia region, the sewage treatment plant South Albufera discharges its effluent waters into the Albufera lake. This effluent still had a relevant concentration of nutrients that contributes to the eutrophication of the lake. To reduce this concentration, the existing treatment plant was upgraded by tertiary treatment; and an irrigation pond was created to reuse effluent water in agriculture. In addition, a post effluent management was needed, and that is why it was decided to create a Green Filter, as a natural and sustainable water treatment system. All these actions had a tot 24,000,000 EUR, of which 5,500,000 corresponded to the construction of the green filter system[2].

2

Spain's Murcia region probably achieves world-leading rates for wastewater recycling. The Region of Murcia forms part of the Segura River catchment – on of the most water-stressed river basin in Spain. Yet these parched lands, home to just over 1.5 million people, are a horticultural powerhouse, producing 20 per cent of Spain's fruit and vegetable exports, which is coupled with high touristic pressure during the summer period. Recurrent drought and this imbalance between water availability and demand has forced ESAMUR (the Entity for Sanitation and Treatment in the Region of Murcia) to drive wastewater re -use to its limits. ESAMUR operates about 50 WWTPs in the region, serving 99% of the population. Most facilities provide tertiary treatment, and virtually all treated wastewater is reused – either directly for irrigation – or indirectly. Some of the indirect-use projects include restoring river flows, creating new, artificial wetlands and replenishing aquifers by filtering treated wastewater through dry channels. According to the info published from Aguas de Murcia , up to 5.134.695 m3/year treated water can be there reused for agriculture, environmental uses and recreation.

2 More information on this Case Study can be found here: Case 3 (globalnature.org)

3

In Tuscany (Italy) the Rosignano Solvay industrial site is one of the oldest and largest in Italy. It produces sodium carbonate, sodium bicarbonate (also for pharmaceutical use), calcium chloride, chlorine, hydrochloric acid, chloromethane, plastic materials, peracetic acid and hydrogen peroxide. In order to deliver more sustainable water management, Consorzio ARETUSA was established in 2001 as PPP among water utility (ASA Livorno), industry (Solvay Chimica Italia) and tech provider (Termomeccanica). Thanks to ARETUSA, since more than 15 years the Solvay chemical plant is implementing a utility-industry (public-private) symbiosis system for optimising the regional water cycle, by reusing about 3 million cubic meters per year of urban wastewater treated in the ARETUSA reclamation plant. The existing Waste Water Reuse Plant (WWRP) contains flocculation, sedimentation, filtration, activated carbon filter (GAC), and UV disinfection (see also www.aquaspice.eu and www.ultimatewater.eu)

4

Full-scale agricultural reuse in Fasano, Apulia (BIO by Deloitte., 2015). Apulia is a south-eastern Italian region without permanent rivers or natural lakes, and whose groundwater quality is heavily jeopardized by salinisation due to seawater intrusion. The latter is caused by groundwater over exploitation by farmers. The Fasano WWTP has an extensive water treatment storage capacity and it is directly connected to a 30 km distribution network. Since 2001, the Fasano tertiary treatment plant has been providing up to 8,000 m3 water/day to 51 farms, thus irrigating about 350 hectares of horticulture, intensive olive yards, and fruit trees. The wastewater treatment plant located in Fasano (location Forcatella - 50,000 population equivalents (p.e.) has a treatment capacity of approximately 8,500 m^3 of urban waste water per day. The treatment plant includes: ▪ activated sludge plant; ▪ more stringent treatments (capable of treating up to 2,800 m^3/day) including: predisinfection with paracetic acid or sodium hypochlorite; coagulation-flocculation with aluminium chloride and slow sedimentation, post-disinfection with paracetic acid or sodium hypochlorite; and post- physical disinfection (optional) with UV light.

5

The treatment systems of Milan represent one of the main examples in the world of the reuse of wastewater for irrigation, thus reducing the quantity of drinking water used and guaranteeing an abundant supply of high-quality water for farmers in the Milan area.

The Milano Nosedo treatment plant treats the entire volume of incoming wastewater for reuse in irrigation, in a vast area southeast of the city. The water treated by the Milano San Rocco treatment plant is reused for irrigation in a vast area that stretches from the southern area of Milan into the province of Pavia.

The entire volume of water treated by the Nosedo and San Rocco plants – the only two plants of this size authorized on a national level – conforms to the extremely strict limits laid down by the legislation applicable to reuse for irrigation purposes (MD 185/2003), as certified by ARPA, and is used to irrigate a substantial portion of farmland with a surface area of over 100 km^2 (in the area between Milan and Melegnano and from the southern area of Milan into the Province of Pavia), valorising also the historical and cultural heritage of the area (from Chiaravalle to the agricultural park of Southern Milan).

It is a practice for irrigating the rural areas outside the city, which has its roots in the past and, today, in Milan, has reached levels of excellence to the point that the municipal wastewater treatment system managed by MM has become one of the most important examples in Europe, with significant repercussions also on the quality of the local farm produce.

The two plants (Milano Nosedo and Milano San Rocco) discharge the treated water into surface water bodies. Milano Nosedo performs the treatments and, once reuse of the water for irrigation has been authorized, discharges it mainly in the Vettabbia irrigation ditch and the Redefossi canal. The Milano San Rocco treatment plant discharges mainly into the Southern Lambro river and treats the water so that it can be reused for irrigation by users only at times of peak demand (normally from May to August), discharging into the Pizzabrasa and Carlesca ditches (MM SPA, n.d.). The wastewater used to irrigate the rural areas outside the urban area of Milan is a particularly precious resource for agriculture, also from the circular economy viewpoint.

How to deal with the limited spread of circular economy options

Through Horizon2020, hundreds of millions of Euros have been invested to fund R&D&I projects (RIA and IA) that delivered or are delivering over one hundred large demonstrations related to water in the circular economy. Some (for example H2020 HYDROUSA) were specifically focused on solutions to close water loops in Mediterranean basin.

Besides the undiscussed value and importance of water for our lives, there is an economic and societal value in water that can be realised also by extracting and valorising substances such as nutrients, minerals, chemicals and metals, as well as energy, embedded in freshwater and used water streams.

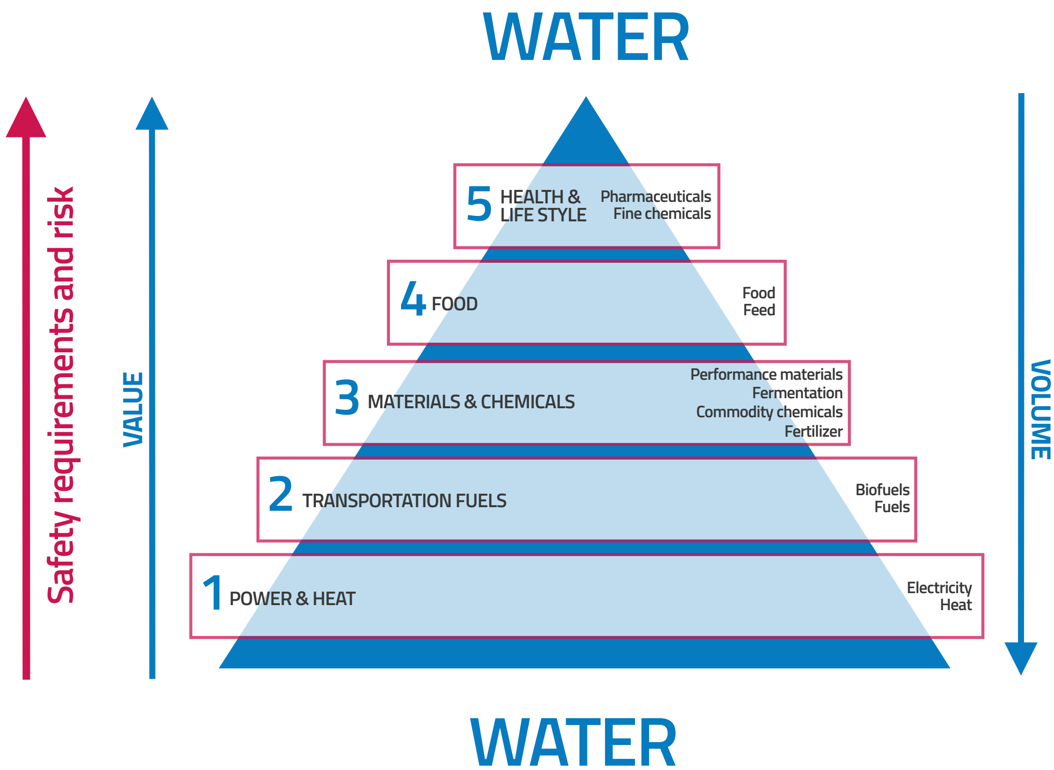


Figure 4: Water and value. Own elaboration, Francesco Fatone.

Currently, there are innovative water/ wastewater treatment technologies that enable actors to go beyond traditional water reuse and resource recovery.

Table 1 provides a list of Horizon 2020 projects funded under SC5 calls and their proposed solutions to extract and reuse the value from wastewater which are, falling mainly under the following categories:

Nutrients: Elemental nutrients, including phosphorus and nitrogen, are essential to all living organisms and key resources to enable food production security and manufacturing in Europe. Economically strategic industries rely on nutrients to deliver products and services, including agriculture, pharmaceutical and chemical industries. Following a circular economy approach, many H2020 projects validated technologies to recover various nutrient products (including phosphorus, struvite, ammonia salts.) from municipal wastewater using innovative technologies.

Bio-based materials: wastewater contains a high amount of suspended solids and material that could be recovered (such as cellulose originating from the use of toilet paper or PHA produced by selected bacteria growing on the organic content of wastewater) and used as intermediates for processing into commercial end products or as feedstock for different industrial applications.

Energy: wastewater is also a source of renewable energy. High prices for sludge disposal and goals of the circular economy demand innovative processes to convert sludge into value-added materials or energy. Many innovative solutions demonstrated the possibility to generate biogas from the treatment processes and to convert cellulosic sludge into biomass biofuel.

ACRONYM (COORD)	DEMOS	RECOVERED MATERIALS
B-WaterSmart (DE)		Brines / salts, energy/biogas, nutrients (ammonia), minerals
HYDROUSA (GR)	6 demo sites in 3 islands in GR	Clean water via evaporation and condensation, edible salt, nutrient rich water (as fertilizer)
INCOVER (ES)	ES (2), DE	PHAs (bioplastic), citric acid, biofertilizer, nutrients
NextGen (NL)	DE, ES, NL (2), CH, UK, SE, EL, UK, RO	Spirulina, struvite, ammonia sulphate, NPK fertilizer, protein
Project-O (IT)	IT, IL, ES, HR	Recovery nutrients, saltwater reuse, fit-for purpose water
REWAISE (ES)	Living Labs: SE, SE, PL, ES (6)	Nutrients (primarily phosphorus), metals, minerals, CRM-Mg, Li, biogas, biopolymers, NPK fertilizers, struvite, vivianite

ACRONYM (COORD)	DEMOS	RECOVERED MATERIALS
RUN4LIFE (ES)	BE, ES, NL, SE	Struvite, ammonium, sulphate and nitrate, phosphoric acid, solid and liquid NPK
SALTGAE (ES)	SI, IT, IL	Algae biomass
SMART-Plant (IT)	NK, UK, IL, IT (2), EL, ES +2 downstream in UK and ES	Cellulose sludge/refined, PHAs, VFAs, nutrients (phosphate, struvite), P-rich sludge, biogas, biofuel
SYSTEMIC (NL)	UK, DE, NL, BE, IT + test-plant in FI	Mineral nutrients, ammonium sulphate, calcium carbonate, biogas, organic soil improver, P-poor soil improver, N+K concentrates, NPK fertilizers;
ULTIMATE (NL)	ES, NL, IT, EL, UK, FR, DK, CZ, IL	Nutrients (ammonia); sulphur for sodium bisulfide; polyphenols, antioxi-dants, metals, copper-rich fertilizer
WATER MINING (NL)	NL, ES, CY, PT, IT	Chemicals, minerals, nutrients, (phos-phates), fit-for-purpose water
Water2REturn	ES (2) +test in SI, RO, LT	Organic source fertilizers, bio stimu-lants products, micro-algal biomass, soluble N and P from slaughterhouse wastewater
WIDER UPTAKE (NO)	IT, NO, CZ, NL, Ghana	Bio composite materials, organic and inorganic fertilizers
ZEROBRINE (NL)	NL, PL, TRK, ES Replication in NL (2), PL, EL, ES	Minerals (for example sodium chlo-ride, sodium sulphate), regenerated acids, caustics, magnesium

Table 1: Horizon 2020 projects funded under SC5 calls and their proposed solutions to extract and reuse the value from wastewater, own elaboration on SMART-Plant final workshop table: Francesco Fatone

- Centralising water in circular economy strategies and action plans in the EU and Mediterranean basin.

- Standardising indicators for assessing circular economy solutions.

- Addressing the water-energy-food-ecosystem-climate nexus when assessing sustainability of circular economy solutions.

- Understanding that small and (low-cost) decentralised schemes have many barriers to close the loop.

- Linking circular economy benefits in water scarce areas.

- Addressing and harmonising end-of-waste criteria for the safe reuse of recovered materials.

- Responding to (i) the (apparent) lack of willingness of customers to accept a premium for circularity and sustainability, as well as possible customer reluctance if waste raw materials are declared; (ii) Public procurement focusing on low cost instead of closed loops; (iii), the lack of a harmonized European regulatory framework, except for Fertilising Products Regulation.

- Making circularity more attractive for the market, for example water reuse and resource recovery should be underpinned by economic feasibility that ensures profitability after investment in technology. Innovative solutions should be accompanied by credible cost-benefit analysis and success stories of real case studies doing business with circular approaches.

- Responding to the social reluctance to use reclaimed water, particularly in terms of the lack of information for end-users (for example farmers) on potential risks and effects. The information might be available in scientific articles, but it is not in the usual communication channels of end-users (for example on television or in specialised magazines.). Studies and materials from relevant EU projects on water reuse such as FIT4REUSE, SUWANU EUROPE, or DEMOWARE should be further disseminated.

CHALLENGE 3:
RESTRAINED OPTIMISATION OF WATER MANAGEMENT THROUGH SMART TOOLS

Setting the context: current state

Smart water management is when information and communication technology is used to provide real-time, automated data as well as computational models to resolve water challenges.

> **Digital solutions, for example big data, artificial intelligence/machine learning, mobile devices/applications, Internet of Things, cyber-physical systems, on-the-ground real-time sensors and remote Earth observation, offer an untapped potential that could be further optimised in a wide variety of applications, including water pollution reduction, regulation of water distribution systems, forecasting of water related risks, and water use optimisation, enabling the efficient management of water supply vs water demand.**

Experience from researchers and policy makers in southern Europe shows that the low availability, dispersion and reliability of data render integrated water management difficult (Martins et al., 2013) Smart monitoring and control tools can provide a solution to this situation through the development and roll-out of innovative capabilities in the collection, analysis and automation of real-time data. It is also commonly perceived that the information obtained by smart tools will allow decision-makers to engage stakeholders and citizens. A benefit of smart tools is the possibility to make more informed, transparent and inclusive decisions on water management and planning through the provision, analysis and communication of prompt and reliable data and information (Martins et al., 2013). A clear example is that of smart tools for agricultural purposes, which help improve water budgeting options by considering a wide variety of parameters (such as soil type and its water retention capacity, climatic conditions, crop water requirements, soil moisture, plant water requirements).

Although more digitally based applications are available, the water sector still lags behind other industries in integrating new, smart technologies into the whole water ecosystem (IWA, 2018). Most of the water infrastructure in the European Union is still managed by expert operators based on traditional best practices, but with little support from smart tools (SAID Project, Horizon 2020). Over the last years, a number of Horizon2020 projects (for example Digital Water City and synergy group digital water 2020) and several other projects clustered in ICT4WATER have developed and validated smart solutions in real environments and are expected to boost business development and market uptake, data sharing, interoperability and standardisation, citizen engagement and policy-support.

Research suggests that the slow adoption of smart tools over the last two decades has led to mismanagement and lower levels of productivity growth in southern Europe than in other developed regions in the world (Schivardi and Schmitz, 2019).

Why is the restrained optimisation of water management through smart tools a real challenge in southern European countries? Analysis of causes

The literature review carried out by the BoK reveals that several factors hold back water companies and water managers from the adoption of smart tools in the water sector. These include:

- Water companies struggle to keep up with the talent and infrastructure demands imposed by the pace of the digital revolution. Companies are frequently challenged by the need to invest in new infrastructures and train their employees in order to reap major benefits from digital technologies.
- Critical investments in digital tools for water management are not considered as a priority for many companies and policy makers. As a result of this stance, investments are postponed and digital capabilities do not become exploited.
- Users of smart tools do not always see the immediate pay back of investments in digital tools.
- The complexity of the technologies to be employed makes the final application of them more difficult. In some cases, and particularly in rural areas, the still somewhat limited access to a reliable internet network limits the final deployment of digital solutions that require high speed wireless connections.
- Limited stakeholder engagement in the design, conception and roll-out of smart tools, leads to a situation of distrust between smart tools providers and users.
- Smart tools are usually not self-sustaining without reliance on government support.
- Security is a critical issue that requires regulation, financial investment and technological innovation. Data security/ privacy violations are likely to occur in the collection of data from remote sensing, smart meters (related to water consumption) and digital trace data (Zipper et al., 2019).
- Data reliability, particularly in the wastewater management cycle, should be improved to allow the better exploitation of advanced data analytics and related tools.

Impacts of the limited spread of smart tools in water management

Smart tools offer a new perspective in water management. As explained above, smart tools have proved useful in the acquisition and analysis of data, but also in the visualisation of policy and management decisions. Existing barriers for the roll-out of smart tools have several effects at the environmental, socioeconomic and strategic levels.

Firstly, the limited adoption and deployment of smart tools impedes water authorities from the identification and implementation of best available solutions and strategies, affecting the protection and restoration of water resources and aquatic ecosystems.

Evidence suggests that productivity growth is negatively impacted by the slow adoption of smart tools. Smart tools could facilitate the detection of water leakages (thereby contributing to the reduction of water costs), or the more efficient use of water resources in manufacturing processes (by measuring the exact amount of water required for different processes). Last but not least, the restrained adoption of smart tools can generate social conflicts around the distribution of water for different uses. Smart tools offer functionalities for the reliable compilation and treatment of data, as well as the communication of strategic decisions. It is generally agreed that decisions built upon the data and information provided by smart tools are more objective and scientific based.

Example of a case study having benefited from the deployment of smart tools

The Mancomunidad de los Canales del Taibilla (MCT), a public State agency created in 1927, manages high water networks that give water supply to approximately 2.5 million people in 79 municipalities in the provinces of Murcia, Alicante and Albacete (southeast of Spain). The agency guarantees water supply through a flexible water management approach based upon the supply of water from different sources i.e. groundwater, surface wate r, water transferred from other river basins, desalinated water.

Recent technological developments and ICT applied to water supply network management, pressure control, leak detection and innovations in metering have strongly improved the efficiency of water supply. Network efficiency has thus risen from 80.49 percent in 1991 to 90 percent in 2015.

