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Wastewater Reuse in the EU and Southern European Countries: Policies, Barriers and Good Practices

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Abstract: Ensuring sustainable consumption of water, which is essential for human development, is not sufficient, therefore, there is an urgent need to improve reuse of treated wastewater. This paper reviews the newest EU legislation related to reclaimed water reuse, which is the main driver for change. While there are some positive developments in the EU, the paper argues that the current EU legislation does not sufficiently encourage circular solutions, especially on how to deal with any bottleneck effects, which prevent to fully utilise wastewater. This reflection is noted based on the national and regional developments in Italy with some comparison with other Southern countries, such as Greece and Spain in attempt to identify good practices as well as any barriers for the reclaimed water to be reused.

Keywords: wastewater reused; regulation 2020/741; the urban wastewater treatment directive; good practices of wastewater reuse

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Citation: Malinauskaite, J.; Delpech, B.; Montorsi, L.; Venturelli, M.; Gernjak, W.; Abily, M.; Stepišnik Perdih, T.; Nyktari, E.; Jouhara, H. Wastewater Reuse in the EU and Southern European Countries: Policies, Barriers and Good Practices. *Sustainability* **2024**, *16*, 11277. https://doi.org/10.3390/su162411277

Academic Editor: Marc Breulmann

Received: 17 November 2024
Revised: 14 December 2024
Accepted: 16 December 2024
Published: 23 December 2024

1. Introduction

Water is the basis of life, essential for human development; it is also at the core of sustainable development and crucial for socio-economic development, energy, food production, and living eco-systems. Yet, its resource is finite: [1] approximately, only 1% is freshwater [2]. Climate change is creating greater unpredictability of the availability of fresh water, however, the demand for water continues to grow worldwide. Therefore, ensuring sustainable consumption of water is not sufficient, as there is an urgent need to improve reuse of treated wastewater. The potential of treated wastewater reuse as an alternative source of water supply has been acknowledged and now embedded within international, European and national strategies. The UN noted that "wastewater, discarded into the environment every day, once treated, can help meet the needs for freshwater as well as for raw materials for energy and agriculture" [3]. One of the UN SDGs (Sustainable Development Goal) is dedicated to the availability and sustainable management of water

(SDG 6) with its specific targets on halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally and supporting countries in wastewater treatment, recycling and reuse technologies (targets 6.3 and 6a, respectably).

About 11% of the world's treated wastewater is reused and around half of the world's untreated wastewater still appears in all water bodies (rivers, lakes, seas and oceans). The untapped potential for wastewater reuse is around 320 billion m^3 per year [4]. In Europe, approximately, 81% of the freshwater is used for agricultural, potable, and industrial purposes and only less than 3% of urban wastewater is reused [5]. Therefore, there is a great need for new technologies. Upgrading or introducing new technologies for wastewater treatments and reuse that are cost effective is in great demand. Traditional wastewater treatment and wastewater treatment plants are no longer only about environmental protection and sanitation functions, but also the starting point for the exploitation of potential resources (including sludge) [5]. Pursuant to the circular economy approach, wastewater is renewable resource in the hydrological cycle, as it can be reused. Reusing treated wastewater has environmental, economic and social benefits. Indeed, treatment of wastewater and removing pollutants as well as effluent reuse have desirable climate benefits, as it helps not only address water scarcity, groundwater recharge, irrigation but also to reduce greenhouse gas emissions, particularly methane, therefore, remarkably decreasing the impact on the environment as well as on health [6]. In terms of economic benefits, wastewater is valuable resource that can be used in wide range, such as energy production (biogas), agriculture (fertiliser) and industrial development [5]. Indeed, metals and chemicals can be recovered from wastewater, which simultaneously can address two global challenges: (i) remove highly phosphorus pollution in water; and (ii) tackle shortage of phosphorus that can be as agricultural fertilisers, replacing costly commercial fertilisers. It would also reduce energy consumption compared to using deep groundwater resources, water importation or desalination. For instance, in the EU, it was noted that the wastewater sector would need to reduce its GHG emissions (34.45 million tonnes CO_2e/year—around 0.86% of the total EU emissions), decrease its energy consumption (around 0.8% of the total energy use in the EU) [7].

There is an increased demand for wastewater to the agriculture sector for farmland irrigation. For instance, farmers could also benefit from a more reliable water supply independent from seasonal drought and weather variability and able to cover peaks of water demand during the irrigation period, therefore, lowering the risk of crop failure and income losses. There is also a call for significant improvement of wastewater management not only in agriculture but also in all the other sectors [8]. Therefore, reuse of wastewater can also create new business opportunities and green jobs in the water-related industry. It has been estimated that a 1% increase in the rate of growth of the water industry in Europe could create up to 20,000 new jobs [9].

Closed-loop water treatment and treated wastewater reuse, as an alternative source of water supply is well acknowledged and embedded within international, European and national strategies. Aligned with the UN strategies, EU policies on water issues and its reuse are fervent: there are new initiatives to drive a change. Pursuant to the EU's strategy set out in the European Green Deal, more circular practices should be embraced, therefore, reusing reclaimed water helps manage water resources more efficiently, simultaneously, adapting systems to climate change. In addition, the European Committee of the Regions urges the European Commission to implement Blue Deal for Europe, signifying water as a strategic priority for its upcoming mandate 2024–2029, also recommending to adopt a water efficiency principle in order to promote effective water reuse and savings not only for agricultural, but also industrial and domestic purposes, while also implementing the 'polluter pays' principle effectively.

Innovative, smart and sustainable technologies applied to wastewater treatment, and resource recovery processes have played an important role in reducing pollutants in wastewater, driving forward the goals of the Urban Wastewater Treatment Directive (UWWTD). In light of the European Green Deal, the European Commission is currently reviewing the UWWTD proposing new rules on water reuse to provide excellent conditions for instilling more sustainability and circularity into the water management sector in the near future [8]. Already in 2015, the European Commission in its Communication "Closing the loop—An EU action plan for the circular economy" [10] committed to develop a series of non-regulatory actions to promote safe and cost effective water reuse. However, in terms of circular solutions, the UWWTD has limited provisions on waste water and sludge reuse or recovery of valuable components. Therefore, to combat increased water scarcity in the EU Member States, this paper will also discuss the new Water Reuse Regulation (effective in 2023) setting the minimum requirement for reclaimed water to be used in the agriculture sector. This Water Reuse Regulation is driven by market, based on the demands and needs of the agricultural sector, especially, in certain Member States that face severe water resource shortages [11]. It is also based on a risk management framework, to deal with health and environmental risks simultaneously assuring a safe use of reclaimed water for agriculture and aquifer recharge. Risk assessment so far have been predominantly addressed in the national norms of only six Member States, inter alia, the analysed countries in this paper, such as Greece, Italy and Spain. Given that risk assessment plays a major role in this context of the environment and human health, it is essential to quantify the risk of possible contamination of surface and groundwater resources as well as the risk attributed to public health, therefore, a more harmonised approached is a welcome move. Furthermore, the supplementary delegated Regulation No 2024/1765 was also issued in 2024 noting the technical specifications on the key aspects of risk management, aiming to form uniform conditions for defining risk management plans necessary for the issuing of the permits essential for the production and supply of refined water intended for irrigation purposes in agriculture [12].

Furthermore, Ganuolis also warns that other factors should not be forgotten, such as the social acceptance, where wastewater reclamation and reuse, for instance, in agriculture is influenced by specific local cultural, religious and socio-economic conditions; economic and technical factors should also be embraced, such as the water and wastewater treatment costs, the cost of maintenance, the structure of irrigation networks and infrastructure, and crop patterns, as well as the labour cost [13]. While the paper acknowledges this important aspect, it does not specifically address it.

One must note that industry is the second biggest abstractor of water in Europe, after agriculture [5], therefore, the potential of reclaimed water reused is largely unutilised beyond the agricultural sector. To some extent this is acknowledged in the Water Reuse Regulation, which states that the indication of specific uses within the Regulation do not preclude the Member States from allowing the use of reclaimed water for other purposes, including industrial purposes, allowing to address national circumstances and needs, provided a high level of protection of the environment and of human and animal health is guaranteed [11].

