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PART 2/3

**COMMISSION STAFF WORKING DOCUMENT**

**IMPACT ASSESSMENT**

*Accompanying the document*

**Proposal for a Regulation of the European Parliament and of the Council on minimum requirements for water reuse**

{COM(2018) 337 final} - {SEC(2018) 249 final} - {SWD(2018) 250 final}

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## ANNEXES

### Annex 1 – Procedural information

Lead DG: <b>DG ENV</b>	Agenda planning/WP reference: 2017/ENV/006
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#### Organisation and timing

Work on this impact assessment started in August 2013, when DG ENV signed a contract with an external contractor to further analyse the possibilities for the maximisation of water reuse in the EU, and to assess the impact of the possible measures.

Taking over a pre-existing Inter-Service Group an Impact Assessment Steering Group (IASG) led by DG ENV was set up and met 9 times, between December 2014 and September 2017. The Directorates-General (DGs) of the Commission SG, SJ, AGRI, CLIMA, CNECT, ECFIN, GROW, JRC, MARE, MOVE, REGIO, RTD, SANTE, and TRADE were invited to participate in the work of this group; all nominated representatives. AGRI, SANTE, JRC, RTD and SG were the DGs that contributed the most actively to the work of the IASG. All nominated members of the group were regularly consulted and informed on progress.

#### Consultation of the Regulatory Scrutiny Board (RSB)

*[NB: section to be replaced in the final draft after RSB "formal" consultation, to briefly explain how the Board's recommendations have led to changes compared to the earlier draft. This will include a table with the first column identifying the Board's recommendation and the second column how the IA Report has been modified in response).]*

A meeting between all members of the RSB and DG ENV was held on 13 February 2017, also attended by members of SG and JRC, aiming at providing early feedback on the main expectations of the Board regarding this initiative. The table below summarises the comments raised by the RSB in the meeting and how they were followed-up:

<b>Preliminary points raised by the RSB on 13 February 17</b>	<b>Follow-up in the present draft IA report</b>
The upcoming IA will need a clearly presented and thorough problem definition. It would be important to identify the main issues, where problems occur, the sectors and the member states it mostly affects, the magnitude of the problem, and how it would develop in the absence of additional action. It should demonstrate that this is a problem present at the EU level, potentially examining the problems at the level of member states. This in turn could be efficiently used to demonstrate the need to act at the EU level, and should feed into the discussion on subsidiarity and proportionality. A good problem definition would also enable DG ENV to better identify potential benefits.	The problem definition elaborates on the issues affecting the different Member States and sectors. Scope and magnitude of the two main objectives (reuse of treated wastewater for irrigation purposes and for maintaining groundwater supply) has been clarified. It is explained why this scope has been chosen and other areas for water reuse, e.g. industrial use have not been considered. Particular attention was paid to subsidiarity and proportionality issues. Different sets of options were developed for these two areas also to take account of proportionality.

<p>The IA should clarify the scope of the initiative and the (possibly different) magnitude of each of the two main objectives: reuse of treated wastewater for irrigation purposes and for maintaining groundwater supply.</p>	
<p>Potential obstacles and bottlenecks should be well presented and backed up by evidence (e.g. the problems for the functioning of the Internal Market described in the inception IA).</p>	<p>There was one case where direct evidence exists on this matter. Otherwise the initiative tackles the perceived health risk and environmental risks associated with a fragmented framework at EU level.</p>
<p>DG ENV mentioned that they believe there is only a limited possibility for quantification, especially concerning the uptake of water reuse. The RSB pointed out that DG ENV could examine other possibilities of providing a convincing justification. This could include evidence from well-designed and well-presented consultations.</p>	<p>In addition to results from modelling evidence from extensive stakeholder consultation has been sought and included in the present report. In order to maintain the robustness of modelling, the amounts of water that become available under the different options has been quantified in order to reduce water stress, but the value of this water has not been monetised as no coherent and conclusive evidence exists on this matter. The report summarises several studies in this field and their diverging conclusions on the value of water in terms of reduced water stress.</p>
<p>The IA should also analyse the possibilities and challenges presented by the quick evolution of technology. If the uptake of water reuse is not known, the IA could look at different scenarios (high/low) explaining the assumptions made. The IA should also explain conditions that would make this initiative useful and proportionate to the costs generated.</p>	<p>The hydro-economic modelling by the JRC has followed this approach. Moreover an assessment of territorial impacts has been carried out, so as to triangulate the information as far as possible and to arrive at more solid conclusions.</p>
<p>Shaping the public perception (or misperception) seems to be an important issue. DG ENV should therefore also pay attention to communication related to reused water and consider non-legislative actions. Health-related problems do not currently seem to be addressed in the main objectives, but seem to be implicitly in the problem definition. This dimension should be included in the IA.</p>	<p>The problem definition identifies explicitly a perceived health risk and environmental risks which are resulting from the uneven framework existing in the EU to regulate water reuse.</p> <p>EU action on common quality requirements is expected to positively contribute to public perception on water reuse and to tackle both risks above.</p>
<p>If the initiative intends to differentiate in the</p>	<p>The initiative aims at setting minimum</p>

