Water Europe

Technology & Innovation

WHITE PAPER ON WATER REUSE

POSSIBLE EFFECTS OF EU REGULATION 2020/741 ON MINIMUM REQUIREMENTS FOR WATER REUSE ON THE AGRI-FOOD VALUE CHAIN AND STRATEGIES FOR ITS IMPLEMENTATION

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Prologue

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Executive summary

The EU Regulation 2020/741 on minimum quality requirements for water reuse in irrigation was approved and published in June 2020 and will enter into force in June 2023. The main rationale behind this piece of legislation was the will to promote water reuse in agriculture as a sustainable and safe practice, with a strong potential to counteract the effects of climate change and the growing pressures on natural water resources. Another important reason for issuing this Regulation was the need to harmonise the scattered and (where existing) uneven national regulations on this subject, with obvious repercussions on the free circulation and trade of agri-food products across the European Union.

This paper, besides presenting an overview of the Regulation and focusing on the roles of the different actors involved, concentrates on the main identified barriers to its implementation and possible strategies to overcome them. Indeed, the ambition here is firstly to provide a useful tool to those professionals who will have to adapt existing water reuse schemes or plan new ones within the framework of the EU Regulation 2020/741. Secondly, the authors aimed at identifying possible gaps and improvement opportunities that may lead to extending the scope of the Regulation beyond its current boundaries (e.g., to cover industrial streams, including the need for capacity building).

This paper consists of four sections. The first one introduces water reuse in irrigation as a necessity and an opportunity for sustainable growth, summarizes the challenges posed by a specific regulation on water reuse in irrigation, and identifies current barriers to the widespread application of reuse practices. The second section provides a quick overview of existing national legislation in Member States, synthesizes the Regulation by highlighting its structure and key points, and examines the roles and responsibilities of the different actors. In the third section existing barriers are evaluated through a PESTEL analysis (Political, Economic, Social, Technological, Environmental and Legal factors), possible strategies for water reuse implementation are outlined, and the capacity building requirements are identified. The fourth section presents concluding remarks, and underlines the opportunities provided by the EU Regulation 2020/741 in spreading the use of reclaimed water in Europe and promoting circular approaches in the water sector, in accordance with the mandate of SDG 6.

1. Introduction

1.1 Need for water reuse in agriculture

Water scarcity has become an issue of growing concern in Europe. Droughts cause losses of millions of euros each year. They are affecting more and more regions, even traditionally wet ones, and represent a major challenge for our society. Far from diminishing, the impact of water scarcity and drought will worsen in the coming years as a result of climate change, increased population pressure and changes in consumption patterns.

Agriculture continues to be the sector that exerts the greatest pressure on water resources, accounting for 40-60% of total water use in Europe according to European Environment Agency figures (EEA, 2021)[1]. This proportion can be as high as 80% in southern European countries such as Spain, Italy, Greece and Portugal. In this context of climate variability, which in addition to scarcity also implies enormous difficulties in forecasting and estimating water resources in the immediate future, the use of non-conventional resources such as reclaimed water is of increasing interest.

Reclaimed water is treated wastewater that meets discharge parameters and subsequently undergoes additional treatment in order to meet the quality standards required for a specific use. The recent ratification of EU Regulation 2020/741 on minimum requirements for water reuse in agriculture, (hereinafter referred to as the 'Regulation') is an indication of Europe's express support for the use of reclaimed water to alleviate water scarcity. The use of this resource implies the availability of a constant source of water independent of the vicissitudes of climate. It represents a net increase in water resources in coastal areas and it also provides nutrients that can be directly assimilated by plants, thus enabling irrigators to cut costs by reducing fertiliser consumption.

There are still significant barriers to harvesting of the enormous potential of reclaimed water for agriculture. There is a lack of awareness and recognition of the extent of the water scarcity we face. Many aquifers are strongly affected by salinisation and falling water table levels, which means that obtaining water is increasingly expensive and the water is of poorer quality. Lack of knowledge and a cultural reluctance concerning the use of reclaimed water prolongs this situation and makes agricultural activity increasingly unsustainable.

The provisions included in the recently approved Regulation are, in some cases, stricter than those previously imposed by Member States (MS). We therefore need to adapt procedures and controls to the new scenario established by the Regulation, for example in the drawing up of the required water reuse risk management plans. Control of reclaimed water quality is essential in order to provide sufficient guarantees for its use. Greater transparency and dissemination of water quality analyses, as well as more information on the effects of emerging contaminants, could help to generate confidence and break down any reluctance that may exist among certain users.

1.2 Challenges of implementing the new EU Regulation 2020/741

The purpose of the Regulation is to facilitate water reuse whenever it is appropriate and cost efficient, by providing an enabling framework for MS that wish or need to adopt this promising practice. Currently only a limited number of MS reuse water and have national guidelines, legislation or standards in this field. This Regulation aims to further promote water reuse, especially in MS that do not practice it yet.

The reuse of treated wastewater, for example from municipal wastewater treatment plants (WWTPs), and compliance with the Urban Waste Water Directive (91/271/EEC), potentially have a lower environmental impact than do other water production methods, such as groundwater abstraction or seawater desalination. Nevertheless, water reuse is practiced only to a limited extent in European countries, partly due to the cost of water reuse systems (including appropriate treatment, monitoring, distribution and management), but also because of the lack of common EU environmental and health standards for water reuse. This absence of common rules may clearly affect the free movement across Europe of agricultural products that have been irrigated with reclaimed water. The purpose of EU Regulation is to fill this legislative gap.

[1] https://www.eea.europa.eu/publications/water-resources-across-europe-confronting.

Water reuse for agricultural irrigation also contributes to the promotion of the circular economy, through the recovery of nutrients contained in the reclaimed water and their application to crops, a technique known as 'fertigation'. Thus, water reuse reduces the need for supplemental applications of mineral fertilizers. Farmers naturally need to be properly informed about the nutrient content of the reclaimed water to avoid overfertilization. This process also contributes to nutrient restoration into natural biogeochemical cycles. The water reuse approach is therefore aligned with the Water Europe Vision on the value of water as water, energy and resource loops shall be closed to foster a circular economy and exploit the true value of water.