The paper argues that the water reuse potentials in Europe are noticeably untapped. More circular integrated solutions need to be embraced especially in industrial processes. One must note that regulations are usually accepted as the main drivers for change. Therefore, the aim of this paper to review the current EU regulatory frameworks and policies that encourage circular solutions, such as reclaimed water reuse. While there are some positive developments, the current EU legislation does not sufficiently encourage circular solutions, especially on how to deal with any bottleneck effects, which prevent to fully utilise wastewater. Given that there are no regulations at the EU level to set minimum requirements of wastewater reused for industrial purposes, this paper also explores the national and regional developments in Italy with some comparison with other Southern countries, such as Greece and Spain in attempt to identify both—good practices as well as any barriers for the reclaimed water to be reused.

The paper is structured as follows. After this introduction (Section 1), Section 2 explains the employed methodology, the current picture of water reuse in the EU is portrayed in Section 3. Section 4 then analyses the most recent EU regulatory developments on reused of wastewater, followed by national developments in Italy (Section 5) and other Mediterranean countries, such as Greece and Spain (Section 6). The Final discussion is then depicted in Section 7 with the conclusions being noted in Section 8.

2. Methodology

For the methodology, this paper has employed an inter-disciplinary perspective (i.e., encompassing legal and scientific disciplines), using several methods to collect the data while drawing upon multiple data sources.

Doctrinal research. First of all, building on doctrinal research, an extensive literature review was conducted, embracing, predominantly, the primary sources, such as the newest EU legislation, policies, and assessment reports published by the European Commission, the EEA, JRC Science and Policy reports as well as national government strategies and policy documents as well as legislative frameworks. Secondary sources in this field are rather limited, with an emphasis on some fragmented aspects of wastewater management, for instance, such as risks associated with reclaimed water use [14], wastewater for irrigation [15,16], or wastewater reused in some specific regions [17,18]. There are also studies related to European and selected national regulations and policies related to water reuse for agriculture [19]. Therefore, in contrast to the previous studies, this paper embraces a holistic approach, exploring treated wastewater effluent levels at both European and national levels, as well as wastewater potentials, noting European and national policies and regulatory frameworks to encourage circular solutions, and finally, identifying barriers preventing the reuse of wastewater.

Empirical research. Secondly, further focus was geared towards identifying good practices facilitating wastewater reuse as well as barriers preventing them based on the existing national projects. In terms of the jurisdictions, Italy and other Southern countries, such as Greece and Spain, were chosen for this analysis. Empirical research was conducted, which entailed a template being designed to collect data from each national rapporteur (i.e., Italy, Greece, and Spain) with specific questions centred on two juxtaposing typologies, such as (i) good practices of wastewater reuse; and (ii) any bottleneck aspects preventing to untap the full potential of reclaimed water reuse, while also providing general context in each jurisdiction. Qualitative data content analysis was then undertaken within each typology. Some comparison between the chosen jurisdictions also guided this analysis. One must note limited examples water reuse examples for industrial purpose. Therefore, the paper had to widen a scope where good practices of reclaimed water were also used in agriculture.

3. Water Reuse in the EU

Water is an essential societal need and therefore, water reuse is significant to reduce the water stress phenomena. In the EU, households and certain industries in 21,708 urban areas approximately generate 544.4 million p.e. of waste water every day, which is equivalent to 108.85 million m^3 [20].

Currently, about 1 billion cubic metres of treated urban wastewater is reused annually in the EU, accounting for approximately 2.4% of the treated urban wastewater effluents; this is also less than 0.5% of annual EU freshwater withdrawals [9]. Therefore, the potential for wastewater reuse in the EU is high, approximately, six times the current volume—around 6 billion cubic metres [9]. There are some initiatives regarding water reuse, for instance, for irrigation, industrial uses and aquifer recharge in some Member States, such as Spain, Italy, Greece, Malta and Cyprus in the Southern part and in Northern Member States like Belgium, Germany and the UK. While ‘island’ countries, such as Cyprus and Malta already reuse more than 90% and 60% of their wastewater respectively, Greece, Italy and Spain reuse between 5% and 12% of their effluents.

The WEI noted by the EEA, records the relationship between amount of water used (withdrawal—return) and the total amount of fresh water resources available, returns a scenario of moderate or strong pressure especially in the Mediterranean countries (see

Figure 1). Specifically, in 2019, Cyprus, Malta, Greece, Portugal, Italy and Spain had the most significant water scarcity conditions on the seasonal scale (seasonal WEI+ > 40%) in the EU. In terms of the non-EU European countries, is the most severely affected [21]. Given that water scarcity (which occurs when insufficient water resources are available to satisfy annual requirements) is most frequent in southern Europe, the paper focuses on large southern countries, predominantly, Italy with further comparison with Greece and Spain.

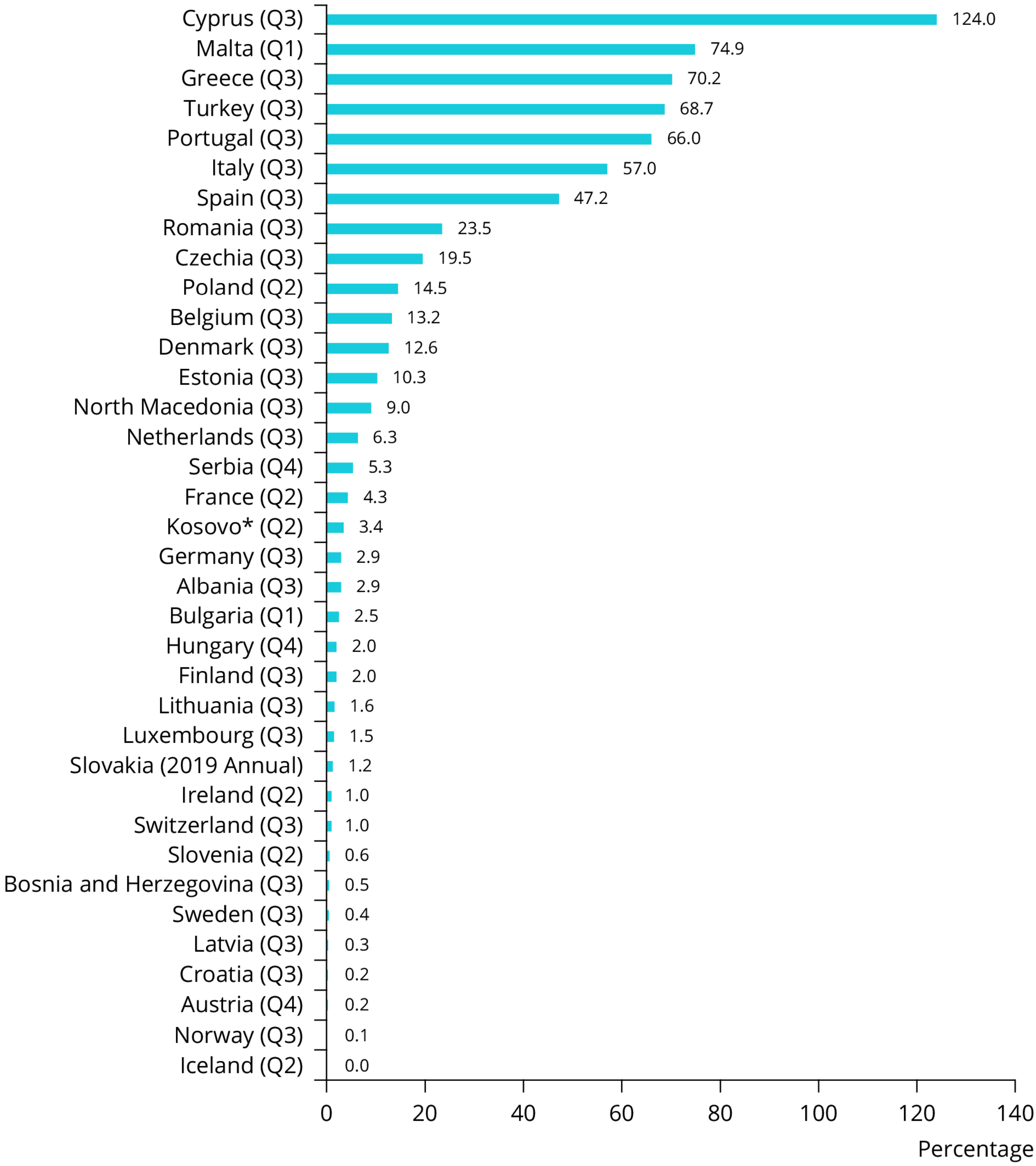

Figure 1. WEI+ by country (2019)—Development of the water exploitation index plus (WEI+) [21]. Note: * indicates Water Exploitation Index.