<p>application of standards between Member States, the reasons should be well substantiated.</p>	<p>quality requirements, so in case a Member State intends to allow this practice, it needs to comply with these as a minimum, but is free to develop more stringent requirements. The approach does not differentiate between Member States in relation to possible cross-border health and environmental impacts.</p> <p>It leaves flexibility to Member States to manage risks associated with reuse on the local public and environment. Reasons for this are linked to the local nature and extent of these risks and application of the subsidiarity principle; they are substantiated in the report.</p>
<p>The "fear" and "uncertainty" dimensions seem to be important for this initiative. The IA should address the question of how to generate more confidence. This does not necessarily require legislation. If results from consultations indicate that there is a strong demand for higher standards, this could provide the basis of a strong argument to accept the higher costs associated with them.</p>	<p>As part of the Circular Economy Action Plan beyond this initiative the Commission already committed to provide support to further knowledge and technological development in order to reduce uncertainty related to water reuse practices.</p> <p>Consultation activities have confirmed the demand for legislation to secure EU-internal trade of agricultural products irrigated with treated waste water.</p> <p>The scientific work underlying the proposed minimum quality requirements including the check by EFSA and SCHEER ensure that these requirements are sound and safe. So the pure existence of such requirements contributes already to reducing uncertainty and fear as consumers can be sure about the safety of European irrigated food products and aquifer recharge practises.</p> <p>Impacts on irrigation water cost have been addressed in the report.</p>

The RSB discussed the Impact Assessment report on 25 October 2017. A negative opinion, requesting a resubmission of the Impact Assessment report, was issued on 27 October 2017. The table below summarises the main and further considerations and adjustment requirements raised by the RSB in its opinion and how they were followed-up:

<b>Main points raised by the RSB in its opinion of 27 October 2017</b>	<b>Follow-up in the revised draft IA report</b>
<b>(B) Main considerations</b>	
(1) The report identifies water scarcity as the main issue but does not clearly document this problem's size, geographical scope or likely	Relevant projections on water scarcity and climate change scenarios were introduced in Section 1.1. Further information

