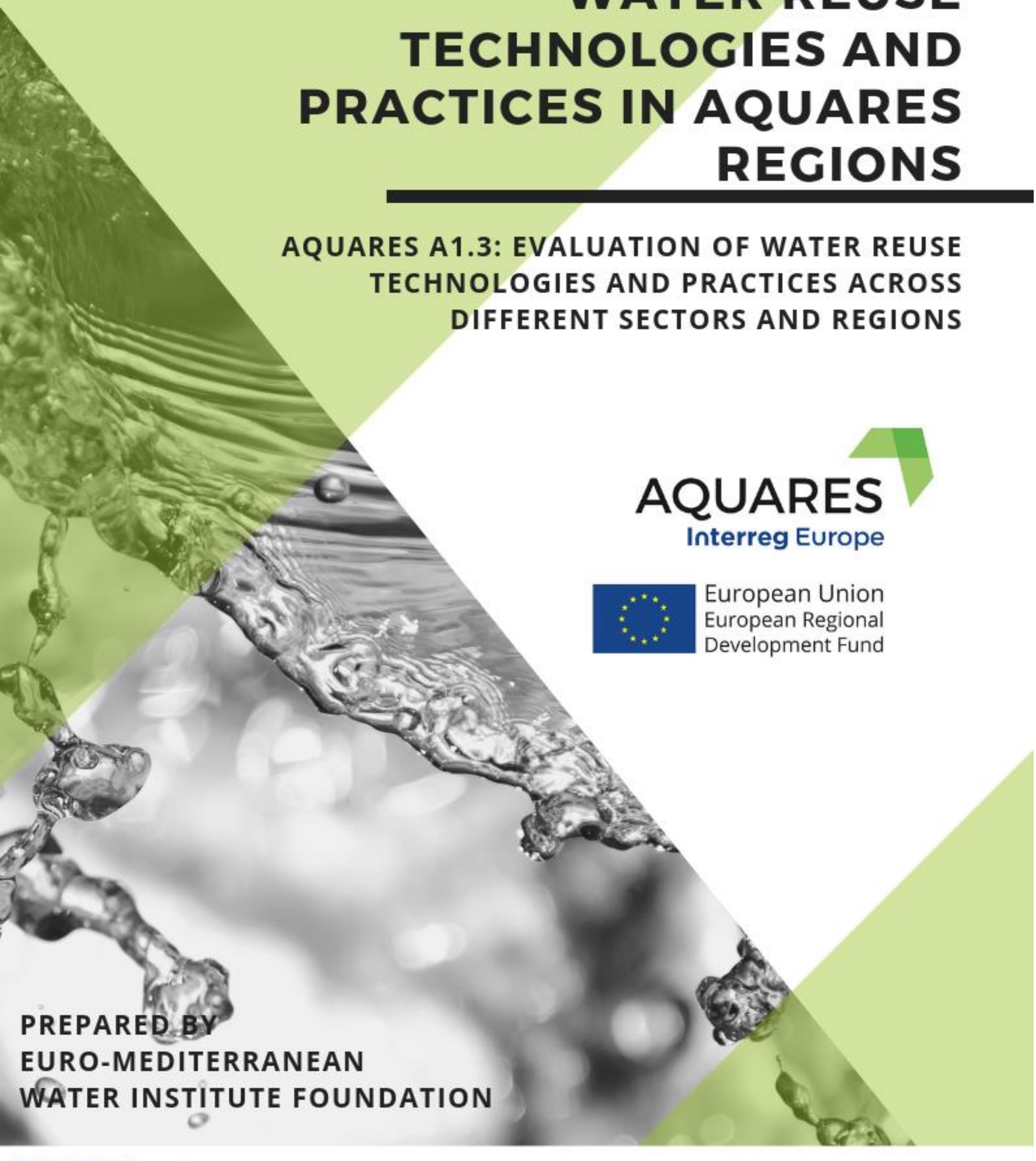
EVALUATION REPORT ON WATER REUSE TECHNOLOGIES AND PRACTICES IN AQUARES REGIONS

AQUARES A1.3: EVALUATION OF WATER REUSE TECHNOLOGIES AND PRACTICES ACROSS DIFFERENT SECTORS AND REGIONS



AQUARES
Interreg Europe

European Union
European Regional Development Fund

PREPARED BY
EURO-MEDITERRANEAN WATER INSTITUTE FOUNDATION

Fundación
Instituto Euromediterráneo
del Agua

Contents

Executive summary

The "Water reuse policies advancement for resource efficient European regions" – AQUARES project is an Interreg Europe project aiming to achieve efficient water management through water reuse, outline opportunities in the water market, and secure the protection of water bodies. The project will support public authorities in identifying viable strategies to utilise water reuse and confront water inefficiencies, making resourceful use of the available EU financial tools as well as encouraging public dialogue and addressing conflicts of interest.

This document is an output of AQUARES Activity 1.3 "Evaluation of water reuse technologies and practices across different sectors and regions". The purpose of the activity is to identify and assess current and future technology uses in different water reuse applications in different sectors of the economy. To this end, the evaluation will enable policy-makers to identify which technological solutions work best in the field of water reuse. This is accomplished through the identification and assessment of current technology uses in different water reuse applications in different sectors of the economy, including the agricultural, industrial, urban and recreational sectors, amongst others. The selected method of data collection for this research activity was desk research.

The key findings and conclusions drawn from the evaluation of water reuse applications include the following:

- The selection of a suitable water treatment scheme depends upon various factors and must be performed taking into consideration the specificities of each case.
- Economic considerations are central when assessing the potential of water reclamation projects. It must be stressed that the cost should be assessed in relevant terms (i.e. compared to other feasible water management alternatives).
- Decentralized water reuse technologies, available in a wide variety of options and scales, emerge as a suitable option for various uses. Furthermore, solutions have been developed to reduce operational costs in small scale applications.
- The development of water reuse policies and regulation would allow for the expansion of water reuse practices, especially for countries where such legislation is absent.

1 Overview of the EU water reuse policy framework

Water shortages and droughts have become increasingly concerning across the EU due to their intensified frequency and severity; 11% of the European population and 17% of the EU territory are exposed to water scarcity, with the Mediterranean region facing the hardest pressures. The two main factors linked to water scarcity are climate conditions and water demand. Water shortages can gravely affect agriculture, industry and tourism and have severe environmental impacts.[1] Water reuse can increase the available water resources, reduce cost and lower energy demand, subject to application, and reduce eutrophication; it is, thus, of vital importance to the EU (Angelakis & Durham, 2008).

Several international organisations, including the World Health Organization (WHO) in 2006[2] the United Nations Environment Programme (UNEP) in 2011[3] and International Organization for Standardization (ISO)[4], have developed guidelines for water reuse.

Despite the success of water reuse in various parts of the world, such as Australia, USA (California) or Israel, the practice has not been as widespread in the EU, mainly for two reasons:

- Lack of awareness by both the general public and relevant actors, and
- Lack of a supportive and coherent policy framework for water reuse

The EU Water Framework Directive[5] (2000) merely lists water reuse as one of the supplementary measures which Member States may choose to adopt. The Directive introduced the progressive reduction of several substances to be considered priority for the EU in the field of water policy. The most recent list of priority substances includes 45 pollutants and establishes standards of environmental quality and maximum permissible concentration in water (Directive 2013/39/EU).

---

[1]See: http://ec.europa.eu/environment/water/pdf/water_reuse_factsheet_en.pdf and https://www.eea.europa.eu/data-and-maps/indicators/use-of-freshwater-resources-2/assessment-3.
[2]See: https://www.who.int/water_sanitation_health/sanitation-waste/wastewater/wastewater-guidelines/en/
[3] See: http://wedocs.unep.org/bitstream/handle/20.500.11822/6623/11wg357_inf9_eng.pdf?sequence=1
[4] See: https://www.iso.org/committee/4856734.html
[5]https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32000L0060

The Communication from the Commission to the European Parliament and the Council addressing the challenge of water scarcity and droughts in the European Union (2007)[6] formed a hierarchy of solutions to address these problems and lists waste water reuse as one of the alternative solutions.

The Communication "Blueprint to safeguard Europe's water resources" (2012)[7] emphasised water reuse as an imperative measure to alleviate water scarcity that requires the attention of the EU. The maximisation of water reuse was set as a specific objective and the opportunity or the development of a legislative instrument for water reuse was identified.

The Communication “An EU action plan for the Circular Economy” (2015)[8] incorporated a number of actions to promote water reuse including the preparation of a legislative proposal on minimum requirements for water reuse for irrigation and groundwater recharge.

The Proposal for a Regulation of the European Parliament and of the Council on minimum requirements for water reuse[9] was adopted in May 2018 and the feedback period closed in August of the same year. The Regulation aspires to contribute to the alleviation of water scarcity while ensuring “a high level of protection for consumers, workers and any other exposed public as well as for the environment” and provide confidence in reuse practices.

[6] https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2007:0414:FIN:EN:PDF
[7] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52012DC0673
[8] https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1453384154337&uri=CELEX:52015DC0614
[9] https://ec.europa.eu/info/law/better-regulation/initiatives/com-2018-337_en

2 Clarification of Key Concepts

Water reuse is the use of wastewater that, after being treated to meet specific water quality criteria, reaches a quality that is appropriate for its intended use. Water reuse can be direct or indirect. Direct water reuse is the introduction of reclaimed water through the necessary infrastructure directly from a water treatment facility to a distribution system while indirect reuse "is the reuse of treated wastewater which is placed into a water body source, such as a lake, river, or aquifer and then some of it retrieved for later use"[10]. Water reclamation is the act of treating wastewater to make it acceptable for reuse. Water reclamation can be centralized or decentralized (also called on-site).

Water reuse can also be planned (or intended) or unplanned (also called unintended or de facto) where the latter refers to "uncontrolled reuse of wastewater after discharge".[11] For the purposes of Activity A1.3 we will focus solely on planned/intended water reuse, either direct or indirect.

2.1 Potential uses of reclaimed water

As pointed out earlier, the intended use of reclaimed water is key in order to determine the quality criteria the water needs to meet upon treatment. The main reclaimed water uses, on a global level, are presented in Table 1.

Table 1: Main reclaimed water applications in the world

Categories of Use	Uses
Urban uses	Irrigation of public parks, sporting facilities, private gardens, roadsides; Street cleaning; Fire protection systems; Vehicle washing; Toilet flushing; Air conditioners; Dust control
Agricultural uses	Food crops not commercially processed; Food crops commercially processed; Pasture for milking animals; Fodder; Fibre; Seed crops; Ornamental flowers; Orchards; Hydroponic culture; Aquaculture; Greenhouses; Viticulture

[10] See: http://ec.europa.eu/environment/water/pdf/Guidelines_on_water_reuse.pdf
[11] See Crook, 2010 and the Guidelines on Integrating Water Reuse into Water Planning and Management in the context of the WFD, available at: http://ec.europa.eu/environment/water/pdf/Guidelines_on_water_reuse.pdf

Categories of Use	Uses
Industrial uses	Processing water; Cooling water; Recirculating cooling towers; Washdown water; Washing aggregate; Making concrete; Soil compaction; Dust control
Recreational uses	Golf course irrigation; Recreational impoundments with/without public access (e.g. fishing, boating, bathing); Aesthetic impoundments without public access; Snowmaking
Environmental uses	Aquifer recharge; Wetlands; Marshes; Stream augmentation; Wildlife habitat; Silviculture
Potable uses	Aquifer recharge for drinking water use; Augmentation of surface drinking water supplies; Treatment until drinking water quality

Source: NRMMC-EPHC-AHMC, 2006; USEPA, 2012 in Alcalde-Sanz & Gawlik, 2014

The proposal for a Regulation of the European Parliament and of the Council on minimum requirements for water reuse (COM-2018-337) aims to regulate the standards of reclaimed water destined for agricultural irrigation use, including the irrigation of: i) food crops intended for raw or unprocessed human consumption, ii) food crops intended for human consumption after a treatment process, and iii) non-food crops (crops not intended for human consumption).

Italian[12], Spanish[13] and Greek[14] legislation concern the use of reclaimed water in irrigation but they also foresee urban non-potable use and industrial use. In addition, the Spanish legislation includes leisure and environmental applications, such as forest irrigation, wetlands maintenance and aquifer recharge, the latter is also foreseen in the Greek legislation.

Each of the aforementioned reclaimed water uses corresponds to appropriate water quality standards. Water quality can be measured by applying four criteria to samples taken from the water flow:

- Individual inorganics present in the samples
- Individual organics present
- Microbiological content of the samples
- Other indicator measures, such as biochemical oxygen demand and total suspended solids and pH

[12] Ministry Decree 185/2003
[13] Royal Decree 1620/2007
[14] Joint Ministerial Decision 145116/2011

Yet, considering the number of individual characteristics that can be spawned by these four criteria, measurement are targeted, mainly by factoring in the appropriate needs of the analysis (Merrett, 2004). Different water uses, thus, call for their appropriate standards, for instance the level of nitrogen concentration in a water volume may render it unsuitable for potable uses and at the same time ideal for agricultural uses.