The above considerations raise some challenging issues, which should be considered when evaluating the Regulation's requirements, and may also serve as input to any future improvements to the Regulation itself and other legislation in this field, namely:

- Irrigation water quality standards need to be defined with reference to all available water sources (conventional and non-conventional). However, this could mean that many conventional sources are no longer suitable for irrigation – e.g., rainwater and surface water may not meet the E. coli standard imposed in the Regulation. The strict irrigation water quality requirements may thus be a hindrance in achieving the objective of promoting the rapid and wide implementation of water reuse projects. On the other hand, the requirements may constitute the first step towards common, source- independent quality standards for irrigation water; this would support the use of reclaimed water when its quality is better than that of conventional water for crop irrigation.
- Risk-based criteria need to be developed to assess the required water quality with respect to the specific context. Risk management procedures are already outlined in Annex II of the Regulation, and work is currently underway on a guideline, though it may not be ready before June 2023. Possible changes in water quality occurring during storage, transport and distribution from the point of generation to the point of use need to be considered. Specifically, in terms of the microbiology, one needs to assess whether the bacteria, fungi and viruses present in the water can survive during storage, on the crop or in the soil. In terms of nutrients, fertigation aspects should be considered bearing in mind the Water Framework Directive. Furthermore soil quality needs to be monitored for the accumulation of salts. The risk assessment should be done in close collaboration with the local water operators and agri-food industry, since their processing steps contribute largely to health and safety.
- Water quality for irrigation should be assessed by taking into consideration the agronomic (plant productivity), pedologic (soil conservation), environmental (ecosystem services), economic (cost sustainability), and policy (legal framework) aspects.
- The current Regulation is limited to treated urban wastewaters, but further steps should be taken to encompass treated industrial wastewaters as well, and thus fully exploit, whenever possible, the potential of the reuse of reclaimed water for irrigation.

The main current barriers to the full development of water reuse, and possible paths for their removal, are the following: [1]

- *Mixed availability of treatment technologies.* In Central and Northern Europe about 30% of municipal WWTPs lack tertiary treatments, and this share is about 40% in Eastern Europe, and about 50% in Southern Europe. Efforts will be needed to extend the use of tertiary treatment in MS.
- *Water tariff structures.* The definition of appropriate prices for water independent of its origin (conventional and non-conventional sources), and according to its production cost, quality, destination, and availability, should reflect a careful evaluation of internal costs and externalities (e.g., indirect benefits).
- *Institutional fragmentation.* Several MS will need to modify their national legislation in order to match the EU Regulation, which will require appropriate adaptation efforts.
- *Social acceptance.* Important actions aimed at stakeholders and the general public will be necessary, so as to raise awareness of the limited nature of natural water resources and the fact that water reuse is an integral component of the water cycle.

2. General overview

2.1 Baseline legal framework: the current legislation in Member States

The majority of MS do not currently have legislation or guidelines on water reuse. Cyprus (CY), France (FR), Greece (GR), Italy (IT) and Spain (SP) have developed standards that are included in the national legislation, while Portugal (PT) has guidelines that the national government follows when issuing water reuse permits.[2] In some MS guidelines for the reuse of water exist or are being prepared, even though the countries do not as yet have any binding legislation or quality standards (e.g., Belgium, Denmark, Malta).[3]

There is no harmonisation among the existing regulations and the aspects they cover. The general criteria assessed in the different standards are: the intended uses for reclaimed water, classes of reclaimed water, quality parameters and their maximum limit, monitoring frequencies, and additional preventive measures.[4]

Table 2.1 below provides an overview of the existing binding legislation/guidelines in MS, detailing the intended uses of reclaimed water, classes of reclaimed water, parameter requirements, monitoring requirements, and risk management plan information. It should be noted that these instruments do not include provisions for validation monitoring; the exception is Greece, where the relevant authority carries out an inspection prior to issuing the reuse permit.

Table 2.1 – Overview of binding legislation/guidelines for water reuse in Member States.[2,3]

	Legislation /Guidelines	Uses of reclaimed water	Classes of reclaimed water	Quality parameters requirements	Minimum monitoring frequencies	Water Reuse Risk Management Plan
CY	Decree no 296/03.06.05	Agricultural, recreational and environmental.	4 classes for agricultural irrigation (plus 1 for recreational uses).	Over 20 parameters are monitored.	From 3 times a week for pH; once every 15 days for most other parameters.	Absent.
FR	JORF num.0153, 4 July 2014	Agricultural, recreational, environmental and urban.	3 classes for agricultural irrigation.	6 parameters are monitored, depending on the class of water reuse.	Depending on the parameter, from once a week to once a month.	Risk analysis required as part of permit application.
GR	Joint Ministerial Decree 145116/11	Agricultural, recreational, urban, environmental and industrial.	2 classes for agricultural irrigation (plus one for urban uses).	65 parameters are monitored, depending on the class of water reuse.	Depending on the parameter, from once or twice a week to every 1-2 weeks.	Absent.
IT	DM 185/2003	Agricultural, industrial, recreational and urban.	No classes stipulated, only water uses.	55 parameters are monitored.	The monitoring requirements are not set out in the national legislation, but in the regional legislation.	Required compliance with a code of good practice in the agricultural sector.
PT	NP 4434 2005	Agricultural, recreational, environm ental, and urban. The technical guide issued in 2010 also includes industrial use.	Applies to all intended uses, except for crops that are eaten raw (higher limits for faecal coliforms).	Several parameters are monitored, depending on the class of water reuse.	Depending on the parameter, weekly, monthly or yearly. Once every 5 years for heavy metals.	A general management plan is requirer as part of the permit application.
SP	RD 1620/2007	Agricultural, recreational, industrial, environmental, and urban.	3 classes for agricultural irrigation.	72 parameters are monitored.	Most parameters must be monitored once a week regardless of the class.	Risk management measures are required for the permit process.

[2] Sánchez-Cerdà C., Salgot M., Folch M. (2020). Reuse of reclaimed water: What is the direction of its evolution from a European perspective? Advances in Chemical Pollution, Environmental Management and Protection, Volume 5, Elsevier Inc., ISSN 2468-9289, https://doi.org/10.1016/bs.apmp.2020.07.001.

[3] "Water Reuse – Legislative Framework in EU Regions", Commission for the Environment, Climate Change and Energy, 2018.

[4] "Water Reuse in Europe – Relevant guidelines, needs for and barriers for innovation", EC, 2014.

2.2 Summary of the new EU Regulation 2020/741

The safety of agricultural irrigation is guaranteed in EU Regulation 2020/741 by two types of requirement for irrigation with reclaimed water, namely: i) monitoring and quality requirements, and ii) water reuse risk management plans. Moreover, end-users of the reclaimed water are required to obtain a permit with the provisions applicable to their specific situation (e.g., quality class, responsibilities of each actor, provisions of the risk management plan).