<p>evolution. It does not explain whether this is an immediate problem or an issue for the future as a result of climate change.</p>	<p>underpinning the projections is available in Annex 4.</p>
<p>(2) The justification for intervention at the EU level is weak. The report does not substantiate lack of consumers' trust in the safety of agricultural products sold between Member States. Neither does it demonstrate the need for EU standards on reused water to alleviate water scarcity, to preserve the internal market for agricultural products, to protect consumers' health or to promote innovation in the circular economy.</p>	<p>The over-arching objective of the EU initiative on water reuse is to increase an uptake of water reuse as a measure contributing to the alleviation of water scarcity in the EU while maintaining the safety of health and addressing environmental risks associated with water reuse practices. The problem definition has been revised accordingly. The potential contribution of an EU legal instrument on water reuse towards reducing water scarcity is presented in Section 5 and further data is available in Annex 4. The Internal market dimension is now better presented in Section 1.3.3.</p>
<p>(3) The report lacks a clear analysis of the different situations across Member States with regard to quality requirements for reused water, and how the initiative would affect these respectively. The report does not adequately describe Member States' and consumer groups' views on this.</p>	<p>The IA report, as well as the JRC technical report is based on thorough analysis and consultation of Member States. Comparison of current standards on water reuse in selected Member States versus the JRC proposal on water reuse has now been included in Annex 6. The Member States views have been updated with recent information of the last CIS ATG on Water Reuse that took place on 6-7 November 2017. Consumer groups' views are covered by the results of the open public consultations, which are presented in Annex 2.</p>
<p>(4) The report does not adequately show how the initiative would be effective. It lacks a clear analysis of links to price setting and clean water prices.</p>	<p>The initiative has been put in the context of water pricing policy; information that was presented in Annex 5a in the previous version has been introduced in the main text. The main reference is Art. 9 of the WFD and its implementation and enforcement. Relevant information is presented in Section 1, and in particular Section 1.3.1 Factor 1. However, it has to be noted that water pricing as such is not going to be addressed by the initiative on water reuse, as there are other means already in place. The effectiveness of the initiative has now been further elaborated, i.e. information that was presented in Annexes in the previous version has been moved to Section 6.</p>
<p><b>(C) Further considerations and adjustment requirements</b></p>	
<p><b>(1) Clarify problem and need for intervention.</b> The report should define from the outset the water reuse that falls within the</p>	<p>The language in the scope definition has been improved. Aquifer recharge has been discarded based on the subsidiarity</p>

<p>scope of the proposal. In particular, it should explain why the initiative deals only with irrigation and aquifer recharge. It should present projections of water scarcity across the EU, and explain why the problem needs to be addressed at the EU level. The report should make clear to what extent existing regulatory standards concerning agricultural product safety fail to create consumer trust needed for a free flow of agricultural goods, and how EU minimum standards for reused water would solve this problem.</p>	<p>assessment (see Annex 11), consequently, no detailed impact assessment is included. Relevant projections on water scarcity and climate change scenarios were introduced in Section 1.1. Further information underpinning the projections is available in Annex 4. The interplay between existing standards and potential new EU minimum standards especially for agricultural irrigation and their expected impact has been set out in more detail.</p>
<p><b>(2) Clarify the choice of objectives.</b> The report should present clear links between the objectives and the main problems. It should explain whether addressing water scarcity is the higher level objective, to which targets for water reuse in agriculture and for aquifer recharge contribute. It should detail how achieving these objectives might conflict with the free flow of agricultural goods. The report should clarify the interlinkage and trade-offs between trade, environmental and public health objectives.</p>	<p>The intervention logic has been clarified. The different levels of objectives have been made more explicit and linked directly to the problem definition.</p>
<p><b>(3) Stakeholder views should be more fully presented.</b> Evidence of Member State support for standardisation should be provided and argued against stakeholder resistance and the current different national levels of requirements for quality of reused water. In the context of stakeholder support, it would be helpful to show more evidence of consumer perception of a problem and how minimum standards would contribute to greater trust.</p>	<p>Stakeholders' views based on the open public consultation are presented in the revised report, making a reference to Annex 2 when relevant.</p>
<p><b>(4) Subsidiarity issues.</b> Given big climate differences across the EU, the justification for EU intervention should explain whether minimum standards would be helpful for all or if they might disadvantage some Member States. The report should clarify whether the legal base to act is an environmental objective or a single market base. It should explain why the regulation of a risk assessment framework for aquifer recharge is not discarded up front, as the report already on page 25 states that aquifer recharge does not directly entail any issue linked with the placement of products on the internal market.</p>	<p>The intention of this initiative is to introduce an enabling framework for water reuse practices for those Member States who wish to implement them. Those who are not affected by water scarcity exacerbated by climate change will not be obliged to pursue any water reuse practice. Given the environmental legal basis, explicitly stated in Section 2.1, those Member States would be able to maintain/apply more stringent requirements. Aquifer recharge is now discarded upfront based on the subsidiarity assessment (more information in Annex 11).</p>
<p><b>(5) Choice of the legal instrument.</b> The</p>	<p>The nature of the instrument is now placed in</p>