To give an example, the Spanish Royal Decree defines maximum thresholds of intestinal nematodes, E. coli, suspended solids, turbidity and other pollutants for each reclaimed water use, as well as information on sampling frequency and analyses, evaluation of effluent quality, and measures to be undertaken when a failure occurs (Paranychianakis et al., 2014).

2.2 Water reclamation technologies and processes

Water reclamation entails different treatment processes taking place individually or combined so as to meet the required water quality standards. The main factors affecting the selection of a water reclamation technology, or a combination of technologies, include the water reuse application and the consequent reclaimed water quality objectives, as well as the characteristics of the source water (National Research Council, 2012).

Water treatment is usually described with general terms, corresponding to the different levels of treatment, as presented in Table 2.

Table 2: Conventional wastewater treatment processes

Treatment level	Objective
Preliminary treatment	Removal of coarse solids and other large materials often found in raw wastewater
Primary treatment	Removal of settleable organic and inorganic solids by sedimentation, and the removal of materials that will float (scum) by skimming
Secondary treatment	Further treatment of the effluent from primary treatment to remove the residual organics and suspended solids
Tertiary and/or advanced treatment	Further treatments to remove specific wastewater constituents which cannot be removed by secondary treatment

Source: FAO, 1992

Water Reclamation systems can be broadly separated into four categories: **Physical** Engineered Systems; **Chemical** Engineered Systems; **Biological** Engineered Systems; and **Natural** Systems (National Research Council, 2012). Reclamation technologies can be further categorised as intensive or conventional and extensive or non-conventional technologies. Intensive technologies refer to accelerated artificial processes that can be rapidly modified if needed and which require large quantities of energy and minimum space as well as highly specialised operation and maintenance personnel. By contrast, extensive technologies demand small amounts of energy and maximum space as they use environmental matrices and rely on natural processes for water treatment, so the processes occur at almost natural rates (Alcalde-Sanz & Gawlik, 2014).

Table 3: Intensive and extensive reclamation technologies

Intensive technologies	Extensive technologies
Physical-chemical systems (coagulation-flocculation, sand filters)	Waste stabilisation ponds (maturation ponds, stabilisation reservoirs,…)
Membrane technologies (ultrafiltration, reverse osmosis, membrane bioreactor, …)	Constructed wetlands (vertical-flow, horizontal-flow,..)
Rotating biological contactors	Infiltration-percolation systems
Disinfection technologies (ultraviolet radiation, chlorine dioxide, ozone, peracetic acid, …)	

Table 3 presents different intensive and extensive reclamation technologies identified by Alcalde-Sanz & Gawlik (2014), each of which has its own characteristics. Additional water reuse technologies include:

- **Surface filtration systems**: removal of suspended solids, organic matter, bacteria, protozoan cysts and helminth eggs.
- **Electrocoagulation**: P removal.
- **Dissolved Air Flotation (DAF)**: elimination of suspended solids, colloidal solids, organic matter, protozoan cysts, helminth eggs and viruses.
- **Advanced Oxidation Processes (AOP)**: elimination of organic matter and microorganisms (bacteria, protozoan cysts, helminth eggs, viruses, emerging contaminants, etc.).

In most cases two or more technologies need to be combined so as to meet the appropriate quality standards (Alcalde-Sanz & Gawlik, 2014).

Storage and distribution systems are also critical for meeting the appropriate standards for water reuse as reclaimed water may suffer changes that affect its chemical and biological quality during storage. Consequently, management strategies, including monitoring, have to be in place so as to prevent the deterioration of reclaimed water quality.

3 Research purpose and methodology

3.1 Purpose and research questions

The purpose of this evaluation report, as mentioned in the introductory section, is to enable policy-makers to identify which technological solutions work best in the field of water reuse. This is accomplished through the identification and assessment of current technology uses in different water reuse applications in different sectors of the economy, including the agricultural, industrial, urban and recreational sectors, amongst others.

Therefore, the research objectives addressed by the study are to:

- Identify the water reclamation technologies that are being applied or being proposed across the AQUARES regions and the EU-28 and,
- Examine which of the identified water reuse technology applications would better work for each region and sector.

The selected method of data collection for this research activity was desk research. This method represents an efficient and cost-effective way to capitalise on the already existing, adequate knowledge, lifting the need to invest time and resources on designing new primary data collection surveys.

3.2 Research methodology and documentation tools

A Data Input Form was designed in order to guide AQUARES project partners through the desk research, by outlining the data to be collected. This common approach ensured that all input collected was documented in a consistent and clearly structured manner, securing that the results of each partner's investigation were easily synthesisable and comparable.

The Data Input Form was divided in two sections:

- The first section of the form (PART I) was designed for the collection of background information on water reuse technologies and practices across the AQUARES regions and the EU-28.
- The second section of the form (PART II) was designed for the collection of information on specific water reuse technology applications across the AQUARES regions and the EU-28.

The project partners were expected to complete the form with information on their respective regions/countries (PART I) and three or more specific water reuse technology applications in their respective regions/countries (PART II). Furthermore, BALTIC COASTS was responsible for performing additional desk research on EU countries not represented in the AQUARES consortium as well as information on five or more specific water reuse technology applications.

The aim was to collect and evaluate the highest possible number and the widest possible variety of current and future water reuse technology applications across different regions and sectors, the project partners were thus encouraged to collect information on as many technology applications as possible.

It must be noted that all consortium partners contributed to the data collection by submitting the first part of the Data Input Form, demonstrating a high level of commitment. However the Regional Development Agency of the Pardubice Region (RRAPK) and the association "Baltic Coasts" were unable to submit the second part of the form filled with water reuse applications in the Czech Republic and Latvia, due to the marginal presence of such applications in their territories, which appears to be linked to the lack of appropriate legislative framework.

3.3 Evaluation criteria

The purpose of activity A1.3 is to locate, compare and evaluate water reuse technologies and practices. The quality specifications (i.e. criteria) presented in Table 4 forms the basis for the evaluation of the identified water reuse practices.

Table 4: Evaluation criteria

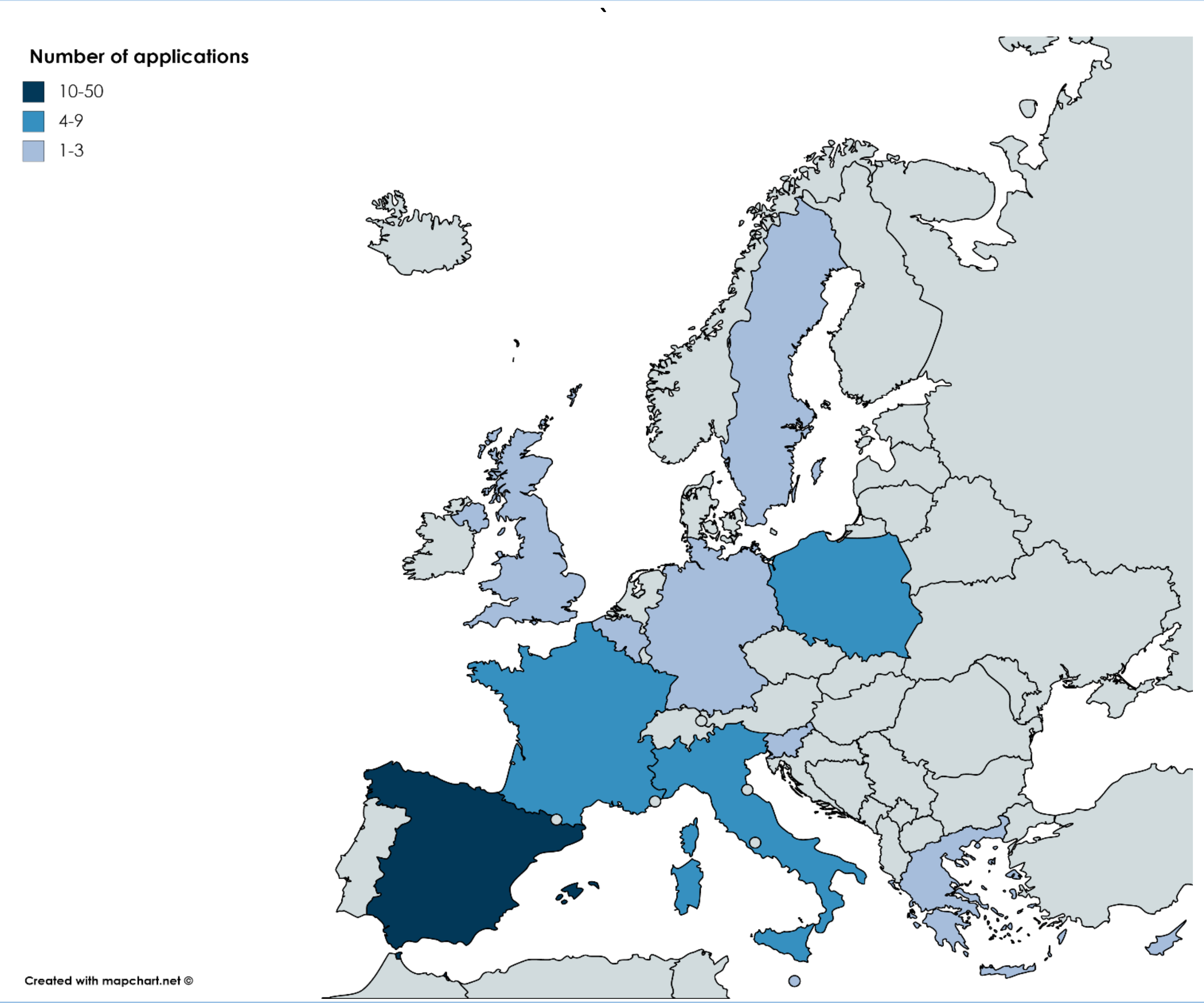
Evaluation criteria	Description
Impact	This criterion identifies the benefits achieved in terms of water quality, taking into consideration the operation and maintenance requirements of the technology or combination of technologies.
Problems encountered	This criterion assesses the extent of encountered problems and difficulties that have hindered the successful application of the identified technology, or combination of technologies.
Institutional and public support	This criterion assesses the support provided by key stakeholders in implementing the identified technology, or combination of technologies, as well as its reception by the wide public.
Economic sustainability	This criterion measures potential of the technology, or combination of technologies, to be maintained in the long-term with the available resources. Economic considerations are highly significant when assessing the potential of water reclamation projects.
Transferability	This criterion measures to what extent the identified water reuse technology, or combination of technologies, addresses common needs related to treated water quality, making possible the transfer into other sectors and/or regions.

The applications of water reuse technologies or combinations of technologies collected by the project partners were evaluated, using the information contained in the Data Input Forms. A scoring system, adjusted to correspond to the input collected by the project partners, which is available in Annex II, was used to perform the evaluation. The maximum amount of points that each water reuse application can gather is 25 (5 points x 5 criteria).

4 Key findings

This section discusses the main findings drawn from the analysis of all water reuse applications collected, seeking to derive common issues and conclusions related to the successful implementation of water reuse technologies.

Figure 1: Geographical distribution



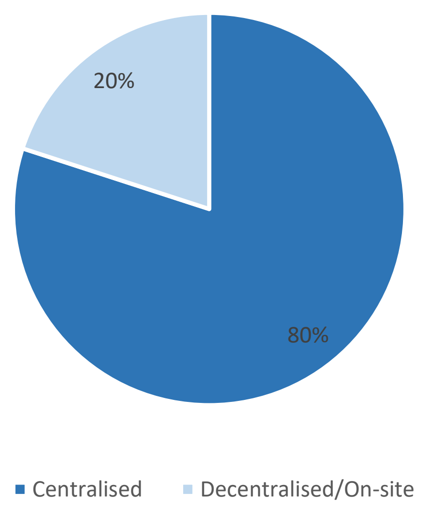
AQUARES partnership countries		Countries beyond the AQUARES partnership	
Germany	2	**Belgium**	1
Greece	1	**Cyprus**	2
Italy	7	**France**	4
Malta	3	**Sweden**	1
Poland	5	**UK**	3
Slovenia	1		
Spain	40		

Source: AQUARES A1.3 results

In total, 70 applications were collected and described by project partners using the Data Input Form. Regarding geographical distribution, Spain is found to contribute with the highest rate, accounting to 57% (i.e. 40 applications). Italy and Poland follow with 10% and 7% correspondingly. 16% (i.e. 11 applications) of the applications come from countries outside the AQUARES partnership (namely Belgium, Cyprus, France, Sweden and the United Kingdom), whereas the remaining applications come from Malta, Germany, Greece and Slovenia.

The vast majority of water reuse applications collected pertain to large scale centralised water reclamation processes; still, a considerable number of applications pertain to smaller scale decentralised ones.