How to deal with the restrained spread of smart tools in water management

The European Commission's Framework Programme aims to pave the way towards sustainable development through enhanced natural resource efficiency whilst favouring innovation ecosystems and economic growth. The digital era offers clear opportunities for new demonstrations, innovations uptake, job creation and productivity growth. Water is not excluded from this vision and a number of Horizon 2020 projects and initiatives have looked at bringing the digital era to water management, for example Smart Water Management Platform, Synergy group Digital Water 2020, ICT4WATER cluster.

Building upon its experience, the following are areas that could be tackled by future research and/or communication activities to enhance the application of smart tools in water management:

- Developing and implementing digital technologies for the monitoring and collection of data on the actual water source-demand balance, and to improve the real time access to water information. There is still a need to improve smart water meters, sensors for water deficiency and quality, technologies for monitoring water-related agro-ecosystem services, and software tools for remotely controlled operational activities.
- Developing tailored tools, fully adapted to the needs of users, and enabling their engagement from the early stages of smart tools development projects.
- Communicating and training water professionals on the use and advantages of smart tools so that they can transition to the digital world.
- Enhancing visibility about the potential of smart tools in both water use optimisation and corporate social sustainability. A more rational use of water in companies creates a better image of corporate social sustainability, helping sustainable firms to attract new customers and increasing the loyalty of current ones.
- Promoting the use of digital solutions and field data to dynamically monitor the environmental sustainability indicators

CHALLENGE 4: MISMATCH BETWEEN WATER DEMAND AND SUPPLY

Setting the context: current state

An assessment by the Institute for Environment and Sustainability (Joint Research Centre) of available water resources revealed that large areas in Spain and Eastern Europe had on average less than 200 mm freshwater available every year while the demand for water was three to ten times higher (Institute for Environment and Sustainability (Joint Research Centre) et al., 2012). More recently, the UN Special Report in Drought (Vogt et al., 2021), selected the Mediterranean Basin as a case study. It places a particular focus on the Middle East, North Africa region and Southern Europe for which projections predict that drought will be increasingly severe as a result of climate change.

With regards to problems of water quantity, we have to add those challenges related to its quality (which have been identified in "Challenge 1") which contribute to making water even more scarce, since they make it impossible or more expensive to use.

Map 4: Drought prone regions within the Mediterranean basin. Source: (Vogt et al., 2021, p. 96)

Why is the mismatch between water demand and supply a real challenge in southern European countries? Analysis of causes

According to second river basin management plans, we can summarise, in the order of relevance, the main sources of pressure on water bodies.

SIGNIFICANT PRESSURES	SURFACE WATER BODIES (%)	GROUNDWATER BODIES (%)
Diffuse sources	**33**	34
Water abstraction	6	17
Hydromorphology	34	-
Diffuse sources (atmosphere)	32	-

Table 2 Overview of significant pressures reported in second river basin management plans (EEA, 2018b)

Agriculture is the largest net water user, accounting for up to 60% of net water use at EU level and 75% to 80% in southern Europe (EEA, 2020, p. 30). The level of agricultural water consumption as a percentage of renewable freshwater resources is particularly high in Cyprus, Greece, Malta, and Spain. More water is used or consumed than sustainably available. Agriculture is also responsible for local and seasonal water stress incidents, which can have severe impacts on environmental river flows.

Moreover, as we can see in the table above morphological pressures are also significant. Europe's rivers are fragmented by more than one million barriers (Belletti et al., 2020). Water storage for hydroelectricity, water supply and irrigation are linked to hydro morphological pressures. Furthermore, large irrigation infrastructure projects (including water transfers from other regions) are more prevalent in southern Europe, even if smaller reservoirs exist across Europe – many of them not registered for statistical purposes (EEA, 2020, p. 30).

Despite growing water shortages and funds provided by the EU's Common Agricultural Policy (CAP), a recent study (Dias and Correia, 2020) concluded that in Portugal (and probably other southern European regions), most farmers still do not measure the water they use (71% do not have a meter and they report they do not have to meet any water saving or efficiency requirements). In addition to these data on the water extracted, it is necessary to highlight the illegal or irregular abstraction of irrigation water that is observed in several regions of southern Europe (and which the authorities have not been able to control, so far).

Consumers are not fully aware of the water footprint of food. 47 million tonnes of food are waster in the EU, with households generating more than half of it[3]. But beyond the amount of food wasted, it must be noted that buying local products is the second most cited evaluation in the decision to buy fruit and vegetables, only after the prize (Dias and Correira, 2020). Awareness on carbon footprint and willigness to foster the local

3 For more information see: https://ec.europa.eu/food/safety/food-waste_es

economy play a key role on this decision. However, many consumers are unaware of the water footprint of the locally grown product. Is it sustainable? Is this product adapted to the climate and resources of the region?

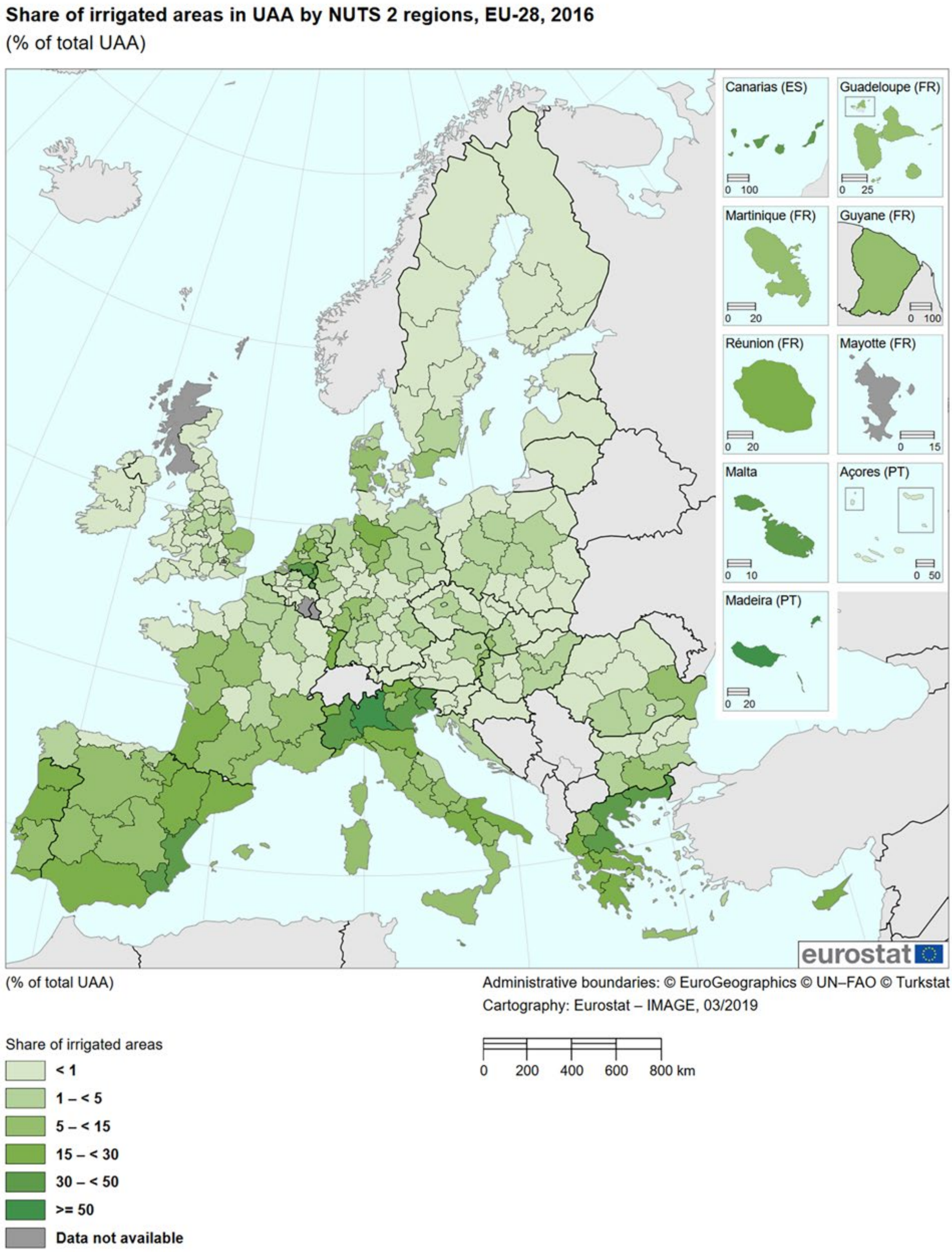
Impacts of the mismatch between water demand and supply

Excessive water use in Europe has led to the overexploitation or 'bad quantitative status' (WFD terminology) of more than 17% of groundwater bodies (cases where more water is abstracted than renewed by rainfalls and infiltration), and to the degradation of more than 7% surface water bodies (lakes, rivers, estuaries, coastal water bodies), because water abstractions do not leave enough water ('ecological flow') to maintain and renew biodiversity and ecosystems. This overwhelming water extraction is also having an impact on sea level rise[4] (Pokhrel et al., 2012).

The European Court of Auditor's recent special report found that the Common Agricultural Policy (CAP) funds of the European Union, implemented since the 2000s, have largely contributed to more efficient irrigation, which, however, does not reduce water consumption overall (ECA, 2021). Investment in irrigation technology has contributed to increased intensity and productivity of water use also known as Jevon's paradox or rebound effect (ECA, 2021; Varela-Ortega, 2007).

The prominence of irrigated agriculture in southern Europe are shown in the below map from EUROSTAT.

4 Alongside thermal expansion of oceans, melting of glaciers and loss of the ice masses in Greenland and Antarctica.



Map 5: Share of irrigable areas in Utilised Agricultural Area (UAA) by EU NUT2 regions, 2016
Source: (EUROSTAT, 2019)

Sectors of water users

We can synthesise the sectors of water users into three main groups: agriculture, industry and domestic (including seasonal water use for tourists in the latter). As mentioned previously, agriculture is the main consumer of water (75-80% on average in southern Europe). Over the past decades the trend in agricultural water use has, in general, been upwards, due to increasing use of water for irrigation. However, during recent years in several countries, the rate of growth has slowed down. The total water abstraction for irrigation in Europe is around 105'068 hm^3/year. Reforms of the Common Agricultural Policy are expected lead to changes in the types of crops being cultivated, the area irrigated, and the amount of water used. Two opposing trends can be distinguished. On the one hand, if production is reduced, the demand for production inputs such as water is bound to diminish. On the other hand, there may be a switch towards more profitable crops which, at least in southern Europe, frequently require irrigation.

The total water use by **industry** in Europe is 34,194 hm^3/year (insert date, source) which amounts for 18% of its consumptive use. In recent years, several changes have occurred and have influenced industrial water use: decline of industrial production; use of more efficient technologies with lower water requirements; and use of economic instruments (charges on abstractions and effluents).

The total water use for urban domestic purposes in Europe is 53'294 hm^3/year which amounts to 18% of total abstraction and to 27% of its consumptive uses (EEA, 2019). In recent years, urban use per capita has decreased and many changes have occurred, influencing the patterns of urban water use: increasing urbanisation; changes in the habits of the population; use of more efficient technologies and water saving devices; alternative sources of water (desalinisation, indirect and direct wastewater reuse); increasing use of metering; and use of economic instruments such as water charges and tariffs. The connection of the population to water supply systems has also increased, especially in Mediterranean countries.

Population distribution and density are key factors influencing the availability of water resources. Increased urbanisation concentrates water demand and can lead to the overexploitation of local water resources. Higher standards of living are changing water demand patterns. This is mainly reflected in increased domestic water use, especially for personal hygiene. Most of the water use in households is for toilet flushing (33%), bathing and showering (20 - 32%), and for washing machines and dishwashers (15%). The proportion of water used for cooking and drinking (3%) is minimal compared to the other uses.

Tourism places a wide range of pressures on the local environment. The impact on water quantity (total and peak) depends on water availability in relation to the timing and location of water demand from tourism and on the capability of the water supply system to meet peak demands.

The intensity of the natural resources used by tourism can conflict with other needs, particularly in regions where water resources are scarce in summer, and with other sectors of economic development such as agriculture and forestry. Uncontrolled tourism development has led to a degradation of the quality of the environment, particularly in coastal and mountainous zones.

Tourist' water use is generally higher than water use by residents. A tourist consumes about 300 l/day; European household consumption is about 150 - 200 l/day (Styles et al., 2013, p. 205). In addition, recreational activities such as swimming pools, golf and aquatic sports contribute to the pressure on water resources.

Furthermore, it is important to emphasise that the moment when more pressure is exacted on water masses is often precisely when there is greater scarcity. In other words, in summer; a time that coincides in many areas of southern Europe with the strong demand of water from tourism.

Case studies

Case studies illustrating mismatch between supply and demand can be found in several southern regions (Schmidt et al., 2020, p. 7) and some of them are illustrated in this White Paper relating to the Control and enforcement of water abstraction (for example, Doñana, Andalusia or the "Caso Mar Menor", Murcia). The mismatch between supply and demand can also be found and even exacerbated in trasboundary water bodies. While 60% of the EU territory is included in the International River Basin District (IRBD), most southern European IRBDs do not have an IRBD plan. Member States have developed separated plans for each part of the IRBD, increasing the environmental impacts caused by water management on both sides of the water. An exemplar case is the Guadiana IRBD included in this White Paper on page 86.

How to deal with mismatch between water demand and supply

Building upon the research outlined above and the experience of the BoK, the following are areas that could be tackled by future activities to reduce the mismatch between water demand and supply:

- Moving from water use efficiency to water use sustainability, bearing in mind, among other things, regularised 'ecological flows' and 'renewable groundwater recharging' (using the new technology addressed in the **Challenges 2** and **3**).
- Checking the actual availability of water in each water body, including unauthorized or non-administratively regulated quantities of water withdrawn (using the new technology addressed in **Challenges 2** and **3**).
- Adapting private water use rights to actual availability and considering the effects of climate change (also addressed in **Challenge 5**).
- Reducing the dependence/exploitation of other regions/basins in the supply of raw water, usually without adequate economic compensation, especially when water is extracted from an international basin.
- Improving cooperation in the International River Basin District (IRBD) through the implementation of a Single Plan of the IRBD.
- Focusing priorities for water use and consumption on activities that add value, in terms of human consumption, respect for the environment (for example protecting water bodies and wetlands), or socio-economic improvement (for example employment, GDP) within the framework of a sustainable use of water resources at the regional / basin level.
- Encouraging participation in public policy debates on water (consumers, NGOs, universities, etc.), the CAP and tourism (and not just to groups with greater lobbying capacity).
- Increasing consumer awareness of agricultural products, in order to avoid/reduce food waste, be aware of the water footprint of food and to apply the principles of the circular economy (addressed in **Challenge 2**).

CHALLENGE 5: SUBOPTIMAL GOVERNANCE AND FINANCIAL SCHEMES TO TACKLE WATER SCARCITY

Setting the context: current state

Good governance of the water sector remains a challenge in the absence of market mechanisms that alone can lead to efficient allocation and use of the water resources.

In a market-based system demand and supply determine the equilibrium price and quantity where demand equals supply and there source/ good is allocated efficiently among the different uses. Water as a private good can be allocated through the market mechanisms. Yet, water is also a public good, and water use can be related to externalities (for example, pollution). These constitute a market failure which can lead to underinvestment in water-related projects and in the misallocation of water resources. Government interventions can also lead to misallocation of resources. For example, subsidies for agricultural production leading to the over exploitation of water resources for irrigation purposes. These market imperfections and externalities result in the inefficient and also unsustainable allocation of water among the different users. Water governance refers to the set of the socio-economic, political and administrative systems that determine water resources management and its competitive uses (for example, agriculture, residential, industry) as described in the The role of governance in managing water scarcity in southern Europe section previously. Following this definition, governance regards interventions in the markets that correct for inefficient water use for example, through water pricing, the regulatory, oversight and management layers of water management, the regional, local, and global socio - economic targets and policies that set the agenda for water management in the decades to come. (OECD, 2008)

Why this challenge

In the case of water, price is often estimated based on water demand and water supply costs (infrastructure, collection, treatment, and distribution. This leads to inefficient allocation as the supply costs that network operators and water providers are faced with, often do not include the environmental and resource costs and benefits related to water use.

Water management through pricing is linked to issues of capturing the "total" costs and benefits of water use, i.e., the financial, environmental and resource costs (Figure 5). Total water cost recovery requires the identification and the monetisation of the financial cost (investment costs related to water provisioning, operation and maintenance costs, administration costs and), resource cost (the opportunity cost of water use) and environmental cost (the cost of environmental externalities like water degradation) of water use. Thus, all water uses should be identified and linked to the respective economic agents and sectors (households, industry, agriculture). Total water cost recovery links with welfare implications. It also connects to allocative efficiency, which requires that all users have clear information regarding the value of water services. This can only be achieved if all costs are recovered through water pricing. In addition, the financial sustainability of operators is a prerequisite for the sustainable operation of water services. Core issues here regard the level of revenues and their predictability. Lastly, total water cost recovery can be seen as a mechanism for producing revenue to compensate for the cost of environmental damage arising from water use.

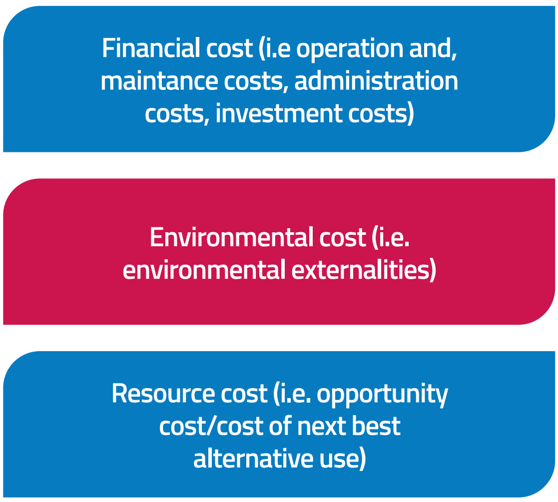


Figure 5: Costs related to water use to be included in total water cost recovery.

Total cost recovery of water services (i.e., the monetisation of the total costs and benefits of water use, whether financial, environmental or resource related) is a cornerstone of any sustainable water management policy. In terms of ease of identification and monetisation of the total water use costs, financial costs might be easier to monetise (for example, through the cost of infrastructure for water provision and maintenance costs). In contrast, it remains difficult to identify and monetise the resource and the environmental costs of water use. The implementation of total cost recovery remains challenging, and it can raise social and redistributive concerns.

From a governance perspective, priority should be given to developing an integrated approach to water management, one that incorporates the economic, social, and environmental value of water, as well as the impact of the implemented measures. From a development perspective, efforts need to look carefully at the social and economic factors that relate to water managment and to the wider regional and global efforts to achieve sustainable economic growth.

The European Commission has put forward several water management related directives. Despite progress in several aspects, policy initiatives and the regulatory framework have not adequately addressed the multiple stressors on water bodies. All these management efforts have been, to a great extent, fragmented in addressing the efficiency challenges related to water governance (Tsani et al., 2021). The Water Framework Directive in 2000 (WFD, Directive 2000/60/EC) is the first systematic approach to water management that addresses simultaneously multiple environmental, social, and economic stressors. The WFD timetable develops in three management cycles: the first management cycle ended in 2015, the second ends in 2021 and the third cycle will run until 2027.