Monitoring and quality requirements are to be met at the 'point of compliance', i.e., the point where a reclamation facility operator delivers reclaimed water to the next actor in the chain. Therefore, sampling and analyses to monitor water quality should be applied to the effluent of the reclamation facility. Annex I of the Regulation sets the different quality parameters for different categories, which depend on the potential contact between water and crop, the final use of the crop (e.g., consumed raw, food processing, industrial uses) and the irrigation method, as shown in Table 2.2.

Table 2.2 – Water quality classes for reclaimed water.

Minimum reclaimed water quality class	Crop category (*)	Irrigation method
A	All food crops consumed raw, where the edible part is in direct contact with reclaimed water, and root crops consumed raw.	All irrigation methods.
B	Food crops consumed raw, where the edible part is produced above ground and is not in direct contact with reclaimed water, processed food crops and non-food crops, including crops used to feed milk- or meat-producing animals.	All irrigation methods.
C	Food crops consumed raw, where the edible part is produced above ground and is not in direct contact with reclaimed water, processed food crops and non-food crops, including crops used to feed milk- or meat-producing animals.	Drip irrigation (**) or other irrigation method that avoids direct contact with the edible part of the crop.
D	Industrial, energy and seeded crops.	All irrigation methods (***).

(*) If the same type of irrigated crop falls under multiple categories of Table 2.2, the requirements of the most stringent category shall apply.

(**) Drip irrigation (also called trickle irrigation) is a micro-irrigation system capable of delivering water drops or tiny streams to the plants and involves dripping water onto the soil or directly under its surface at very low rates (2–20 litres/hour) from a system of small-diameter plastic pipes fitted with outlets called emitters or drippers.

(***) In the case of irrigation methods which imitate rain, special attention should be paid to the protection of the health of workers or bystanders. For this purpose, appropriate preventive measures shall be applied.

For these four quality classes, the Regulation sets out quality requirements for several parameters, namely E. Coli, Biological Oxygen Demand (BOD_5), Total Suspended Solids (TSS), Turbidity and, in specific cases, Legionella and intestinal nematodes. These requirements are additional to the requirements for the discharge of treated wastewater set out in the Urban Wastewater Treatment Directive, or Directive 91/271/EEC.

Tab. 2.3 – Quality requirements for irrigation with reclaimed water according to quality class.

Reclaimed water quality class	Indicative technology target	Quality requirements				
		E.coli (number/100 ml)	BOD_5 (mg/l)	TSS (mg/l)	Turbidity (NTU)	Other
A	Secondary treatment, filtration, and disinfection.	≤ 10	≤ 10	≤ 10	≤ 5	Legionella spp.: < 1 000 cfu/l where there is a risk of aerosolisati on Intestinal nematodes (helminth eggs): ≤ 1 egg/l for irrigation of pastures or forage.
B	Secondary treatment, and disinfection.	≤ 100	In accordance with Directive 91/271/EEC (Annex I, Table 1).	In accordance with Directive 91/271/EEC (Annex I, Table 1).	-	
C	Secondary treatment, and disinfection.	≤ 1 000			-	
D	Secondary treatment, and disinfection.	≤ 10 000			-	

Moreover, the Regulation also includes the obligation to validate any new reclamation facility put into operation, equipment upgrades, or newly added equipment or processes. To this end, Annex I of the Regulation sets out reduction performance targets for indicators associated with each group of pathogens, namely bacteria, viruses and protozoa.

Tab. 2.4 – Performance targets for pathogen indicators to validate new or upgraded reclamation facilities.

Reclaimed water quality class	Indicator microorganisms	Performance targets for the treatment chain (log10 reduction)
A	E. coli	≥ 5.0
	Total coliphages/F-specific coliphages/somatic coliphages/coliphages	≥ 6.0
	Clostridium perfringens spores/spore- forming sulfa-te-reducing bacteria	≥ 4.0 (in case of Clostridium perfringens spores)

Furthermore, Annex II of the Regulation includes general provisions for the preparation of water reuse risk management plans. Three sections are stipulated for the plans:

A) **Key elements of risk management.** This section includes a description of the entire water reuse system, the roles and responsibilities of all the actors involved, the identification of hazards, environments and populations at risk, as well as the exposure routes. This information should enable an assessment of risks to the environment and to human and animal health.

B) **Conditions relating to the additional requirements.** The risk assessment might conclude that stricter and/or additional requirements for water quality and monitoring are needed beyond those specified in Annex I, in order to ensure adequate protection of the environment and of human and animal health.

C) **Identification of preventive measures.** Measures that are already in place or that should be taken to limit risks, so that all identified risks can be adequately managed. Special attention should be paid to water bodies used for the abstraction of water intended for human consumption and relevant safeguard zones.

Lastly, the EU Regulation also fosters information transparency and access. MS should ensure that adequate and up-to-date information on water reuse is available to the public, including the quantity and the quality of the reclaimed water supplied, the percentage of total water supplied that is reclaimed,, the permits granted or modified, the results of any compliance checks carried out, and the contact points designated.

The Regulation was published in the Official Journal of the EU on 5 June 2020 and will apply from 26 June 2023.

2.3 Roles and responsibilities of different actors

The Regulation identifies a chain of actors for the 'water reuse system', including: the WWTP operator, the reclamation facility operators, the reclaimed water distribution operator, the reclaimed water storage operator and the end-users. The number of involved parties is strictly related to the specific site and infrastructures/facilities for reclaimed water production, storage, supply and final use.

The Regulation entrusts the reclamation facility operator, in collaboration with other responsible parties and end-users if appropriate, to carry out the risk analysis and to issue the water reuse risk management plan (WRRMP). Such plans identify potential dangers (e.g., presence of pollutants and pathogens), possible dangerous events (e.g., treatment malfunctions, spills or any accidental contamination in the reuse system, environments and populations at risk), appropriate preventive and/or corrective measures, any additional barriers in the water reuse system and, on this basis, sets out any additional requirements to ensure the sufficient protection of the environment and human and animal health.