Figure 2: Type of water reclamation



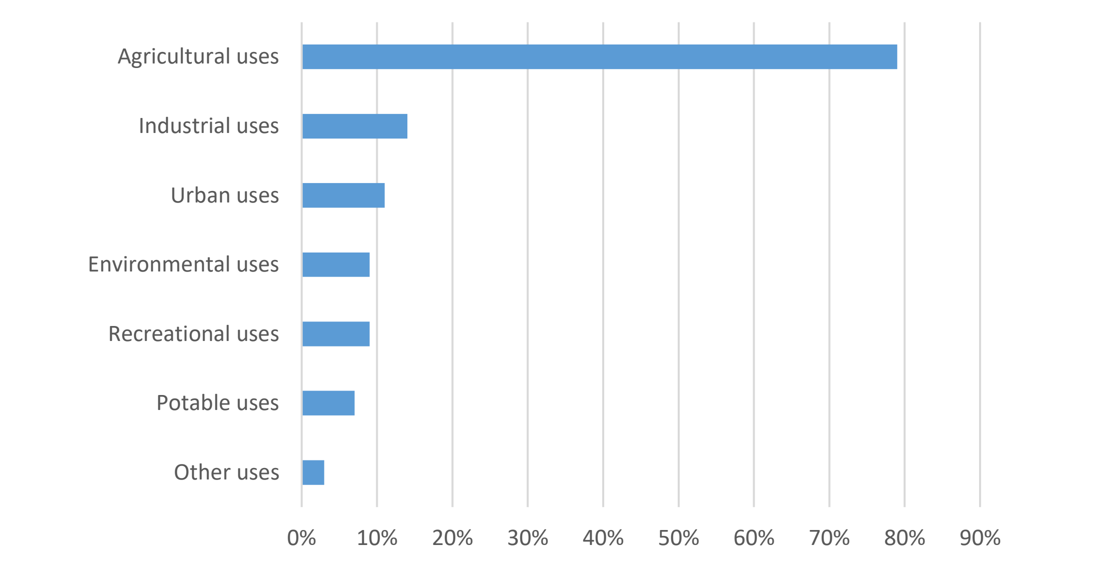
Type of water reclamation	Number of applications
Centralised	56
Decentralised/On-site	14

Source: AQUARES A1.3 results

As regards the uses of reclaimed water, the majority of applications collected (79%) concerned agricultural uses followed by industrial (14%) and urban (11%) uses, while the remaining applications concerned environmental, recreational, potable and other uses.

It should be noted that multiple answers were possible regarding the reclaimed water application sector; 20% of the applications collected (14 applications) concerned various combinations of uses.

Figure 3: Reclaimed water application sector



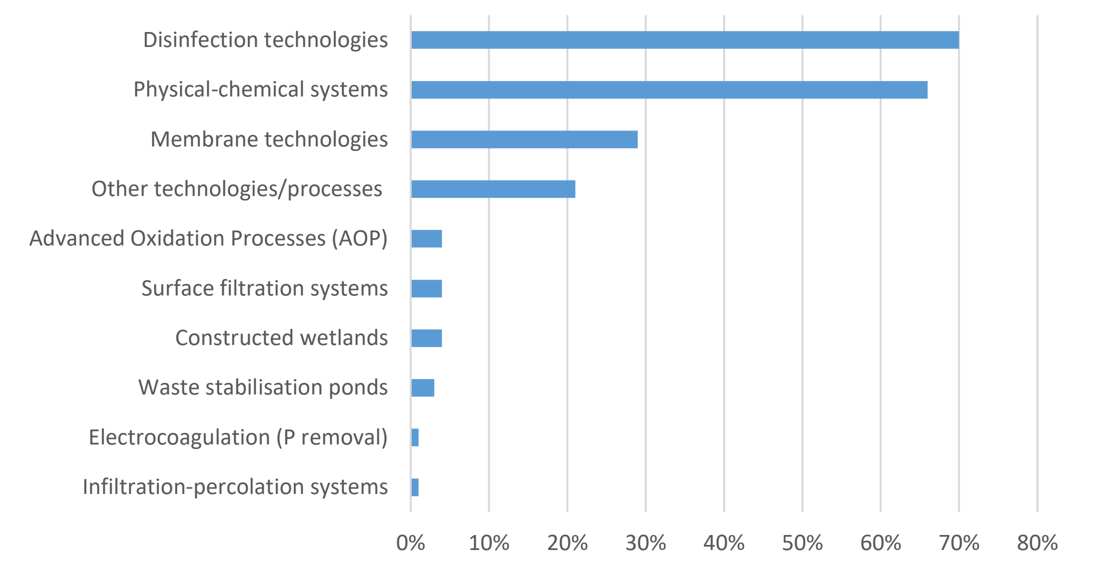
Application sector/use	Number of applications	Percentage of applications
Agricultural uses	55	79%
Industrial uses	10	14%
Urban uses	8	11%
Recreational uses	6	9%
Environmental uses	6	9%
Potable uses	5	7%
Other uses	2	3%

Source: AQUARES A1.3 results

With regard to the technologies and combination of technologies used, disinfection technologies and physical-chemical systems are in the lead, with 70% and 66% respectively, followed by membrane technologies accounting to 29%. Constructed wetlands, surface filtration systems and Advanced Oxidation Processes (AOP) follow with 4%, waste stabilisation ponds with 3% and infiltration-percolation systems and electrocoagulation (P removal) with 1%. Finally, 21% of the applications collected are using “other” technologies, not listed in the Data Input Form.

Multiple answers were, again, possible and a combination of multiple types of technologies was used in 81% (57 applications) of the applications collected.

Figure 4: Water reclamation technologies used



Water reclamation technology	Number of applications	Percentage of applications
Disinfection technologies	49	70%
Physical-chemical systems	46	66%
Membrane technologies	20	29%
"Other" technologies/processes	15	21%
Constructed wetlands	3	4%
Surface filtration systems	3	4%
Advanced Oxidation Processes (AOP)	3	4%
Waste stabilisation ponds	2	3%
Infiltration-percolation systems	1	1%
Electrocoagulation (P removal)	1	1%

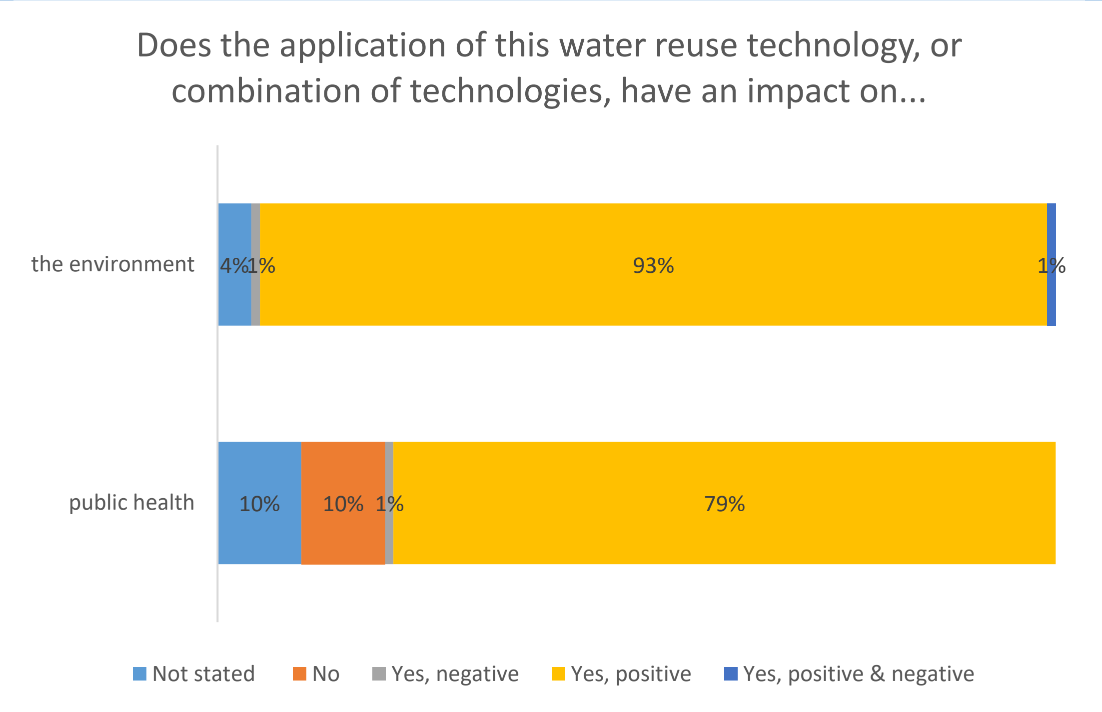
Source: AQUARES A1.3 results

Almost all applications collected appear to have a positive impact on the environment (93%)[15]. Relevant information could not be found regarding 4% of the applications examined while one application appears to have a negative impact. Furthermore, one application appears to have generated both negative and positive impact on the environment.

[15] MURCIA GDW address the question regarding the impact of the water reuse applications examined on the environment for the documented applications (reference numbers ES1-ES40). Based on a. relevant information included in the submitted form as well as b. the response of f-IEA on ES25 and ES38 regarding the same question, the applications were viewed as having a positive impact on the environment.

As regards public health, the impact was positive for 79% of the applications collected, relevant information could not be found for 10% of the applications examined, while the same percentage of applications did not have an impact on public health. It should be noted that one of the applications examined appears to have generated a negative impact on public health.

Figure 5: Impact of water reuse applications on the environment and on public health



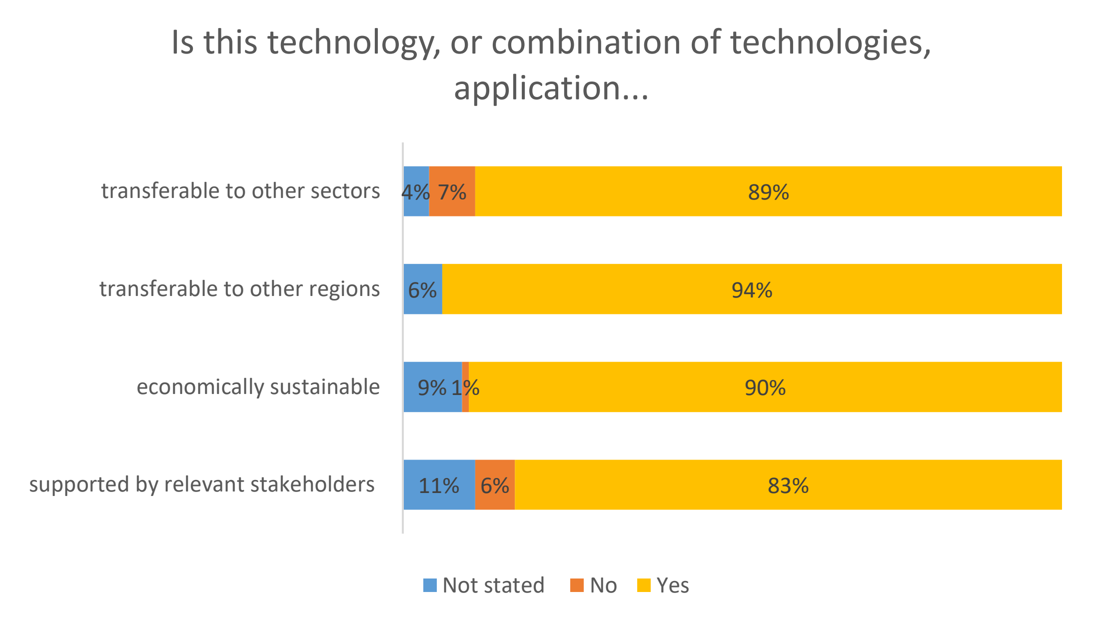
Responses (number of applications)	**Impact on the environment**	**Impact on public health**
Not stated	3	7
No	-	7
Yes, negative	1	1
Yes, positive	65	55
Yes, positive & negative	1	-

Source: AQUARES A1.3 results

Transferability refers to the process of applying a particular approach to other similar situations or settings and is a significant element in the context of AQUARES A1.3. Most of the water reuse application collected are transferable to other regions (94%) and can be transferred to other sectors (89%), with modifications according to the input water characteristics and the desired quality of the output.

Economic sustainability and stakeholder support are crucial to the viability of any water reuse endeavour. The vast majority of the applications examined are economically sustainable (90%) and supported by relevant stakeholders (83%).

Figure 6: Transferability, economic sustainability and stakeholder support



Responses (number of applications)	**Sectoral transferability**	**Regional transferability**	**Economic sustainability**	**Stakeholder support**
Not stated	3	4	6	8
No	5	-	1	4
Yes	62	66	63	58

Source: AQUARES A1.3 results

5 Evaluation of water reuse practices

The water reuse applications collected and documented by the project partners were evaluated based on the criteria outlined in section 3.3. The results of the evaluation are presented in Table 5.

A number of applications[16] did not receive a full score as they were not accompanied with complete, accurate and concrete information.