4. EU Policies and Regulatory Frameworks on Reuse of Wastewater

4.1. Overview

The EU Strategic Implementation Plan of the European Innovation Partnership on Water prioritises water reuse, and maximisation of water reuse is a specific objective in the Communication "Blueprint to safeguard Europe's water resources". The Blueprint notes that.

Water reuse can improve the status of the environment quantitatively (i.e., alleviating pressure by replacing abstraction), as well as qualitatively [22]. Pursuant to the Blueprint when compared to alternative sources of water supply, for instance, desalination or water transfer, water reuse often requires lower investment costs and energy, therefore, contributing to greenhouse gas emissions reduction [22]. It has also been pointed that there is a need for an EU level framework to regulate standards for water reuse in order to help to reduce waste scarcity and lessen the vulnerability of supply systems.

Aligned with the UN's SDGs, particularly SDG 6, the EU with its European Green Deal provides a roadmap towards sustainable economies turning climate and environmental challenges into opportunities. The European Green Deal aims to boost the efficient use of resources mobilising industry for a clean and circular economy.

Water reuse in the EU Member States is currently far below its potential. Lead MEP Simona Bonafè noted: "We could potentially reuse 6.6 billion cubic metres of water by 2025, compared to the current 1.1 billion cubic metres per year" [23].

The EU has expansive legislation in relation to water (see Figure 2), with several of them, such as the Water Framework Directive (WFD) [24]; the Environmental Quality Standards Directive [25]; the Groundwater Directive [26]; the Floods Directive [27] being subject to a comprehensive policy evaluation as part of the fitness check in 2019. For instance, the WFD defines a framework for integrated watershed management in the EU, slowing down the deterioration of water status and reducing chemical pollution. Among other things, it also promotes sustainable water use. While there has been a good progress in the implementation of these Directives, the evaluation report noted that better integration of water objectives in other policy areas such as agriculture, energy or transport is needed [28].

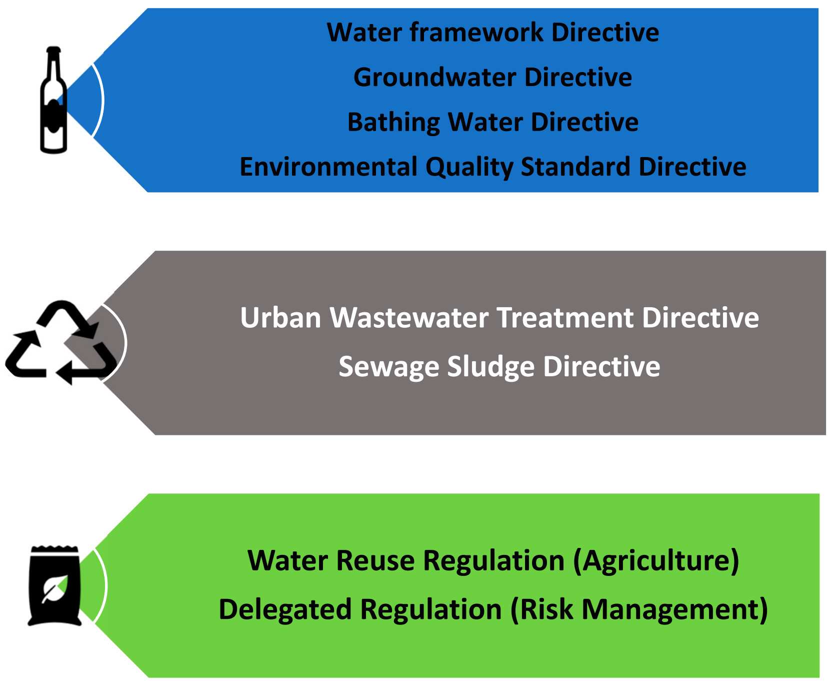

Figure 2. The main EU directives and regulations in a water reuse system (redesigned based on the Commission guidelines on water reuse [29]).

4.2. Regulation 2020/741: Water Reuse for Agriculture

Building on the Blueprint, the European Commission in its 2020 Circular Economy Action Plan noted that it will aim to introduce new regulatory tools (or policies) to facilitate water reuse and efficiency in different sectors, including agriculture and industrial processes. Therefore, for the first time a new Regulation was introduced (Regulation 2020/741, with the rules being effective from 26 June 2023), which is aimed at harmonising minimum water quality requirements at EU level ensuring that waste water is more widely used to reduce a pressure on water abstraction from surface and groundwaters. Specifically, this regulation encompasses the safe reuse of treated urban wastewaters in agricultural irrigation, simultaneously, protecting the environment and people. Falls in groundwater levels, mainly because agricultural irrigation (as well as industrial and urban development), have been identified as one of the major threats to the EU's water environment [23].

Apart from filling the gap in the EU legislation to incorporate harmonised minimum water quality requirements for the safe reuse of treated wastewaters, the Regulation also provides minimum monitoring requirements as well as risk management to assess any potential health and environmental risks. It also notes permitting requirements and the provisions on transparency ensuring that main information about water reuse projects is publicly available.

Specifically, this Regulation covers reclaimed water which is obtained from waste water that has been collected in collecting systems and has been treated in urban waste water treatment plants pursuant to the UWWTD [30] and which undergoes further treatment to meet the parameters set out in Annex I of the Regulation (see Table 1). The Guidelines [29] that supplement the Regulation further notes that the Member States after careful consideration of the advantages and disadvantages of water reuse, may decide not to reuse water in a given area as part of integrated water management. Additionally, the Regulation incorporates the multi-barrier approach, where the log reductions to obtain the required water quality class can be achieved by different treatment and non-treatment measures in combination (barriers) [29].

Table 1. Minimum Reclaimed Water Requirements for Agricultural Irrigation [11].

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.: <1000 cfu/L where there is a risk of aerosolisation 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	≤1000			-	
D	Secondary treatment, and disinfection	≤10,000			-	

As noted above, most recently, to supplement this Regulation, the delegated Regulation No 2024/1765 was launched identifying the technical specifications related to risk management [12]. This delegated Regulation defines technical specifications encompassing 23 elements that the Member States must consider when drafting their risk management plans in consultation to the Commission guidelines (i.e., reclaimed water production processes, storage, distribution, irrigation techniques, intended uses, crop categories etc.), This, therefore, should establish uniform conditions for defining risk management plans necessary for the issuing of the permits essential for the production and supply of refined water intended for irrigation purposes in agriculture across the Member States.

Finally, the Regulation states that the Member State can use treated waste water for other purposes, such as industrial assuring a high level of protection of the environment and of human and animal health. This is also noted in the revised Industrial Emissions Directive [31]. One must expect that more harmonised regulations will follow at EU level embracing minimum reclaimed water requirements for industrial processes, as part of integrated water management and the circular economy. In addition, the Regulation has been criticised for its limited impact on circular economy objectives (with the emphasis being placed on water scarcity and crop profitability) [32].

4.3. The Urban Waste Water Treatment

Already 1991, the UWWTD [33], set the objective to protect the environment from the adverse effects of urban waste water discharges and discharges from certain industrial sectors. It also included specific requirements, such as pre-authorisation of all discharges of urban wastewater, of discharges from the food-processing industry and of industrial discharges into urban wastewater collection systems; and monitoring of the performance of treatment plants and receiving waters. It also required controls of sewage sludge disposal and re-use, and treated waste water re-use (where possible). Specifically, the directive requires the collection and treatment of wastewater in all agglomerations of more than 2000 p.e. In addition, there is a requirement of secondary treatment of all discharges from agglomerations of >2000 p.e. and more advanced treatment for agglomerations >10,000 p.e. in designated sensitive areas.