The implementation of the EU WFD coincides with the implementation of the UN Agenda to 2030 and the global and EU commitment to meet the 17 Sustainable Development Goals (SDG). Two out of the 17 SDGs refer explicitly to water-related issues: SDG 6: Clean Water and Sanitation and SDG14: Life below Water (Akinsete et al., 2019a) while more than one SDG are relevant to the sustainable management and to the addressing of multiple pressures on water bodies (for example, eradication of poverty and hunger and high sectoral pressures put on water bodies or targeted good health and well-being and access to safe and affordable drinking water). In the context of the SDGs all national and regional policies in the EU need to look beyond national boundaries ensuring at the same time the inclusion of local communities in the decision-making process and implementation phase.

Who is mainly impacted?

Water governance has far-reaching implications for the EU in meeting efficient resource allocation in its Member States, for the national and regional economies and societies, for the sectoral users of water (agriculture, industry, households impacted by decisions on water prices) and for the environmental sustainability and resilience in the continent. Implementation of the WFD requires that Member States characterise the pressures and water uses, inter-calibrate the national systems to assess the ecological status of water bodies, identify and materialise cost-effective actions to achieve the WFD's environmental objectives and implement sustainable water pricing policies. Article 5, on the review of environmental impact of human activity and economic analysis of water use, and Article 9 on the recovery of costs for water services, of the WFD, require the recovery of the total economic cost of water services.

Total cost recovery can be achieved through the efficient water pricing that can correct for the market externalities, governance, and management failures. Water pricing approaches often include: fixed charges through water bills irrespective of the volume of water consumed; uniform volumetric tariffs that apply same rate charges to water consumption, irrespective of the total amount water consumed; increasing or decreasing step-wise volumetric charges where volumes of water are priced at the same rate in blocks (volumes) in an increasing or decreasing accordingly rate irrespective of actual total consumption; and two parts tariffs that have both a fixed and a variable charge component.

Efficient water pricing comes with the advantage of incentive provision for water use and quality protection. Changes in prices can provide signals to the consumers and producers alike with regards to real water costs and water scarcity. Through the pricing mechanism, the necessary revenues for infrastructure maintenance and upgrade can also be collected. Lastly, efficient pricing can ensure that all consumers have fair and sustainable access to the resource. On the downside, water pricing often comes with opposing views on the objectives that water pricing and tariff design should meet. It is also often the case that the water prices are not set in a transparent manner, or the setting is based in a complex system. This lack of transparency and high complexity often leads to misunderstanding on the real value of water or the aims that are to be met from the revenues collected from water pricing.

Where are challenges taking place?

Ongoing governance developments in the EU indicate existing challenges in WFD timely implementation, coordinated action across Member States, alignment with the SDGs and ability to mobilise the required capital to support innovation in the water sector that, among other challenges, could address water scarcity. Management plans prepared by the Member States include lengthy presentations of the status, methods, objectives, financing, economic assessment for water management in accordance with the EU WFD (Tsani et al., 2021). The documents include numerous measures and differ largely in several aspects, including the detail and the depth of the information and/or the description provided. Definition of water services (that follows national legislation) ranges and it can cover households as well as sectors of production (for example, industry and agriculture). The legislation requires the implementation of the principle of cost recovery for water services, estimated on the grounds that the 'polluter pays' principle, with prices that provide adequate incentives for efficient use and take into consideration the environmental and resource costs of water use. Nevertheless, the implementation and monetisation of this requirement across the Member States ranges considerably.

The WFD indicates the consensus at EU level that knowledge transfer systems, common governance approaches and management systems need to be put in place for the sustainable management of shared water bodies. Indicative of this is the establishment of the International Sava River Basin Commission which is responsible for the implementation of the WFD in the Sava River Basin. This understanding is in line with SDGs 9 and 17 that prioritise the establishment of global partnerships and infrastructure projects that can adequately address regional and transboundary environmental, economic, and social pressures to sustainable resource management and economic development. Different governance structures and levels apply even in the same country (see, for instance, the comparative discussion for Adige-Italy, Ebro-Spain and Sava-Slovenia, Croatia, Bosnia and Herzegovina and Serbia, in (Tsani et al., 2021)). A common governance framework approach with regards to EU waters that could facilitate the progress in sustainable water management in Europe or it could provide useful insights for other relevant initiatives worldwide, is still missing.

Additional challenges are identified with regards to the alignment of regional water governance to global sustainable development and the meeting of the SDGs. The review (Koundouri et al., 2019) of selected South EU countries shows that they perform at various degrees with regards to SDGs achievement. With regards to the water-related SDGs, countries score relatively low. With the exception of Serbia, which achieved a green rating under SDG 6, all other countries achieved mostly yellow ratings. Under SDG 14, most countries received a red rating, excluding Croatia which received an amber rating and Serbia which failed to receive a rating due to insufficient data. This snapshot indicates that the selected countries must make significant steps towards the achievement of the SDGs to 2030 and this will be related to important outcomes with regards to sustainable resource management.

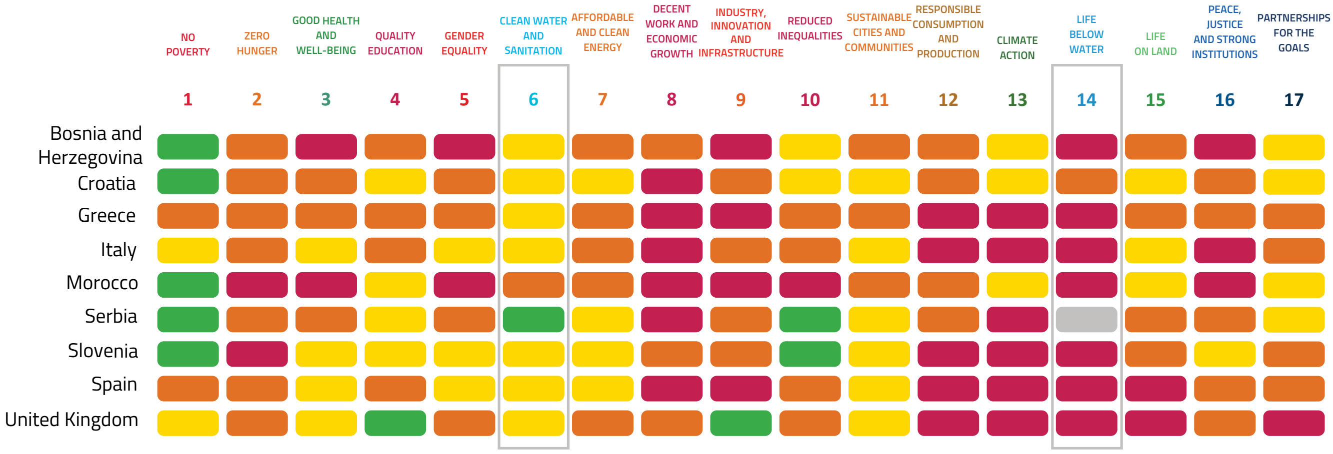


Table 3 SDG index dashboard highlighting performance on water-related SDGs 6 and 14
(Source: (Koundouri et al., 2019), adopted from the Sustainable Development Solutions Network (2015))

How can challenges be overcome?

Two clear end goals can be identified with regards to governance issues related to water scarcity in the EU. The first considers the ensuring of efficient allocation of water resources. The second includes coordination of governance among Member States and joint alignment with the UN's 17 SDGs.

In meeting these targets several propositions can be considered:

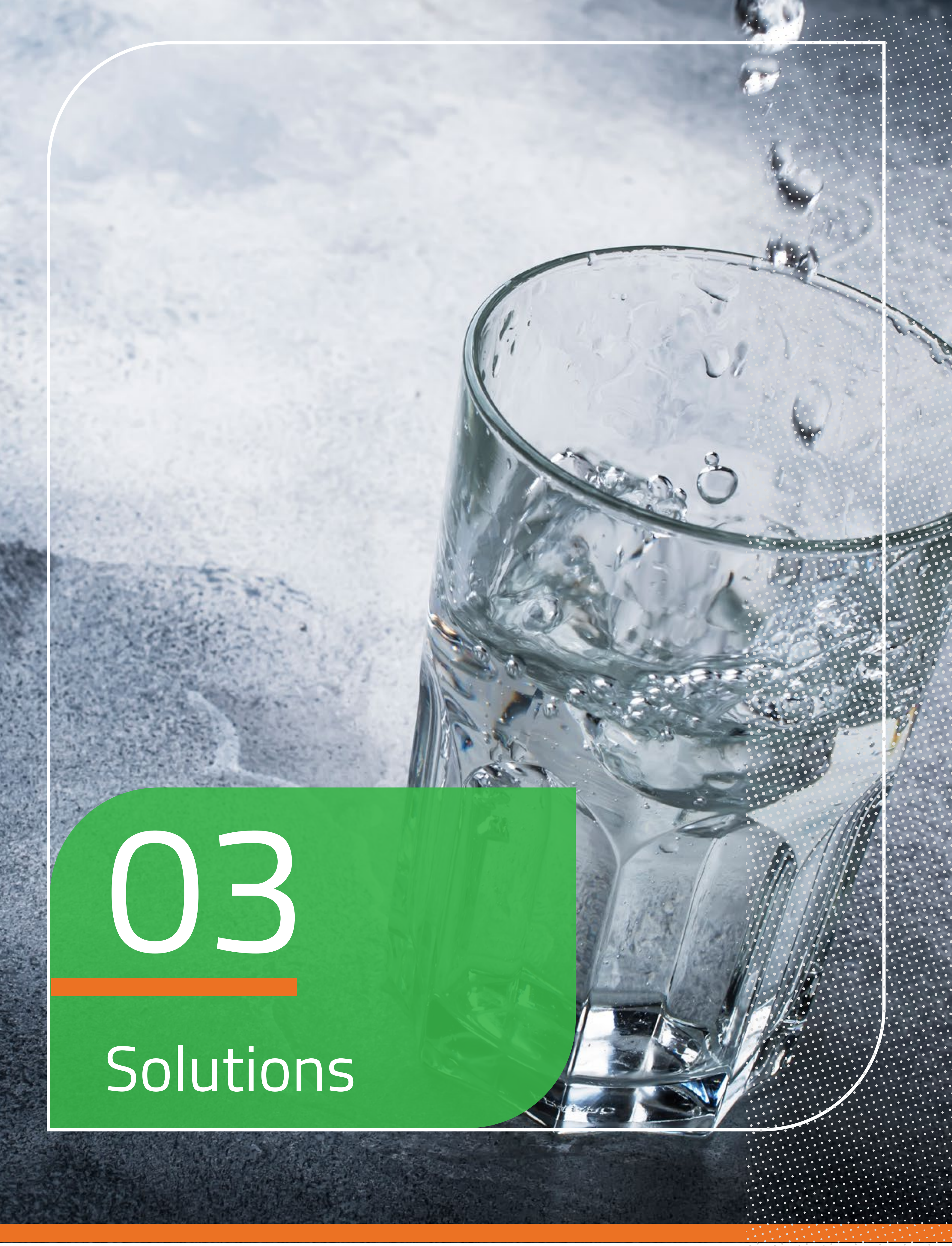
- A record system of the relevant costs across the EU and to use them in water cost recovery approaches would support the alignment with SDGs.

- A common approach across EU Member States on how environmental and resource cost should be monetised and who should bear these costs. While these costs might significantly exceed the financial costs of water use, they are often difficult to estimate and integrate with the water pricing system in an efficient and fair system.

- Impact analysis of sector specific measures (put forward by EU Member States in their management plans) and sector specific development scenarios would allow for the appropriate capturing and monetisation of sectoral impact on water bodies.

-Development and use of advanced IT technologies and innovation sharing platforms with the aim to accelerate knowledge and good practices transfer at EU, regional and global level.

Cooperation and information flow efforts could also consider the need to invest in water-related innovation in Europe. As discussed in the paper 'Finding innovative financial solutions to water scarcity in Southern Europe' prepared for this project, (reference of financing tools doc here) water related financing has been, to a great extent, focused on infrastructure building and renewal. Finance has been less targeted at innovation. One of the key takeaways from the Investors' Café event that EASME (the European Agency for SMEs) organised in June 2018 was that 'in Europe, a proper and structured "eco-system" for investments in water is missing'. This is an issue, which may be tackled through a renewed approach to water governance as brought forward by the Green Deal targets. While novel ideas and public and private funding may be available, it is often the case that information asymmetries render the matching of innovators and available funding sources difficult, consequently impacting on innovation deployment. Governance changes that can improve these information asymmetries, for example, through incentive provisioning, improved transparency on available public/private funding and closing the information gap, could have a catalytic impact on addressing water scarcity issues in south Europe.



03

Solutions

This section presents more specific solutions that can be undertaken, bearing in mind that all share the limitations of dealing with the challenge of water scarcity driven by the biophysical characteristics of a given region, the current socio-economic structure and the complexities of water governance in each region.

FULL COST RECOVERY IMPLEMENTATION

Related challenges:

- **Restrained optimisation of water management through smart tools**
- **Mismatch between water demand and supply**

The use of economic instruments in environmental policy in general and water management specifically is part of the 'polluter-pays principle' (PPP) in the Treaty on the Functioning of the European Union 1957 (Art. 191(2)) as a basic guide for environmental policy; it is also recognised in the 1992 Rio Declaration. Article 9 of the Water Framework (WFD) relates the PPP to the principle of cost recovery in the sense that it requires an 'adequate contribution' of alternative water uses towards the full recovery of the costs of water services, including environmental and resource costs.

Full cost recovery can be deconstructed into financial, environmental and resource costs, known as ERC, and the practical definition to internalise them is still under multifaceted methodological debate without a clear consensus regarding its practical implementation. Regarding 'financial' costs, any assessment should include an estimate of asset depreciation, maintenance, financing and operational cost and be subject to economic cost accounting theory requiring some practical definitions regarding assets, economic life, interest rate, etc., as any other economic cost assessment.

There are three critical points addressed by cost recovery policy:

1. **It is a convenient policy for the financing of existing and future water infrastructure (particularly when climate change will require additional investment).**
2. **It induces to economic efficiency by promoting water saving and the use of water in the more economic and social efficient uses (as water rights are generally allocated in a chronological seniority system).**
3. **It promotes social equity by avoiding cross subsidisation by general taxation that allocates public resources to economic activities that maybe are not the optimal public preference, and may respond to rent-seeking behaviour.**

The practice of cost recovery is mainly focused on the monetisation of financial costs as they are more computable and its recovery is necessary to finance present and future financial needs (for example, water infrastructure). Regarding the non-financial cost that are known as 'environmental and resource cost' (ERC), there is no common methodology for recovery.

Generally, States apply cost recovery for water services focusing on water abstraction and wastewater discharge. Regarding abstraction in the EU, some water scarce countries (Spain, Portugal, France, Italy) have defined by law the compulsory recovery of water cost that is done at local or basin level according to financial recovery procedures. The solution regarding ERC implementation has been implemented by an 'ad-hoc' tax in addition to the water tariff such as in France, Portugal or Italy (Berbel et al., 2019a). A majority of river basin management plans under WFD declare that cost recovery rate for financial cost close to 100% or in any case above 80%.

Regarding wastewater discharge and treatment, the general approach to internalize cost recovery relies on a pragmatic mixed approach which includes both the definition of environmental quality standards for discharge (normative instruments) and the imposition of wastewater tariffs (economic instrument). This combination (standards and tariffs) has been demonstrated to be very effective in reducing pollution in many countries, such as the case of the 'Effluent tax' in Germany (Möller-Gulland et al., 2015)

As a conclusion, full financial cost recovery is a goal generally stated in water regulations both regarding abstraction and discharge. The total (or partial) financial cost recovery is complemented with some additional tax or increased tariff in water scarce areas that functions as a surrogate for ERC.

Picture 1: Water meter (Credit: Poetra Dimatra)

Related problems/challenges

States that have incorporated full financial cost recovery in the legislation and implemented some mechanism include Spain (1985), France (2006), Portugal (2010) or Italy (2015). However, some problems remain. Firstly, the methodology to estimate the cost is not standardised (for example, the infrastructure depreciation rate or the inclusion of future investment required for climate change adaptation).

Secondly, although there are hundreds of references that demonstrate that water demand is responsive to prices, most of the studies agree that demand is inelastic thus increasing the water expenses for the user (farmer, citizen) as a higher percentage than water saving is achieved.

There are different tariff structures with advantages and inconveniences such as: flat rate (fixed fee), volumetric, two-tier (flat plus volumetric), increasing blocks, and connection fee (Leflaive and Hjort, 2020). A critical problem is the implementation of volumetric tariffs avoiding 'flat rate', but this measure requires investment in metering devices, monitoring and control that is sometimes complex in rural environments.

Finally, political resistance to changes in normative systems makes cost recovery legislation difficult to implement in the practice.

STRENGTHS

- There is global consensus on the advantages of economic instruments in general, and cost recovery of water services specifically. Cost recovery achieves water saving (through water pricing) and secures financial resources for future investment and maintenance of existing infrastructure.

- When financial cost recovery through water tariffs maybe is supplemented with some form of taxation (to serve as a surrogate for ERC).

- The benefits of water pricing (water saving) require a volumetric implementation.

- Water tariffs and cost recovery should be combined with normative standards for water abstraction and wastewater discharge to achieve policy goals.

- Economic instruments do not have negative effects on the environment and the negative impact in disadvantaged social groups can be avoided by defining affordability levels (see next paragraph).

WEAKNESSES

- Negative effects of full cost recovery have not been documented, with the exception of affordability. Cost recovery may generate a social problem regarding affordability for urban users or low-income farmers. Some EU cities include provisions for disadvantaged citizens to support affordability of water supply (for example 'vital minimum' or 'tarification sociale de l'eau' in some French cities). A recent OECD report, based on current household expenditure levels, found that all EU countries remain below a 3% threshold (Leflaive and Hjort, 2020)

- The deficient implamentation of full cost recovery is due to the influence of some economic groups (for example farmers, hydroelectric power producers) on policy decisions in order to delay or reduce the complete development of full cost recovery legislation.

- When cost recovery is undertaken through volumetric water pricing in order to induce water savings, there can be a practical problem due the nature of water services cost. These are often characterised by a large share of fixed cost, sometimes close to 95% (for example urban or irrigation water supply), meanwhile the volumetric billing requires that as much as possible (over 50% as a rule of thumb) is integrated in the volumetric component. This increases the complexity of the process of water tariff definition.

- Abstraction charges have been defined by some States for surface water when infrastructure exists (for example reservoirs, channels), or for wastewater treatments (WWTP). Some water services are more difficult to valuate such as groundwater, hydropower or navigation where the cost recovery of public and ecosystem services need to be developed in practice. At present, there is no groundwater tax operating in the EU for irrigation and small consumers (Berbel and Expósito, 2020).

Lessons learned

Financial cost recovery through water pricing has been successfully implemented with positive results both in irrigation and urban sectors.

- In Germany, the effluent charge was introduced in 1976 as and it was earmarked for investments in water quality programs by the Länder. The combination of discharge standards, monitoring and the tariff contributed to the substantial increase in the quality of water bodies, with 85% of all surface water bodies achieving a water quality II chemical status (Möller-Gulland et al., 2015)

- Irrigated agriculture in Emilia Romagna (Italy) has moved from a flat-rate tariff (2013-2015) to a two-part scheme with a volumetric tariff (2016-2018). Farmers reacted to volumetric pricing by reducing water use per hectare by 55% on average, illustrating the high responsiveness of volumetric metering and (small) price increase from the previous flat rate to a level between 0.025 to 0.044 €/m3 (Pronti and Berbel, 2020)

- Since 1992, Denmark has implemented full recovery of financial (including some environmental costs) of the water cycle. The consumption is the lowest in the EU (104 litres/day) and the average price 8 EUR/m^3 the highest in the EU.