Table 5: Evaluation of water reuse applications

Ref. number	Country	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5	Total score
MT1	Malta	5	5	4	5	4	23
MT2	Malta	5	5	4	5	4	23
MT3	Malta	5	5	4	5	4	23
PL1	Poland	5	5	4	5	4	23
PL2	Poland	5	4	4	5	5	23
PL3	Poland	5	4	4	5	5	23
SE1	Sweden	5	4	4	5	5	23
BE1	Belgium	5	4	4	5	4	22
FR3	France	4	4	5	5	4	22
FR4	France	4	4	4	5	4	21
GR1	Greece	5	4	4	4	4	21
PLT5	Poland	5	4	3	5	4	21
CY1	Cyprus	5	4	3	5	3	20
SI1	Slovenia	4	4	5	3	4	20
UK1	UK	5	4	4	3	4	20
ES1	Spain	4	4	4	3	4	19
ES2	Spain	4	4	4	3	4	19
ES3	Spain	4	4	4	3	4	19
ES4	Spain	4	4	4	3	4	19
ES5	Spain	4	4	4	3	4	19
ES6	Spain	4	4	4	3	4	19
ES7	Spain	4	4	4	3	4	19
ES8	Spain	4	4	4	3	4	19
ES9	Spain	4	4	4	3	4	19
ES10	Spain	4	4	4	3	4	19
ES11	Spain	4	4	4	3	4	19
ES12	Spain	4	4	4	3	4	19

[16] This is the case for 12 water reuse applications appearing in the bottom of Table 5, namely: CY2, DE1, DE2, FR1, IT1, IT2, IT3, IT5, IT6, IT7, UK2 and UK3.

Ref. number	Country	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5	Total score
ES13	Spain	4	4	4	3	4	19
ES14	Spain	4	4	4	3	4	19
ES15	Spain	4	4	4	3	4	19
ES16	Spain	4	4	4	3	4	19
ES17	Spain	4	4	4	3	4	19
ES18	Spain	4	4	4	3	4	19
ES19	Spain	4	4	4	3	4	19
ES20	Spain	4	4	4	3	4	19
ES21	Spain	4	4	4	3	4	19
ES22	Spain	4	4	4	3	4	19
ES23	Spain	4	4	4	3	4	19
ES24	Spain	4	4	4	3	4	19
ES25	Spain	4	4	4	3	4	19
ES26	Spain	4	4	4	3	4	19
ES27	Spain	4	4	4	3	4	19
ES28	Spain	4	4	4	3	4	19
ES29	Spain	4	4	4	3	4	19
ES30	Spain	4	4	4	3	4	19
ES31	Spain	4	4	4	3	4	19
ES32	Spain	4	4	4	3	4	19
ES33	Spain	4	4	4	3	4	19
ES34	Spain	4	4	4	3	4	19
ES35	Spain	4	4	4	3	4	19
ES36	Spain	4	4	4	3	4	19
ES37	Spain	4	4	4	3	4	19
ES38	Spain	4	4	4	3	4	19
ES39	Spain	4	4	4	3	4	19
ES40	Spain	4	4	4	3	4	19
IT4	Italy	4	3	4	3	4	18
FR2	France	4	2	3	5	3	17
PLT4	Poland	4	3	3	4	3	17
IT7	Italy	5	5		5	4	
CY2	Cyprus	5		3	5	3	
FR1	France	4		4	4	4	
IT6	Italy	5			5	4	
UK2	UK	5	5		4		
DE1	Germany		4	4	4	1	
IT3	Italy	5			4	4	
IT5	Italy	4		4		4	
IT1	Italy	4			3	4	

Ref. number	Country	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5	Total score
IT2	Italy	4			3	4	
DE2	Germany						
UK3	UK						

A detailed list of the water reuse applications collected is available in Annex I.

6 Water reuse practices in AQUARES countries and beyond

This section offers a description of several notable water reuse practices identified by the project partners. The practices presented, while highly rated, are not necessarily the ones that received the highest ratings. Their selection was made so as to present a geographic and sectoral dispersion. A list of the selected water reuse applications is available in Figure 7.

Figure 7: Selected water reuse applications and associated technologies

Germany

- **Steinhof treatment plant** (primary sedimentation & activated sludge treatment)

Greece

- **Pilot sewer-mining application** (membrane technologies)

Italy

- **Residential building water treatment and reuse system** (physical-chemical systems, membrane technologies, disinfection technologies)
- **Fiordelisi s.r.l.** (physical-chemical systems, membrane technologies, disinfection technologies, activated sludge process, coagulation, secondary sedimentation & sand filtration)

Malta

- **Mellieha, Ghajnsielem and Xghajra treatment plants** (membrane technologies & advanced oxidation processes)

Poland

- **Rinse water purification plants** (physical-chemical systems, disinfection technologies & surface filtration systems)
- **Bilinski Textile Factory** (physical-chemical systems, membrane technologies, disinfection technologies, waste stabilisation ponds & electrocoagulation)

Slovenia

- **RusaLCA project** (nanoremediation)

Spain

- **Molina de Segura Wastewater Treatment Plant** (physical-chemical system, primary sedimentation, disinfection technologies, activated sludge & sand filtration)

Applications beyond the AQUARES partnership

- **Henriksdal Wastewater Treatment Plant in Sweden** (membrane technologies & disinfection technologies)
- **Torreele project in Belgium** (membrane technologies)
- **Island of Noirmoutier in France** (disinfection technologies & waste stabilisation ponds)

6.1 Germany

The legislative framework of water reuse for irrigation or further end-uses requires the consideration of a range of protected goods, effects and exposure pathways. These include the soil, the groundwater, the plant, and last but not least, human health. Corresponding to the protected goods concerned, the subject matter comprises the legal areas of environmental protection (in particular the water regulations), consumer and health protection, as well as product liability.

Figures on the total amount of wastewater reuse in Germany are not reported in the relevant literature, but are most likely marginal. The potential of water reuse for Germany was estimated to be 144 Mm^3/yr by the year 2025 (TYPSA, 2013). Overall, Germany has little experience in the use of treated wastewater for agricultural irrigation (Seis et al., 2016) and other end-uses. Multiple use of wastewater including agricultural irrigation and groundwater recharge is practiced in two locations: Brunswig and Wolfsburg. There are no sites known where direct or indirect potable reuse is practised. However, it should be noted that de-facto water reuse occurs where the degree of treated wastewater in surface waters is substantial and used via induced bank filtration or groundwater augmentation. These Managed Aquifer Recharge sites contribute around 14% to Germany's drinking water that is supplied by the public water networks (Sprenger et al., 2017). A recent study on the occurrence of increased levels of treated wastewater in surface water used through bank filtration or groundwater augmentation for drinking water purposes concluded that the decisive factors for the evaluation of an increased risk are site-specific hydro-bio-geological conditions of the subsurface passage as well as the quality of the surface water (Drewes et al., 2018).

Apart from communal wastewater reuse only few known application of industrial reuse are known. Since 1987, purified production wastewater from the sugar industry has been made available in Northeastern Lower Saxony (Uelzen). In two reservoirs of the Uelzen Water Association, 1 Mm^3 of water, which is produced every year in the winter months in the Uelzen plant of Nordzucker AG and was anaerobically cleaned, is stored and used by the agricultural industry for irrigation during the growing season (Ostermann, 2017). Furthermore, there are examples of decentralized reuse schemes. For instance, there is a new residential area in Hamburg (Jenfelder Au) where source separation of domestic wastewater into blackwater and greywater as well as local utilization of energy is implemented. The greywater and the blackwater streams are directed to a decentralized treatment facility and subsequently discharged along with stormwater to a water cascade and pond system (DWA, 2019).

6.1.1 Steinhof treatment plant (Braunschweig, Germany)

The Steinhof sewage treatment plant (STP) was built in 1979. The treatment plant includes primary sedimentation as well as activated sludge treatment for the removal of bulk organic carbon. The nutrients nitrogen and phosphorus are partially removed biologically. The STP has a capacity of 350,000PT and treats an average volume of 21,000,000 m³ wastewater each year. Two thirds of the treated wastewater, an average amount of 15,000,000m³ per year, are used for the irrigation of the 3000ha of the sewage association Braunschweig (AVBS) agricultural area. The remaining third enters irrigation fields as a final treatment step, before it is discharged into the Aue-Oker-Canal (Seis, 2012).

The wastewater recycling scheme is supported by the local policy in Braunschweig, by the involved districts as well as the water authority. The main objective of the reuse scheme was wastewater disposal and, at the same time, meeting the high water demand and nutrient requirements of the irrigation land. In addition, the reuse scheme should be cheaper for the citizens than conventional wastewater treatment system.

Based on a Life Cycle Assessment analysis (Kraus et al., 2016) of the environmental impacts of the wastewater reuse scheme at Braunschweig, the application has both positive and negative impact on the environment as:

- local nutrient loads and resulting eutrophication potential of the receiving surface water (Oker) are reduced by more than 50% compared to direct discharge of secondary effluent,
- water footprint of agricultural irrigation is reduced by substituting the use of groundwater resources,
- water reuse leads to additional energy demand and associated emissions of the system (29 % increase in net energy demand).

The main challenges encountered include the increasing demands on water quality and the revised fertilizer and sewage sludge legislation that restricts agricultural utilization of sewage sludge as well as the heavy metals in the sewage sludge which is added to the sprinkled water. The latter is addressed through the construction of the indirect discharger monitoring, thereby sustainably lowering, the heavy metal concentrations in the wastewater and thus also in the sewage sludge.

Currently the reuse application is economically sustainable, however, if further costly treatment steps, such as the removal of micro pollutants, are added, the economic advantage of the sprinkling may become neglectable. As regards sectoral and regional transferability, a transfer of the Braunschweig model is not readily possible. Even if the demand for additional water is high, there may be great reservations regarding agricultural products, especially food, irrigated by waste water (Oehlschläger & Bock-Polach, 2015).

6.2 Greece

Greece, and predominantly several south-eastern and island areas, receives severe pressure on water resources, further intensified by the seasonal high water demand of the tourism and agriculture sector. Thus, the integration of treated wastewater into water resources management is significant for meeting future water demands (Ilias et al., 2014).

The Joint Ministerial Decision on water reuse quality levels and treatment processes (JMD 145116/2011, amended by JMD 191002/2013), foresees water reuse for:

- **Urban uses** (including landscape irrigation, recreational uses, car washing, and firefighting).
- **Irrigation of crops** and commercial nurseries (with or without restrictions).
- **Industrial uses** (including cooling, boiler feeding, and processing).
- **Aquifer recharge** not used for potable uses.

6.2.1 Pilot sewer-mining application (Athens, Greece)

Sewer-mining is a less known decentralized wastewater reuse technology option which can be deployed at an intermediate scale. It entails extracting wastewater from local sewers, treating it at the suitable quality level and using the output for local non-potable uses while returning treatment residuals to the sewer system. As a result, the need for both expensive conveyance systems from end of pipe treatment installations and dual reticulation infrastructure is eliminated (Makropoulos et al., 2018).

The pilot application, managed by Athens Water and Sewerage Company S.A (EYDAP) and the Department of Water Resources and Environmental Engineering, School of Civil Engineering, National Technical University of Athens and was developed under the Dessin project[17]. The pilot application examined sewer mining, as an innovative concept for distributed reuse within the urban environment, making use of advanced Information and Communication Technology solutions for monitoring and management.

The application involved a double-membrane treatment scheme (i.e. compact membrane bioreactor and reverse osmosis MBR-RO) and the treatment unit had a capacity of 10 m^3/d (Plevri et al., 2016). As regards the ICT monitoring and management system, 21 physical and

[17] https://dessin-project.eu/

chemical characteristics are measured through the use of 10 sensors which are connected to a sensor controller turning the signals received from the sensors into digital data. The integration of an ICT system into the application allows for a. **automated maintenance** and **b. remote operation** thus reducing operational costs (Makropoulos et al., 2018).

The application can be transferred to other regions while tools have been developed to support and facilitate its transferability to a variety of cases. The estimated costs range from from 0.86 euros/m^3 for the MBR-UV scheme to 1.07 euros/m^3 for the MBR-UV-RO scheme, thus providing a satisfactory starting point for the diffusion of sewer mining technology. However, under the "full cost" method, accounting for both economic and environmental costs, "the sewer mining technology is expected to become significantly more attractive, while a large part of its cost reduction rate depends on 'learning curve' attributes". (Makropoulos et al., 2018: 12).

6.3 Italy

Italy is classified as a medium-high water-stressed country. Nearly 50% of abstracted water is used in the agricultural sector, and about 32% in industrial and energy sectors. Furthermore, water distribution is uneven in the country: about 59% of water resources (70% of groundwater) are located in the North and less than 25% in the South and the islands.

During the last decades, several water reclamation and reuse projects have been implemented in Italy, mainly aimed at agricultural irrigation (over 4,000 ha) and at industrial applications. Water reuse for irrigation is especially applied in southern regions (Puglia, Sardegna, Sicilia), where agriculture is the driving economic sector and water scarcity is a spreading issue (particularly during the dry season), in the Po Valley (Emilia Romagna, Lombardia), and for specialized activities (e.g. horticultural sector in Toscana). Instead, water reuse in industrial applications is pursued mainly in the northern and central regions of the Country (Piemonte, Lombardia, Torscana).

Ministerial Decree (M. D.) 185/2003 (in application of Legislative Decree 152/1999, "Water Framework" and confirmed by the more recent Leg. Decree 152/2006, "Environment Framework"), provides technical specifications and stringent quality standards for water reuse, including more than 50 parameters, both microbiological and chemical, for a highly precautionary approach. Nonetheless, the law is quite old and does not take into account pollutants and pathogens of emerging concern, nor the results of recent research works and experiences.