<p>report should explain why minimum standards would be best enforced by a Regulation rather than a Directive, especially when the case of subsidiarity is not clear and the proposal covers minimum standards with possibility for derogation. The report should explain why "relevant health risks for food products placed on the Internal Market" (p. 20) justify the choice of a Regulation, although other water related EU acts, including drinking water, are Directives. Stakeholders also broadly appear to favour a Directive. The report should make clear that Member States with more restrictive limits will have to justify derogations from minimum standards. It should consider the implications of lowering existing standards in such cases</p>	<p>Section 6, in which arguments both in favour or against a Directive or Regulation are listed. The conclusions of the Blueprint were the departure point for this impact assessment, hence a Regulation has been identified as preferred option. However, following further consideration, the possibility of a Directive is analysed as well in more detail.</p>
<p><b>(6) The preferred option Regulation "fit-for-purpose" and the development of standards in collaboration with Member States.</b> The preferred option, with a collaborative setup with Member States, should be more clearly explained. The report needs to explain how minimum standards would result in greater reuse of water for irrigation. The report should discuss what motivates farmers to substitute reused water for fresh water for irrigation. It should point out that the willingness to pay for reused water will differ across regions, depending on differences in freshwater pricing. It should indicate that costs for the supply of reused water may be greater than the assumed willingness to pay of 0.5 €/m<sup>3</sup>. The report should explain that this qualifies the calculation of uptake and consequent benefits.</p>	<p>Section 5 has been revised to better reflect the willingness to pay based on the modelling data included in Annex 4.</p>
<p><b>(7) The lack of trust issues in the safety of agricultural products sold between Member States</b> The report needs to spell out how standards will protect public health and the extent of scientific evidence supporting them. The report should provide evidence that reuse of water for irrigation leads to marketing problems for agricultural goods. It should critically discuss how minimum standards for reused water have to complement agricultural product safety standards. The impact assessment should</p>	<p>This has now been clarified in the problem definition, Section 1.3.</p>



critically discuss whether minimum standards, with the possibility of more stringent national or regional standards, overcome the problem of consumers discriminating between products from different regions.	
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The RSB received a revised version of the draft Impact Assessment report on 1 December 2017. A positive opinion with reservations was issued on 19 January 2018. The table below summarises the main and further considerations and adjustment requirements raised by the RSB in its opinion and how they were followed-up:

<b>Main points raised by the RSB in its opinion of 19 January 2018</b>	<b>Follow-up in the revised draft IA report</b>
<b>(B) Main considerations</b>	
The context section of the report does not sufficiently reflect the shift in emphasis from water management to environmental standards for trade in agricultural goods. Information about parallel EU initiatives and alternatives in this area has not been sufficiently detailed in the problem definition of this initiative.	The context section 1.1. (pg. 4) was modified accordingly to ensure coherence with the main objective of this initiative, i.e. addressing water scarcity through an increased uptake of water reuse wherever it is relevant and cost-efficient, as well as contributing to the better functioning of the internal market through creating an enabling framework for water reuse. The problem definition section was modified accordingly (pg. 8).
<b>(C) Further considerations and adjustment requirements</b>	
(1) The problem definition and the scope consider reuse of waste water in the context of an integrated approach to water management. The report could provide additional information on the potential of reused water and the alternatives. It could comment further on the proportionality of this proposal in light of other initiatives. This might strengthen the case for the scope of the initiative and in particular for the creation of an enabling framework for increased uptake of water reuse, in particular for agricultural irrigation. The report does not refer to the Fitness Check of EU environmental monitoring until very late in the report. The report could use an early reference to all relevant information for a good understanding of the EU context and scope of the initiative.	The information included on alternatives to water reuse has been expanded to make clearer what alternatives could exist and how they would compare to water reuse. Reference to the Fitness Check of EU environmental monitoring introduced in Section 1.1.
(2) The report states that Member States' inaction to address the problem of environmental risks of water reuse results in a Single Market issue. The report could	Section 4.2 modified accordingly to reflect the contribution of the proposed action to the functioning of the Single Market.