- A combination of increases in water cost, volumetric billing and water saving equipment has achieved water savings around 25% in irrigated schemes in Spain (Berbel et al., 2019c)

Policy frame

In the EU is a well-established principle included in WFD (Article 9) of that stipulates "Member States (MS) shall take account of the principle of recovery of the costs of water services, including environmental and resource costs [...] in accordance with the 'Polluter Pays Principle'. MS must ensure by 2010:

- that water-pricing policies provide adequate incentives for users to use water resources efficiently (..)

- an adequate contribution of the different water uses, disaggregated into at least industry, households and agriculture, to the recovery of the costs of water services [...] and taking account of the polluter pays principle.

This principle has been incorporated into MS legislative instruments and beyond the EU, many other countries have developed the water pricing and financing water infrastructure through cost recovery, a revision of success cases at international level can be seen in (Leflaive and Hjort, 2020).

NATURE-BASED SOLUTIONS AND HYBRID GREY-GREEN INFRASTRUCTURES

Related challenges:

- **Water pollution**
- **Limited spread of circular economy options and practices**

Nature-based solutions, actions which are inspired by or supported by nature and hybrid grey-green infrastructures with which combine natural (forests, peatland) and human made conventional elements (dams, seawalls) have been recognised as potential solutions to water scarcity.

Natural water retention measures (NWRM) are particularly relevant are as they aim to protect and manage water resources and address water-related challenges by restoring or maintaining ecosystems as well as the natural characteristics of water bodies using natural means and processes. Their goal is to improve, as well as preserve, the water retention capacity of groundwater, soil and ecosystems (FAO, 2017).

NWRM have the potential to provide multiple benefits, including flood risk reduction, water quality improvement, ground water recharge and habitat improvement. They can help to achieve the goals of the key EU policies such as the Water Framework Directive (WFD), the Floods Directive (FD) and the Habits and Bird Directive. The fields of application of NWRM are agriculture, forestry, hydro-morphology and urban planning (European NWRM Platform, 2014).

Picture 2: Marshlands in Cantabria, Spain (Credit: MaioGuti)

Type	Class	NWRM Measure
Direct modification in ecosystems	Rivers and connected wetlands	Restoration and maintenance of rivers, basins, ponds, and wetlands; floodplain reconnection and restoration; reconnection of hydraulic annexes; elimination of riverbank protection...
	Lakes and connected wetlands	Restoration of lakes
	Aquifers	Aquifer restoration
Change & adaptation in land-use & water management practices	Agriculture	Restoring and maintaining meadows and pastures; buffer strips and shelter belts; soil conservation practices (crop rotation, intercropping, conservation tillage...); green cover, mulching...
	Forestry and pastures	Afforestation of headwater areas/ mountainous areas/reservoir catchments; targeted planting for "catching" precipitation; land-use conversion for water quality improvements; continuous cover forestry; maintenance of riparian buffers; appropriate design of roads and stream crossing; urban forests...
	Urban development	Green Roofs; rainwater harvesting; permeable paving; Sustainable Drainage Systems: swales, soakaways, infiltration trenches, rain gardens, detention basins, retention ponds, urban channel restoration...

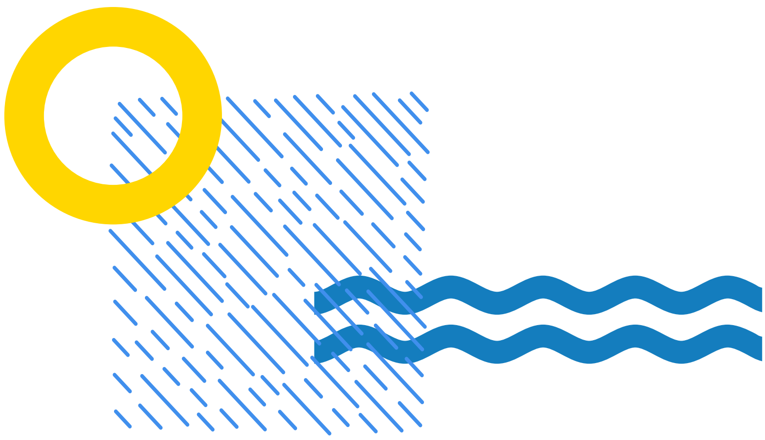
Table 3: Types of Natural water retention and recharge measures

NWRM are not completely new measures. They include approaches that overlap, in part, or follow similar concepts and objectives, such as Room for the River, Ecosystem-based Adaptation, Natural Flood Risk Management or Green Infrastructure. NWRMs can be considered complementary to grey infrastructure such as dams, concrete reservoirs or wastewater treatment plants (Strosser et al., 2014).

NWRM can address the main causes of failure to achieve good water status and major threats to biodiversity, primarily through natural flow regulation and natural water treatment. Natural flow regulation can lead to a reduction in the risk of flooding in humid conditions, and also to a better water supply of ground and surface water in drought conditions.

Through the dilution and natural filtering function of water, some NWRMs also provide natural water treatment. NWRM can restore natural functions or actively preserve functional habitats such as wetlands of floodplains. NWRM can help reverse biodiversity loss by creating small landscape features such as buffer strips, small pools or wetlands. In general, NWRMs:

- have the ability to store water (retention ponds, constructed wetlands) for promoting water reuse.
- provide groundwater recharge through natural infiltration; this assists in increasing the groundwater level and the water table; deal with groundwater salinisation (above ground and below ground infiltration systems, i.e., infiltration trenches, swales, infiltration beds).
- restore natural functions like soil restoration by increasing the soil moisture; this prevents waterlogging due to agriculture practices (mainly below ground infiltration systems, i.e., infiltration trenches, swales, infiltration beds, raingardens). attenuate flow and reduce peak flows that are linked to flooding, following prolonged drought (all types including retention and detention ponds).



Some significant examples of NWRM use include:

Flood meadows in the Marais Poitevin, France

Located in the regions Pays de la Loire and Poitou Charentes, the Marais Poitevin is the second largest wetland in France. Around 2000 ha of flood meadows are owned by local municipalities and commonly managed by local farmers. Such meadows play an important role for water regulation: they contribute to the storage of water during flood events, to groundwater recharge, and to the removal of pollutants.

Managed Aquifer Recharge in Los Arenales (Segovia, Spain)

Data obtained after eight effective recharge cycles carried out in an experimental area (Cubeta de San Tiuste) at Los Arenales Aquifer (Segovia, Duero River Basin, Spain), provided evidence that Managed Aquifer Recharge can be more than an effective measure for storing large quantities of water in underground aquifers to naturally increase the quantity of groundwater in times of shortage: it can also result in an enhanced natural condition of aquifers and water availability. In addition, the natural cleaning process of water percolating through the soils when entering the artificial groundwater recharge (AGR) showed its potential for providing improved water quality.

Natural bank stabilisation and riparian buffer galleries along the Odelouca River, Portugal

Natural bank stabilisation and riparian buffer galleries were used as part of mitigation and compensatory measures and through the use of bio-engineering techniques. in the Odelouca River (sub-catchment of the Arade River Basin, Algarve Region, South of Portugal). The project entailed the implementation of measures focused on the use of bio-engineering or natural techniques for rehabilitation of riparian buffer zones and riverbanks (such as river banks re-sectioning and placement of geotextile; live crib walls and vegetated gabions/rock armour construction and placement; planting of rehabilitated banks with native plant species; construction of artificial islands in the river channel, and clearance of invasive riparian plant species).

Reforestation in Veneto, Italy

The case study site is located upstream of a capture area, where aqueducts abstract water for Venice, Vicenza and other towns: there is thus a demand for increased groundwater recharge and water purification. In addition, Bosco Limite provides a wide range of goods and services, such as groundwater recharge, CO_2 fixation, biodiversity safeguard, production of high-quality wood and biomass for energy production purposes, and recreational-touristic services. The reforestation measure was implemented in an area previously used for intensive agriculture, and activities with high economic returns. Therefore, the main challenge of the project was to find alternative, competitive sources of income for landowners who made their land available for reforestation.

STRENGTHS

- Improve water status by reducing the impact of diffuse pollution (filtering, bio-oxidation, and dilution function), in particular for agricultural run-off.

- Reduce the risk of more frequent lower intensity floods.

- Improve water availability, under conditions of water scarcity and drought, by attenuating runoff naturally regulating the flow regime and recharging soils and aquifers though increasing infiltration by natural means (i.e., afforestation, land-use changes, green covers, wetland restoration, rain gardens, infiltration trenches, etc.).

- Improve the hydro-morphological conditions of riverbanks and the floodplains.

-Promote climate change adaptation and mitigation.

WEAKNESSES

The weaknesses of NWRM systems can be summarised as follows:

- The lack of an integrated framework to assess the costs-benefit ratio and cost-effectiveness of NWRM to achieve multiple-policy goals is a major concern. This is, together with an insufficient understanding of the benefits at various scales, a major impediment to the widespread implementation of NWRM.

- The implementation of NWRM often requires large areas of land, which might not be available or difficult to access due to private ownership of land and water or regulations on spatial planning. Land may be challenging to acquire when financial compensation and land consolidation is required.

- Limited financial resources are often mentioned as a barrier to the implementation of NWRMs. Many projects that aim at constructing and maintaining NWRM benefit from European, national, regional or local public funds (OECD, 2016). However, the financing potentials of public funds often remains largely untapped. Factors to explain this include: co-financing rules that make funds less attractive in some regions; the absence of binding targets within certain policies and funding instruments; the related administrative burden makes access difficult for individual professionals and small municipalities; the short duration of these funds (a few years only); possible conflicts with state aid rules.

- Public safety concerns for large scale NWRM that comprise open water bodies, especially when those are placed within urban areas. Raising public awareness on the benefits of the systems and on ways to increase safety are key to public acceptance.

In conclusion, NWRM have the potential to provide multiple benefits for various sectors and policies. To enjoy the range of benefits, the selection for NWRM is best coordinated across sectors and scales and hence included in the respective action plans, for example River Basin Management Plans, Flood Risk Management Plans, Rural Development Programmes, Adaptation Strategies, local development plans (including those in urban environment).

Lessons learned

NWRM can contribute to reducing the risk of floods and water scarcity and drought while also improving the status of surface and ground water bodies.

- NWRM can support the achievement of the goals of a range of EU policies, including those for surface water, groundwater and coastal management, nature conservation, agriculture, forestry, urban, disaster risk management, green growth and climate change mitigation and adaptation. NWRM can contribute to achieving the objectives of the Water Framework Directive and the Floods Directive. NWRM can contribute to achieving objectives of the Birds and Habitats Directives, for example as measures for achieving favourable conservation status, the connectivity requirements of Natura2000 and the restoration target of the EU 2020 Biodiversity Strategy.

-Growing evidence supports that the integration and coordination of planning across sectors and scales is vital for many EU policies, and for NWRM in particular.

- In order to fully enjoy the multiple benefits, the selection of sites for NWRM is best coordinated across River Basin Management Plans, Flood Risk Management Plans, Natura 2000 Management Plans, the Rural Development Programmes and urban stormwater management. Considering that the implementation of large-scale NWRM can be very challenging, especially regarding compensation and land consolidation, there is a need to coordinate river basin planning with land use and spatial planning.

- Limited financial resources are often mentioned as a barrier to the implementation of NWRMs. While a range of funding sources is available at European and other levels, utilisation remains limited. At the institutional level, approaches should be explored to develop innovative financial methods and payment schemes giving incentives to deliver the multiple benefits NWRM can provide.

The following tips can be helpful in improving the effectiveness of NWRM:

- Exchange best practices, tools and methodologies. These can act as a catalyst to increase the usage of NWRM.

- Increase local awareness of the possibilities and multi-benefit aspects of these measures, together with the training of experts to help decision-makers implement NWRM or propose better options.

- Involve local communities and organisations early in the process, especially in order to identify the triggers that communities need to engage in lasting change.

Policy frame

NWRM should be included under the Water Framework Directive and the Floods Directive (FD) as they can improve implementation synergies of both directives and support coordination between River Basin Management Plans (RBMP) and Flood Risk Management Plans (FRMPs).

Link between NWRM and the following European Union policies:

- Water Framework Directive, which aims to achieve a good ecological and chemical status of all water bodies within the EC.

- Directive 2007/60 / EC of the Parliament of the European council, on the assessment and management of flood risks.

- "White paper" on adaptation to climate change of 2009, with which the EC presented the framework of adaptation measures to climate change and policies to reduce the impact assessment.

- Birds and Habitats Directives, for example as measures for achieving favourable conservation status, the connectivity requirements of Natura2000 and the restoration target of the EU 2020 Biodiversity Strategy (Target 2).

WATER REUSE IMPLEMENTATION INCLUDING LIFE CYCLE ASSESSMENT

Related challenges:

- Water pollution
- Limited spread of circular economy options and practices

Water reuse has been gaining importance as a solution to cope with water scarcity. The idea behind water reuse is that treated wastewater from urban wastewater treatment plants (UWWTPs), which is usually discharged to surface water, can be further processed through adequate tertiary treatment to obtain 'reclaimed water'. This can be reused for different purposes such as agricultural irrigation, industrial uses (for example cooling) urban uses (for example streets cleaning) and replace water of higher quality which could be used for other purposes such as human consumption. From the Life Cycle Assessment (LCA) perspective, treated wastewater obtained from tertiary treatment does not lead to a significant improvement for most of the environmental impact indicators, but it is recommended when the demand for water exceeds the available amount, because it represents a net saving of water from nature (Pintilie et al., 2016).

Related problems/challenges

The use of reclaimed water has risk associated with the fact that the origin of this water is very chemically and microbiologically contaminated. Proper technologies should be implemented alongside a multi-barrier approach, control and monitoring procedures for risk management. This is a challenge at governance and regulatory level, and the roles and responsibilities of the different actors involved should be clearly defined, ranging from wastewater treatment plants operators, reclamation plant operators, irrigation infrastructure managers, farmers, and authorities.

Picture 3: Water treatment plant aerial view (Credit: Riccardo_Mojana)

STRENGTHS

- Reclaimed water is a relatively stable source of water which can be available independently of climate events (for example drought periods) if the appropriate infrastructure for sustainable wastewater treatment and safe reclamation is in place.

- The tertiary treatment of waste water leads to saving in the amount of water extracted from natural resources, therefore it is recommended in southern Europe, as the demand for water is high.

- In coastal areas, water reuse implies a net increase of water resources available. If properly managed, the use of reclaimed water can reduce the pressure on other water resources.

- Reclaimed water contains nutrients which may imply savings in the use for fertilizers when it is used for agricultural irrigation/fertigation.

- Water reuse provides an economic incentive to provide adequate treatment to wastewaters and avoid the negative impacts of discharging non treated wastewater to water bodies.

- Water reuse is more cost effective than other solutions to alleviate water scarcity such as water transfers or sea water desalination.

WEAKNESSES

- Water reuse requires the investment in adequate infrastructure and control measures that guarantee that effluents from wastewater treatment and reclamation comply with the required quality standards for different uses.

- Related to this, there is a need to analyse and disseminate case studies with positive technical, socio-economic and environmental performances.

- Water reuse is generally more attractive in coastal areas. For inland areas, treated water can be indirectly reused when it is discharged, so there is no net increase of water resources with direct use of reclaimed water in inland areas.

- Besides conventional contaminants and toxic compounds, the presence of chemical and microbial contaminants of emerging concern (for example micropollutants) leads to uncertainty among the users of reclaimed water because the effects after the irrigation with reclaimed water are not always sufficiently clear. Studies and research results about the impact of micropollutants are not sufficiently known by the different stakeholders and this situation has created a lack of trust.

- The use of reclaimed water does not necessarily imply to alleviate pressure on existing water resources as it happens when end-users have access to additional water resources through reclaimed water instead of replacing the existing resources.

- Social reluctance: There is a cultural reluctance associated to origin of the reclaimed water, for example wastewater coming from human excreta. This feeling of 'disgust', or 'discomfort' is also called the 'yuck factor'.

Lessons learned

- **RichWater** project: This is an Innovation Action funded by Horizon 2020 and coordinated by BIOAZUL. The main result has been the demonstration and validation of a prototype for wastewater treatment and reclamation to obtain an effluent ready for irrigation, complying with the standards of the new regulation EU 2020/741. The prototype includes a tool to optimise nutrient content (and therefore savings in fertilizers). RichWater technology has been validated by an external body following the Environmental Technology Verification (ETV)programme launched by the EC, which is a market tool to provide guarantees to potential clients about the system performance (and thereby overcome the reluctance associated to the use of reclaimed water). More information can be found at: https://richwater.eu/

- **The case of Murcia region**: This is a success story of a governance scheme to facilitate the use of reclaimed water whilst reducing the associated risks. In Murcia, the regional sanitation authority, ESAMUR, is also the end user of the effluent from the Municipal Wastewater Treatment Plants (i.e., the reclaimed water) instead of farmers. With this approach, farmers pay ESAMUR for the reclaimed water they use for irrigation, but ESAMUR remains the responsible body to guarantee the water quality. This approach has several advantages: the responsibility to keep water quality high relies on water engineers with expertise in water treatment and not on farmers. With this approach the region of Murcia is one of regions in Europe with highest reuse rates with more than 70% of reuse (and more than 90% when considering indirect reuse).

Policy frame

The Water Reuse Regulation (2020/741) provides minimum requirements for water reuse in agriculture. However, there are no EU regulations for other uses of reclaimed water from sources other than agriculture.

Water Reuse Regulation lays down minimum requirements for water quality and monitoring as well as the provisions for the development of water reuse risk management plans which are generally described in Annex II of the regulation. The EC is currently working on guidelines on risk management to support Member States with this task.

Several EU Member States have regulated the use of reclaimed water (for example Cyprus, Italy, France, Greece, Portugal, Spain and Malta). For instance, in Spain the Royal Decree 1620/2007 regulates the use of reclaimed water for agriculture, urban uses (for example street cleaning) or industrial purposes. These regulations will need to be updated in order to be aligned with the Water Reuse Regulation.

WATER CONSERVATION MEASURES IN IRRIGATION

Related challenges:

- Restrained optimisation of water management through smart tools
- Mismatch between water demand and supply

Irrigation scheduling strategies based on the measurement and modelling of the soil-plant-atmosphere water continuum

To determine the amounts and frequencies (scheduling) for irrigation, available methods include those based on climate and crop evapotranspiration data, soil moisture and crop water status.

The most common methodology currently used for irrigation scheduling is the estimation of crop water requirements using a procedure (Allen et al., 1998) that accounts for weather variables (ETo) and a factor linked to the plant species (crop coefficient, Kc). This information is provided to the farmers by advisory services of regional institutions. However, this approach presents several uncertainties due to the plantation - even for the same species and cultivar - since the crop water requirements are closely related with plot management and also with the agronomical characteristics of the cultivars. Therefore, the indications provided by this method can be a good approximation but not an accurate one. Moreover, this procedure does not provide any information about the frequency and water amount to apply in each irrigation event, since this depends on soil characteristics and the irrigation equipment installed in a given field. Therefore, it is pertinent to use new technologies for irrigation scheduling based on soil and plant water status.