M. D. 185/2003 foresees water reuse for:

- **Agricultural uses (**irrigation, with no distinctions based on kind of crop and type of irrigation option).
- **Industrial uses** (cooling, cleaning, fire control, no food or cosmetics production).
- **Non-potable urban uses** (streets washing, toilet flushing).

The Decree prescribes that environmental and hygiene safety must always be preserved and any harm to ecosystems, soil, crops and human health must be avoided. Regional Authorities can add control parameters or implement stricter local norms.

M. D. 100/2016 regarding aquifer recharge criteria does not include reclaimed water among the possible water sources for this purpose, therefore eliminating a consistent contribution to environmental restoration activities.

6.3.1 Residential building water treatment and reuse system (Milano, Lombardy region, Italy)

The water treatment and reuse system installed in a residential building in Milano, renovated in 2016/2017, allows energy and water savings, thus increasing the building value. The technologies in place allow the collection, treatment and reuse of grey water (from bathroom sinks and showers) and meteoric waters. The uses of reclaimed water include toilet flushing, domestic laundry washing, car washing, irrigation and external pavement cleaning. As a result, drinking water consumption is reduced by up to 50%, therefore alleviating the abstraction stress for drinking water production and the treatment requirements.

The treatment and reuse system is a compact solution located in the basement of the building. It includes a 3 m^3 pre-treatment storage tank for grey water, an 8 m^3 reclaimed water tank, and a lifting station with a submersible electric pump. Grey waters go through a preliminary filtration and membrane ultrafiltration, then into the 8 m^3 tank for equalisation with meteoric water before treatment with physical (multi-stage) filter, activated carbons and UV disinfection.

The treatment capacity of the system is 4 m^3 per day while the daily treated volume can vary according to rain events and variations in domestic consumptions. The treatment system is compact and designed for requiring minimal maintenance and operational costs. The pumping system is equipped with inverters for optimal performances and lower consumptions.

All of the technologies applied in this scheme are commercially available and have no particular working conditions, therefore can be transferred in other regions. Furthermore, the system can be installed in other types of buildings including hotels, resorts or touristic villages, malls, or offices.

6.3.2 Fiordelisi s.r.l. (Capitanata, Apulia region, Italy)

In 2012 Fiordelisi s.r.l. decided to reuse part of the wastewater produced during the processing and packaging operations for irrigating its own fields and thus reducing the groundwater demand. For this purpose, a full-scale tertiary treatment was commissioned and added to the conventional primary and secondary treatments already in place.

The desired outcome is the production of water for irrigation of the company's own fields in order to reduce groundwater exploitation and ensure constant availability of the resource. In addition, the possibility of reduction of fertilizers usage due to the presence of residual nutrients (K, N) in the treated water was evaluated.

Before implementing the reuse of reclaimed water, the company used to extract groundwater for both cultivating the crops and for processing the food; however the water availability was scarce (about 85 m^3/h). Due to growing production, the water requirements significantly increased up to reaching, during the warm season, the maximum flow rate available for irrigation.

The company produces approximately 80,000 m^3/y of potentially reusable water. The waste water contains oils, pasteurization additives, suspended solids and salts, the organic pollution can vary according to the type of vegetable processed. This waste water is mixed with the water coming from toilets and cleaning procedures (containing faecal contamination and detergents) before treatment.

The implementation started in 2014, the plant was used as a demonstration site for the DEMOWARE project (2013-2016)[18]. The treatment plant operation was monitored for two years.

[18] http://www.demoware.eu/en

6.4 Malta

Malta is a semi-arid country located in the centre of the Mediterranean Sea. The scarcity of water has always been an issue since documented history and meeting the demand for both municipal water supply as well as the needs of the agricultural and commercial sectors has always provided an important challenge.

Malta's natural water resources are insufficient to meet the demand for water of the country. This imbalance between water availability and the demand for water creates a situation of permanent water scarcity in the Maltese islands. This natural low availability of water in the Maltese islands has always required that due consideration is given to the conjunctive use of water supply augmentation and water demand management measures to ensure that the national demand for water is met in a sustainable manner. Within this context water reuse is considered as one of the available tools to increase efficiency in the national water cycle and reduce the reliance on natural water resources.

In the recent years Malta has embarked on a large water reuse project, termed New Water, whereby treated effluent is being polished to high quality standards and distributed for reuse by the agricultural and industrial sectors. It is expected that by the end of the project approximately 7million cubic meters of reclaimed water will be produced from the three polishing plants developed under this project. This volume of reused water will help alleviate the existing pressures on Malta's natural water resources by providing an alternative source of water for the agriculture and industrial sectors. The New Water project is thus one of the key measures under Malta's Program of Measures intended to enable the achievement of good groundwater quantitative status in all groundwater bodies in the Maltese islands by 2021. The project, which is now well underway involved the development of three water polishing plants which upgrade the quality of treated water from the islands' three Urban Wastewater Treatment Plants to irrigation standards.

Malta's 2nd River Basin Management Plan highlights Water Reuse as one of the main measures within Malta's water management framework required for the achievement of the environmental objectives of the EU Water Framework Directive. The regulation of water reuse is being developed in parallel with the EU Regulation for Water Reuse in Irrigation, and currently the quality standards proposed by JRC for the purpose of this Regulation are being temporarily applied in Malta until such Regulation enters into force.

6.4.1 Mellieha, Ghajnsielem and Xghajra treatment plants (Malta)

The main objectives of the water reuse programme in Malta are:

- Diversification of water supply for the agricultural and industrial sector.
- Reduction in the reliance on groundwater resources.
- Optimise water supply security in view of water scarcity impacts.
- Increase agricultural production whilst limiting the dependency on natural resources.

The treatment process in the three plants involves the polishing of treated wastewaters produced from a conventional (biological) urban wastewater treatment plant, through the successive application of Ultrafiltraton, Reverse Osmosis and Advanced Oxidation treatment phases. In as much the treatment system can be considered to include four treatment barriers to ensure the quality and safety of the produced water.

Reclaimed water is pumped from the polishing plants to dedicated distribution reservoirs, from where it is distributed through a dedicated network by gravity to automated supply points. Users can access the reclaimed water from these supply points through the use of an electronic key-card. Consumption is monitored remotely at a centralised control unit operated by the Water Utility.

The production capacities of the respective plants in operation are as follows:

- Mellieha (Malta North) – 6,400 m^3/day
- Ghajnsielem (Gozo) – 3,200 m^3/day
- Xghajra (Malta South) – 9,600 m^3 /day

The motivation behind the application of this combination of technologies is the development of an alternative water resource which is safe to use both for the public and the environment. Water reuse will enable the diversification of the national water resource base, enabling the national water demand for the agricultural and industrial sectors to be met whilst ensuring the sustainable use of natural water resources.

The project gives due consideration to risk assessments to ensure the safety of the water produced to human health. In addition by reducing the dependence on groundwater resources, reclaimed water will contribute to the future sustainability of groundwater dependent terrestrial ecosystems which are considered as important natural areas of high recreational value important for human health. As regards the impact of the applications on the environment, reclaimed water is being used in lieu of natural water resources (groundwater) hence enabling this resource to recover and progressively achieve good quantitative status objectives required under the EU Water Framework Directive.

Under conditions of water scarcity and unavailability of sufficient water resources, the cost of reclaimed water needs to be compared to the replacement cost of natural water resources. In the case of Malta, the next cheapest source of non-conventional water resource is desalinated water. Hence, until the production of reclaimed water is cheaper than the production of desalinated water, such process can be considered as economically sustainable.

The technologies used are transferable to regions suffering from a chronic scarcity of water resources and where an alternative resource of high quality water is required for uses such as agriculture, landscaping and industry. The modular nature of the technology makes it transferable to industrial or tourism enterprises requiring on-site water reclamation for secondary purposes or process water. It should however be noted, that primary treatment of water is required in such cases hence making other technologies which directly treat wastewater much more suitable for such cases.

6.5 Poland

The Polish legislative framework pertaining to water reuse includes:

- The Water Law (Act of 20.07.2017 amended by Dz. U. of 2018, item 2268, of 2019, item 125, 534).
- The Act on collective water supply and collective waste water disposal (Act of 07.06.2001 amended by Dz. U. of 2018, item 1152, 1629).
- The National Urban Waste Water Treatment Programme (Monitor Polski 2017 item 1183- Announcement of the Minister of the Environment of 11 December 2017 on the announcement of the update of the National Urban Waste Water Treatment Programme).

The following sections will present two water reuse applications in the industrial sector.

6.5.1 Rinse water purification plants (Łódzkie Region, Poland)

Rinse water purification plants for self-rinsing filters for water purification plants in the Łódzkie Region (e.g. in Kutno, Łęczyca, Sieradz Męka, Sieradz Górka Kłocka) are managed by companies responsible for production and distribution of tap water.

Filtration is the basic process of water treatment during which waste is produced in the form of so-called rinse water, which constitutes about 8 - 10% of the amount of raw water subjected to treatment. The installation of rinse water treatment eliminates its own losses up to the level of even less than 1% of water collected for raw water treatment. The treated rinse water is returned at the beginning of the water treatment process. The application is on-site, entailing physical-chemical systems, surface filtration systems and disinfection technologies.

The motivations behind this application are both economic and environmental as it establishes the reduction of costs of water supply as a result of the reduction of own water losses in the water treatment plant as well as limiting the use of natural water resources (groundwater, surface water).

The amount of water treated per day is approximately 8 - 10% of the amount of raw water drawn from the environment for the production of tap water. There are practically no variation for seasonal or other reasons. As regards the costs: operating costs are up to 0.1

PLN/ m^3 of recovered water while the installation cost depends on local conditions and the size (capacity of the installation in m^3/h) of the installation.

The technology is transferable to other regions and other industrial uses including the paper industry, power industry, mine water, food industry and others.

6.5.2 Bilinski Textile Factory (Konstantynow, Lodzki, Poland)

According to the OECD, the textile industry is one of the most water-intensive industries (OECD, 2018). Textile production processes (textile refinement) require an excessive amount of water - an average of 100L/kg. The Biliński Textile Factory decided to introduce technologies enabling the recovery of treated wastewater thus bearing economic and environmental benefits.

The application is on-site, entailing physical-chemical systems, membrane technologies, disinfection technologies, waste stabilisation ponds and electrocoagulation (P removal) and the process is monitored on a daily basis. The wastewater treatment and recycling system assumes its division into three streams with respect to biodegradability:

- The first stream (approximately 50% of the sewage generated by the plant) is low-loaded sewage with mineral pollution and is subject to biological treatment.
- The second stream consists of wastewater whose components could adversely affect the operation of the activated sludge, thus it is pre-treated with coagulation-flocculation and is consequently directed to the municipal sewerage system.
- The third stream consists of highly salinated waste water from the dyeing processes which is treated by means of electrocoagulation, creating a brine used again in the same process.

The technology is transferable to other textile industries and can be adapted to the needs of other industries.

The economic results consist of an increase in the profitability of production by reducing the cost of raw material (i.e. water) and the fees for sewage emissions. Environmental results include improving the quality of wastewater discharged, reducing the amount of wastewater discharged, reducing the consumption of water resources, and minimizing the intake of groundwater as well as the minimisation of environmental emissions on a regional scale (i.e.

improvement of the quality of the WWTP operation and reduction of low-molecular salt emissions in the Ner River basin) and the minimisation of the impact of groundwater intake.

The insufficiency of the country's relevant legal and regulatory framework poses the biggest challenge faced throughout the development of this water reuse application. Specifically, there are no regulations targeting industrial wastewater, therefore the application is subject to general regulations that are, in this case, inadequate. Challenges encountered prior and during the water reuse application that have, to an extent, already been addressed include the lack of specialists in industrial wastewater treatment with actual implementation experience, the specific nature of the wastewater and the adaptation of the appropriate treatment methods as well as the construction of a water cycle management system.

Stakeholders, such as public authorities, environmental agencies and professional bodies do not provide their support to the application as the authorities are not interested in determining the actual activities supporting entrepreneurs in their pro-environment activities, especially by determining the rational legal framework concerning the production of wastewater and its treatment.

6.6 Slovenia

The extent of treated wastewater reuse practices in Slovenia is rather limited, as the country does not face water scarcity issues. In 2014, the annual Water Exploitation Index (WEI) was approximately 2%, or, compared to the periodic average of water availability, 3% (SEA, 2016). However, some regions of the country (Slovenian Coast, Dry Carniola, Over Mura region) do face extreme droughts and water scarcity, mainly for agriculture use. Adaptation to climate change and water scarcity, safeguarding of natural sources of drinking water and recycling of wastewater are, thus, some of the country's greatest challenges and priorities.

In Slovenia, more than 73% of wastewater from sewerage systems is cleaned at wastewater treatment plants, but almost all of it is left further unused (SURS, 2017). The wastewater leaving wastewater treatment plants contains different amounts of various pollutants, but these amounts (i.e. concentrations) are, according to the relevant Slovenian legislation, suitable to release into surface waters, mainly to the rivers. Hence, downstream is this water often used for irrigation, but according to available figures in Slovenia so far, no farmland is

Wastewater reuse practices in Slovenia are limited to few pilot (research) projects and initiatives/investments of some companies. The industry realised that water reuse can generate substantial savings: closing the loops in industry and use of secondary resources in construction sector, based on EU action plan for the Circular Economy.