strengthen this argument by highlighting how the options include the Single Market dimension and how the Single Market will function despite diverging quality requirement limits in Member States.	
(3) The report now makes a more robust case for the EU to act. It explains the level of support among most Member States. The subsidiarity analysis added in Annex 11 justifies discarding the measure about aquifer recharge, while also documenting substantial stakeholder interest in the issue. To clarify the EU intervention, the report could include further specific reference to the most EU-relevant problem drivers in section 2.1.	Section 2.1 slightly modified.
(4) The report has appropriately adjusted the objectives to the changed scope. If there is a corresponding shift in operational objectives, the report might explain what the implications would be for future monitoring and evaluation. This would include changes to the intervention logic, indicators for monitoring and benchmarks that those indicators would be monitored against.	
(5) The report could be made more reader-friendly by incorporating the problem tree into the main text, conventionally labelling, numbering and footnoting tables and figures, and more sparing use of bolding, underlining and italics.	The problem tree was incorporated in the main report (pg. 11, Section 1.3). The formatting was improved.
The Board takes note of the quantification of the various costs and benefits associated to the preferred options of this initiative, as assessed in the report considered by the Board and summarised in the attached quantification tables. <i>Some more technical comments have been transmitted directly to the author DG.</i>	Following the revision of the JRC modelling, the quantification of the various costs and benefits associated to the preferred options of this initiative has been revised accordingly.
<b>(D) RSB scrutiny process</b>	
The attached quantification tables may need to be adjusted to reflect changes in the choice or the design of the preferred option in the final version of the report.	Following the revision of the JRC modelling, the quantification of the various costs and benefits associated to the preferred options of this initiative has been revised accordingly.

### Sources used in the impact assessment

The main information sources for this Impact Assessment are the preceding impact assessment (2012) and subsequent supporting studies as well as the scientific basis developed by JRC (minimum quality requirements), together with a hydro-modelling by JRC. Moreover,

by teaming up with other Directorate-Generals (DG REGIO and DG RTD) specific aspects have been assessed, namely the impacts on innovation and territorial impacts.

**Quality of the information collected:** Significant effort was put into the collection of evidence and where possible, triangulation was performed to cross check the validity and robustness of information. Nevertheless, it was not feasible to arrive at monetised and quantified impacts on all aspects. In these cases, a qualitative assessment was performed. The Impact Assessment builds on detailed data on water scarcity and droughts in Europe, as well as future projections and a cost-benefit analysis of the use of treated waste water for agricultural irrigation. The modelling assumptions were based on expert judgements. The choice of options and the underlying scientific work developing minimum quality requirements was discussed with Member States and stakeholders in the context of the Common Implementation Strategy under the Water Framework Directive, and adapted accordingly.

**Usefulness of the information collected.** The underlying scientific work of developing the minimum quality requirements, the data collected and the modelling for the Impact Assessment are a useful basis for further decision-making.

COM(2012) 672, Report on the Review of the European Water Scarcity and Droughts Policy

COM(2012) 673, Impact Assessment for the Blueprint

BIO-Deloitte (2014), Optimising water reuse in the EU

COM/2015/614, Communication on Closing the loop - An EU action plan for the Circular Economy, Annex I

SWD (2015) 50, Report on the progress in implementation of the Water Framework Directive Programmes of Measures: The Water Framework Directive and the Floods Directive: Actions towards the 'good status' of EU water and to reduce flood risks

SWD(2017) 153, Commission SWD on Agriculture and Sustainable Water Management in the EU

Forzieri, G., Feyen, L., Rojas, R., Flörke, M., Wimmer, F., Bianchi, A.  
Ensemble projections of future streamflow droughts in Europe (2014) *Hydrology and Earth System Sciences*, 18 (1), pp. 85-108. DOI: 10.5194/hess-18-85-2014

JRC (2014) Water Reuse in Europe: Relevant guidelines, needs for and barriers to innovation

Forzieri, G., Feyen, L., Russo, S., Vousdoukas, M., Alfieri, L., Outten, S., Migliavacca, M., Bianchi, A., Rojas, R., Cid, A. Multi-hazard assessment in Europe under climate change (2016) *Climatic Change*, 137 (1-2), pp. 105-119. DOI: 10.1007/s10584-016-1661-x

Amec Foster Wheeler Environment & Infrastructure (2016) UK Ltd, IEEP, ACTeon, IMDEA and NTUA, EU-level instruments on water reuse

CIS Guidelines on Integrating Water Reuse into Water Planning and Management in the context of the Water Framework Directive (2016)  
[http://ec.europa.eu/environment/water/pdf/Guidelines\\_on\\_water\\_reuse.pdf](http://ec.europa.eu/environment/water/pdf/Guidelines_on_water_reuse.pdf)