Picture 4: A soil moisture sensor capacitance probe installed in an irrigated vineyard (Credit D. Intrigliolo)

Irrigation scheduling based on soil water measurements requires a good knowledge of root distribution and relative density, with the limitation that uncertainty increases when the wetted soil volume varies in three dimensions, as it does in drip irrigation. Usually, these methods aim at maintaining soil water content within a range of values by setting upper and lower thresholds. A more precise irrigation scheduling can be achieved by using plant-based water status indicators, which have become more popular in the Mediterranean agriculture, because the plant itself is the best indicator of its water status. Moreover, physiological processes and crop productivity is controlled by plant water status and, hence, this information would be very useful for scheduling irrigation.

Related problems/challenges

In the Mediterranean basin, agriculture is by far the main user of water resources, and irrigation is a crucial field practice influencing crop productivity and product quality. In addition, irrigation is a major driver of solute transport in arid and semi-arid environments, affecting the (potentially negative) impacts of improper water management on soil salinisation and aquifer pollution. The challenge, therefore, is to improve irrigation water productivity while minimising the possible environmental risks associated with irrigation, whilst also considering factors related with the efficient use of energy in pressurised irrigation networks.

STRENGTHS

- Soil moisture sensors provide a means to adjust irrigation management to the particular characteristics of individual crops and fields. They are useful for the implementation of deficit irrigation strategies particularly under conditions of water scarcity.

- The use of soil moisture sensors for irrigation scheduling is particularly well-suited to horticultural systems because of the widespread use of advanced irrigation systems (for example drip irrigation).

- Plant measurements have the advantage of integrating the soil and atmospheric water status, as well as the response of the plant to the surrounding conditions.

- On-the-ground measurements can be integrated with remote sensing determinations to upscale the point measurements taken by single sensors to larger area better accounting to the on-farm variability.

- On-the ground installed sensors will provide real time information system continuously collecting data about the dynamic water status in the plant, soil and atmosphere, while remote sensing will allow determining biophysical variables at larger scale but with low temporal resolution.

WEAKNESSES

- A potential problem with all the soil-water based approaches described is that many plants' physiological processes respond directly to changes in water status in the plant tissues rather than to changes in the bulk soil water content (or potential). The actual tissue water potential at any time therefore depends both on soil moisture and on the rate of water flow through the plant and the corresponding hydraulic flow resistances between the bulk soil and the plant tissues. Therefore, plant response to a given amount of soil moisture varies as a complex function of evaporative demand.

-Additional general issues with the use of soil moisture sensors are the accuracy of default calibrations for specific conditions and the issue of representative sampling.

Lessons learned

The usefulness of capacitance probes was evaluated in large citrus irrigation districts during several seasons where irrigation practices were changed over years from the ETo * Kc model to the analysis of soil water status trend (Bonet et al., 2010). Around 25% water savings with no substantial yield penalty could be obtained when the information provided by capacitance probes was correctly applied for irrigation management. Based on these outputs, several companies are nowadays offering these type of technologies including not only the hardware infrastructure (sensors and loggers) but also the service of interpretation of the data and results. A good example for this vibrating are of innovation it is the participation of several high-tech companies in the recent InnoWise Scale competition (https://www.eitfood.eu/media/clc-documents/INNOWISE_SCALE_PROGRAMME_PARTICIPANTS_2021-comprimido.pdf)

There are, however, some other non-technical limitations for the wide-spread use of any type of sensors. A common aspect in the Mediterranean agriculture structure is the small scale farming systems with with more than 60% of orchards smaller than 2 ha. Hence these growers face some difficulties paying the high cost of equipment. However, this kind of higher parcellation of the agricultural can also bring some benefits in controlling the emission of fertilisers, herbicides, and pesticides to the drainage network and consequently the receiving water bodies. The consequent economic advantage in terms of saved natural capital should be considered for subsidising the use of advanced technologies to the small growers.

Policy frame

In the last few years, great economic efforts have been made to supply water-user associations (group of fields that share facilities for the collective use of irrigation water) with efficient hydraulic installations. In addition, new technologies, such as localized and pressurized irrigation systems, have been introduced. Nevertheless, the effort devoted to optimise irrigation scheduling (amount and frequency of water to be supplied to the crops) has been lower, although this would ultimately allow for a more efficient use of water resources. This issue is nowadays of paramount importance due to the high increase in energy costs associated to irrigation, which directly influence on the cost of water use. Moreover, the current scenario of water scarcity makes necessary to use all the available tools for increasing water use efficiency.

A policy scenario where more emphasis to the water productivity levels attained should be promoted. This implies the possibility of pricing water allocations according to some threshold values for water use efficiency, promoting private water markets or providing incentives for using the described tools for scheduling irrigation.

INNOVATIVE ALTERNATIVE WATER SOURCES

Related challenges:

- Water pollution
- Limited spread of circular economy options and practices.
  Mismatch between water demand and supply

Commonly used water resources, such as freshwater from rivers or lakes or groundwater reservoirs, will not be sufficient to meet the growing water supply demand in water scarce areas, especially if climate change worsens the local climatic conditions and rainfall patterns. Therefore, a paradigm shift is needed to include non-conventional water resources and innovative technologies in current and future sustainable water management strategies and in water reuse options.

The use of non-conventional water sources implies a wide range of methods for accessing water, combined with modern technologies for ensuring the quality is appropriate for the specific use. This can include using abandoned ancient approaches (i.e., rainwater harvesting, fog or vapor capturing) to the transformation of 'by-product water' into 'new water', following the most recent Circular Economy strategies aimed at closing resources cycles and avoiding waste. We can refer to non-conventional sources when we deal with:

- micro-scale or large-scale harvesting of rainwater, the latter being coupled with Managed Aquifer Recharge (MAR) practices.

- atmospheric moisture harvesting such as cloud seeding, fog water collection by nets or condensation structures (Jarimi et al., 2020).

- extraction of groundwater and possible treatment in unexploited regions (or in deep geological formations or in off-shore or polluted aquifers) (Water Reuse Association, 2011).

- desalination of seawater or highly brackish groundwater (Slater et al., 2020).

- segregating the collection and treatment of wastewater, greywater, stormwater (Masi et al., 2018).

- collection and use of agricultural drainage water (Rossi, 2019).

The reuse of water from different unconventional sources will render the organisational separation between supply and evacuation outdated, the latter being currently the main task of sanitation.

In cities and towns, urban water systems should be integrated and harmonised to manage all urban water (drinking, rain, ground and surface water) in an integrated and efficient way to make it available for as many cycles of use as possible and function as part of the urban fabric.

Water may be retained and further used within a unit or in its vicinity, reducing wastage (so-called 'zero-outflow' concepts).

One possible way to achieve this is a widespread and timely integration of multipurpose NBS projects into the urban structure, each of which provides as many ecosystem services as possible. NBSs use water for their survival and the interaction with such solutions allows numerous benefits for urban well-being and for the sustainable use of water resources.

HYDROUSA

HYDROUSA is a H2020 project aiming at closing water loops in Mediterranean basin. Within the project, several pilots have been established. The aim of the Lesvos pilot site (HYDRO1+HYDRO 2) is to demonstrate the possibility of treating wastewater produced by a touristic site (HYDRO1, high fluctuation in sewage production due to seasonality of touristic activities) and producing an effluent suitable for reuse in irrigation under strict Greek water quality standards. The treatment chain of the Lesvos pilot includes: Upflow Anaerobic Sludge Blanket (UASB) + Constructed Wetlands (CWs) + Ultrafiltration (UF) + UV lamp.

The effluent is reused in an Agroforestry site (HYDRO 2) for food production. HYDRO 1+HYDRO 2 and the monitoring tools were designed by a multi-disciplinary group involving different European partners and is intended to have a full circular economy approach for wastewater, recovering energy and sludge from UASB, water and nutrients from CWs, and finally producing valuable food in HYDRO 2. HYDRO 1 and HYDRO 2 are two of the six pilots of the HYDROUSA project. For more information: hydrousa.org

Water categories	HYDROUSA systems	Recoverd products	Marketed products
Rainwater	Harvesting	Water for domextic non-drinking use	Service water
Groundwater	Recharge & storage	Irrigation water	Mediterranean crops
Wastewater	UASB & wetlands	Fertigation liquid Biogas	Plant-based products Energy (heat&power)
Water vapour	Vapour condensation	Drinking water	Drinking water
Seawater	Tropical greenhouse	Irrigation water Salt	Tropical fruits Edible salt

Figure 6: Innovative water use in the Hydrousa project

GREYWATER CLOSED-LOOP RECYCLING AT HOUSEHOLD LEVEL: A TOURISTIC FACILITY IN TUSCANY

Tertulia is a Co-living / Coworking space in the municipality of Vicchio (Florence, IT), immersed in the natural environment of the Tuscany Apennines mountains. The facility is managed by a family of five permanent residents and it has guest space in different apartments for 30 additional people, mainly remote workers, digital and creative nomads but also tourists. The small settlement was renovated in 2008, at which time sustainable solutions for water management were built. Greywater is segregated from blackwater and treated in a Subsurface horizontal flow Constructed Wetland (net surface 85 m^2) and collected in an underground tank, together with stormwater harvested by the roofs. The treated water, after additional UV disinfection, is reused for irrigation and toilet flushing. A second subsurface flow constructed wetland (net surface 45 m^2) permits the treatment of blackwater, which is then discharged in the environment according to local regulations for discharge in fresh water. For more information: tertulia.farm/

STRENGTHS

-Local sources can better minimise the costs and impacts related to water transfer

- NBS can be widely applicable for water reuse and offer several other advantages as biodiversity increase, flood mitigation, aesthetic improvements and landscaping, heat islands reduction, water storage and increased evapotranspiration, nutrient recovery, energy recovery, CO^2 storage

- Innovative NBS for nonconventional water sources usage is generally well perceived and accepted by the public in urban areas; green infrastructures are also proven to be more accepted than grey

-Closed-loop water reuse is increasing the resilience of cities not only from climate-induced drought, but also from water shortages resulting from the forced occupation of homes, such as during Covid-19 pandemic lockdowns

- Reduced surface water abstraction according to WFD requirements for ecological flow

- Water reuse can minimise the cost of grey infrastructures for conveying wastewater to treatment units, as well as decreasing the amount of water to be treated. This has economic advantages as well as significant positive impacts, such as reducing the discharge of WWTP effluents in a single point of the water body receiver. This theoretically leads to an increase in the quality of the water downstream.

WEAKNESSES

- Lack of standardisation of technologies used for the exploitation of unconventional water sources, which is reflected in the lack of tools for decision makers, relative to their large-scale implementation

- Lack of economic tools for the monetisation of different ecosystem services that can be connected to the application of NBS for water reuse

- Land occupation: NBS are usually presenting a much higher footprint in comparison to other energy-demanding technologies

- Slow payback period within current economic models applied to the water tariff: the cost of water does not contain environmental externalities

- Lack of awareness of the available technologies both for technicians and stakeholders/ decision-makers

- Fragmented framework of legislation at EU level

- Need for harmonised guidelines for water reuse risk management planning, which can address best early warning and decision support systems with regards to environmental and human health risk assessment and management

- For hi-tech solutions (such as membrane filtration): energy-intensity; required infrastructure & investment; elevated cost of production

- Infrastructure requirement for storage

- For atmospheric water (fog capture and similar): adjustments in water quality for final use, implementation costs, production level

Lessons learned

- The decentralisation of water supply and treatment/reuse are still linked to the need for maintenance, even if performed by unskilled personnel

- NBS are the most effective innovative solutions for water reuse with qualitative characteristics aimed at specific uses; NBS appear to be advantageous both in urban and agricultural settings

- Multidisciplinary approaches to multi-objectives projects require more iterative processes between different experts

- The innovative nature of these solutions requires particular attention during the implementation phase, in particular for passive systems such as some NBS

- The current technical uncertainties related to the short history of existing plants continue to lead to conservative design and the consequent economic disadvantages (Hardy et al., 2015; "Technological Water Innovations - PIANO project," n.d.; Water Reuse Europe, 2020)

Policy frame

The European Union has increasingly focused on advancing NBS: a recent study (Davies et al., 2021) traces the roadmap of the EU's plans to promote and implement NBS.

The EU definition of NBS is "solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions."(European Commission, n.d.)

The European Commission outlines further that NBS must benefit biodiversity and support the delivery of multiple ecosystem services. NBS are recognised by the EC as a crucial component for a socially inclusive, economically functional and ecologically resilient society. This is the main reason for the EU to support research and innovation in the field, through funding mechanisms such as Horizon 2020, which has resulted in extensive implementation of NBS in Europe and globally, and robust scientific research. The EU is aiming to position itself as a world leader in NBS research.

- Nature-based solutions: Nature-based solutions and how the Commission defines them, funding, collaboration and jobs, projects, results and publications ec.europa.eu/info/research-and-innovation/research-area/environment/nature-based-solutions_en

- Nature-based solutions in Europe: Policy, knowledge and practice for climate change adaptation and disaster risk reduction eea.europa.eu/publications/nature-based-solutions-in-europe

- Towards an EU research and innovation policy agenda for nature-based solutions & re-naturing cities - Final report of the Horizon 2020 expert group on 'Nature-based solutions and re-naturing cities': (full version) https://op.europa.eu/s/tayN

- European Commission, 2014. In-depth Report: E-Consultation on Nature-Based Solutions. Available at: ec.europa.eu/research/environment/pdf/e-consultation_on_nature-based_solutions_in-depth_report.pdf#view=fit&pagemode=none.

- European Commission, 2016. Policy Topics: Nature-Based Solutions. ec.europa.eu/research/environment.

CONTROL AND ENFORCEMENT OF WATER ABSTRACTION

Related challenges:

- Mismatch between water demand and supply
- Suboptimal schemes to tackle water scarcity

Illegal or non-authorised water abstractions – primarily in irrigation agriculture - have long been present in most EU Mediterranean Member States and have contributed to local and sub-regional overexploitation of water resources (for example Upper Guadiana, Doñana, Mar Menor in Spain, Puglia in Italy, Korenia in Greece, Cyprus[5]). Control and enforcement of abstractions has not usually taken place until severe problems were discovered either to the associated biodiversity or other users.

Since 2010, the water crisis has increasingly been considered as a risk to economy and society[6], promoting enforcement policy, supported by newly available (digital) tools, and including business and civil society. Three strands of action can improve control and enforcement of water abstraction:

- Development and implementation of regulation which specifies in detail water rights (and the permitting process and obligations, including installing water meters) and significant infringement penalties, including the obligation to restore the environmental damage.

- Improved control actions, by expanding and training rangers, undertaking earth observation data analysis[7] and water user and citizen support, for example based on increased transparency about water rights.

- Improved governance, including cooperation between involved departments (water, mining, agriculture) on data exchanges, permitting and subsidies; the corporate social responsibility of the added value chains; and increased awareness of the public and especially of large water users.

5 See a recent global list in (Schmidt et al., 2020, p. 7), and an earlier EU overview in (Dworak et al., 2010, pp. 29–30).

6 For example (WEF, 2021)

7 For example, Horizon 2020 project ("Detection and Integrated Assessment of Non-authorised water Abstractions using EO | DIANA Project | Fact Sheet | H2020 | CORDIS | European Commission," n.d.) at: https://cordis.europa.eu/project/id/730109

STRENGTHS

- Transparency: The availability of a public register and accessible online data visualisation tool on water rights provides transparency and enables civil society to support control actions; the Guadalquivir River Basin Authority's Geoportal is a good practice example to follow.

- Market awareness and value chain action: several product certification schema for fruits and vegetables (for example GlobalGAP, AWS, EU Organic Farming) have established different levels of control points addressing the legal use of water; the training of auditors is of high relevance for such schema[8].

- The European Digital Strategy can facilitate data integration and big data management[9], and ease the detection of illegal water abstractions by, for example, combing information about mining permits, agricultural subsidies and controls, water rights and energy consumption.

8 More information in (Fuentelsaz et al., 2020); planned to be rolled out to other Mediterranean countries; (Fuentelsaz, 2019)

9 For example, (Water Ledger, 2020) White Paper: Water – a token economy? Available at: https://waterledger.com/water-a-token-economy/

WEAKNESSES

- The vast numbers of illegal abstractions[10] in irrigation and, given these are based on huge economic benefits for the water user, social norms and gaps in governance weaken the success chances of a simple 'control and command' approach. There is strong – and sometimes violent[11] – opposition by farmers, local politicians and inhabitants.

- Though 'threatening' sanctions/fines are a fundamental part of the water abstraction enforcement system, the few individual legal processes are too sporadic and not enough to solve illegal water use problems. In addition, legal processes are long and resource intensive. Sometimes, rules contained in water sharing plans are highly technical, making it difficult for the community to interpret them[12].

- Even the best control mechanisms can be manipulated, for example water meters, may not be perceived as sufficient evidence by the courts[13]; thus, a combination of tools may be more robust.

10 For example https://es.greenpeace.org/es/noticias/los-pozos-ilegales-nos-roban-el-agua/ refers to > 1,000,000 illegal boreholes in Spain; and https://www.asociacionanse.org/wwf-anse-desvelan-crecimiento-masivo-agricultura-ilegal-regadio-zonas-aridas-europa/20180607/ to 12,000 hectares of illegal irrigation in Murcia.

11 For example in the Spanish Doñana area, as recorded by https://www.huelvainformacion.es/provincia/alcaldesa-Almonte-declarar-sobreexplotado-precipitado_0_1327667676.html and http://agrodiariohuelva.es/2019/06/24/los-agricultores-de-lucena-del-puerto-impiden-a-los-tecnicos-de-la-chg-iniciar-el-sellado-de-los-pozos/ and in the Segura basin: https://www.laverdad.es/murcia/yecla/inspector-denuncia-encanonado-20180925010818-ntvo.html

12 (Schmidt et al., 2020, p. 20); (Carmody, 2018)

13 For example, the ECJ ruling on the Doñana case in 2021 (ECJ, 2021)

Lessons learned

- There is no 'silver bullet' to tackle illegal water use. However, within case studies and literature, different strategies have been (partially) successful, for example, by combining actions to have a faster or stronger impact. Tailor-made approaches with negotiations and trade-offs have also been reported (Schmidt et al., 2020, p. 17)

- Multi-stakeholder negotiations can lead to the definition of a baseline for the agreement of an enforceable water rights system but can be difficult and time-consuming (Schmidt et al., 2020, p. 17).

- Water meters are a fundamental tool for control and enforcement but are relatively easy to manipulate; online-data-submission and validation on-site and by satellite data can provide robustness, even if such tools face challenges such as the lack of reliable geographical information on the spatial distribution of water rights for irrigation (Schmidt et al., 2020, pp. 16–17). The Spanish Mancha Oriental aquifer self-regulation system is handled by the Central Irrigation Board of Mancha Oriental, monitoring and managing groundwater abstractions based on Earth Observation (EO) data. Since 1997, the Irrigation Board has developed capacities to integrate and use the routine procedures by agreeing an Annual Irrigation Plan and a continuous EO-assisted monitoring and control, focusing on 'suspicious' fields for inspections, supported by well-calibrated flowmeters on the ground. Over the years, the number of sanctions has dropped below 0,1% of total water abstraction in the aquifer (Calera et al., 2017).