As part of its 2021 Action plan “Towards Zero Pollution for Air, Water and Soil”, there is a strong pressure to revise the UWWTD, which recently underwent the REFIT (Regulatory Fitness and Performance) assessment aimed at protection of the environment from the adverse effects of urban wastewater discharges and discharges from certain industrial sectors.

It has been noted that the UWWTD has been successful in a significant reduction of urban wastewater emissions of organic matter, nutrients and coliforms to surface waters. However, the UWWTD does not cover some chemicals which are virtually unaffected by conventional wastewater treatment. Given that the Directive permits the Member States to adopt individual and appropriate systems (IAS) to treat parts of the agglomerations where connections cannot be economically justified, these IAS do not guarantee compliance with the Directive’s standards with significant negative local impacts on the quality of receiving waters. Indeed, small countries, such as Lithuania heavily rely on IAS, which means that it is to monitor performance and therefore, compliance enforcement is challenging [34].

The UWWTD is also not applicable to scattered dwellings (i.e., individual households/agglomerations of less than 2000 p.e.) [35]. Therefore, differences among the Member States persist, as there are still regions lagging behind in terms of the Directive’s implementation in practice. For instance, in 2022 the Commission referred Spain to the Court of Justice of the European Union for failure to comply with the UWWTD in relation to 133 agglomerations. Similarly, Greece, in 2024, was also referred to the Court for the same reason in relation to 157 agglomerations [36]. The Commission noted that Spain and Greece should ensure that waste waters collected are sufficiently treated to meet the relevant treatment standards [37]. Overall, there have been serious breaches of the implementation of the UWWTD requirements and infringement decisions were initiated against 17 Member States for various reasons [37].

The UWWTD has been criticised for being out-of-date; it has also been acknowledged that improvements to ensure consistency between the UWWTD and climate and energy policies are needed. This sector is regarded as one of the biggest consumers of energy in the public domain, therefore, it has a great potential to reduce greenhouse gas emissions, also contributing for economies to become energy- and climate-neutral. Therefore, in 2022 the Commission has proposed major revisions, which, include reduce pollution, energy use and greenhouse gas emissions, improve water quality by addressing remaining urban wastewater pollution, as well as employ more circular solutions. Specifically, the proposal also notes energy neutrality by 2040 (after the revision—by 2045) for purification plants with over 10,000 p.e., which is in line with best practices in place in some Member States [7]. It is proposed that the energy used by the sector will have to be equivalent to the production of renewables from the sector. Building on the Energy Efficiency Directive [38] energy audits will be required for all facilities above 10,000 p.e. The revised text of recast UWWTD was approved by the European Parliament in April 2024. The strengthen requirements include that urban wastewater to undergo secondary treatment before being discharged into the environment by 2035 in all agglomerations of the size of 1000 p.e. or more; and tertiary treatment (i.e., the removal of nitrogen and phosphorus) will have to be applied in all wastewater treatment plants covering 150,000 p.e. (and more) by 2039 and by 2045 in those covering 10,000 p.e. and above. There will be mandatory application of quaternary treatment (removing a broad spectrum of micro-pollutants) for all plants over 150,000 p.e. and over 10,000 p.e. by 2045. The recast UWWTD proposes to improve the monitoring of various viruses and emerging pathogens, microplastics, antimicrobial resistance and chemical pollutants, embracing PFAS. Building on the polluter pays principle, there is the extended producer responsibility for the cosmetic and medical sectors, which will have to bear at least to 80% of the cost for the quaternary treatment (to remove micro-pollutants from urban wastewater). Overall, the EU Member States, especially Southern European countries, such as Italy, Greece and Spain) will be under pressure to unlock the potential of water reuse, particularly in water-stressed areas.

5. National Developments: Italy

5.1. Overview

With the population of 59,312,653 (based on 2024 data) [39], Italy is the third largest Member State of the EU. Italy is situated in southern Europe in access to the Adriatic Sea, Tyrrhenian Sea, Mediterranean Sea, and other waters, characterised by significant diversity of its landscapes due to its complex geological history, repeated climate changes and increasing human impact through time [40].

In terms of water use, in 2017, the total volumes withdrawn amounted to approximately 33 billion m^3, of which 43% for agricultural use (14.4 billion m^3), 25% for the supply of the Water Service (8.3 billion), 18% to produce hydroelectric energy (6.1 billion), and 12% for industry and manufacturing (4.3 billion) [41].

The integrated water service is characterized by significant energy consumption. The electrical energy is a fundamental input for the integrated water service. Most of the consumption is related to the water supply segment, which accounts for about 60% of the total energy used, and to purification systems, where another 30% can be attributed, specifically for powering the equipment dedicated to aeration and the movement of wastewater and sludge.

Even though electrical energy is essential for the proper functioning of the service and its current demand represents more than 2% of the national total consumption, approximately 6 TWh per year, the sector is not classified as an "energy-intensive" sector according to European and national nomenclature.

Depending on the necessary activities and the surrounding area, between 1 and 8 kWh of electricity are consumed for a single cubic meter of water. Based on the tariff data prepared in 2020, the cost of electricity supply represents a significant portion of the operating management costs, accounting for approximately 18%.

For this reason, its full optimization and increasing the water reuse are available options for integrated planning in smart cities and industries' transition towards decarbonization.

In 2018, 18,140 water treatment plants for the urban wastewater purification were registered in the national territory [42]. The purification plants are distinguished according to the type of treatment carried out, that is the efficiency of abatement of the polluting loads flowed into the purifiers through appropriate chemical-physical processes. They are grouped, from the simplest to the most effective, in the following types: Imhoff tank, primary, secondary (includes all biological treatments) and tertiary advanced (includes refinement phases such as nitrification and denitrification and de-phosphating, as well as final filtration).

More than 50% (see Figure 3) of the water treatment plants consists of Imhoff tanks, while approximately 11% of the plants carry out more advanced treatments (tertiary and advanced). In terms of treatment potential, 84% of the plants have a potential of less than 2000 p.e., 10% have potential between 2000 and 10,000 p.e., 6% has potential between 10,000 and 100,000 p.e. and about 1% has potential higher than 100,000 p.e. [43].