The Regulation establishes the various roles and responsibilities, starting at the reclamation facilities at the point of compliance, where the operator is required to monitor water quality in relation to the minimum requirements (Section 2 of Annex I), and any additional mandatory provisions included in the permit issued by the competent authority. These permits should be based on the contents of the WRRMP referred to the specific situation, and include the minimum requirements for water quality and monitoring established accordingly. The reclamation facility operator is the first of the multiple actors with a role and responsibility in the water reclamation process, while the other actors are responsible for ensuring the safety and the risk minimization along the rest of the chain. Moreover, depending on MS decisions on regulation application procedures, the reclaimed water storage operators, distribution operators and end- users might also need to receive specific permits before fulfilling additional requirements and implementing barriers as identified in the WRRMP.

The framework laid down by the Regulation for agricultural water reuse is based on a strong cooperation and interaction between the various actors involved, so as to ensure that reclaimed water is produced and provided to the end-user at minimal risk, and with full quality and quantity assurance in accordance with the crop type. The risk analysis plays a key role in defining the relations among the different actors, and in establishing their specific responsibilities, on the basis of an in-depth analysis of the systems and facilities along the reclaimed water treatment and management chain, and taking due account of the local and territorial context.

In order to promote the Regulation's implementation, new government models should be introduced to facilitate the interaction among the involved actors, who, apart from the regulatory provisions, also need to comply with other legislative frameworks and follow their own internal procedures.

3. Analysis of barriers and proposed strategies

Reclaimed water offers multiple new opportunities but, as an unconventional water resource, its use also faces numerous challenges that need to be clearly defined and addressed.

The identification of barriers and drivers for water reuse implementation is based on a two step process (Strathou et al 2017):

- Indentification of the factors influencing after reuse implementation,
- Characterisation of the factors as drivers or barriers and assessment of their relative influence: the Cross Impact analysis.

Let's us note that the factor influencing the implementation the water reuse are considered in this article and during the participative stakeholder workshop supporting associated with this research as either driving the implementation, thus refered as drivers, or as being a barriers to the implementation and thus refered as barriers in the following text.

3.1 Participative identification of main barriers and drivers for water reuse implementation

Reclaimed water offers multiple new opportunities but, as an unconventional water resource, its use also faces numerous challenges that need to be clearly defined and addressed. In this context, PESTEL, which is the acronym for Political, Economic, Social, Technological, Environmental and Legal, provides a useful analytical framework to identify the main barriers and drivers that can impact the implementation of circular-oriented water strategies. Specifically, the process of grouping barriers according to interrelated increase the uptake of new technologies, such as those for greater wastewater reuse. The details of the PESTEL framework factors are as follows:

- *Political* refers to the political situation with regard to government, political stability and relations with other governments. Factors that could affect the implementation of new technologies include trade barriers, taxation and campaigns. Examples of sub-themes include governance and political cost.
- *Economic* refers to how organizations consider the wider macroeconomic environment in which they operate. Factors such as national income, investment incentives, levels of foreign investment, energy and water costs are critical to the uptake of water reuse technologies. Examples of sub-themes include the value chain, resource efficiency, price competition, value added, waste efficiency and the circular economy.
- *Social* refers to societal trends and the impact that water reuse would have on wider society. This can reflect societal values on water conservation and wastewater reduction, or considerations of how new technologies may impact existing communities. Examples of sub-themes include community impact, community acceptance and public health.
- *Technological* refers to the rates of and adaptation to technological change. For the water reuse process, new technologies can concern the development of new processes, new wastewater treatment plants and new wastewater treatment techniques. Examples of sub-themes include technological evaluations, the comparison of technologies and monitoring processes. Furthermore, several parameters need to be monitored depending on the class of water reuse. Since the measurements are highly infrequent, the data quality assessment becomes important in the risk management. Trend analysis with uncertainty processing needs to be included, so as to ensure the appropriate operation of the irrigation system and the delivery of water in accordance with crop type. Advanced data analysis can provide indicators for decision-making and control.
- *Environmental* refers to the reduction of the environmental impact, which often concerns pollution episodes, but can be extended to wider ecosystem impacts. Examples of sub-themes include soil salinity and pollution avoidance.
- *Legal* refers to the legal, regulatory and institutional elements such as the implementation of new laws, international treaties and enforcement of regulations. Examples of sub-themes include directives and legislation.

During a participative workshop held in Tunisia in May 2017 [5], stakeholders in treated wastewater reuse were first asked to identify the barriers to and drivers of the reuse of treated wastewater for irrigation for each of the PESTEL factors. The stakeholders were then asked to give each barrier a relative weight (0, 1, 2, 3) in order to determine and rank the most important ones. The results of the identified barriers are presented in Table 3.1 below.

[5] MADFORWATER project. D7.5-Stakeholder-consultation-workshops.pdf (madforwater.eu).

Tab. 3.1 – Most important selected barriers to reuse of treated wastewater for irrigation.

Factors	Selected Barriers
Policy	P1 - Absence of commercial policy
	P2 - Absence of agricultural policy
	P3 - Absence of financial policy
	P4 - Weak implementation of WRRMP
Economic	E1 - Lack of funds, high cost of technologies
	E2 - Lack of financial resources for tertiary treatment
	E3 - Lack of indirect financial incentives (free health check for farmers)
	E4 - Routing cost
Social	S1 – General lack of awareness for Water Reuse
	S2 - Resistance of farmers
	S3 - Reluctance of consumers
	S4 - Health risk for consumers
Technological	T1 - Problems with irrigation systems by treated waste water
	T2 - Lack of know-how (farmers, Ministry of Agriculture staff)
	T3 - Lack of processing efficiency / undersized infrastructure / overload
	T4 - Limitation / restriction of different types of crops
Legal & Institutional	I1 - Absence of a coordinating entity between the institutions involved: 'lack of conductor'
	I2 - Non-compliance with specifications, application of standards, non-compliance with regulations
	I3 - Lack of control and monitoring by the state
	I4 - Structural and governance problem of the Ministry of the Environment, which is both judge and party
	I5 - Poor governance at the level of the Agricultural Development Group (Irrigators' Union)

3.2 Key barriers for water reuse

The second stage of the process consisted of a comparative analysis of the relative impact of the selected barriers. The comparative analysis also called the Cross Impact Analysis (Gordon & Haward 1968) is used to assess the causal interrelationship and relative impact among the set of barriers identified in step 1. The aim was to define the impact of each individual barrier, and to determine:

- Which barriers have a strong impact and leverage effect on other barriers.
- Which barriers are strongly influenced by others.