Policy frame

The EU Common Agricultural Policy includes a subsidy cross-compliance system to ensure minimum standards, including a 'Good agricultural and environmental condition' (GAEC) requesting legal water use, and resulting in a reduction of 1-5% of the EU farm subsidies. It is, however, uncertain if this amount is sufficient, given that approximately 10% of Spanish inspected farms infringe this standard (FEGA, 2021); and the system is only implemented in eight EU Member States (Spain, France, Croatia, Italy, Netherlands, Poland, Romania, Finland) (European Commission, 2020a).

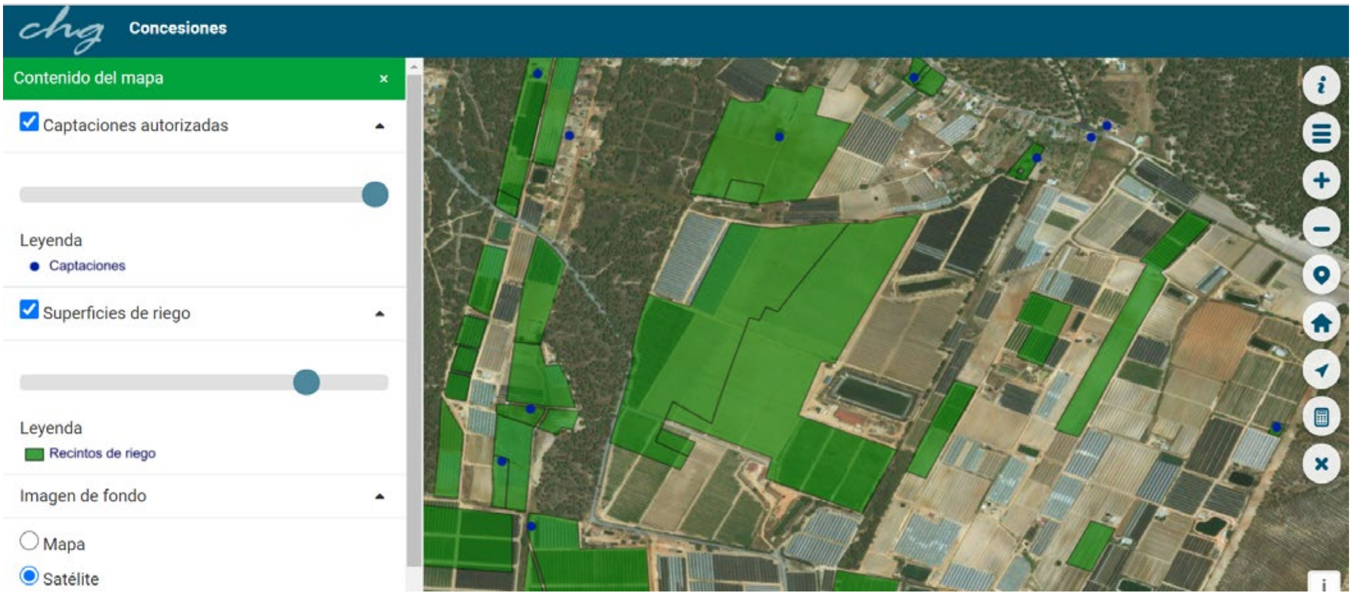


Image 1 : Guadalquivir River Basin Authority's Geoportal. Source: CHGuadalquivir, n.d

The Guadalquivir River Basin Authority's Geoportal allows to visualise, for example, authorised water abstraction points (blue dots) and authorised irrigation areas (green layer). When comparing with the satellite image, it can be seen that a large part of greenhouse irrigation fields lack such permits.

CASE STUDY: INTERNATIONAL WATER SHARING PRACTICE – GUADIANA RIVER

Spain and Portugal share five International River Basin Demarcations (IRBD). The Guadiana (map below) is the one located furthest South and, therefore, is most affected by water shortages and cyclical droughts caused by climate change. The Spanish-Portuguese cooperation in IRBD is regulated by the Albufeira Convention (AC) that has been in force since 2000, like the WFD and which is highly influenced by this directive. Relations between the two EU States in the matter of Water Policy improved considerably after the entry into force of the AC, but joint plans for the IRBDs were never drawn up, the focus is on coordination of the plans that each State draws up separately.

In the case of Guadiana, the Spanish-Portuguese relations of the last decades (from 2000 to 2021) occurred with 'lights and shadows'[14]. Among the best moments of cooperation was the agreement to 'buy-sell' water from the Portuguese Alqueva Reservoir (the largest artificial lake in the EU) to users located in Spanish territory (Villanueva del Fresno, Badajoz province). Furthermore, the Portuguese authorities decided to charge Spanish users the same tariffs as they charged the Portuguese users.

Map 6: Guadiana International River Basin Demarcation, Source: CHGuadalquivir, n.d

However, further south, to follow the Alqueva reservoir, at the flow control point known as 'Pomarão' – located in the Guadiana in Portuguese territory (Mértola district) before the confluence with the Chanza (tributary of the Guadiana on its left bank) –, the two States do not agree on the volume of water that corresponds to each. Since 2008 (Art. 8° 2 Adicional Protocol AC), studies are pending completion to determine the flows that should be provided in this section of the Guadiana, taking into account the sustainability of the international section of the Guadiana until reaching the Estuary. The current volume (5m^3/s) was established unilaterally by Portugal, taking into account the availability of the Alqueva-Pedrogão System (SAP).

According to the Minutes of the 10th Plenary Meeting of the CADC[15] (CADC, 2008) the 'Agencia Andaluza del Agua' submitted a request to increase the capture of the Boca-Chança Station (located before Pomarão) by an average annual volume of 35hm^3 of water (as was collected in the last 10 years) to 80hm^3. The approval of this request depended on the results of the studies on the environmental sustainability of the 'Lower Guadiana' (as detailed above). To date, none of the studies have been published or disseminated and Portugal has never authorised the request of the 'Agencia Andaluza del Agua'. Therefore, States must respect the agreement adopted in 1999 within the predecessor Commission of the CADC, that is, the Commission on Rivers International (CRI). CRI decided that there should be no irrigation catchments on the left bank of the Guadiana. That is, from Boca-Chança – which had been authorised, exclusively, for the public supply of Huelva. However, abstractions for irrigation have been increasing and references to them are found in different minutes of the CADC, in which the Portuguese delegation of the CADC expresses its discomfort with them, requesting control by the corresponding Spanish authorities.

CADC minutes can be consulted on its website (cadc-albufeira.eu) or requested by correspondence from the Spanish or Portuguese authorities.

14 More detailed analysis in (Sereno Rosado, 2021, 2011) and (Dias, 2021)

15 Commission for the Application and Development of the Albufeira Convention (Comissão para a Aplicação e o Desenvolvimento da Convenção de Albufeira). More information at: http://www.cadc-albufeira.eu/pt/

CAP WATER RIGHTS IN OVEREXPLOITED BASINS AND AQUIFERS

Related challenges:

- Suboptimal governance and financial schemes to tackle water scarcity.

Water resources in arid regions have evolved through a historical trajectory that drives the resource stocks from open access to fully exploited and later to overexploited. This evolution can be observed in many water bodies and aquifers, river basins or subbasins. Once full exploitation is reached, the water management requires control of water rights entitlement (long term management) and annual water abstraction (seasonal quota). This is called 'cap', as the process of decision making on the maximum available water that should be defined long term (water rights allocation) and short term (quota) by yearly adaptation to available resources grants flexibility to the system. Under this scheme, water allocation is reduced temporally when a drought is declared.

Definition of the 'cap' (maximum level of abstractions) must consider firstly the environmental constraints (environmental flow), secondly the priority uses (generally domestic/urban needs) and finally a safety buffer (due to future needs, uncertainty regarding available resources). Once these prerequisites are met and available resources are estimated, the remaining resources can be allocated to lower-priority economic uses such as agriculture, energy, and mining (EEA, 2011).

Once the allocation is completed, the system needs to be provided with some flexibility by adapting annual quota to available resources (for example drought).

The system should also provide flexibility for changes between water users, both long term (water entitlement transfer) and short term (water transfer within a season). This can be done by self-management adaptation (agreement between users with or without money transfer) or by the intervention of a public institution.

Related problems

The decision to 'cap' the available resources is generally taken too late, when evidence of overexploitation appears. Ideally it should be taken in advance of a scarcity crisis, but policy makers and agents keep exploiting the resource (aquifer, basin) until the evidence of environmental damage (low flows, dry streams, decreasing piezometric lkevels) is overwhelming.

Once the decision to limit abstraction is taken, water entitlements are usually distributed proportional to water right entitlements (acknowledging seniority and priority uses). The process is complex and depends upon each country's institutions and legal framework. The process is politically difficult, and many social groups try to influence the allocation procedure.

When the available volume is reduced (for example, drought), the water allocated to lower priority uses (for example, agriculture) is reduced but usually urban volume is not affected which may create conflicts between stakeholders.

The system requires strict abstraction monitoring by remote sensing and metering devices.

A difficult technical task involves the estimation of return flows (the difference between water abstracted and water consumed), that are a significant part of the water balance and are determined with a level of uncertainty.

STRENGTHS

- Resource 'cap' and flexible allocation has been applied in overexploited resources, either surface (river basins) or groundwater in many regions of the world. Examples are the Southwest USA (California, Kansas, Arizona, Nevada, Colorado, Nebraska), Australia (Murray-Darling basin and aquifers) or EU (France, Spain).

- The approach has either been top-down or self-management, depending on the complexity of the process. In large schemes (river basin, or complex groundwater systems) the intervention of the State or Water Authority is required. Some States try to promote self-regulation under State monitoring such as California or Nebraska (Milman et al., 2018).

- In the EU, success cases are found in Spain (La Puebla aquifer,(Berbel et al., 2019b)) and France (Beauce aquifer, (Petit, 2009). Both examples guarantee long term equilibrium, including provisions for environmental flow and priority uses but are also designed to cope with droughts as the rules for reduced quota are defined previously. This avoids 'ad-hoc' committees and negotiations when a drought event is declared. These previous known rules allow users to be prepared for supply changes and adapt more efficiently to droughts.

WEAKNESSES

The system weaknesses are:

- Complexity of hydrological systems: It is usually adopted too late when some damage to ecosystem is already evident. The management of groundwater resources is especially difficult as the evidence is less visible, and the control of abstraction wells is more problematic than surface water.

- The need for constant monitoring and control of illegal abstractions (either users with no rights or users that abstract over their quota). When value of water is high, the sanctions may not prevent illegal behaviour, and they may be difficult to impose by an authority.

- One of the main problems is that the definition of environmental flow must be respected and is considered a higher priority constraint. This process requires sound science to define the reasonable water flow and public participation to reach agreement (Grafton et al., 2020)

- The initial allocation decision needs to be made flexible to allow new activities to emerge. However, the rules for reallocation (through market or central decision body) are subject to ideological conflict as some social groups oppose to water right trade (between users) or to territorial re-allocation (from less competitive to more competitive regions).

- It requires the existence of developed institutions (democracy, rule of the law, transparency) that maybe a constraint in less developed regions.

Lessons learned

The need for a sound and substantial definition of environmental flows as can be seen in two examples:

1. The Murray-Darling (Australia) basin initially defined a cap and allocated water rights that did not reserve enough resources for the environment and is currently struggling to achieve environmental goals under the existing allocation regime (defined in the 1980s) (Grafton et al., 2019; Hanemann and Young, 2020).

2. A more extreme example is in Chile where allocation of water resources (1970s) did not consider any environmental flow provision and the State is now in a legal dispute to recuperate this volume from the water right holders who ask for compensation.

The solution is to define environmental flow using sound science and broad public participation.

The experiences outlined above demonstrate the need for strong State intervention to catalyse change. Groundwater monitoring is more difficult to implement compared to surface water resources. However, new technologies are facilitating the management of the 'invisible'. Some success cases show that this goal is feasible:

- In the EU, we can follow the example of 'Beauce aquifer' (France) and'La Puebla-Fuencaliente' (Spain) as the dynamic management of former overexploited aquifers that are currently under control. Both cases have required State (Water Authority) intervention and strict monitoring, they require previous intervention of Water Agency (for technical reports), users' involvement and continuous monitoring.

- California adopted the Groundwater Management Act during the long drought (2012-2017), based upon self-regulation under State surveillance (Milman et al., 2018). Results are positive after years of mismanagement (some areas of California have sunk varying depths of meters due to subsidence caused by over abstraction).

Policy frame

In the EU, the WFD objective is good environmental status (GES) for all water bodies and this goal has been implemented in all MS national legislation, including in instruments to enforce the measures to achieve GES.

Cases mentioned previously (USA, Australia, France, Spain) have a legal framework, a national (State) level that gives power to Water Agency to enforce allocation and quotas. The existence of a certain institutional quality (democracy, rule of the law, transparency) is a requisite for implementation. We have not been able to find success stories in developing countries that lack the State resources for the definition of water rights and subsequent monitoring and enforcement policy. Policy makers should intervene as soon as there are some indications of overexploitation (or risk), undertake a transparent and proper definition of water resources supply and existing water rights, promote public participation and users' involvement in future management of the resource.

GLOBAL VIEW - REDUCE FOOD WASTE

Related challenges:

- Limited spread of circular economy options and practices

Reducing food waste represents an important environmental, economic and social issue at the global scale. Food waste is connected with climate change, consumption, food security and water scarcity – it is related to water over-consumption, especially for food that are not finally consumed. In addition, food waste comprises a large part of domestic waste, increasing dramatically the 'waste stream', placing a heavy load in the solid waste treatment systems and contributing to pollution of water resources.

The Food and Agriculture Organization of the United Nations (FAO) estimated that the blue water footprint (the consumption of surface and groundwater resources) for the agricultural production of total food wastage in the world was around 250 km3. In relation to volume, represents approximately three times the volume of Lake Geneva, or the annual water discharge of the Volga River (FAO, 2013). FAO calculated that global food loss and waste represents one third of all globally produced food, which is directly linked to costs estimated at $936 billion (FAO, 2014). Food loss and waste generates annually 4.4 Gt of CO_2-eq, or around 8% of total global anthropogenic greenhouse gases (GHG) emissions. In the EU, around 88 million tonnes of food waste are generated annually, with associated costs estimated at €143 billion (Stenmarck et al., 2016).

Picture 5: Remains of half rotten food and another rubbish in waste basket.
(Credit:SaskiaAcht)

1. OLIO APP

OLIO app is active in 121 countries, including Malta, Cyprus, Spain and Italy and has over 4.7 million users. It connects local communities and people who are giving away food to their neighbours who need it. Surplus food can be donated by individuals or companies such as food retailers, restaurants, and corporate canteens. The food can be raw or cooked but has to be edible. Volunteers at OLIO's Food Waste Heroes programme collect unsold food from food retailers and distribute it to OLIO members via the app, saving it from being thrown away in the evening. By providing food to those in need, Olio app has reduced food waste and saved over 27 million meals globally. While fighting food waste, it has helped fought water scarcity by saving over 4.1 billion litres of water[16].

2. TOO GOOD TO GO APP

Too Good to Go app is active in 15 countries, including Spain and Italy[17]. It helps to achieve a significant reduction of food waste (90.5 million meals saved globally) and includes 109,508 business partners — including restaurants, hotels, supermarkets and bakeries — and 44.1 million users. The person who downloads the app finds a nearby partner, places their order and collects their meal at a specified time, while saving that food from going in the garbage. The app is currently developing ways to lower food waste in the entire chain – by also including production, handling and storage, processing and packaging and distribution stage. In this way, it will continue to significantly reduce environmental impact.

16 For more information: olioex.com

17 For more information: toogoodtogo.com/en-us.

STRENGTHS

- Food waste reduction will lessen the overall negative impact of food production and consumption on the environment, as it will have positive effects for water use and other environmental impact categories. Water over-consumption for crops that are not finally consumed, as well as over-utilisation of fertilisers (nutrients) used for crop production may be reduced. As the result, GHG emissions, as well as biodiversity impact related to the deforestation and degradation of habitats may be lowered. This is particularly relevant for food production that involves the use of external water resources like irrigation. Considerable water savings could be achieved by avoiding the cultivation of surplus food that is not finally consumed and that is wasted.

- According to the FAO, around 800 million people do not have enough to eat and reducing food waste will have significant social impact on a global scale.

- Decreasing food waste will help fight world hunger and water scarcity, and it will improve the environment, food security, food safety, and nutrition.

WEAKNESSES

- Food waste occurs at every stage of the agri-food value chain, from agricultural production to household consumption, which makes difficult to estimate how much of the production could actually be reduced..

- Each part of the value chain is connected to the other parts and actions are bidirectional. As the result there would be needed global action to tackle each part of the chain, as well as a significant time frame to make a notable reduction in food waste on a global level.

- OLIO app and Too Good To Go app case studies are currently only fighting food waste in the household and retail stage of the value chain, but not in the entire chain. The production stage represents around 25% of global food waste, while handling and storage, processing and packaging and distribution and market account for 40% and consumption for 35%

Lessons learned

- In order to reduce food waste, the agri-food value chain needs to become circular and activities that aim to reduce food waste must contribute to this development.

- Food waste is a complex issue and collaboration between different sectors and actors in value chain is needed.

- In high-income and medium-income countries, over half of the food loss and waste occur in distribution and consumption stages (Vilariño et al., 2017).

- In low-income countries food loss and waste occurs during the production and post-harvest, mainly due to losses during the handling and storage phase (Vilariño et al., 2017).

- Occurrence of food waste during the last stages of the agri-food value chain is considered more harmful, as larger number of resources have already been used.