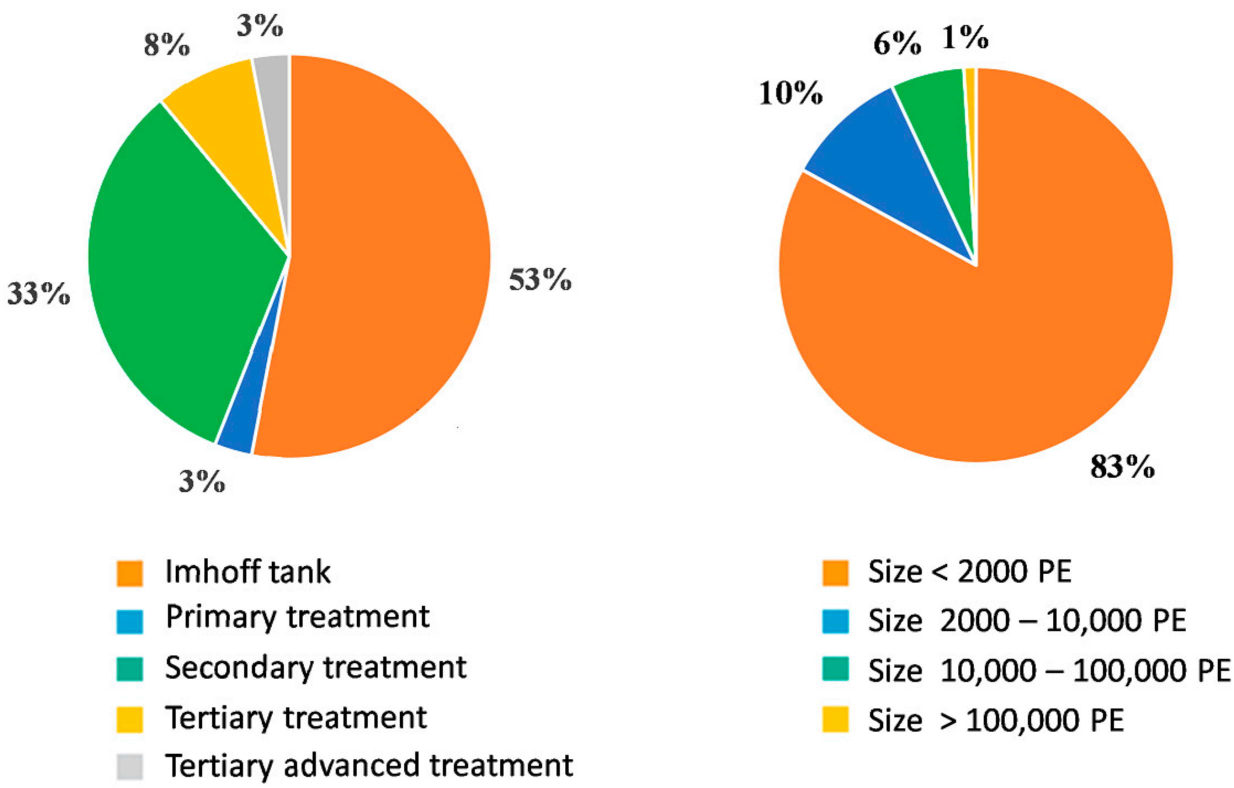

Figure 3. Classification of the water treatment plants according to the typology of the treatment (**left**) and the size (**right**) [44].

The water treatment plants of the urban wastewater mainly are used for the purification of the domestic wastewater and industrial wastewater, where available. Almost the 48% of the industrial wastewater is treated in the water purification plants of the North of Italy. This percentage reaches approximately the 70% when considering the industrial wastewater treated in the plants of the North and Center of Italy.

With reference to the year 2019, Figure 4 shows that a potential is already equal to 23% of the total purified volume (in m^3), and only 4% is actually reused (mainly for irrigation applications) and almost exclusively in the northern regions [41].

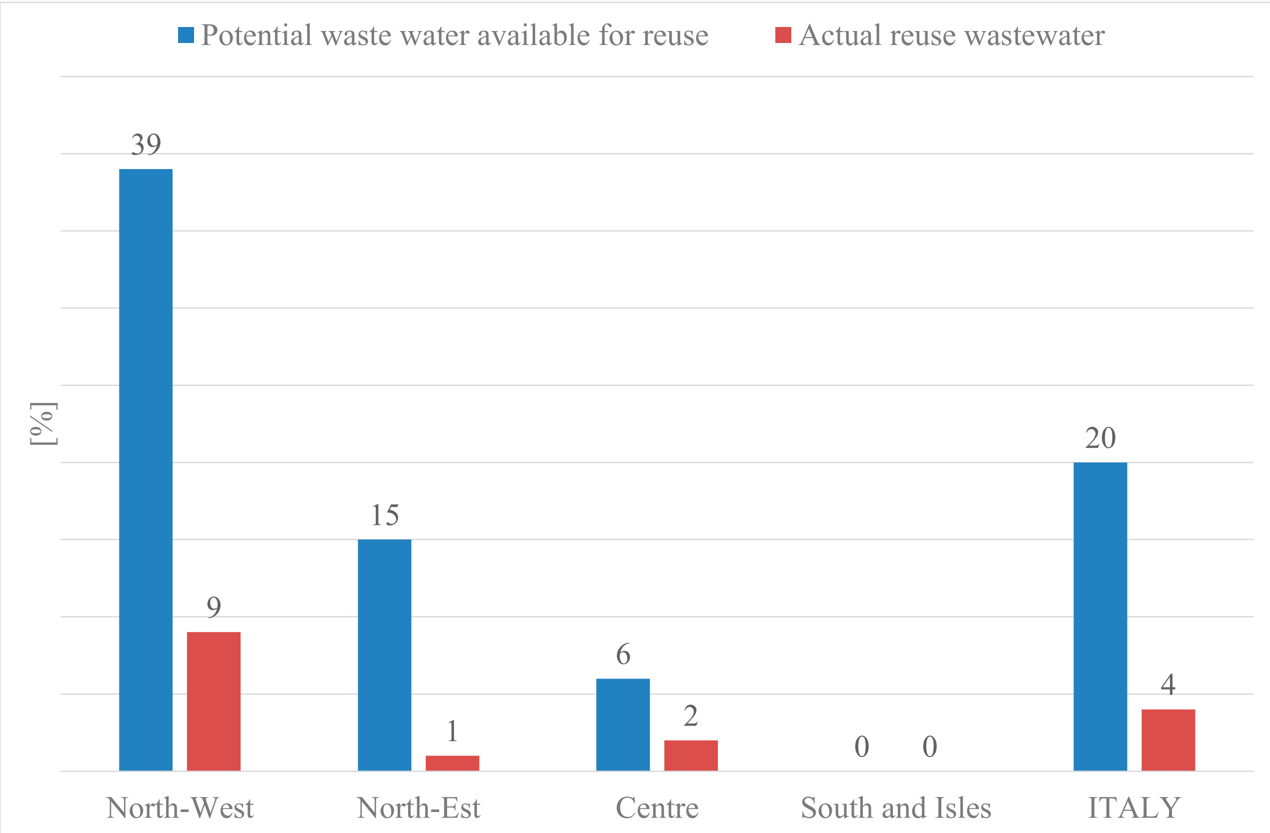

Figure 4. Percentages of the purified water potentially available for reuse and effectively reused.

According to a study [41], the water reuse is approximately 200 million m^3. This practice is mainly used in the area characterised by an intensive urbanisation or intensive agriculture (Lombardia and Emilia Romagna regions). The water reuse is also practiced in dry areas where there is a scarce availability of water.

5.2. National Policies and Legislation

The climate and geographical features of the Italian peninsula have led to a regulation of the wastewater reuse for farm irrigation purposes. Since 1977, a decree of the Ministry for the water and environment protection (4th of February 1977) established the limits for the wastewater reuse in agriculture sector. The former Decree no. 152/1999 and its further amendments transposed the UWWTD).

With the Ministerial Decree n. 185 of 12 June 2003, the technical rules for the reuse of domestic, urban and industrial wastewater have been established, defining the current regulatory framework. The Decree, having the aim of the qualitative and quantitative protection of water resources, regulates the withdrawal of surface water and groundwater, reducing the impact of discharges on rivers and promoting water savings through the multiple use of sewage water. There are strict requirements for safe reuse of water in terms of the environment and health, avoiding modifications to the different ecosystems, soil and crops [45].

The reclaimed water can be used in Italy for the following purposes:

Farm irrigation: irrigation of crops destined to the human and animal consumption, to non-food purposes and for the irrigation of green area or sport and recreational area.

Urban use: for the road and streets cleaning in urban centres for the feeding of heating or cooling systems; for the feeding of dual supply networks, separated from those of drinking water, with the exclusion of direct use of this water in buildings for civil use, with the exception of drainage systems in the toilets.

Industrial use: such as fire-fighting, process and washing water and for thermal cycles of industrial processes, with the exclusion of uses that involve contact between recovered wastewater and food or pharmaceutical and cosmetic products.

The water reuse for potable purposes is forbidden. In addition, the decree does not regulate the reuse of wastewater within the same factory or industrial consortium that produced it.

For irrigation and civil reuse, there are the minimum quality requirements (i.e., the limit values for 55 chemical-physical and microbiological parameters waste water at the exit of recovery plants), while for industrial uses it is established that interested parties agree on specific limits in relation to needs of the production cycles in which reuse takes place.

Each Region, on the basis of consolidated knowledge acquired for the different uses and methods of reuse, can introduce specific limits for the chemical-physical parameters than those foreseen in the annex of the decree; however, the limits introduced by the Regions could not exceed the limits that regulates the discharge into surface waters.

Furthermore, the Regions are allowed to adopt, in compliance with national technical regulations, further rules and measures aimed at encouraging the recycling and reuse of purified waste water especially with reference to sensitive areas, to cope with permanent scarcity situations of the water resource. These are rules that become an integral part of the Protection Plans of the Waters.

At the local level, the Regions can regulate the water reuse matter on various aspects. In addition to the possibility to define the parameters and review the limit values to be monitored on the basis of territorial characteristics, the Regions can play an important role by adopting policies aimed at promoting and implementing reuse on the regional territory.