In Slovenia, the legislation on waste water management in terms of reuse is still in its infancy. Slovenian regulation follows the applicable international rules, but they are deficient. The main guidelines are the Urban Waste Water Directive (Directive 91/271/EEC; UWWTD) and the Water Framework Directive (Directive 2000/60/ES). The UWWTD requires that "Treated waste water shall be reused whenever appropriate." Nevertheless, since 2017 there is no national legislation devoted to this particular question, except for the requirements from the UWWTD.

The monitoring of reclaimed water of municipal and industrial waste water treatment plants in Slovenia (Official Gazette of RS, Nos. 94/14 and 98/15) does not require verification of all parameters that are important for water reuse in different sectors. A Decree on the limit input concentration values of dangerous substances and fertilizers in soil (Official Gazzette of RS, No. 84/2005, 62/2008, 113/2009, 99/2013 and 19/2017) in use between 2005 and 2017, focused on the effectiveness of treatment in phosphorus, nitrogen and COD. Information about the microbiological sustainability and sodium contents of such water, which is important for irrigation use, is not available. The specific monitoring data could be obtained only on request. The National Laboratory of Health, Environment and Food in charge for monitoring follows EU and WHO guidelines e.g. the Commission guidance document on addressing microbiological risks in fresh fruits and vegetables at primary production through good hygiene.

Thus, there is a pressing need for the establishment of specific and detailed guidelines or policy in the field of water reuse which would define the monitoring of quality, possible types of use, and quality standards.

6.6.1 RusaLCA project (Šentrupert, Slovenia)

The availability of drinking water of suitable quality and in sufficient amounts is the fundamental source of all ecological and sociological activities including food production, industrial activities, and the health and sanitary conditions of the population. Water scarcity poses a major global issue. Currently, one third of the global population is affected by insufficient availability of drinking water on a daily basis, and the issue is expected to become more severe in the future due to various factors, including climate change, rapid population growth, pollution of water sources, urbanisation, and changes in life style. Sustainable water management in areas with dispersed settlements, as in the case of Slovenia, represents specific problems. In these areas, the construction of large municipal wastewater treatment plants, long branched sewage systems and pumping stations is financially unattainable. Thus, the use of small wastewater treatment plants with improved efficiency of cleaning emerges as a sustainable alternative and shows the great potential. This pilot project aimed at addressing the mitigation and adaptation of European regions which have been already affected by water scarcity and drought because of the rise of average annual temperatures to climate changes (Mladenovič et al., 2018).

The development and construction of a prototype waste water treatment system allowed the reuse of treated water for secondary purposes in households and for common public needs achieving up to 30% reduction of drinking water consumption. The system is especially appropriate for regions with dispersed settlement, as in the case of the Municipality of Šentrupert, where the prototype system was located. Decentralized wastewater treatment systems show considerable benefits compared with centralized ones in dispersed rural areas the (Oprčkal et al., 2017).

The first phase of the multistage treatment of urban waste water is performed in a small waste water treatment plant (< 100 PE), through a commonly used treatment technology for urban waste waters in the parts of Slovenia with dispersed settlements. Primary treatment in a small waste water treatment plant consists of physical separation and sedimentation of solid waste particles from waste water. Secondary treatment represents aerobic and anaerobic microbiological treatment. Aerobic treatment takes place in aerated basin of small waste water treatment plant, where ammonia is removed by nitrification process by transformation into nitrates. In compartments of the small waste water treatment plant where anaerobic conditions are established, nitrates are transformed into nitrogen gas by facultative anaerobe bacteria. Organic pollutants, phosphates, excess nutrients, and potentially toxic elements are accumulated in the organic matter of growing bacteria, which form flocks that gradually settle as the active sludge in the settling basins – clarifiers. Part of active sludge is later inoculated back into the aerobic treatment to enhance the microbiological treatment process. Partly purified water, which is suitable for release into surface waters, is at the outflow from the small waste water treatment plant collected and pumped in an advanced multistage batch water treatment system for additional purification to reach quality suitable for reuse. The first stage entails nanoremediation, which is based on the use of an innovative treatment process with the utilization of nanoscale Zero-Valent Iron (nZVI). This nanomaterial, due to high redox activity and through Fenton type chemical reactions, is capable of disinfection, degradation of several organic pollutants, and removal of potentially toxic elements – heavy metals from waste water. Nanoscale Zero-Valent Iron owes its remediation capabilities and reactivity to its nanoscale characteristics, which are high specific surface area, size below 100 nm, core-shell structure and colloidal stability, which depends on zeta potential and pH changes (Mladenovič et al., 2018). The nanoremediation stage is followed by additional stages of water treatment, namely: i) treatment with oxidizing agents, ii) sand and activated carbon filtration, and iii) ion exchange. The combination of nanoremediation with conventional treatment processes ensures that all pollutants are efficiently removed from water and that use of purified water does not represent any threat for the end-users.

The water reuse technology described above was implemented between 2013 and 2016 within a scope of LIFE RusaLCA project "Nanoremediation of water from small waste treatment plants and reuse of water and solid remains for local needs”. Furthermore, representatives of local Municipality of Šentrupert and Municipal Public Services of Trebnje were involved during the project and are in charge of SWTP after the end of project. The project gained approval of the society and the local community.

Currently, the remediation of municipal wastewater through the use of nanoscale zaro-valent iron particles (nZVI), to the degree that it acquires the status of drinking water, is relatively expensive. On average, the cost of purifying $1m^3$ of wastewater amounts to 13 EUR. The costs of purchasing the nZVI contribute a share of 91% of this price. The current cost of 1 kg of nZVI is 120 EUR. (Mladenovič et al., 2018).

The LIFE RusaLCA project could be replicated and transferred, as a whole (i.e. both the developed technology and the accompanying approach) to any location which needs to improve its water management system, while simultaneously fighting against the problems caused by climate change, droughts, and water shortage. The development of the pilot remediation system and of its technology was well planned and documented during its construction. The plans for the pilot remediation system can thus be replicated and used for the construction of similar devices anywhere in the world.

The life cycle analysis (LCA) and life cycle cost analysis (LCCA) tools have shown that, at this point, more progress needs to be made in the field of the commercial availability of nZVI. The relatively high price of the nZVI is probably currently the only potentially "limiting factor" for the transferring of this remediation technique. However, the price of nZVI is expected to become substantially lower in the near future, which will be partly due to the rapid development of cheaper synthesis procedures. The system's cost-effectiveness could also be enhanced after further development of the initial recipe in such a way that a lower concentration of nanoparticles would be needed. The cost efficiency of the presented good practices could be increased even further if regional or national decision-makers worked towards the stimulation of more sustainable solutions through, for instance, green public procurements (Mladenovič et al., 2018).

6.7 Spain

According to Spanish Association of Water Supply and Wastewater (AEAS-AGA), one of the characteristics of the purification system in Spain is the reuse of water once it has been treated, as a response to the irregularities of rainfall in different areas of Spain, especially in the East, the Balearic and Canary Islands. In the case of Murcia 64.7% of the total water supplied is reused. The reclaimed water is used in agriculture, industry or the irrigation of gardens and leisure areas.

The legislative framework applicable on water-reuse of the Region of Murcia is established on:

- Law 3/2000 on Wastewater Treatment and Treatment and Implementation of the Sanitation Canon.
- Decree No. 90/2002 approving the Statutes of the Sanitation and Purification Entity of the Region of Murcia.
- Law 3/2002 on the Tariff of the Sanitation Canon.
- Decree No. 316/2007 approving the Regulation of the Sanitation Canon of the Region of Murcia.
- The Royal Decree 1620/2007 establishing the legal regime in Spain for the reuse of treated water in agricultural irrigation which ensures the quality and safety of this practice.

The Royal Decree 1620/2007, foresees water reuse for:

- **Urban uses** (including garden irrigation, street cleaning, firefighting and internal uses such as toilet flushing).
- **Irrigation of agricultural crops** (with or without restrictions) **and use in aquaculture.**
- **Industrial uses** (including cooling towers, evaporative condensers and as process and cleaning water in food industry).
- **Leisure**.
- **Environmental applications** (including aquifer recharge, forest irrigation and wetlands maintenance).

Table 6: Murcia's annual volume of treated water

WWTP	City	Treated Water (m^3/year)
Abanilla	Abanilla	531.697
Abarán	Abarán	638.420
Águilas	Águilas	1.631.389
Aguilas MBR	Águilas	538.827
Alcantarilla	Alcantarilla	2.607.025
Alguazas	Alguazas	1.257.997
Alhama	Alhama	1.165.474
Archena	Archena	1.676.594
Beniel	Beniel	997.976
Blanca	Blanca	321.417
Bullas	Bullas	841.388
Calasparra	Calasparra	615.514
Caravaca	Caravaca	1.460.125
Cehegín	Cehegín	685.263
Ceutí	Ceutí	2.338.673
Cieza	Cieza	1.001.427
Fortuna	Fortuna	382.695
Fuente Álamo	Fuente Álamo	572.609
Jumilla	Jumilla	1.712.053
Librilla	Librilla	241.628
La Hoya	Lorca	3.366.919
Lorquí	Lorquí	1.299.790
Mazarrón	Mazarrón	2.059.693
Camposol	Mazarrón	372.233
Molina	Molina	5.699.390
Moratalla	Moratalla	651.672
Mula	Mula	641.583
Pliego	Pliego	174.192
Puerto Lumbreras	Puerto Lumbreras	505.613
San Javier	San Javier	2.177.269
San Pedro	San Pedro	2.622.230
Torrepacheco	Torrepacheco	1.232.749
Roldán	Torrepacheco	528.764
Urb Mar Menor	Torrepacheco	127.587
Torres de Cotillas	Torres de Cotillas	1.515.539
Totana	Totana	1.440.463
La Unión	La Unión	565.767
Yecla	Yecla	1.833.478
Santomera	Santomera	1.000.568
Los Alcázares	Los Alcázares	1.929.473
TOTAL		**50.963.163**

Source: ESAMUR (Entity of Sanitation and wastewater treatment in Murcia Region)

The volume of the annual direct water reuse in the Region of Murcia is approximately 53 Hm3 and the annual indirect water reuse is approximately 47 Hm3. Table 6 presents the annual volume of treated water in the region’s waste water treatment plants, which are managed by ESAMUR, while the following section presents in more detail the case of the Molina waste water treatment plant.

6.7.1 Molina de Segura Wastewater Treatment Plant (Molina de Segura, Spain)

The WWTP of Molina de Segura treats 5.7 Hm3/year from the urban area of the town, various residential areas and five industrial estates. The objectives of the reuse of reclaimed water are to ensure good quality water to the agricultural sector with continuity while extending the life of the resource in a circular economy perspective. The sewage treatment plant has a discharge authorization to the Segura River, but previously the water is stored in lagoons, where five water concessionaires carry out the catchment. The quality of the reclaimed water has allowed the transformation of these lagoons into an artificial wetland of international interest, included in the Ramsar List[19].

The WWTP uses a combination of physical-chemical systems (bar screening, grit and oil removal), primary sedimentation, disinfection technologies (UV), activated sludge and sand filtration to treat approximately 15.600 m^3/d (dry weather average ≈ 650 m^3/h; wet weather maximum ≈ 2.500 m^3/h). Reclaimed water is stored in 5 lagoons, with a total capacity of 360,000 m^3. The last lagoon acts as a point of capture on the part of the 5 concessionaires of the waters, keeping the rest always full to maintain the ecological activity of the wetland.

The implementation of the scheme is supported by the application of water treatment fees to the urban residents connected to the WWTPs. The scheme consists of mature technologies and is thus transferable to any other region.

[19] https://www.ramsar.org/sites-countries/the-ramsar-sites, https://murciatoday.com/the-protected-wetlands-of-lagunas-de-campotejar-in-molina-de-segura_122374-a.html??search=true&town=57&town_search=true&town_inside=1

6.8 Applications beyond the AQUARES partnership

6.8.1 Henriksdal Wastewater Treatment Plant (Stockholm, Sweden)

Sweden has committed to the Baltic Sea Action Plan (BSAP) and EU Water Directive calling for more stringent discharge re-quirements into local receiving water bodies. As well, the city of Stockholm is currently one of the fastest growing cities in the Europe, growing at a rate of 1.5% per year, creating a need for increased capacity. The Henriksdal WWTP in central Stockholm is the largest underground plant in the world, covering 300,000 square metres and consisting of 18km of tunnels. Sweco's project was to develop and implement a solution for future wastewater treatment that would result in cleaner water in Lake Malaren, fewer discharges into the Baltic Sea and an end to shipments of sludge through residential areas. The plant treats wastewater using mechanical, chemical, biological and sand filtration processes following which the treated water is emptied into the Baltic Sea.