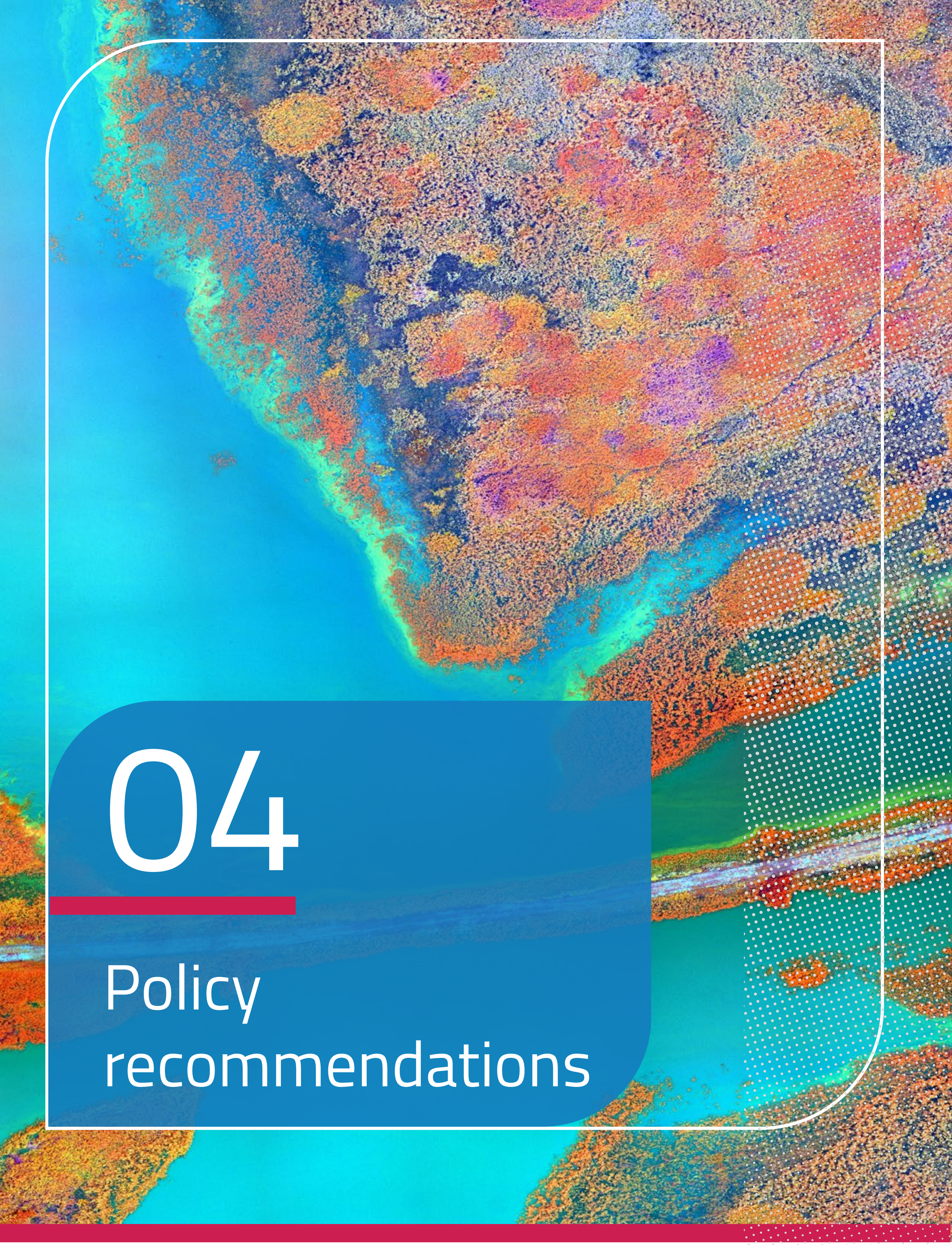
Policy frame

Reducing food waste is considered a priority by the UN 2030 Agenda for Sustainable Development, European Commission EU Green Deal (European Commission, 2019) and its Farm to Fork Strategy (European Commission, 2020b). Target 12.3 of the Sustainable Development Goals (UN, 2016) calls for halving per capita global food waste at the retail and consumer levels by 2030, as well as reducing food losses along the production and supply chains. The EU Green Deal addresses the Target 12.3 and reduction of food waste through the Farm to Fork Strategy, in which it is also stated that the European Commission will integrate food waste prevention in other EU policies and investigate food losses at the production stage and explore prevention methods.

EU's research and innovation policy FOOD 2030: Future-Proofing our Food systems through Research and Innovation (European Commission, 2017b) highlights certain fields with high potential for Research & Innovation - turning fish waste into functional food, finding high-tech solutions for efficient food production, engaging consumers to reduce packaging waste, taking cooperative action to reduce food waste, tackling food waste with ICT networks and extracting high value protein from vegetable residues[18].

The EU policy frame could further contribute to lowering food waste, by introducing obligatory policies regarding role of SMEs and large enterprises in minimising and recycling food waste, as well as policies that would bring benefits for companies which purchase products made from food waste recycling(European Commission, 2020c).

18 More information: European Commission, Food Waste: https://ec.europa.eu/food/safety/food_waste_en; European Commission, EU Platform on Food Losses and Food Waste: https://ec.europa.eu/food/food/food-waste/eu-actions-against-food-waste/eu-platform-food-losses-and-food-waste_en; The Food and Agriculture Organization (FAO) of the United Nations, Technical Platform on the Measurement and Reduction of Food Loss and Waste: http://www.fao.org/platform-food-loss-waste/en/; World Resources Institute, Reducing Food Loss and Waste (2013): https://files.wri.org/d8/s3fs-public/reducing_food_loss_and_waste.pdf ; FAO, Global Food Losses and Food Waste: Extent, Causes, and Prevention (2011): http://www.fao.org/3/i2697e/i2697e.pdf



04

Policy recommendations

The previous chapter outlined a set of solutions to cope with water scarcity with the objective of sharing experiences and lessons learnt. These solutions require an adequate policy framework to thrive. Innovation oriented policies may provide incentives for companies, foster cooperation and knowledge sharing among innovators and help reduce market barriers. The role of government and public bodies is therefore crucial to spread new ideas, approaches, and technologies.

The recommendations described below are a compilation of policy briefs oriented to facilitate the implementation of the different solutions described in the previous chapter.

The EU has a wide policy framework that has supported the response to water crisis. However, EU Directives and Regulations require adapted implementation and specific measures depending on the context of each country and region. The recommendations of this White Paper are oriented to support policymakers in this task and contribute to a more sustainable management of water resources.

FULL COST RECOVERY IMPLEMENTATION

Strengths	Constraints
▪ Required for financing current and future water infrastructure; climate change will require additional investment. ▪ Induces to economic efficiency by boosting water saving. ▪ Promotes the use of water in more economic and social efficient ways. ▪ Guarantees social equity by avoiding cross subsidisation (from social groups or sectors) by general taxation. ▪ Strengthens the environmental awareness of societies and the understanding of the economic, social and environmental aspects of water management.	▪ Cost recovery positive impact requires volumetric billing, which implies investment and control of water consumption (capital and Operation and Maintenance (O&M) cost). ▪ Estimation of water service cost is complex (water infrastructure is multifunctional and externalities are complex to valuate) and the methodology to estimate cost is not standardised (for example, depreciation rate of infrastructure, inclusion of future investment need for climate change adaptation). ▪ Political resistance by traditionally favoured sectors (rent-seeking behaviour). ▪ Cost recovery may generate a social problem with regards to affordability for low-income urban users or farmers.

Recommendations for implementation

- Estimation of cost recovery should proceed stepwise, implementing the full recovery of financial cost (current), followed by a second stage where environmental cost (externalities) is internalised and provisions for future adaptation to climate change are introduced.

- When introducing full cost recovery, policy makers should try, if possible, to implement a consensus-based approach with all stakeholders, avoiding 'criminalisation' of some traditionally favoured sectors (urban wastewater treatment, irrigation, hydroelectric, navigation) and proposing a gradual and continuous implementation.

- Volumetric billing should be included, avoiding 'flat rate systems'. This requires metering devices and policy monitoring, which should start with larger consumers and gradually reach complete coverage.

- Water tariffs and cost recovery should be combined with standards for water abstraction and wastewater discharge to achieve policy goals.

- When cost recovery requires an increase in water tariffs, it is convenient to include provisions for disadvantaged citizens to support affordability of water supply.

NATURAL WATER RETENTION AND RECHARGE MEASURES / SUSTAINABLE URBAN DRAINAGE SYSTEMS (SUDS)

Strengths	Constraints
▪ Holistic ecosystem-based water resource management approach, spatially integrated at strategic, regional and local levels ▪ Potential for resolution of conflicts at transboundary level, in cases of large-scale systems ▪ Provides for climate change mitigation through carbon sequestration and storage,forclimate adaptationthrough flood prevention and the enhanced ecosystem balances as well as increase in resilience ▪ Example of circular economy due to the water storage ability and the potential for water reuse ▪ Reduced risk of flash flooding, reduced loss of properties, drop in insurance costs and raising property value ▪ Successfully exploit natural variations in climate rather than physically separating activities (for example water for irrigation, support of natural habitats) ▪ Reduce stormwater treatment costs (capital infrastructure, maintenance and operating costs) ▪ Enhance natural environments and community aesthetics while providing recreational opportunities and social interaction ▪ Potential for low-cost land-use management and land restoration	▪ Land take of above ground systems ▪ Site-to-site variability in quantity and quality with variations in cost ▪ Monitoring and maintenance costs of non-centralised treatment units ▪ Retrofitting in built areas may pose social and economic constraints ▪ Institutional barriers ▪ Restricted implementation of a sound regulatory and policy framework that will support transitions and changes in infrastructure ▪ Public concerns over safety of above ground water retention systems ▪ Conflicts over trade-offs between land take for NBS and land use for crops to ensure food security

Recommendations for implementation

- Enhance the framework conditions for Nature Based Solutions at EU policy level.

- Strengthen an EU Research and Innovation Community for implementation.

- Legislative and financial support for NBS

- Develop databases and planning support for uptake and upscaling of solutions

- Strengthen collaborative partnerships and participatory processes in support of developing a shared vision of risks, drivers and opportunities and eventually the decision-making process.

- Introduce cultural and economic incentives to boost the implementation of nature-based solutions

- Improve management of existing wetlands, peatlands and peri-urban forests

- Subsidise land-take for the implementation of NBS

WATER REUSE IMPLEMENTATION-LCA

Strengths	Constraints
▪ Reclaimed water is a stable source of water, independent of climate ▪ Harmonised legal framework in the EU with the same quality standards for all MS: i.e., Water Reuse Regulation ▪ Availability of nutrients in the reclaimed water helps to reduce fertiliser use in agriculture ▪ Net increase of water resources in coastal areas	▪ Potential risks to humans and environment ▪ Social reluctance (for example yuck factor) ▪ Uncertainty about the effects of certain pollutants (for example pharmaceuticals, micropollutants) ▪ Need to investment in upgrading wastewater treatment infrastructure ▪ Need for proper governance schemes to monitor adequate implementation

Recommendations for implementation

- To ensure the quality standards required for reuse, it is usually required to invest in infrastructure upgrade and planning (for example ensuring operation and maintenance needs of reclamation facilities are covered). Adequate water pricing and tariff schemes are needed to ensure the economic sustainability and proper operation of wastewater treatment plants (WWTPs) and reclamation facilities.

- The Water Reuse Regulation includes provisions for risk management plans which need to be taken into account for reuse in agriculture. The EC is currently preparing guidelines to support practitioners which will be available soon.

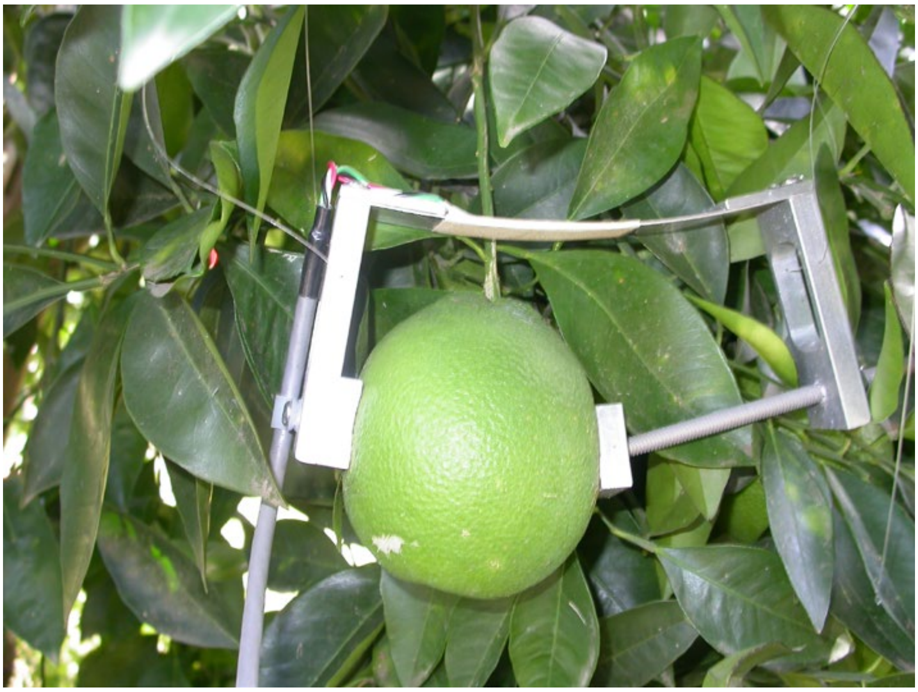
- Authorities are entitled to issue licences/permits for users of reclaimed water. This implies that qualified staff will be responsible for this task in order to evaluate applicants, include in the licences the provisions required for reuse, identify the adequate category depending on the final use, and set the monitoring measures to ensure that all provisions and standards are met.

- End-users may need to install reclamation facilities near the point of use (for example, on farms). This implies a high level of responsibility of the Municipal WWTP to avoid failures that might affect the treatment performance of the reclamation plant. Early warning systems may be recommended.

- Authorities may need to provide technical assistance to practitioners in order to reduce risks and social reluctance. For instance, storage systems for reclaimed water Will need to take into account that the high nutrient content of the water may lead to algae and pathogen growth, even after disinfection takes place. Some practical solutions are available to reduce algae, such as the use of ultra-sonics in storage ponds. In case of use in agriculture, some practical things to consider in relation to irrigation practices include: reclaimed water has usually higher salinity and this affects crop productivity and quality. In these cases, mixing with clear water to reduce salinity or irrigating crops more tolerant to salinity can be the solution. Likewise, when using drip irrigation there is more risk of clogging, adequate irrigation equipment more resilient to clogging is therefore advised.

WATER CONSERVATION MEASURES IN IRRIGATION

Strengths	Constraints
▪ Required for balancing scarce supply with growing demand ▪ Increases water, land, and labour productivity ▪ Reduction of diffuse pollution (reduced return flows and chemicals exported) ▪ Increases reliability against future drought episodes ▪ High social acceptance ▪ Opportunity to improve agriculture products quality, particularly in cash crops (i.e., olives and grapevines)	▪ Increase of financial cost (capital and operating expenses) ▪ Increase of energy consumption that may drive CO2 emissions (if not coupled with renewable energy) ▪ Water saving in non-agricultural sectors is limited to coastal areas (as most of the urban and industry water is returned to the system ▪ Increase of water cost may generate a social problem regarding affordability for low-income urban users or farmers. ▪ Potential rebound (increased consumption) if precautionary measures are not adopted ▪ Difficulties of employing these tools when water, in addition to be scarce, is also of low quality (i.e., high salinity)



Picture 6: Fruit dendrometer: a fruit growth sensor able to determine continuously the orange growth in response to the irrigation regime applied (Credit: D. Intrigliolo)

Recommendations for implementation

- Adoption of a global 'basin/aquifer' view to prioritise 'real water savings' in cases where financial resources are limited.

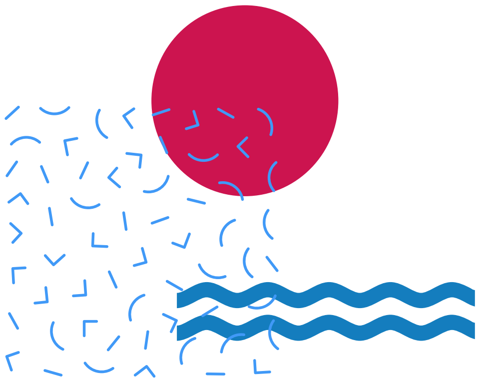
- Estimation of 'real water savings' to avoid 'double counting' as return flows are reduced after water saving are implemented and those return flows maybe required downstream for natural or economic uses.

- Implementation of measures to avoid 'rebound effect' in agricultural sector, those are: a) limitation of irrigated area to ex-ante boundaries; b) reduction of water quota according the 'real water savings.' Both measures should be implemented to avoid the possibility of farmers increasing consumption by appropriating ex-ante return flows.

- Avoidance of irrigation or water use increased at basin level justified by 'theoretical water savings' and rely in well documented real water savings to allocate (eventually) new uses.

- Estimation of cost increase for final users and cost recovery schemes for capital and operational expenses of infrastructure and equipment.

- Recognition that private profitability of water saving investment is low and subject to high water reliability and high crop returns, therefore, public support (for example subsidies) may be required to incentivise technology uptake.



INNOVATIVE ALTERNATIVE WATER SOURCES

Strengths	Constraints
▪ There are alternative water sources which can increase water availability: for example, managed aquifer recharge, rainwater harvesting, fog water collection, desalination, drainage water from agriculture ▪ Alternative water sources are strategic to ensure the supply to new urban growth and food production in a context of water scarcity and growing population. ▪ Sources are generally non-dependent of climatic conditions or on the variations in availability of surface water resources	▪ Unconventional water may need pre-treatment, require on-farm management when used for irrigation, or require specific techniques to collect/access the water ▪ The use of alternative water sources (for example reclaimed and desalinated water) may lead to an increase in the price of water to cover infrastructure and operation and management costs ▪ There is a lack of consolidated information to evaluate the potential of unconventional water resources as a water augmentation resource

Picture 7: System for collecting rainwater from two barrels with overflow
(Credit: tanyss)

- Economic assessment of unconventional water resources is needed to guide policymakers and investors to make evidence-based decisions. The evaluation of the benefits of taking action compared to the costs of no action is necessary to justify investments. The perceived high costs of technology may limit the implementation and scaling up of suitable solutions. Economic analyses shall consider alternative options such as tankers or water transportation from wells from far distances. It is also necessary to consider the environmental and socio-political costs (for example end of inter-territorial conflicts).

- Reductions in production and operation costs support the feasibility of desalination solutions. However, energy consumption is still critical. Policy makers should include adequate funding provisions and tariffs to fund not only the setup of the desalination infrastructure but also the necessary requirements for operation and maintenance of the systems.

- Cloud seeding implies significant challenges in terms of governance. This solution is based on artificially weather modification, hence altered precipitation would affect the distribution and intensity of atmospheric water and precipitation between regions and/or countries. This requires an intensive transboundary dialogue between actors.

- Successful fog collection requires high humidity, such conditions are often found in mountainous and isolated regions with low income. Questions regarding ownership (public-private), monitoring, and quotas need to be solved with adapted measures and adequate planning involving all relevant actors.

- Circular economy approaches are essential to harness the full potential of alternative water resources. For example, brine generated from desalination plants can be used as a source of valuable minerals, such as calcium, magnesium and sodium chloride. Moreover, Circular Economy is supported by major EU policy priorities, in particular the European Green Deal, Biodiversity Strategy and Climate Adaptation strategy. This means potential opportunities for funding in programmes like Next Generation EU and/or Horizon Europe.

CONTROL AND ENFORCEMENT OF WATER ABSTRACTION

Strengths	Constraints
▪ Ensures the good ecological status and long-term sustainability of water resources and conservation of ecosystem services	▪ Lack of instruments for water management and law enforcement.
▪ Fair allocation of water to different uses and end-users	▪ Lack of political will for strict application of law regarding illegal abstractions and use that derive from the pressure beneficiaries are putting to maintain the use of the respective water resource
▪ Reduces conflicts over water use, especially significant in shared or transboundary water resources	▪ Difficult to outbalance the profits from illegal abstraction affecting the end user
▪ Control of water abstractions is a low-cost measure compared to identifying alternative water resources	▪ Difficult to monitor water abstractions
▪ Prevents over-abstraction from groundwater resources and drop of the water table, reduces the risk of groundwater salinization	▪ Distrust in the water authorities that water users might experience, leading to a decreased legitimacy of official decisions and rules.
▪ Reduces vulnerability of surface water resources during droughts, the adverse effects on river flows and the risk of erosion.	

Recommendations for implementation

- Multi-stakeholder involvement in defining an appropriate and implementable water rights system

- Development and maintenance of inventories and databases of water uses.