Compared to the regulations of other countries, the Italian legislation regarding agricultural or civil reuse does not provide any distinction between the two types of reuse, providing the same chemical and microbiological limits for the two cases. With regard to microbiological parameters, for example, in the regulations of other countries, there are also significant variations in the accepted limit values passing from the irrigation of non-food crops to the irrigation of food crops [41].

In line with the Regulation 2020/741, Italy has recently issued a new piece of legislation—the so-called Drought Decree Law No. 68/2023, directed at simplifying and accelerating authorisation procedures, for instance, in relation to the construction of desalination plants, increasing the resilience of water systems and reducing the loss of these resources, augmenting the useful volumes of reservoirs, creating water collection systems by reusing purified wastewater as well as, overall, improving the efficiency of the Government's and Regions' response to the water crisis.

5.3. Identified Barriers of Water Reuse

There are different types of barrier for water reuse identified in Italy.

Economic barriers. One of the main obstacles is the difference between the cost of producing reuse water with the respect to the cost of conventional water resources ("withdraw" from the environment). For instance, the average costs for reuse, as calculated by ISPRA in a Survey of several Italian recycling plants (different plants for different uses: urban, industrial, agriculture) range between 0.0083 and 0.48 €/m^3. As a comparison, the costs of abstracting water from rivers and groundwater bodies is estimated at 0.015–0.2 €/m^3 [46]. Thus, in absence of financial support, it will be difficult for this practice to be competitive from an economic point of view. Furthermore, the water demand for irrigation is seasonal since it is predominant during the summer period. For this reason, the installation of water treatment systems that satisfy mainly a summer water demand is not sustainable to cover the direct costs of the plant. Therefore, high cost associated with the process to reclaim water is one of the main barriers for water reuse.

Regulatory barriers. There are no common standards and rules for the water reuse. In Italy, the law allowing the reuse of urban wastewater and sewage sludge is different region by region, complicating logistics and the industrial process.

Technical barriers. The infrastructure networks have to be taken into account. When considering a potential irrigation for the reuse, the existing infrastructure system needs to be evaluated, including purification systems (type of treatments used), the adduction and distribution infrastructures.

5.4. Best Practices of Water Reuse

In Emilia Romagna region, the European project (life program) ReQPro ("A model to Reclaim and reuse wastewater for Quality crop production), which took place 2014–2016, [46] has demonstrated how to contribute to the protection of the water resources by means of the reuse of waste water of an urban water treatment plant. The objectives of the project have been fulfilled by means of the interaction of different subjects: an advanced/tertiary wastewater treatment plant, a network of channels for the purified water distribution to the irrigation basin and a pool of farms that use the reclaimed water for the irrigation of their crops.

Specifically, this project designed for the tertiary water purification plant to be fed with the waste water from the urban water treatment plant. The water is treated with a combined process made by of a multilayer granular bed filtration for the suspended solid removal, and then chemical oxidation with hydrogen peroxide followed by low emission UV treatment. The second part of the purification has been selected for the abatement of the pollutants and the reduction of the bacterial load. The water treatment plant has a capacity of 1500 m^3/h. In the year 2016, 3,500,000 m^3 have been reused with the respect to the 5,500,000 m^3 treated. The irrigation area where the reclaimed water is used has an extension of 2000 hectare and the channels for the water distribution have an extension of 80 km. It has been estimated that the net present value is positive, more than 2 million euro.

6. Experiences in Other Mediterranean Countries Greece and Spain

6.1. Overview

For comparison, other Mediterranean countries, such as Greece and Spain with the highest WEI (after Cyprus) as noted in Figure 1 with their territories facing different levels of water scarcity (some of their river basin districts being among the most water scarce in the EU. Therefore, these countries are in a great need for innovative solutions. Pursuant to the 2024 data the population of Spain was 47,907,370 [47] whereas the Greek population was 10,031,007 [48]. In 2018, Spain had 2059 and Greece 464 urban waste water agglomerations of more than 2000 p.e. These agglomerations in Spain generated a total load of 64 535,402 p.e. with 99% of which is connected to collecting systems and 1% addressed through IAS (i.e., storage or septic tanks, micro-stations, etc.). Whereas in Greece these agglomerations produced a total load of 11,870,177 p.e. with 91% of it being connected to collecting systems and 9% addressed through Individual and IAS. The agglomerations in Spain are connected to 30 primary treatment plant, 566 secondary treatment plants and 1203 more stringent treatment plants with a total design capacity of these plants being 99,794,323 p.e. [49] In Greece, on the other hand, these agglomerations are linked to 6 secondary treatment plants and 226 more stringent treatment plants with a total design capacity of 13,982,461 p.e. [50].

In Spain, the total water reclamation is estimated to be around 400 hm^3/year, 12% of this total reclaimed water volume comes from the use of municipal reclaimed water to cover industrial needs [51]. The territory of Spain is divided into autonomies communities with diverse practices in terms of water reuse. For instance, one of Spanish autonomous communities, the Catalan autonomous region with 7,522,596 habitants corresponding to 16% of the whole Spanish population, has its water resources administrated over its territory (32,113 km^2) by two river basin districts authorities: (i) River Basin District of Catalonia (ACA) and (ii) Ebro River Basin District. While water reuse has increased for agricultural purpose, the reclaimed water volume reuse has also steadily increased from

2013 (1.37%) to 2021 (5.74%) in the industrial sector. In terms of more recent data, there are some promising examples of agricultural water reused, as 5 out of 17 autonomies regions in Spain reused 2/3 of their wastewater in agriculture in 2022, while the national level this amounted to 37.8% [52].

Greece had the highest freshwater abstraction for public supply in 2017, 179 m^3 per person [53]. Direct use of treated municipal wastewater amounts to approximately 20 million m^3 annually [54]. Most of the direct and indirect wastewater reuse, approximately 100 million m^3 are used for irrigation of agricultural land [54]. Overall, irrigation water reuse rates remain very low in Greece, at only 2% [55].

The Spanish regulation [regulation RD1620/2007 as amended] contains specific parameters and limit values for agricultural uses, such as SAR and heavy metals, and applies limit values for nitrogen and nitrates for aquifer recharge, and phosphorus for ornamental ponds and lakes with standing water. In addition, it provides stricter limit values for total suspended solids for certain uses, such as urban uses, use in cooling towers and evaporative condensers, golf course irrigation and aquifer recharge by direct injection [56]. In addition to national legislation, there are more comprehensive guidelines developed by certain regions (for example, Catalonia) [57].

In Greece, a national legislation on quality standards for wastewater reuse has been in place since 1965, setting limit values on various pollutants for wastewater reuse in agriculture, industry as well as for urban purposes [54]. Currently, the Greek regulations apply to a high number of permitted uses, as there are more uses and reclaimed water categories than in the EU, with the majority of them including a detailed description. For instance, the Greek standards apply strict limits for biochemical oxygen demand (BOD5) and total suspended solids for urban uses, some industrial uses, unrestricted irrigation and aquifer recharge by wells [56]. There are also differences in the scope and frequency of monitoring [58]. One must also note that there are currently no explicit provisions in the national framework for risk management plan development, which will have to change in line with the new EU supplementary regulation.

The distribution of powers and responsibilities involves different administrative structures both at national and at local levels (i.e., ministry, decentralised administration, regional administration, municipal administration etc.). Indeed, at the administration level, both the Natural Environment and Climate Change Agency [59] and the Centre of Renewable Energy Sources [60] play important roles in terms of providing technical and scientific support to the Ministries (i.e., Environment) on implementation of policies and on enforcing innovative programmes on environmental protection and rational use of energy, respectively [61]. In addition, according to the Law 3199/2003, the National Water Committee (NWCt) cooperates with ministries in terms of defining river basins and competent regional authorities, implementing national policy on water protection and management and approving national water programs together with the prime competent agency, the General Directorate of Water under the Ministry of Environment and Energy.