The plant serves 800,000 people from Stockholm and surrounding municipalities. The main purpose of the plant is to reduce eutrophication and oxygen deficiency in the recipient, Lake Saltsjön, and the Baltic Sea. Stockholm Vatten continuously works to reduce the impact that the organic substances, phosphates and nitrogen will have on the environment. At least 95% of the organic substances and 98% of phosphates, plus at least 50% of the nitrogen are removed during purification, thus satisfying the demands of the authorities. Furthermore, every week 32 tonnes of trash, which has been flushed down the toilet, ends up in the sewage treatment works in Stockholm. To reduce the amount of trash, as well as the environmental toxins that may disturb both the processes in the treatment works as well as the aquatic environment, measures are continuously taken to improve the treatment process and prevent the toxins and trash from ending up in the wastewater.

The plant uses membrane and disinfection technologies and is economically sustainable. Membranes, as an advanced ultrafiltration technology that separates solids, bacteria and viruses from water or wastewater can be used in other sectors, such as agriculture. Furthermore, it is notable that that this particular WWTP is located in the centre of Stockholm without altering the environment or living conditions in the city. Henrinksdal can constitute a best practice and motivate the implementation of similar projects in other regions and countries.

6.8.2 Torreele project (Koksijde, Belgium)

The Torreele water reclamation plant is located in Koksijde at the Belgian North Sea coast. It is an indirect potable reuse scheme, combining the reuse of treated effluent with groundwater recharge to the unconfined sandy dune aquifer in the St. Andre dune water catchment. The dune catchment St. Andre has a long history as a site for drinking water production for the neighbouring communities. Because the freshwater reservoir beneath the dunes is surrounded by saline groundwater from the sea in the north and the polder area in the south, wells are at a high risk of salinization in case of over abstraction. A rising water demand, especially during the summer season when many tourists visit the area, have thus created a demand-supply gap, which the water supplier closed by buying additional water from neighbouring companies.

The urban effluent is pre-treated by a mechanical screen with 1 mm openings to remove all bigger particles and sodium hypochlorite (NaOCl) is dosed, then it is treated by Ultrafiltration (UF), Reverse osmosis (RO), and, stored for one to two months in the aquifer, and then used for water supply augmentation.

A sustainable management of the dune area has been achieved as the extraction of natural dune water has been decreased (30 % less extraction of natural dune water). The water reuse/infiltration project has allowed sustainable management of an area with high ecological value. This could prove the key factor for the future of drinking-water production in these dunes. As the water table rises it is also a preventive and pro-active measure against the expected effects of climate change. Preserving the production close to the point of consumption is very important in a tourist area where water consumption not only varies on seasonal basis (winter/summer) but also on daily basis subject to the weather conditions, especially during vacation periods when sudden high peaks in drinking water demand are frequent. Furthermore, the drinking water quality has been improved due to the infiltration of highly treated, good quality water (Lazarova et al., 2013).

6.8.3 Island of Noirmoutier (Noirmoutier, France)

The water reclamation scheme was designed and set-up by the Noirmoutier' Community of Municipalities in such a way as to take account of the seasonal variations of population. The wastewater treatment system includes two water reclamation plants, one in the north of the island called "La Salaisière", which receives wastewater from three municipalities

(Noirmoutier-en-l'Île, l'Epine and Guérinière) and the other in the south of the island, called "La Casie", which receives wastewater from the municipality of Barbâtre.

The project of water reuse for irrigation was established two years after the start-up of the activated sludge treatment on the "La Salaisière" wastewater treatment plant in 1980s (hydraulic capacity of 1600 m^3/d). Three years later, with the increase of collected wastewater volumes, an "aerated lagoon", with a hydraulic capacity of 2200 m^3/d, was designed alongside the activated sludge treatment station. Fourteen years later, in 1997, with another increase in wastewater volumes and new regulations, a new activated sludge plant was launched alongside the two other plants, with a hydraulic capacity of 4200 m^3/d. This is currently the only wastewater treatment and reclamation plant which is used throughout the year.

The smallest treatment plant "La Casie", which was initially designed as a natural wetland, is today refurbished to an activated sludge plant, and the natural wetland has been kept for polishing treatment before reuse or discharge. Because the low recycled water volume produced, this plant will be not presented and discussed in this chapter.

The water reuse programme in Noirmoutier has become a crucial element in decision makers' overall strategy for integrated water resource management. This approach includes maintaining agricultural activity, limiting the importation of drinking water from the mainland for human consumption and reducing pollution discharge into the natural environment. This water reuse project has been possible thanks to the strong involvement of local politicians and farmers who founded an association named ASDI (Trade Union Association of Drainage and Irrigation). Currently, and since the project start-up, the only use of recycled water is the irrigation of potato plantations. The feasibility of water reuse for landscape irrigation and groundwater recharge have been also discussed and evaluated.

The use of reclaimed water for irrigation instead of potable water is generating significant economic benefits for farmers using this irrigation system. The cost saving is about 50% on the water bill, as the cost of drinking water is 1.30 E/m^3 compared to 0.54 E/m^3 for reclaimed water. Thus, the total average annual cost saving is about 225,000 euros per year, or 22.5 euros per tonne of potatoes produced. Moreover, it should be noted that water reuse has enabled the production of potatoes to be extended over the summer period and thus the increase of production by nearly 40%. In addition, without recycling water, the community would have had to manage continuous discharge of wastewater throughout the year. Various impact analyses have shown the need not only for polishing treatment, but also for moving the discharge point far from the coast, which would have led to significant additional costs, estimated at approximately 2 million euros.

The La Salaisière site was also one of the pilot sites for the European CatchWater programme (1999–2001), bringing together scientists, companies and regional groups from Italy, Spain, England, Israel, and France. The objectives of the programme were to evaluate the scope of application of water recycling in Europe and the conditions for developing a design methodology for water reuse projects, as well as to participate in the European effort to normalise the use of this alternative water resource. In the context of this project, Noirmoutier was then chosen to host a workshop on the theme of "Integrated water management and water reuse" in September 2001, where participants discussed the results of their work alongside the experiences and expectations of users and technicians, public sector stakeholders and local groups in charge of managing water resources and water treatment. It should be noted that the La Salaisière site is regularly visited by authorities and scientists from around France and also from abroad (Lazarova et al., 2013).

7 Conclusions and recommendations

The desk research performed by the AQUARES project partners has resulted in the collection of a significant number of water reuse applications across and beyond the partnership regions. The technologies and schemes identified and described range from mature technologies, such as the combination of physical-chemical systems, primary sedimentation, disinfection technologies, activated sludge and sand filtration used in the wastewater treatment plants of the region of Murcia, to innovative approaches, such as the combination of nanoremediation with conventional treatment processes performed in Slovenia.

The selection of a suitable water treatment scheme depends upon a number of factors, including the **location, the quality of the input water and the desired quality of the output water**, and thus must be performed taking into consideration the specificities of each case. Nevertheless, the majority of the technology combinations examined is transferable to other settings.

Economic considerations are highly significant when assessing the potential of water reclamation projects. When assessing the economic impact of a water reuse project one needs to assess the cost in relevant terms, by comparing the costs of the water reuse project at hand to the costs of other feasible water management alternatives and the cost of not pursuing any water management changes.

Taking into consideration that centralised wastewater treatment plants are usually located in urban settings, **decentralised technologies emerge as a suitable solution** for various uses (agricultural, industrial etc.), reducing or eliminating the transmission costs. Decentralized water recycling technologies are available in a wide variety of options and scales while solutions have been developed to reduce operational costs in small scale applications.

Finally, it should be noted that despite increasing levels of water stress across the EU and a large potential to reuse treated wastewater, the water reuse remains limited and unregulated in the different Member States. Currently only five countries have compulsory standards on water reuse enforced through specific water reuse legislation – Cyprus, France, Greece, Italy and Spain. Water reuse standards exist also in Portugal but they become binding only when included in water reuse permits. It is thus evident that the **development of water reuse policy and regulation would allow for the expansion of water reuse practices**.

References

Alcalde-Sanz, L., Gawlik, (2014) Water Reuse in Europe Relevant guidelines, needs for and barriers to innovation - A synoptic overview. European Commission, Joint Research Centre Institute for Environment and Sustainability. ISBN 978-92-79-44399-2, doi: 10.2788/29234. Available at: http://publications.jrc.ec.europa.eu/repository/handle/JRC92582

Angelakis, A.N., Durham, B. (2008). Water recycling and reuse in EUREAU countries: Trends and challenges. Desalination, Volume 218, Issues 1–3,2008, Pages 3-12, ISSN 0011-9164, https://doi.org/10.1016/j.desal.2006.07.015. Available at: http://www.sciencedirect.com/science/article/pii/S0011916407005061

Crook, J. 2010. Regulatory Aspects of Direct Potable Reuse in California. National Water Research Institute. Fountain Valley, California, available at http://nwri-usa.org/pdfs/NWRIPaperDirectPotableReuse2010.pdf

DEMOWARE project (2016) Deliverable 1.5 - Innovative water reuse schemes in the agricultural sector

Drewes, J., Karakurt, S., Schmid, L., Bachmaier, M., Hübner, U., Clausnitzer, V., Timmermann, R., Schätzl, P. and McCurdy, S. (2018) Dynamik der Klarwasseranteile in Oberflächengewässern und mögliche Herausforderung für die Trinkwassergewinnung in Deutschland - TEXTE 59/2018 Projektnummer 91 182 Umweltbundesamt.

DWA (2019) German Association for Water, Wastewater and Waste, Non-Potable Water Reuse - Development, Technologies and International Framework for Agricultural, Urban and Industrial Uses.

FAO (1992). Wastewater Treatment and Use in Agriculture. Irrigation and Drainage Paper 47, FAO, Rome. Available at: http://www.fao.org/docrep/t0551e/t0551e00.htm#Contents

Ilias, A., Panoras, A., & Angelakis, A. (2014). Wastewater Recycling in Greece: The Case of Thessaloniki. Sustainability, 6(5), 2876–2892.doi:10.3390/su6052876

Kraus, F., Seis, W., Remy, C., Rustler, M., Jubany i Guell, I., Espi, J.J. and Clarens, F. (2016) Deliverable D3.2: Show case of the environmental benefits and risk assessment of reuse schemes. public report in the DEMOWARE project (www.demoware.eu), KWB, Berlin.

Lazarova, V., Asano,T., Bahri, A. & Anderson, J. (2013). Milestones in Water Reuse, The Best Success Stories. IWA Publishing, Vol. 12. DOI: https://doi.org/10.2166/9781780400716

Makropoulos, C., Rozos, E., Tsoukalas, I., Plevri, A., Karakatsanis, G., Karagiannidis, L., Lytras, E. (2018). Sewer-mining: A water reuse option supporting circular economy, public service provision and entrepreneurship. Journal of Environmental Management, 216, 285–298. doi:10.1016/j.jenvman.2017.07.026

Merrett, S. (2004). Integrated Water Resources Management and the Hydrosocial Balance, Water International, 29:2, 148-157, DOI: 10.1080/02508060408691764

Mladenovič, A., Oprčkal, P., Milačič, R., Pranjić, A. M., Turk, J., Nadrah, P., Cotič, Z., Geršič, P., Gole, R., Ivanušič, M., Ličina, M., Ščančar, J., Šprinzer, M., Vidmar, J., Vranc, V., Zakrajšek, J., Žurman, T. (2018). LIFE RusaLCA "Nanoremediation of water small waste treatment plants and reuse of water and solid remains for local needs". Final report. Available at: http://www.rusalca.si/uploads/Life-RusaLCA-Final-Report.pdf

National Research Council (2012). Water Reuse: Potential for Expanding the Nation's Water Supply Through Reuse of Municipal Wastewater, Washington, DC: The National Academis Press, doi: 10.17226/13303

OECD (2018). Due Diligence Guidance for Responsible Supply Chains in the Garment and Footwear Sector. OECD Publishing: Paris, France.

Oehlschläger, K. & Bock-Polach, C.v. (2015) Nutzung von Sonderstandorten durch Bewässerung mit gereinigtem Abwasser – Fallbeispiel Braunschweig, in: Nölting, B., Balla, D., Daedlow, K., Grundmann, P., Oehlschläger, K., Maaß, O., Moss, T., Uta Steinhardt, Polach, C.v.B.u. (Eds.), Gereinigtes Abwasser in der Landschaft Ein Orientierungsrahmen für strategische Entscheidungsprozesse.

Oprčkal, P., Mladenovič, A., Milačič, R., Ščančar, J., Sever Škarpin, A., Nadrah, P. (2014). LIFE+ RusaLCA – Sustainable approach towards water-efficient society. In: 4. Slovenski geološki kongres. Abstracts and field trips. Rožič, B., Verbovšek, T., Vrabec, M. (ed.). Ljubljana, Naravoslovnotehniška fakulteta.

Ostermann, U. (2017) Beregnung in Nordostniedersachen - Anpassungsstrategien an den Klimawandel. Wasser, Energie und Umwelt, 482-490.