If barrier 'a' changes and behaves like a 'promoter', that is, has an impact on, say, barrier 'b', what is the specific level of that impact? The potential impact scale runs from 0 = no improvement, 1 = slight improvement, 2 = strong improvement, to 3 = very strong improvement. The barriers were organized in a square matrix (22x22), the Cross Impact Matrix, in which the associated impact factors (0,1,2,3) are indicated (Figure 3.1). The impact factors are then added up and each barrier is then characterised by two indexes [6]:

- One index representing the overall influence of the barrier, which is known as the 'active sum'.
- One index representing how the barrier is influenced by other barriers, the 'passive sum'.

Tab. 3.2 – Cross Impact Matric of the Barriers for water reuse implementation in Tunisia.

	P1	P2	P3	P4	E1	E2	E3	E4	S1	S2	S3	S4	T1	T2	T3	T4	I1	I2	I3	I4	I5	Active sum
P1		3	3	0	2	3	3	0	2	2	2	0	0	2	1	3	3	3	3	3	2	**40**
P2	3		3	2	2	1	2	2	3	3	2	3	3	3	0	3	3	3	3	3	3	**50**
P3	1	1		1	1	3	1	0	0	1	1	1	0	0	0	0	2	2	1	2	1	**19**
P4	0	2	0		0	2	1	1	3	2	2	0	1	1	1	1	2	2	3	3	3	**30**
E1	2	2	3	2		3	0	3	1	3	1	0	3	1	3	2	0	2	1	1	3	**36**
E2	2	3	2	3	3		1	1	2	3	3	3	3	3	3	3	0	2	1	0	1	**42**
E3	1	2	1	2	2	2		0	2	3	3	3	3	3	3	2	2	2	3	3	3	**45**
E4	0	3	0	2	2	1	1		2	3	1	1	3	1	0	3	0	2	0	0	3	**28**
S1	3	3	2	3	2	3	3	0		3	3	1	3	3	1	3	3	3	3	3	2	**50**
S2	3	3	2	2	2	1	3	3	3		2	3	3	3	3	3	2	3	3	2	3	**52**
S3	3	3	3	1	0	0	0	0	3	3		3	0	1	2	3	1	2	2	2	2	**34**
S4	3	3	3	1	0	3	3	1	2	3	3		1	2	2	3	3	3	3	3	2	**47**
T1	0	0	0	1	2	1	1	1	1	1	1	3		2	0	3	0	1	0	0	1	**19**
T2	1	3	2	2	0	0	2	0	3	3	3	3	0		0	3	3	3	3	3	3	**40**
T3	1	3	1	3	1	1	1	0	1	3	3	3	3	3		3	0	3	3	1	0	**37**
T4	3	3	3	3	1	3	3	1	3	3	3	3	3	3	3		1	1	1	1	1	**46**
I1	3	3	3	3	3	3	3	1	3	3	3	3	1	3	3	3		3	3	3	3	**56**
I2	3	3	3	3	0	0	1	0	2	3	3	3	2	3	3	3	3		2	3	3	**46**
I3	3	3	3	3	2	2	3	0	2	3	3	3	0	1	3	3	2	3		3	3	**48**
I4	3	3	3	3	2	3	1	2	3	3	3	3	0	1	1	3	3	3	3		3	**49**
I5	2	3	1	3	2	3	3	3	3	3	3	3	2	3	2	3	2	3	2	2		**51**
Passive Sum	**40**	**52**	**41**	**43**	**29**	**38**	**36**	**19**	**44**	**54**	**48**	**45**	**34**	**42**	**34**	**53**	**35**	**49**	**43**	**41**	**45**	

Each barrier is plotted according to the two indexes (Figure 3.2). This enabled a characterisation of the barriers into 3 categories:

- **Active barriers,** which have a strong impact, leverage effect. These have a strong influence on other barriers and are themselves less influenced.
- **Critical barriers,** which both influence other barriers and are themselves influenced. These are the most important and complex barriers to address.
- **Reactive barriers,** which have a weak impact on other barriers, but are strongly influenced by them. These barriers are 'followers', and they will be tackled once Active barriers become promoters. Strategy does not need to focus on them initially.

The strategy needs to focus on the Active barriers because of their leverage effect on the Critical and Reactive barriers.

[6] Stathatou P.M, E. Kampragou, H. Grigoropoulou, D. Assimacopoulos, C. Karavitis, M.F.A. Porto, J.Gironás, M. Vanegas & S. Reyna (2015): Vulnerability of water systems: a comprehensive framework for its assessment and identification of adaptation strategies, Desalination and Water Treatment, DOI: 10.1080/19443994.2015.1012341.

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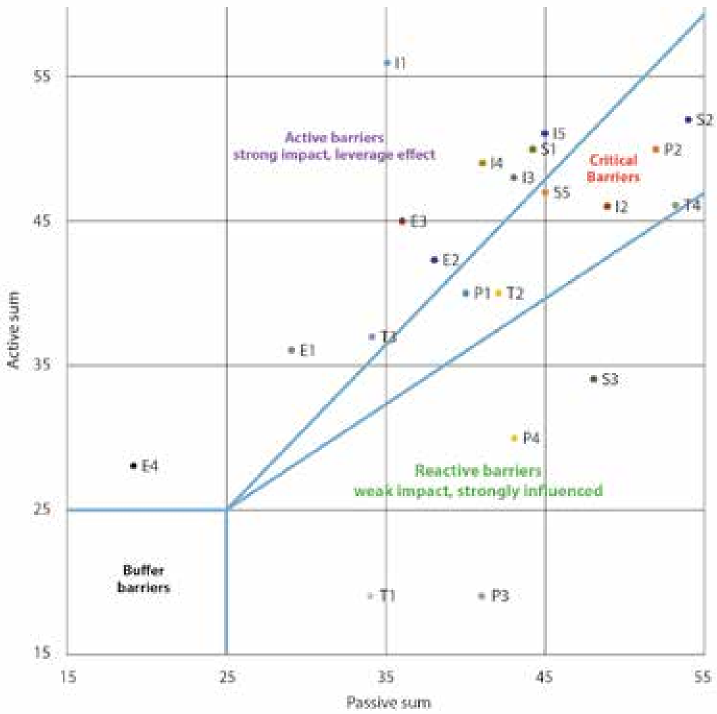

Figure 3.1 – Relative Impact of Barriers: Active, Reactive and Critical Barriers

As a result of the two-stage selection of barriers, the key Barriers to build a strategy to implement water reuse are as follows:

- **E1** - Lack of funds, high cost of technologies.
- **E2** - Lack of financial resources for tertiary treatment.
- **E3** - Lack of indirect financial incentives (free health check for farmers).
- **E4** - Routing cost.
    - S1 - Lack of awareness for reclaimed water use in general.
- **T3** - Lack of processing efficiency / undersized infrastructure / overload.
- **I1** - Absence of a coordinating institution between the institutions involved: 'lack of conductor'.
- **I2** - Non-compliance with specifications by waste water treatement works WWTW, application of standards, non-compliance with regulations.
- **I4** - Structural and governance problem of the Ministry of the Environment, which is both judge and party.
- **I5** - Poor governance at the level of the Agricultural Development Group (Irrigators' Union).