COM (2016)105, Eighth Report on the Implementation Status and the Programmes for Implementation (as required by Article 17) of Council Directive 91/271/EEC concerning urban waste water treatment

Alberto Pistocchi, Alberto Aloe, Chiara Dorati, Laura Alcalde Sanz, Bernard Bisselink, Fayçal Bouraoui, Bernd Gawlik, Emiliano Gelati, Bruna Grizzetti, Marco Pastori, Ine Vandecasteele, Olga Vigiak, Hydro-economic analysis of the water reuse potential for agricultural irrigation in the EU. JRC Science for Policy Reports, 2017 (*draft*).

REGIO (2017) Assessment of territorial impacts

RTD (2017) Assessment of impacts on research and innovation

JRC (2017) Development of minimum quality requirements for water reuse in agricultural irrigation and aquifer recharge

SCHEER (2017) Scientific advice on proposed EU minimum quality requirements for water reuse in agricultural irrigation and aquifer recharge  
[https://ec.europa.eu/health/sites/health/files/scientific\\_committees/scheer/docs/scheer\\_o\\_010.pdf](https://ec.europa.eu/health/sites/health/files/scientific_committees/scheer/docs/scheer_o_010.pdf)

EFSA (2017) Technical report on proposed EU minimum quality requirements for water reuse in agricultural irrigation and aquifer recharge  
<http://onlinelibrary.wiley.com/doi/10.2903/sp.efsa.2017.EN-1247/epdf>.

Report on Water reuse and recycling within EU reference documents  
<https://circabc.europa.eu/sd/a/c2f004b6-4c4b-4bbc-8d7d-37938c6c6390/Water%20reuse%20%26%20recycling%20within%20EU%20Reference%20Documents.pdf>

Characterization of unplanned water reuse in the EU (Final Report 2017), Jörg E. Drewes, Uwe Hübner, Veronika Zhiteneva, Sema Karakurt, TUM  
[http://ec.europa.eu/environment/water/pdf/Report-UnplannedReuse\\_TUM\\_FINAL\\_Oct-2017.pdf](http://ec.europa.eu/environment/water/pdf/Report-UnplannedReuse_TUM_FINAL_Oct-2017.pdf)

Report by FP7 project DEMOWARE: <http://demoware.eu/en/results/deliverables/deliverable-d5-2-trust-in-reuse.pdf>

WHO Guidelines for the safe use of wastewater, excreta and greywater  
[http://www.who.int/water\\_sanitation\\_health/wastewater/wwuvol2intro.pdf](http://www.who.int/water_sanitation_health/wastewater/wwuvol2intro.pdf)

CDPH (2014) Regulations related to recycled water. California Code of Regulations. California Department of Public Health, Sacramento, California, USA.

EEA (2012) Towards efficient use of water resources in Europe. EEA report No 1/2012. European Environment Agency, Copenhagen, Denmark.

## **Annex 1a – Water reuse in impact assessment of Blueprint (excerpt)**

The Commission has been considering the issue of water reuse for a number of years and has documented its findings to date in several steps. In the 2012 Communication "A Blueprint to Safeguard Europe's Water Resources" (COM(2012) 673) water reuse for irrigation or industrial purposes was found to have a lower environmental impact and potentially lower costs than other alternative water supplies, whereas it is only used to a limited extent in the EU. A Fitness check of EU Freshwater policy (SWD(2012) 393) published in November 2012, as a building block of the Blueprint, assessed the performance of the measures taken, both in environment and in other policy areas, in achieving the objectives already agreed in the context of water policy. It also identified the major gaps to be closed in order to deliver environmental objectives more efficiently. In relation to wastewater reuse, the Fitness check concluded that "alternative water supply options with low environmental impact need to be further relied upon" in order to address water scarcity. A particular issue emphasised by stakeholders in the public consultation of the Fitness Check was the lack of EU common quality requirements for reuse of wastewater in irrigation. Several policy options to promote water reuse were considered in the impact assessment of the Blueprint (SWD(2012) 382)

*The following are more detailed excerpts from the relevant sections of the above mentioned documents, including the major gaps identified, whose closure can be partly addressed with increased water reuse:*

### **Fitness Check of EU Freshwater Policy – SWD/2012/393<sup>1</sup>**

#### 2.3. Gaps - Managing water demand and availability

Moreover, alternative water supply options with low environmental impact such as water re-use need to be further relied upon. In this context, a particular issue that was emphasised by industry stakeholders in the public consultation was the lack of EU standards for re-use of waste water in irrigation. The concern expressed is that the lack of EU-level standards could inhibit free movement of agricultural produce in the single market and inhibit investment by the water industry.