6.2. Best Practices of Water Reuse

6.2.1. Greece

The HYDROUSA project. This project set up a circular sewage management system on the island of Lesvos, which is appropriate for decentralised areas with high seasonal loads. The system treats the domestic wastewater of a town of Antissa (500 inhabitants). It combines anaerobic processes with a two-stage vertical flow treatment wetland. First of all, a subsurface flow constructed wetlands and disinfection to treat domestic wastewater as a completely circular solution where water, nutrients and the produced sludge are reused. Furthermore, the anaerobic process recovers energy in the form of biogas, which is then upgraded to produce high purity methane used to fuel local vehicles. The excess sludge from the UASB (Up flow Anaerobic Sludge Blanket) is treated in an integrated closed system which promotes efficient composting and odour treatment. This reclaimed wastewater meets the Greek Water reuse law for unrestricted agricultural irrigation and the

EU Water Reuse Regulation for Class A Agricultural use. The produced biogas is upgraded to biomethane to be valorised as a fuel.

Thessaloniki Water Reuse Project. The land around the city of Thessaloniki in the northern Greece is one of the most important agricultural areas of the country. A variety of crops is cultivated in this area, such as rice, corn, cotton, sugar beet, alfalfa and orchards. Within this project, initiated in 2007 a wastewater effluent of 165,000 m^3/day from the Thessaloniki WWTP is mixed with river water from the Axios and is used to irrigate approximately 2500 ha of agricultural fields. Mixing ratio between the WWTP effluent and the river water is maximum 1:5, where the exact mixing ratio depends on the treated effluent quality properties. Measurements of the water quality show, that the mixed water values of SS, COD and BOD5 were much less than those deemed satisfactory. In addition, concentrations of TC, *E. coli*, and *Enterococcus* spp. in the wastewater effluent were significantly lower than those of the Axios' river water. Thessaloniki wastewater reuse project also utilises the nutrients in the WWTP effluent. Amounts of 70–125 kg N/ha and 140–320 kg P/ha are applied with the irrigation water in the rice fields and 17–30 kg N/ha and 35–80 kg P/ha to other crops. Finally, other nutrients and heavy metals are also within the limits [62].

6.2.2. Spain

Whilst the examples in Greece indicate wastewater reuse for agricultural purpose, in Spain there are have successful water reuse initiatives for the industrial purposes.

Industrial water reuse—(AITASA) Tarragona petrochemical park. An advanced water reclamation plant (AWRP) was put into effect in 2011 in Tarragona (Catalunya) for cooling purposes in industries of the Tarragona petrochemical park. The capital investment of the first phase of the water reclamation and reuse project was 47 million euros, jointly provided by EU cohesion funds, the Catalonian Government and the Spanish Ministry of the Environment. The production capacity of reclaimed water is 90,000 m^3 a day. The production of reclaimed water increased from around 1 Hm^3 per year during its first year of operation to 2 Hm^3/year in the following years.

The AWRP collects secondary effluents from two municipal wastewater treatment plans. After clarification and filtration steps, this effluent is treated by reverse osmosis (RO). Depending on the raw secondary effluent quality (function of the mixing of the different sources) and on the quality requirement for the reclaimed water reused several passes in the RO can be performed and oxidation processes (UV and chlorination) are performed as a complementary treatment measure.

The reclaimed water is mostly used for the cooling tower supply of petrochemical companies. Moreover, the reclaimed water is also suitable due to its quality to be used for boiler feed water. For that purpose, the reclaimed water goes through an extra process: a satellite water demineralization, using an ion-exchange process and to produce highly demineralized water (0.2 µS/cm).

Quality controls are continuously performed. The main water quality variations observed in the raw wastewater reaching the WWTPs are caused by seawater infiltration through the main sewer lines along coastal areas, bulking episodes (increasing TSS), overloading of the biological processes and sudden increases in coagulant demand [63].

The production cost during the first year of operation was of 0.5 €/m^3 for advanced reclaimed water. Price is based on reclaimed water quality, on water volumes used and water use planification. The demineralisation process for high purity water production, at satellite facilities located within the industrial sites, has a production cost of around 1.2 €/m^3.

7. Final Discussions

EU and National regulations and policies. The EU legislation related to wastewater treatment is far from new. Indeed, the Urban Wastewater Treatment Directive (UWWTD) has been in place for more than 30 years, directed at protecting the environment and human health. The Directive is evidently out-of-date lacking consistency with other EU policies on climate and energy. In addition, there are worrying breaches of the transposition of the Directive in national legal systems, with infringement decisions being instigated against 17 Member States, including Greece and Spain. Given that the recast Directive has not been issued yet, the paper has placed further emphasis on the newest Regulation 2020/741 based on water reuse for agriculture. It also deliberated on the delegated Regulation 2024/1765 with the defined technical specifications embracing 23 elements to be considered in risk management plans. There are specific agronomic potential risks and therefore, the effects on the physical, hydraulic and chemical characteristics of the soil must be assessed in relation to the effects on the cultures. Often the purified wastewater has an ionic composition which is not very suitable for the characteristics of agricultural soils (sodium, calcium, magnesium, sulphates, chlorides etc.). The compatibility between the reused water, the soil and the crops must be assessed carefully. Apart from the agricultural sector, one must expect that more harmonised regulations will follow at EU level embracing minimum reclaimed water requirements for industrial processes, as part of integrated water management and the circular economy.

As far as national developments are concerned, Italy has a diversified regulatory framework in regions, creating additional obstacles for industry. Greece and Spain, on the other hand, have national guidelines, which mainly dictate treated water quality requirements. Further changes will need to be implemented in light of Regulation 2020/741, embracing comprehensive risk assessment, including the edition of water safety plans. As part of the water safety plan, all individual treatment barriers need to be 'validated' (initial performance validation during commissioning or through a validation conducted at any given time) and treatment performance needs to be 'verified' during operation, particularly to ensure microbial safety. Verification typically happens through a sensor or a similar approach that ensures that right now, at the moment of verification, the treatment barrier works correctly, i.e., delivers according to the validated performance. The difficulty may often be that there is no appropriate surrogate parameter or indicator present to verify the treatment performance in real-time. Hence, the ability to easily validate and verify treatment performance may become a selection factor for treatment technology beyond the actual performance. For example, technologies, such as chlorination or UV disinfection have well established validation and verification procedures, whereas low- and high-pressure membranes have less well-established procedures.

Waste water treatment technologies. The growing global demand for clean water necessitates the implementation of efficient wastewater treatment technologies. These systems are essential for reducing environmental pollution, safeguarding public health, and recovering valuable resources from wastewater. A range of treatment methods, encompassing both traditional and innovative approaches, has been developed to tackle these challenges. This review examines the primary categories of wastewater treatment—primary, secondary, tertiary, and advanced processes—focusing on their principles, applications, and recent developments [64,65]. Additionally, wastewater treatment typically includes preliminary processes at the start and sludge management at the end [66,67].

The primary treatment phase aims to remove larger particles and sediments using physical methods such as screening and sedimentation. Melo et al. [68] explain that wastewater passes through grit tanks during this stage, enabling fine sand particles to settle. However, finer sand particles may remain suspended in the water [69]. To address this, wastewater flows into large primary sedimentation tanks, where most of the solid materials settle to form sludge [70]. According to Al-Juaidi et al. [71], primary treatment can remove approximately 60–70% of suspended solids.

Secondary treatment is designed to eliminate 70–90% of suspended solids and involves biological processes where microorganisms break down organic matter [72]. Aerobic bacteria are commonly used due to their ability to oxidize and decompose organic compounds efficiently [73–75]. The availability of oxygen plays a critical role in determining the rate of removal of suspended materials by these microorganisms. Two common methods employed during this phase are filter beds and the activated sludge process. In filter beds, wastewater is sprayed over layers of broken stones or gravel, increasing the surface area available for oxidation [76]. Any suspended solids remaining in the effluent are removed in a secondary sedimentation step. The activated sludge process also utilizes microorganisms that oxidize and digest suspended organic matter to achieve further purification. In recent years, Nature-based Solutions are increasingly becoming recognised as competitive technologies for secondary treatment. Especially treatment wetlands, as already described in Section 6.2.1, exhibit comparative or superior treatment capabilities to the conventional methods [77].

Tertiary treatment targets the removal of toxic compounds, that are not addressed in earlier stages. This phase includes thermal and membrane-based processes. Thermal techniques such as MSF, MED, and VC are commonly used. Membrane technologies include, MF, NF, UF, ED, and TMD.