- Regular monitoring and inspections of water resources to identify water uses and withdrawals (legal and illegal)

- Engage technological means to improve monitoring of water abstractions (for example via remote sensing).

- Increase transparency in monitoring and improve the reporting channels

- Draw attention on research and management of unauthorised water use

- Legal actions, fines and closure of illegal abstraction points

- Cross sectoral incentives (for example reduction of agricultural subsidies) to cover the water demand through legal municipal or regional supply

- Capacity building of end-users to convince them to comply with water rights and abstraction restrictions.

- Raising awareness on the impacts of illegal abstraction and over abstraction in the natural environment, the ecological status of water resources and long-term water availability to cover the demand that can lead to behavioural change.

RESOURCE CAP

Strengths	Constraints
▪ Sustainability of a water body implies regulating water abstractions by setting an administrative limit to water rights ▪ Water management requires control of water rights (long term planning) and annual water abstraction (seasonal quota) ▪ Users have realistic information when a resource 'cap' is decided collectively, and individual rights distributed according to predefined rules ▪ Resource limits (cap) avoid 'rent-seeking' behaviour from additional users ▪ Water rights trade accommodate resource initial allocation by facilitating transfer of water from low to high value uses	▪ Uncertainty regarding exact resource availability (easier for surface resources, harder for groundwater) ▪ Frequently, when 'closure' is decided, the resources are already overallocated (over 100% of available volume); this implies acceptance of economic losses for many stakeholders ▪ Reservation of volume for environmental flow requires complex scientific models and stakeholder negotiation ▪ Hydrologic models have difficulties to estimate 'real water consumption' as return flows cannot be known with precision

Recommendations for implementation

- Water rights and water abstractions should be controlled and 'closed' (setting an administrative limit) as soon as early signal of the risk of over abstraction are known. This limit must also include provisions for impact of climatic change and extreme events (droughts).

- Water rights should be defined for long term 'normal years' but also short-term protocols with flexible quotas implemented under drought or water body deterioration episodes.

- Public participation and flexibility for intra-sector and inter-sector reallocation is recommended in the process of 'closure definition' and allocation rules approval.

- The regulatory agency should be transparent and empowered with national (international) trust.

- Scientific evaluation of available water resources should enabled with the provision of appropriate economic and human resources. Periodic revisions should be also guaranteed (if possible, by the resource users).

- Locally defined solutions and cooperative arrangements are more likely to be sustainable in the face of changes (environmental conditions or socioeconomic context).

GLOBAL VIEW - REDUCE FOOD WASTE

Strengths	Constraints
▪ Reducing food waste as a way to increase food security, and eliminate hunger and poverty ▪ Food loss and waste reduction as well as processing food waste have significant economic benefits as it creates a new food resource ▪ Food waste reduction can result in high water savings. Food that is produced but ultimately wasted, consumes about one-quarter of all water used in agriculture each year. Water savings comprise a new water resource ▪ Reducing food waste saves land resources and can achieve high reduction in the release of greenhouse gas emissions annually	▪ Monitoring of food waste production – regular measurements of food waste in kind and quantity ▪ Lack of a regulative system for inclusion of food waste reduction in planning ▪ Processing of food waste in the food industry and at domestic level is limited ▪ Lack of awareness on how to minimise and use food waste results in negative perceptions and safety concerns regarding consumption of food from food waste

Recommendations for implementation

- Set clear targets and action plans for food waste reduction aligned with SDG 12.3.

- EU Member States and public authorities should integrate food loss and waste reduction at every stage of the agri-food value chain, from agricultural production to household consumption, into their national climate action strategies and the water management plans through multi-stakeholder involvement (for example National Climate Action and Adaptation Plans, River Basin Management Plans). Similar initiatives could be down-scaled at regional, municipality and public-private partnerships level.

- Take a collaborative problem-solving approach to reduce 'farm to fork' food waste.

- Initiatives at EU, country, regional and multi-stakeholder level aiming to control the food chain and scale-up to reduce water use, energy use and food waste at all stages, from crop production to retail and waste hotspots, to domestic level.

- Establish and expand the network of food production and retail companies that adopt holistic approaches at different levels (Production – Monitoring – Distribution – Disposal) and promote cross-sectoral collaborations and cooperation.

- Support schemes for food waste treatment (composting) or alternative food waste use (for example new food products, planting, alternatives for leather)

- Focus on food waste prevention programmes for the food industry.

- Provide incentives to adopt the waste hierarchy according to Articles 4 and 9 of the revised Waste Framework Directive (for example facilitation of food donations, lower prices for food close to expiration date).

- Integrate the food waste and water loss concepts into all levels of education, from primary to higher education, and promote professional training and lifelong learning opportunities to lift safety concerns and target behavioural change.

05

Potential Impact

Through this White Paper, important challenges to prevent / mitigate water scarcity have been defined and relevant solutions related to these challenges have been identified to support water managers, water users, stakeholders and legislators. The achievement of the targets set, relating to each challenge, has made it possible to identify potential long-term impacts that determine environmental and socio-economic implications.

The reduction of water pollution can make it possible to increase the availability of water resources in the various sectors of use, to have safer and more reliable water reserves and to reuse water in irrigation processes for the benefit of agricultural production. The prerogatives of measures to favour the circular economy will allow to face the challenges that the water scarcity imposes, improving the profitability of investments in water reuse technology, favouring the reduction of food waste, allowing to reach the targets of EU policies. Water resource management can benefit from the use of new monitoring technologies to reduce waste and to mitigate the gap between water demand and availability allowing the re-design of farm processes with greater involvement of interested parties. This will allow the combination of water supply and demand to adapt to seasonal and structural imbalances, implementing innovative protocols and using international regulatory tools for the integrated planning of water resources. Governance and financial schemes can be optimal for addressing water scarcity by implementing control over water abstraction, increasing lawful uses of water, and investing in metering, monitoring and control devices.

In the following section, with reference to each challenge, the most significant impacts have been identified.

WATER POLLUTION

Related solutions:

- Nature-Based Solutions and Hybrid Grey-Green Infrastructures
- Water reuse implementation including LCA Innovative alternative water sources
- Innovative alternative water sources

Monitoring, detection, and reduction of water pollution are essential for enhancing the ecological quality of aquatic ecosystems, human health, lowering water treatment costs, as well as availability of water resourcesforhumanconsumptionandagriculture use. Activities related to reducing water pollution can have substantial impact in the following areas:

- Rapid reduction and control of pollutants by implementing cost-effective and eco-friendly technologies for calculating water pollution environmental impact in real time.

- Alleviating water scarcity by increasing the quantity of water for reuse through implementation of mitigation options for water pollution related environmental impacts identified by Life Cycle Assessment (LCA) analysis.

- Enabling availability of stable and safe water reserve regardless of climatic events, through adequate treatment and reuse.

- Allowing sufficient savings in the fertilizer use when reused water, which contains nutrients, is utilised for agricultural irrigation/fertigation.

- Ensuring adequate wastewater treatment and related reduction of the environmental impact of untreated wastewater discharge into water bodies by implementing an extensive number of economic incentives related to water reuse.

LIMITED SPREAD OF CIRCULAR ECONOMY OPTIONS AND PRACTICES

Related solutions:

- Nature-Based Solutions and Hybrid Grey-Green Infrastructures
- Water reuse implementation including LCA
- Innovative alternative water sources
- Global view - reduce food waste

Developing partnerships and establishing critical interdependencies in the Water-Energy-Food-Ecosystem (WEFE) Nexus makes communities more resilient and better equipped to respond to a water resource crisis and recover from it. Implementation of the WEFE Nexus concept is critical for achieving circular economy principles and adequate resource (water, energy, food) security, while preserving the natural environment, and it can have considerable impact in the following:

- Cost-benefit analysis proving profitability of the technology investment for water reuse and resource recovery innovative solutions would make them attractive for investors.

- Alleviating water scarcity by reducing food waste, which is related to water over-consumption, especially for crops that are not finally consumed.

- Providing information to end-users (for example farmers) regarding potential risks and effects of the use of reclaimed water in their communication channels (for example tv, specialised magazines) will eliminate their reluctance for use.

- Greater diffusion of integrated planning, to the different territorial scales, which combines the use of natural solutions and technologies (NBSs and NWRMs).

- Achievement of the objectives of a range of EU policies, including those for surface water management, groundwater and coastal water management, nature conservation, agriculture, forestry, urban areas, disaster risk management, green growth and climate change mitigation and adaptation.

RESTRAINED OPTIMISATION OF WATER MANAGEMENT THROUGH SMART TOOLS

Related solutions

- Water conservation measures in irrigation

The use of digital technologies and intelligent tools for the management of water resources in the various scenarios of use can concretely contribute to reducing the gap between water demand and water availability. The optimisation of water resource planning, via digital and smart tools, for the purpose of satisfying demand has a significant impact in the various sectors of use, with reference to the following aspects:

- Acquisition of new capabilities to access, analyse, automate, correct in real time, predict and minimize the risks of the imbalance between water availability and demand.

- Improve the management of water availability by the Water Service Companies, through the reduction of losses and anomalies in the distribution networks, the improvement of the monitoring of water quality and service levels, the improvement of supply reliability, promoting water conservation and increasing revenues through efficient operations.

- Reimagine business processes and facilitate their adoption across the enterprise through the use of digital and remote technologies.

- Increase stakeholder involvement in digital and intelligent planning of water resources to avoid waste.

- Improve the image of social sustainability of companies, through the adoption of technologies that aim at a rational use of water resources.

MISMATCH BETWEEN WATER DEMAND AND SUPPLY

Related solutions:

- Full cost recovery implementation
  Water conservation measures in irrigation
- Innovative alternative water sources
- Control and enforcement of water abstraction

Many European countries are subject to waves of water deficit that affect their inhabitants and the ecosystems they depend on. In addition to drought impacts, overexploitation of water resources in some European countries and in the Mediterranean in general, especially for agriculture, increases the risk of water deficit and, consequently, environmental hazards. Mitigation measures and practices represent an important challenge to guarantee the sustainability of water resources and their use. The implementation of mitigation strategies, to achieve this important challenge, can contribute to the following impacts:

- An increase the sustainability of water use, taking into account the regularised 'ecological flows' and the 'renewable recharge of aquifers'

- More qualitative/quantitative information on the water resources withdrawn from the various sources, for the purpose of their rational planning

- Promotion of the integrated planning of water resources between the various sectors of use, using international regulatory instruments (IRBD)

- Improve participation in public policy debates on water (consumers, NGOs, universities), the CAP and tourism (and not just for groups with greater lobbying capacity)

- Reduce food waste by raising consumer awareness of the water footprint of food.

- The recovery of financial costs through the pricing of water in the irrigation and urban sectors

- More financial resources for future investments and maintenance of existing infrastructure

- Protocols based on continuous real-time determinations of water demand

GOVERNANCE AND FINANCIAL SCHEMES ARE SUBOPTIMAL TO TACKLE WATER SCARCITY

Related solutions:

- Full cost recovery implementation Control and enforcement of water abstraction
- Cap water rights in overexploited basins and aquifers

The use of economic instruments in environmental policy is part of the 'polluter-pays principle' as a basic guide for environmental policy, while the principle of cost recovery requires an 'adequate contribution' of alternative water uses towards the full recovery of the costs of water services, including environmental and resource costs. Tackling water scarcity through governance and financial schemes can have considerable impact with the following considerations:

- When EU member states incorporate full financial cost recovery into legislation, the methodology to estimate cost should be standardised (for example, depreciation rate of infrastructure, inclusion of future investment need for climate change adaptation).

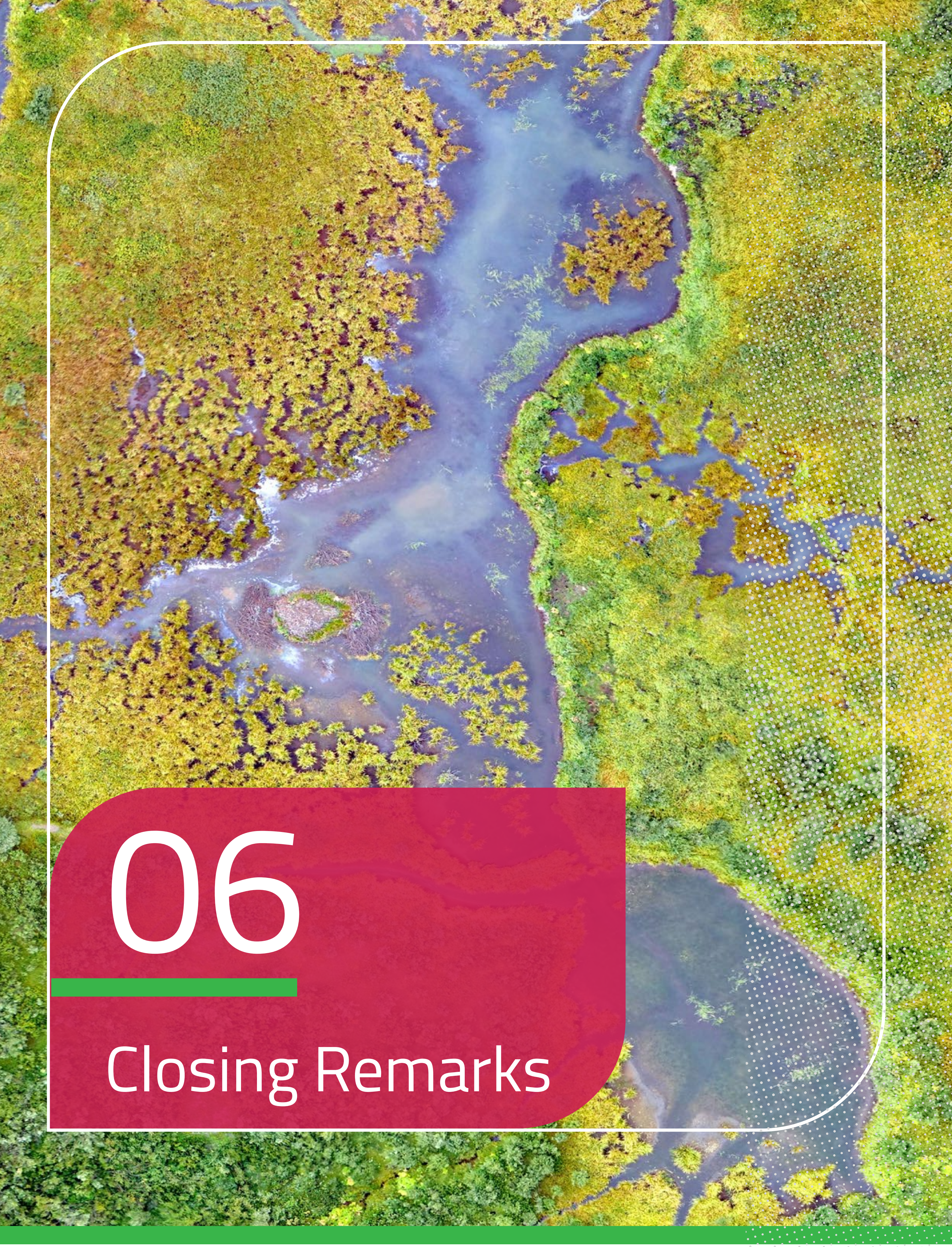
- Investment in metering devices, monitoring and control, which can be complex in rural environments, is required for the implementation of volumetric tariffs avoiding 'flat rate'.

- Political resistance to changes in normative practices makes cost recovery legislation difficult to implement.

- Control and enforcement of water abstraction, to reduce its illegal use should be expanded.

- Increase of lawful uses of water through the digitisation of information.

- Reduction of food waste in the different regions, through the circularisation of the food chain and strengthening of collaboration between the various sectors and actors in the value chain should be part of a wider policy portfolio to contribute to a reduction in water scarcity.



06

Closing Remarks

Water scarcity is a complex challenge with technological, policy, governance, and environmental aspects.

> **Southern European countries need to implement regulatory frameworks enabling the early adoption and widespread use of innovations, the participation of citizens in policy processes and the clear definition and formal allocation of roles and responsibilities in water cycle management.**

Water resource management can benefit from the use of new monitoring technologies and digital solutions to reduce waste and to mitigate the gap between water demand and availability, allowing the re-design of, for example, farm processes with greater involvement of interested parties.

> **There are no silver bullet solutions; complex and systemic solutions are needed with multistakeholder collaborations.**

These can lead to the definition of a baseline for the agreement of enforceable water rights systems. Collaboration between different actors can enable the agri-food value chain to become circular, and help fight food waste, as considerable water savings can be achieved by avoiding the cultivation of surplus food.

> **Southern Europe is currently facing one of the highest increases in average temperature due to climate change and, therefore, the highest impacts on water resources.**

Although population is not increasing exponentially in southern Europe, the economic activities that add stress into water resources are on the rise: tourism is a large economic sector in southern Europe and a significant consumer of water. Agricultural production remains the biggest water user, with a direct impact on water resources and availability. Over-abstraction of water has resulted in groundwater aquifer depletion and salinisation, adding stress to resources and linked to increasing risk of drought. The proportion of the population connected to urban wastewater treatment in southern Europe is still relatively low compared to central and northern Europe. This type of treatment is crucial, as it represents a net saving of water from nature.

> **Nature based solutions are the most effective innovative solutions for water reuse in urban and agricultural settings, with qualitative characteristics aimed at specific uses.**

Implementation of natural water retention and recharge measures can contribute to reducing the risk of floods, water scarcity and drought, whilst also improving the status of surface and groundwater bodies and acting as carbon sinks. The reduction of water pollution can make it possible to increase the availability of water resources in the various sectors, to have safer and more reliable water reserves and to reuse water in irrigation processes for the benefit of agricultural production.

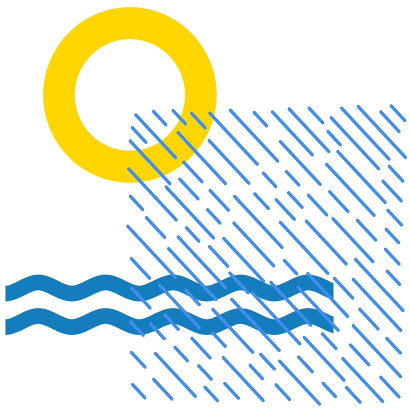
> **The legal framework in the EU is adequate, however the implementation is complex and difficult. Governance and financial schemes can prove optimal for addressing water scarcity by implementing control over water abstraction, increasing lawful uses of water, and investing in metering, monitoring and control devices.**

A policy scenario where more emphasis on the water productivity levels attained must be promoted. This implies the possibility of pricing water allocations according to some threshold values for water use efficiency, promoting private water markets or providing incentives for using the described tools for scheduling irrigation. Financial cost recovery through water pricing has been successfully implemented with positive results both in irrigation and urban sectors.

Reducing food waste is a holistic approach to food security and savings in land and water resources.

Food that is produced but ultimately wasted consumes a high proportion of the water used in agriculture each year. Food waste reduction can result in high water savings to the extent it comprises a new water resource and can achieve high reductions in the release of greenhouse gas emissions annually. Reducing food waste can be achieved by adopting soft measures, such as education at all levels, professional training and lifelong learning to lift safety concerns and target behavioural change.

The solutions we have proposed in this report are a fragment of the available solutions. This is not comprehensive review, rather a first attempt to systematically consider the reasons why water scarcity is not being tackled in southern Europe.



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