In conclusion, the PESTLE framework associated to the Cross-Impact Analysis enable to highlight that the main barriers to the implementation of water reuse with the most leverage effect (on other barriers) are legal & institutional and economical. Policy and social barriers are also important since they are identified by the stakeholders, but the Cross-Impact Analysis reveals that those are either critical barriers (P1, P2, S2, S5) the most important and complex barriers to address or Reactive barriers (P3, P4, S3) i.e. strategy does not need to focus on them initially.

The following specific comments can be made concerning the barriers to the implementation of water reuse for irrigation:

- Lack of funding for tertiary treatment, for the monitoring of treated wastewater, and for its supply for irrigation purposes.
- Hight cost of suitable irrigation equipment.
- Lack of financial incitation.
- There are financial constraints: Who is going to pay for the analysis and the use by third parties: water agencies, health agencies or agriculture agencies? Will the cost of treatment and management impact the end users?

- Lack of coordinating institution: areas of responsibilities with regard to the water reuse are not clearly defined.
- There is a lack of coordination and communication between the institutions involved in the wastewater treatment.
- There is a lack of clear legislation with regard to wastewater quality, type of irrigation and associated agricultural product.
- With regard to societal acceptance, the question is: Who is going to control the quality of agriculture products irrigated with treated wastewater?.
- A transdisciplinary institution, with a new mandate focused on treated wastewater reuse in agriculture, is needed to overcome the fragmentation of responsibility, and to coordinate all existing institutions.

This analysis reveals the diversity in the nature of the barriers. The barriers preventing an effective, integrated wastewater reuse strategy included a lack of institutional support, resources and political will; various administrative barriers; and an absence of cooperation between the existing management agencies for water resources, wastewater, groundwater, water supply and agriculture.

Furthermore, the most critical ones are the legal and institutional barriers along side the economic one, rather than the technical. As is the case of any transaction of goods or services, the legal and institutional dimensions frame the constraints within which the economic and technical solutions need to be developed.

The expectations of today's consumers regarding the prices, quality and standards of agricultural and food products have a potential influence on production systems and regulators. With this in mind, public awareness campaigns might have a leverage effect on farmers' practices, wastewater operators and regulators.

One approach that can structure both technical and institutional dimensions is to define which class of treated wastewater will be used for which crop type, at which production stage, and for which purpose. This is the approach followed in the presentation of some potential strategies for implementation presented below.

3.3 Strategies for implementation

The possibility to reuse wastewater for irrigation depends on a variety of factors, which include:

- Current wastewater treatment plant capacity and treatment capability.
- Types and needs of irrigated crops in the proximity of the wastewater treatment plants (which will identify the appropriate reclaimed water quality class).
- Type of irrigation systems used (which will identify the appropriate reclaimed water quality class).
- Requirements for further process equipment to meet quality requirements (e.g., tertiary treatment and/or disinfection).
- Presence of adequate distribution networks.
- Irrigation consortia with which to stipulate agreements.
- Existence of national or local laws that may impose stricter limits than the Regulation.

For these reasons, a community or treatment facility considering implementing a reuse programme should conduct a preliminary assessment to consider the above factors and identify the best solution.

In general, wastewater treatment facilities can be grouped into two main categories: **centralized** and **decentralized treatment plants**. Centralized plants, tend to be larger and treat wastewater for larger communities or regions encompassing several communities. These plants also tend to have **fit-for-all solutions (universal, suitable for all cases)**, and these should be adopted where possible to generate the increased cost efficiencies due to economies of scale.

Decentralized plants tend to be smaller, and while small plants could be developed for particular applications, after specific risk analysis, their construction and operation may not prove to make economic sense given the volume of wastewater treated.

Probably the quickest implementation solution is to start with the existing, centralized and decentralized, wastewater treatment plants. The reasons for this are the following:

- For those systems that will need to meet the requirements of Class A[7], it may be necessary to add tertiary treatment where it is not already present. As already mentioned, in Central and Northern Europe approximately 30% of municipal WWTPs lack tertiary treatment. This share increases to approximately 40% in Eastern Europe and about 50% in Southern Europe. Tertiary treatment typically consists of filtration to remove additional organic and inorganic solids. Filtration systems commonly incorporate granular media filters using a deep bed (>1m) of filtration media. In locations where meeting BOD or COD requirements is a challenge, biologically active filters may also be used. Membrane filters (ultrafiltration) can also be used where appropriate. In addition, Class A requires that disinfection systems be employed (for further discussion, see next bullet). In some cases, particularly where tertiary filtration is already present, the community or wastewater treatment facility may wish to consider going directly to Class A to make the water more readily available to any type of farm.

- In cases of reclaimed water quality of classes B, C and D, it is assumed that the wastewater treatment plants already comply with Directive 91/271 / EEC (Annex I, Table 1), in their use of secondary treatment in their wastewater treatment process train. Therefore, it is likely that the only additional treatment required (if it does not already exist) is disinfection. Disinfection is used to maintain the cleanliness of the distribution system, and reduce maintenance in both the distribution system and the farm irrigation system. This is accomplished by removing and/or controlling biofilm that may form in the reuse water distribution system. Preferred disinfection methods are those that maintain a residual throughout the system, all the way through to the point of use. As a result, chlorination systems are the most common. Chlorination systems can include gas chlorine, bulk hypochlorite dosing, on-site hypochlorite generation (OSHD) or chlorine dioxide generation systems. The sizing of the systems should be based on the chlorine demand of the wastewater, plus additional dosing, to ensure that residuals are maintained throughout the distribution network. The expected residence time in the system is a critical factor when conducting an analysis of the amount of chlorine required. In addition, backflow-prevention systems should be considered to reduce risks of recontamination of the distribution system. In evaluating the disinfection system and in the dosage of disinfectants, particular attention must be paid to the possible formation of disinfection by-products.