Thermal processes operate by evaporating water, leaving behind dissolved salts (non-volatile compounds). This concentrated brine undergoes further recycling and eventual disposal. Membrane processes, on the other hand, rely on various configurations to separate dissolved salts. RO applies dynamic pressure to reject salts, while ED uses electrical power to enable ion-selective separation, leaving behind diluted water. NF is often used to partially remove heavy salts, UF is effective in eliminating bacteria and viruses, and MF removes suspended particles and some viruses [78].

The primary objective of tertiary treatment is to produce water that is free from harmful compounds, making it safe for reuse, especially for irrigation. The tools employed in this stage are designed to target specific chemical contaminants present in the wastewater. Additionally, thorough screening ensures that the final product is free of any potentially harmful substances or compounds [79].

Waste water reuse barriers. Traditionally, the barriers can be classified in internal and external categories, based on whether they originated within the water utilities or from external sources. This distinction is crucial for understanding their origins and determining the actors responsible. Among the internal barriers, economic factors such as maintenance costs were highlighted, consistent with findings by Cipolletta et al. (2021) [80]. Additionally, a lack of expertise in managing non-standard governance structures was evident, as highlighted in the study conducted by P. Garrone et al. [81].

External barriers, on the other hand, encompassed a wide range of factors. Policy-related challenges were prominent, including the absence of mandatory regulations for water reuse and fragmented, inconsistent policies [82]. Market issues were also critical, particularly the limited demand for reclaimed water in industrial and agricultural sectors. Social and stakeholder-related barriers, such as negative perceptions of reclaimed water and low levels of awareness, further compounded the issue [83].

Other significant external barriers included infrastructure inadequacies, particularly the lack of networks required for environmental reuse. These challenges emerged as distinct from earlier literature, where they were often grouped under technological issues. Legal and institutional barriers were also noteworthy, especially the bureaucratic difficulties in securing permits for new users.

In line with the previous studies noted above, this paper has identified that there are further complications due to multifaceted administrative and legislative backgrounds. For instance, the complexity of the national standards has been noted as one of the barriers for reclaimed water use in Greece [84]. Even though there are competent authorities responsible for water management (including wastewater) (according to Law 3199/2003), their responsibilities are not clearly defined. This situation creates a horizontal fragmentation among the government agencies in the application of regulatory framework in environmental policies [85]. In fact, although several organisational responsibilities have been given to local authorities, regional administrations did not reach fully operative independence, due to the lack of experience in self-governance and absence of substantial financial resources and qualified staffs. Specifically, their responsibilities are correlated to the implementation of regulatory standards (set at national level) or to the environmental impact assessments of economic activities. Furthermore, in terms of legislation enforcement, there are issues related to divergent policies/regulations applied at different levels, for instance, even in the case of land development policy. In addition, conflicts among actors with different priorities, aims and approaches bring a fragmentation. Therefore, it can be noted that Greek institutional landscape highlights a governance fragmentation, overlapping of responsibilities and lack of cooperation in bureaucratic functions that act as barriers in water planning and implementation of river basin management plans [86]. One must also note, that there is a need for the modernisation of water rights. For instance, in Spain, a more flexible and efficient system is essential for water right entitlement pursuant to the River Basin Authority. Therefore, it is crucial, for instance, to promote the rights exchange from fresh water to reclaimed water [32].

The infrastructure networks have also been identified as creating further barriers for further usage of reclaimed water. For instance, agriculture is the largest water consumer in Greece similar to Spain. The area of irrigated land in the country is almost 103,860,000 ha. However, only an estimated 78,000 ha are irrigated via direct or indirect water reuse. This is because most wastewater treatment plants (WWTPs) are located at a considerable distance from agricultural land [86]. For example, the largest WWTP in the greater Athens area is located on a small island of Psyttalia, receiving an average wastewater flow of approximately 730,000 m^3/d. The Psyttalia WWTP capacity is 5,600,000 p.e. and covers the needs of approximately 35% of the population of Greece, being one of the biggest WWTPs in Europe. However, the feasibility assessment by the Water Utility Athens revealed, that only the cost of the transport of treated effluent from the island back to the city would be 0.4 €/m^3. Thus, use of reused water for landscape irrigation as well as for industrial use would not be economically justifiable [54].

In Italy, according to statistics of the Confederation of the Italian multi-utility companies (Utilitalia), the potential reuse for the purified waste water is 8.5 billion m^3, but only the 5% is actually reuse. The 83% of the water reuse is mainly for agriculture, while only 9% is reused for industrial purposes [87]. Indeed, the water reuse potential in Italy is largely untapped. Yet, one must note it is essential to carefully evaluate each individual initiative considering a cost and benefits analysis, as the high cost of recycled water is generally indicated as one of the main barriers to water reuse. Similar to Greece, this, the lack of infrastructure is another obstacle for the usage of reclaimed water; intensifying the reuse of purified water requires investment to reduce the transportation losses and to create distribution networks that facilitate the reuse of the reclaimed water [87].

8. Conclusions

The uptake of water reuse solutions remains limited in comparison with their potential, which remains largely untapped in the EU Member States. There is a vast difference of reclaimed water reuse across the Member States. This paper has identified various barriers for wastewater reuse. A legislative gap has been noted, due to the lack of strong harmonised standards at EU level and the potential risks to human health and the environment. For instance, irrigation of crops with reused water, the non-homogeneity of the standards across EU member state, or even across different regions cause onerous technological and monitoring costs. In addition, different standard of reclaimed water reuse has also implications on the development of a common market for the agricultural goods in the EU. This should be rectified by the forthcoming regulation, yet, with the predominant focus on the agricultural sector. Furthermore, the new EU regulation will prompt much-needed national regulations, which currently are rather fragmented, creating regulatory barriers for wastewater reuse.

Given that the water reuse potentials are clearly untapped, more circular integrated solutions need to be embraced especially in industrial processes. A few examples of good practice identified in this paper are insufficient. One would hope that legislation will be improved and expanded to encourage the safe and environmentally friendly use of recycled water for various uses, and lessons learnt from the agriculture sector will be transformed widely into industries. This, for instance, can be facilitated by banning the use of drinking water for irrigation, and industrial purposes.

Author Contributions: Conceptualization, J.M. and H.J.; methodology, J.M.; validation, J.M., B.D., L.M., M.V., W.G., M.A., T.S.P., E.N. and H.J.; formal analysis, J.M., M.V. and H.J.; investigation, J.M., B.D., L.M., M.V., W.G., M.A., T.S.P., E.N. and H.J.; resources, B.D. and M.V.; data curation, B.D., M.V., W.G., M.A., T.S.P. and E.N.; writing—original draft preparation, J.M., M.V., W.G., M.A. and T.S.P.; writing—review and editing, J.M.; visualization, M.V.; supervision, J.M.; project administration, H.J. and L.M.; funding acquisition, H.J., L.M. and J.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the European Commission grant number 958274 (iWAYS, iWays—Water closed loop in industrial processes—iWays). The APC was funded by MDPI Sustainability. W. G. acknowledges funding obtained from the Generalitat de Catalunya through the CERCA program and the Consolidated Research Group program (SGR-Cat2021_TECH, Codi ajut: 2021 SGR 01283.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: This study reanalyse predominantly the existing publicly available data as cited in the "References" section. Further information can also be accessed from iWAYS web-site: iWays—Water closed loop in industrial processes—iWays.

Acknowledgments: The paper was supported by the European Union's Horizon 2020 funded project iWAYS (the grant agreement No 958274). Additional information about the project is available at: iWays—Water closed loop in industrial processes—iWays.

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

BOD	biochemical oxygen demand
ED	electrodialysis
EEA	European Environment Agency
EU	European Union
GHG	Greenhouse gas
MED	Multiple Effect Distillation
MF	microfiltration
MSF	Multi-Stage Flash
NF	Nanofiltration
p.e	population equivalents
PFAS	per- and polyfluoroalkyl substances
RO	reverse osmosis
TMD	Thermal Membrane Distillation
UF	ultrafiltration
UN	United Nations
UWWTD	Urban Wastewater Treatment Directive
VC	Vapor Compression Distillation
WEI	Water Exploitation Index

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