Paranychianakis, N. V., Salgot, M., Snyder, S. A., & Angelakis, A. N. (2014). Water Reuse in EU States: Necessity for Uniform Criteria to Mitigate Human and Environmental Risks. Critical Reviews in Environmental Science and Technology, 45(13), 1409–1468. doi:10.1080/10643389.2014.955629

Plevri, A., Mamais, D., Noutsopoulos, C., Makropoulos, C., Andreadakis, A., Rippis, C., Smeti, E., 2016. Promoting on-site urban wastewater reuse through MBR-RO treatment. In: 13th IWA Specialized Conference on Small Water and Wastewater Systems. Athens, Greece, 2016.

Republic of Slovenia Statistical Office – SURS (2019). Available at: https://www.stat.si/statweb/en

Seis, W. (2012) Risk assessment auf Braunschweig wastewater reuse scheme. KWB, Berlin

Seis, W., Lesjean, B., Maaßen, S., Balla, D., Hochstrat, R. and Düppenbecker, B. (2016) Rahmenbedingungen für die umweltgerechte Nutzung von behandeltem Abwasser zur landwirtschaftlichen Bewässerung, p. 216.

Slovenian Environment Agency - SEA (2016). Water Index. 2016. Available at: http://kazalci.arso.gov.si/en/teme/water

Sprenger, C., Hartog, N., Hernández-García, M., Vilanova, E., Grützmacher, G., Scheibler, F. and Hannappel, S. (2017) Inventory of Managed Aquifer Recharge sites in Europe – historical development, current situation and perspectives. Hydrogeology Journal 25, 1909–1922.

TYPSA (2013) Wastewater Reuse in the European Union. TYPSA Consulting Engineers & Architects.

Fundación Instituto Euromediterráneo del Agua

AQUARES Interreg Europe

Annex I: Detailed list of collected water reuse applications

Ref. number	Country	Title	City	Managing authority	Application sector
BE1	Belgium	Municipal Wastewater Treatment Plant Wulpen ('Torreele')	Koksijde	Aquafin (the utility company of the Flemish government) & Intermunicipal Water Company of the Veurne region (IWVA)	Potable uses
CY1	Cyprus	Larnaca Wastewater Treatment Plant	Larnaca	Cypriot Government	Agricultural uses, Recreational uses
CY2	Cyprus	Limassol Waste Water Treatment Plant	Limassol	Joint venture Kruger A/S and Zachariades construction company	Agricultural uses
DE1	Germany	Steinhof treatment plant	Braunschweig	The legislative permission for wastewater reuse in Braunschweig is given by the district government of Braunschweig (Weikert, 2001)	Agricultural uses, Environmental uses
DE2	Germany	Zum Stahlberg treatment plant	Wolfsburg	Ministry of Environment, Energy and Climate Protection of Lower Saxony, lower water authorities of the city and the district (NLWKN, 2017)	Agricultural uses, Environmental uses
ES1	Spain	Abanilla	Abanilla	Regional Entity for sanitation and wastewater treatment in Murcia Region (ESAMUR)	Agricultural uses
ES10	Spain	Blanca	Blanca	ESAMUR	Agricultural uses
ES11	Spain	Bullas	Bullas	ESAMUR	Agricultural uses
ES12	Spain	Calasparra	Calasparra	ESAMUR	Agricultural uses
ES13	Spain	Caravaca	Caravaca	ESAMUR	Agricultural uses
ES14	Spain	Cehegín	Cehegín	ESAMUR	Agricultural uses
ES15	Spain	Ceutí	Ceutí	ESAMUR	Agricultural uses
ES16	Spain	Cieza	Cieza	ESAMUR	Agricultural uses
ES17	Spain	Fortuna	Fortuna	ESAMUR	Agricultural uses
ES18	Spain	Fuente Álamo	Fuente Álamo	ESAMUR	Agricultural uses
ES19	Spain	Jumilla	Jumilla	ESAMUR	Agricultural uses
ES2	Spain	Abarán	Abarán	ESAMUR	Agricultural uses
ES20	Spain	Librilla	Librilla	ESAMUR	Agricultural uses
ES21	Spain	La Hoya	Lorca	ESAMUR	Agricultural uses
ES22	Spain	Lorquí	Lorquí	ESAMUR	Agricultural uses
ES23	Spain	Mazarrón	Mazarrón	ESAMUR	Agricultural uses
ES24	Spain	Camposol	Mazarrón	ESAMUR	Agricultural uses
ES25	Spain	Molina	Molina	ESAMUR	Urban uses, Agricultural uses, Recreational uses, Environmental uses
ES26	Spain	Moratalla	Moratalla	ESAMUR	Agricultural uses
ES27	Spain	Mula	Mula	ESAMUR	Agricultural uses

Ref. number	Country	Title	City	Managing authority	Application sector
ES28	Spain	Pliego	Pliego	ESAMUR	Agricultural uses
ES29	Spain	Puerto Lumbreras	Puerto Lumbreras	ESAMUR	Agricultural uses
ES3	Spain	Águilas	Águilas	ESAMUR	Agricultural uses
ES30	Spain	San Javier	San Javier	ESAMUR	Agricultural uses
ES31	Spain	San Pedro	San Pedro	ESAMUR	Agricultural uses
ES32	Spain	Torrepacheco	Torrepacheco	ESAMUR	Agricultural uses
ES33	Spain	Roldán	Torrepacheco	ESAMUR	Agricultural uses
ES34	Spain	Urb Mar Menor	Torrepacheco	ESAMUR	Agricultural uses
ES35	Spain	Torres de Cotillas	Torres de Cotillas	ESAMUR	Agricultural uses
ES36	Spain	Totana	Totana	ESAMUR	Agricultural uses
ES37	Spain	La Unión	La Unión	ESAMUR	Agricultural uses
ES38	Spain	Yecla	Yecla	ESAMUR	Agricultural uses
ES39	Spain	Santomera	Santomera	ESAMUR	Agricultural uses
ES4	Spain	Aguilas MBR	Águilas	ESAMUR	Agricultural uses
ES40	Spain	Los Alcázares	Los Alcázares	ESAMUR	Agricultural uses
ES5	Spain	Alcantarilla	Alcantarilla	ESAMUR	Agricultural uses
ES6	Spain	Alguazas	Alguazas	ESAMUR	Agricultural uses
ES7	Spain	Alhama	Alhama	ESAMUR	Agricultural uses
ES8	Spain	Archena	Archena	ESAMUR	Agricultural uses
ES9	Spain	Beniel	Beniel	ESAMUR	Agricultural uses
FR1	France	Cap d'Agde international golf course project	Agde	Hérault Mediterranée Urban Community, SUEZ and Rhône Méditerranée Corse (RMC) Water Agency	Recreational uses
FR2	France	The Jourdain project	Sables d'Olonne/ West France	Sables-d'Olonne Agglomération and Vendée Eau	Potable uses
FR3	France	The island of Noirmoutier	Noirmoutier	SAUR on behalf of the Noirmoutier Community of Municipalities	Agricultural uses
FR4	France	The SmartFertiReuse project	Languedoc-Roussillon	SEDE Environnement	Agricultural uses
GR1	Greece	Pilot sewer-mining application	Athens	Athens Water and Sewerage Company S.A (EYDAP), Department of Water Resources and Environmental Engineering, School of Civil Engineering, National Technical University of Athens, Dessin project	Urban uses
IT1	Italy	Nosedo WWTP	Milano	MilanoDepur S.p.A. (Nosedo)	Agricultural uses
IT2	Italy	S. Rocco WWTP	Milano	MM S.p.A. (S. Rocco)	Agricultural uses

Ref. number	Country	Title	City	Managing authority	Application sector
IT3	Italy	Residential building water treatment and reuse system	Milano	Residential building owners	Domestic uses
IT4	Italy	Fiordelisi s.r.l.	Capitanata (Apulia region)	Fiordelisi s.r.l. (agro-food industry), IRSA-CNR	Agricultural uses
IT5	Italy	Aretusa	Rosignano (Tuscany)	Azienda Servizi Ambientali (ASA) S.p.A., Termomeccanica Ecologica (TM.E.) S.p.A., Solvay Chimica Italia S.p.A.	Industrial uses
IT6	Italy	Alpine hut "Casera-Bosconero"	Forno di Zoldo, Belluno (Veneto)	Environmental section of IMAGE Dpt. (Padua University); "Giovanni Angelini" Foundation for Mountain Studies (Belluno); CAI – Alpine Club Italy (Val di Zoldo Section).	Agricultural uses, Environmental uses, Domestic uses
IT7	Italy	"I Malatesta" mall	Rimini (Emilia Romagna)	Coop Adriatica Scarl	Urban uses (Irrigation of green areas, fire protection), Domestic uses (toilet flushing)
MT1	Malta	Mellieha treatment plant	Mellieha (Malta North)	Water Services Corporation	Agricultural uses, Industrial uses
MT2	Malta	Ghajnsielem treatment plant	Ghajnsielem (Gozo)	Water Services Corporation	Agricultural uses, Industrial uses
MT3	Malta	Xghajra treatment plant	Xghajra (Malta South)	Water Services Corporation	Agricultural uses, Industrial uses
PL1	Poland	Rinse water purification plants for self-rinsing filters for water purification plants	Łódzkie Region	Municipalities of the Łódzkie Region, companies responsible for production and distribution of tap water.	Industrial uses
PL2	Poland	Arturówek	Lodz	Municipal Forestry in Łódź, Municipal Sports and Recreation Centre in Łódź	Recreational uses, Environmental uses
PL3	Poland	Sokolowka	Lodz	The Board of Urban Greenery in Łódź	Recreational uses, Environmental uses
PL4	Poland	Bilinski Textile Factory	Konstantynow Lodzki	Bilinski Textile Factory	Industrial uses
PLT5	Poland	Municipal sewage treatment plants in the Łódź Region	Łódź Region	Municipalities of the Łódź Region, enterprises responsible for urban waste water treatment in the municipalities	Urban uses, Agricultural uses, Industrial uses
SE1	Sweden	Henriksdal Wastewater Treatment Plant	Stockholm	Stockholm Water Company/ Stockholm Vatten AB	Urban uses
SI1	Slovenia	RusaLCA	Šentrupert	LIFE RusaLCA project group: Slovenian National Building and Civil Engineering Institute (coordinator), Jožef Stefan Institute, Municipality of Šentrupert, Esplanada d.o.o., Structum d.o.o., PKG Mirko Šprinzer, d.o.o., National Laboratory of Health, Environment and Foodstuff	Urban uses, Agricultural uses, Industrial uses
UK1	UK	Millennium Dome	Greenwich	Thames Water / New Millennium Experience Company (NMEC), Water reuse system in the Millennium Dome	Urban uses

Ref. number	Country	Title	City	Managing authority	Application sector
UK2	UK	Cucina Sano Plant	Old Leake, Nr Boston, Lincolnshire	Owner: Bakkavor (Cucina Sano) / Operator: Aquabio, UK	Potable uses, Industrial uses
UK3	UK	Langford recycling scheme	Langford	Essex & Suffolk Water, part of Northumbrian Water Ltd.	Potable uses

Annex II: Evaluation criteria and scoring indicators

	SCORE				
CRITERIA	**1**	**2**	**3**	**4**	**5**
Impact	The reclaimed water quality fails to meet the standards for the intended use.	The reclaimed water quality meets the standards for the intended use. However, the water reuse application failed to meet its main objectives (desired outcomes) for reasons other than meeting water quality standards.	The reclaimed water quality meets the standards for the intended use. The water reuse application meets its main objectives (desired outcomes). Operational requirements (e.g. energy and/or specialised staff) or maintenance complexity are high.	The reclaimed water quality meets the standards for the intended use. The water reuse application meets its main objectives (desired outcomes). Operational requirements (e.g. energy and/or specialised staff) or maintenance complexity are acceptable.	The reclaimed water quality meets the standards for the intended use. The water reuse application meets its main objectives (desired outcomes). Operational requirements (e.g. energy and/or specialised staff) or maintenance complexity are low.
Extent of problems encountered in implementation	Significant problems were encountered prior to the adoption and during the implementation of the application	The application had some problems that hindered its implementation.	The application had only occasional problems that have not hindered its implementation.	Minor difficulties were faced considering the implementation of the application.	The implementation of the application had no problems or difficulties whatsoever.
Level of institutional and public support	The surrounding environment did not allow (cancelled) the adoption of the application.	Conflicts of interest and/or public concern delayed the adoption of the application.	The application was implemented despite stakeholder disagreements and/or public concern.	The application was endorsed by some relevant stakeholders.	The application was widely accepted.
Level of economic sustainability	The application has been replaced/cancelled or there is an intention to replace/cancel the implementation of this measure.	The application's continuation is questionable due to unstable political environment and financial conditions.	The continuation of the application is ensured through ownership by relevant stakeholders.	The economic sustainability of the application ensures continuation of the application.	The continuation of the application is ensured through its economic sustainability and ownership by relevant stakeholders.
Level of transferability	The application has not shown any indications of transferability to different settings (sectors, regions).	The application has shown indications of possible replication in a limited number of sectors/ geographical contexts.	The application can be easily transferred into other regions **or** uses.	The application can be easily transferred into other regions **and** uses.	The application has already been transferred to other regions or sectors/uses.