- Annex II also mentions additional requirements that may be imposed following a risk assessment for specific supplies. Particular concerns may include heavy metals, pesticides, disinfection by- products, micropollutants, and resistance to antimicrobial agents. The removal of such contaminants can be improved with various technologies, including advanced oxidation systems, and technologies for the production of oxidants and disinfectants on-site (capable of reducing the presence of disinfection by-products).

Centralized plants are typically able to carry out more sophisticated analyses of key treated water quality parameters, which could make it easier to control the reclaimed water that would be used for irrigation purposes. Not only with regard to regulatory parameters, but for reuse water, there may be some nutrients present in higher concentrations than in rainwater or surface waters. Therefore, it may be necessary to provide farmers with a series of data that can allow them to proportionally reduce any fertilizers or nutrients they normally use.

Decentralized plants, on the other hand, would allow for the reuse of wastewater in remote locations without having to create long distribution systems; for example, they could be used in locations with seasonal peaks in the production of wastewater as well as seasonal demand for irrigation water during the summer season (e.g., tourist resorts, marinas, etc.). In the design and implementation of distribution systems, it will be necessary to have them be of sufficient size to obtain economies of scale. Furthermore, they should not impact farmers through the creation of new equipment management and maintenance requirements or new analyses obligations. It is also key that these plants be low-cost, reliable, safe and easy to use.

It is clear that an analysis of the technical feasibility and economic sustainability of the system will need to be conducted, based not only on the characteristics of the region served, but also on the type of plant and productivity of the crop systems. Some additional considerations would include:

- The management of the time discrepancies between the rate of production and the rate of consumption of the reused water; it may for example be necessary to provide buffer or storage systems with suitable capacity to meet the irrigation needs.

- The seasonality of water demand, such as a low demand levels in winter; this would mean building flexibility into the system's reuse treatment components, allowing it to be easily shut down and quickly brought back online.

- The possibility that a community may wish to consider a phased approach in implementing a system, and choosing to initially serve only locations relatively near the wastewater treatment facility, and planning on the future expansion of the

[7] Classes of reclaimed water quality and permitted agricultural use and irrigation method according to Regulation 741/2020: Class A- Crop category: All food crops consumed raw where the edible part is in direct contact with reclaimed water and root crops consumed raw, Irrigation method: All irrigation methods; Class B- Crop category: Food crops consumed raw where the edible part is produced above ground and is not in direct contact with reclaimed water, processed food crops and non-food crops including crops used to feed milk- or meat-producing animals, Irrigation method: All irrigation methods; Class C- Crop category: Food crops consumed raw where the edible part is produced above ground and is not in direct contact with reclaimed water, processed food crops and non-food crops including crops used to feed milk- or meat-producing animals, Irrigation method: Drip irrigation or other irrigation method that avoids direct contact with the edible part of the crop; and Class D- Crop category: Industrial, energy and seeded crops, Irrigation method: All irrigation methods.

programme depending on its success and the locations of additional farms. Future expansion should also be planned for by leaving room for additional equipment at the plant, and ensuring that the main distribution piping is sized properly for future flows. Careful communication with local farmers and operators will also help determine their water volume requirements, seasonality, and other factors which will influence the sizing of the treatment systems and distribution network. A community may also wish to develop a 5-year, 10-year and 20-year implementation plan (or whatever timeframe makes sense for the community).

The Regulation will clearly require additional infrastructure, or at a minimum, an adaptation of existing distribution networks to transport the treated wastewater; ideal candidate regions are those where distribution networks are already present or where linear arrangements can be made. In the choice, the existing irrigation infrastructures will also be analysed to identify where reused water is a better option, and thus technical refurbishment of the irrigation infrastructure is to be implemented.

In order to quickly initiate the adoption of the water reuse is important to be able to count on funds and financing to encourage the adoption of solutions. Quickly building experience and case studies will prove the concept and get additional farmers excited about joining the programme, allowing it to grow and thrive.

This operation also requires actions on tariff structures in order to obtain sustainable financing: pricing and tariff structures of water and water related service must be re-modelled to promote efficiency and manage water demand.

At the same time, we must address the societal reluctance and stakeholder collaboration: Member States should take the responsibility of creating awareness among citizens of water scarcity issues in the respective MS and the benefits of reused water for irrigation. These awareness campaigns should be developed jointly with the water, agri-food and health sectors to reduce the pressure on farmers, who will otherwise be left entirely with the burden of proving the safety of their products to consumers.

In the implementation of water reuse for irrigation, MS should take into consideration recalculations of their water balance models, and model the effects of water availability resulting from increased wastewater reuse. Collaboration between water management authorities and water utilities and farmers on this topic should be made explicit, as it is not always self-evident and present. The effects on mitigating water scarcity, which this Regulation is addressing, will then become clearer and quantifiable.

Further engagement with other industries and sectors would be necessary, not just for purposes of promoting societal acceptance, but also a means of identifying potential unconventional investment sources. This approach will provide further incentives for shared ownership, where new water use authorisation models might emerge, especially in areas with high water scarcity. Many MS have regulations in place that establish a hierarchy of water use in situations of temporary insufficient water availability. Agriculture is usually positioned higher in these hierarchies than certain industrial sectors. If farmers and water operators were in a position to point to the quantity of water from conventional sources that is 'freed up' thanks to the use of treated wastewater, they could potentially unlock unconventional investment from the private sector to finance the reclaiming facilities. Such new inter- sectorial collaborations based on circular models should be explored and exemplified from the outset to make implementation of the Regulation more attractive.

3.4 Capacity building needs

Capacity building needs for a new approach to water reuse have been identified in cooperation with the Working Group Human Capital. These capacities will be an individual but mainly an organizational and even a system challenge. One of the main challenges is related to social acceptance, which has to be addressed first, at the level of work force, users and consumers. The society needs a change of behaviour and mind-set.

Within capacity building this means there is a need to obtain, improve, and retain skills, knowledge, tools, equipment, and other resources to create a new system to be able to broadly implement water reuse projects. Capacity building is urgently needed at different levels: operators, educators, academics and management. Achieving this target requires more specific training efforts in water technologies to encompass the principles, practice, operation and maintenance, design, human resources management, as well as research and development. A capacity building programme is necessary not only to operate and improve existing plants but also to develop new sustainable technologies. Wastewater treatment and water reuse technologies should also be included in capacity building programmes to achieve a better integration in water resource management. Important elements in the technical staff training include organizational issues, facilitation and collaboration skills, and technical aspects. The technical staff are, for their part, responsible for the implementation of the training of the agricultural extension staff.

In most EU countries the following agencies could be engaged in the programme to fulfil the four basic support functions. Extension Departments or Units maintain direct contacts with the farmers for transfer of knowledge. Therefore, it is sensible that the extension agents be directly involved as facilitators of the Farmers' Seasonal Planning and Farmers' Seasonal Training. *The Irrigation Agency* usually has the responsibility for technical designs, construction, operation and maintenance of the irrigation infrastructure. *The Agricultural Agency* will also be responsible for providing various technical advice and guidance services, in relation to agricultural inputs such as agricultural research, and agricultural extension NGOs are often involved in community development at village level. As they have experience in working with the farmers, the NGOs' support of the programme consists in developing and strengthening the Water User Associations. Also, when additional extension staff or extension skills are required, NGOs may be included in the training and extension activities. *Banks or NGOs* that implement credit programmes may be involved for the supply of credit systems to enable farmers to acquire the agricultural inputs.

To create a holistic and collaborative approach to human capital development we need to empower people and organizations working on water reuse, focusing not only on co-creation, but also on co-responsibility within an integrated approach to knowledge, skills and network.

The main gaps in human capacity building concern the knowledge, at all levels, of workers and users, including consumers. This is the cause and underpinning of the cultural reluctance, as previously noted. The goal of the human capacity building is to support the transparency and the flow of information by means of education, training, democratization, and the collaborative creation and implementation of a new system of human participation within water reuse. To bring these transformations into fruition, we need to invest in forging a blueprint that outlines actions options and paradigms to guarantee moving forward.[8]

To strengthen the capacity building and further understand the necessary steps to develop a new approach, the following **needs** were identified during workshops and interviews within Water Europe:[9]

The individual / work force level	The organizational level	Requisites on the Individual / work force level
* Knowledge creation on technical possibilities. * Developing knowledge on regulation and safety. * Strengthencollaboration, stakeholder and public engagement skills. * Upgrading skills in dealing with complexity. * Creation of training and developing an adaptive mind-set.	* Performing impact assessment human capacity. * Developing strategic plans and budget for training and maintenance for skilled staff. * Creation of collaborative network of shared ownership. * Supporting ownership and training options across organizations at all levels.	* Integrating the water reuse concept in all levels of education curricula. * Forging participatory processes and responsibilities throughout society in water reuse projects. * Creation of shared ownership. * Supportinga positive narrative by highlighting experience practices.

4. Conclusions

The use of reclaimed water in agriculture has a significant potential to alleviate water scarcity and is an important measure for climate change adaptation. The millions of cubic meters of wastewater discharged to the environment represent an *'untapped resource',* which we cannot afford to waste at a time when resource recovery is to become a cornerstone of our economic development. The EU Green Deal shapes Europe's strategy towards a more efficient use of resources. This is all the more important for water: a strategic resource essential for life and the economy.

Regulation 2020/741 on minimum requirements for water reuse in agriculture offers an opportunity in Europe to spread the use of reclaimed water. The existence of a single and harmonised regulatory framework for all Member States provides confidence to end-users and consumers. The consumer stakeholder group is often forgotten, but they are absolutely central, because if they refuse to purchase agricultural products irrigated with reclaimed water, the incentive to move towards circular approaches disappears. The credibility provided by the Regulation is a significant intangible asset for the water sector, given the fact that social perception has been identified as one of the main barriers to the use of reclaimed water.

The regulation is therefore a step forward in extending circular approaches in the water sector. However, it also echoes the challenges society faces in implementing water reuse. For instance, the contrast between the standards required for conventional

[8] Erasmus+ project plan, 2021-2027, AK 2, lot 2.
[9] Working Group Human Capital, Water Europe, 2019-2021.

and non-conventional water resources suggests that the Regulation somehow assimilates the reluctance to use reclaimed water, by subjecting such water to more stringent standards. Success in the Regulation's implementation will depend on how this is perceived. It is crucial that the stringent requirements be perceived as a guarantee to farmers and consumers, and not as an obstacle that may hinder the necessary investment in water treatment and reclamation infrastructure. There will therefore be a need to explain the benefits of water reuse to, and ultimately convince, not only farmers and consumers but also national and regional authorities. Likewise, efforts to provide further guidance on water reuse risk management plans by the European Commission are absolutely necessary, and guidelines to this end should be available in due time, ideally, prior to June 2023, when Regulation 2020/741 becomes compulsory.

EU Regulation 2020/741 will be of immediate application in all EU Member States. Unlike EU Directives, EU Regulations do not need to follow the transposition process, so that their provisions are directly applicable in MS once the Regulation comes into force. This means that by June 2023, standards and provisions of the Regulation will be of direct application for water reuse practices in Europe. But the simple existence of a regulation does not mean that MS are ready to implement it. The lack of appropriate water treatment and reclamation infrastructure will be a common obstacle, especially given the stringent standards for water quality already mentioned. Adequate water pricing and tariff structures are therefore needed to ensure the financial feasibility of the infrastructure. Governance schemes will also need to be adapted, national and regional agencies will need to develop measures to issue licences for water reuse as required by the Regulation 2020/74, and they will also have to monitor compliance with all the requirements. Carrying out all these activities will require appropriate human capital, that is, sufficient and qualified staff with the necessary resources. Water reuse calls for a proactive and collaborative approach, in which all voices are taken seriously in developing solutions that will be implemented throughout society. We have to remember that Regulation 2020/741 only sets the conditions for the reuse of reclaimed water, it does not imply any obligation to do so. Water reuse needs to become a priority for regional and national governments, otherwise, EU Regulation 2020/741 will, in some regions, amount to no more than a piece of paper.

Lastly, data transparency, digitalization and Water IoT will clearly play a significant role in the future. Reliable and real-time measuring and monitoring of water use, both from conventional and alternative sources, will allow not just water utilities but all water users to become efficient, sustainable and equitable water stewards. MS that apply wastewater reuse for irrigation on a large scale will significantly lower the water footprint of their agricultural sectors and increase their own and the EU's overall **water security**.

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Notes

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WHITE PAPER ON WATER REUSE

POSSIBLE EFFECTS OF EU REGULATION 2020/741 ON MINIMUM REQUIREMENTS FOR WATER REUSE ON THE AGRI-FOOD VALUE CHAIN AND STRATEGIES FOR ITS IMPLEMENTATION

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