#### 2.5. Appropriateness of Policy instruments

The slow progress in relation to water efficiency in buildings and agriculture or on alternative water supply sources such as water re-use also raises questions about the relevance of continued reliance on voluntary approaches.

#### 5.2. Coherence within EU water policy

It should be noted that the issue of re-use of waste water for different purposes (such as irrigation or industrial uses) is not specifically addressed by EU water policy through EU wide re-use standards (public consultation and stakeholder workshop). Although relevant to the Urban Waste Water Treatment Directive, this is not an issue of coherence between water legislation, but rather a gap in the policy framework (see section on relevance).

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<sup>1</sup> <http://ec.europa.eu/environment/water/blueprint/pdf/SWD-2012-393.pdf>

## **A Blueprint to Safeguard Europe's Water Resources - COM(2012) 673**

### 2.4. The vulnerability of EU waters: problems and solutions

In the stakeholder consultations leading to the Blueprint, one alternative supply option – water re-use for irrigation or industrial purposes – has emerged as an issue requiring EU attention. Re-use of water (e.g. from waste water treatment or industrial installations) is considered to have a lower environmental impact than other alternative water supplies (e.g. water transfers or desalinisation), but it is only used to a limited extent in the EU. This appears to be due to the lack of common EU environmental/health standards for re-used water and the potential obstacles to the free movement of agricultural products irrigated with re-used water. The Commission will look into the most suitable EU-level instrument to encourage water re-use, including a regulation establishing common standards. In 2015, it will make a proposal, subject to an appropriate impact assessment, to ensure the maintenance of a high level of public health and environmental protection in the EU.

Table 4

Blueprint's proposed action	Who will take it?	By when?
Propose (regulatory) instrument on standards for water re-use.	Commission	2015

### 3. CONCLUSIONS AND OUTLOOK FOR EU WATER POLICY

The Commission will consider developing a regulatory instrument setting EU-wide standards for water re-use, thereby removing obstacles to the widespread use of this alternative water supply. This would help alleviate water scarcity and reduce vulnerability.

## **Impact Assessment (IA) of the Blueprint - Executive summary (SWD/2012/381)<sup>2</sup>**

### **1. PROCEDURAL ISSUES AND CONSULTATION OF INTERESTED PARTIES**

[...] Overall, stakeholders were supportive of non-legislative EU action to tackle water problems. [...] Some legislative options were also supported, such as a possible new regulation on water re-use standards. [...]

### **2. POLICY CONTEXT, PROBLEM DEFINITION AND SUBSIDIARITY**

Second, there is a risk that the WFD goals will not be achieved because of a lack of integration and coherence with other policy areas [...], further support is needed:

[...](7) for the uptake of water re-use through common EU standards.

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<sup>2</sup> [http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52012SC0381R\(01\)](http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52012SC0381R(01))

## 5. IDENTIFYING THE PREFERRED OPTIONS PACKAGE AND ITS IMPACTS

The assessment of the options can be considered as a screening of the various approaches for each of the 12 issues identified. On the basis of the assessment performed, it appears that in most of the cases, the most appropriate options fall under a guidance approach. The regulatory approach is recommended for only 3 issues (water efficiency in appliances/water related products, water re-use and knowledge dissemination) as the current policy context, in particular with respect to the implementation of the WFD and the MFF, leads to postponing most of the regulatory and conditionality policy options to a later stage. The preferred options are those in red and underlined in table 1.

Table 1: List of options considered in the Impact Assessment - options in red and underlined are retained

	Approaches			
specific objective	a) Voluntary	b) Regulation	c) Conditionality	d) Priority in funding
7 Water reuse	CIS Guidance  CEN standard	Regulation	n/a	Under CSF & EIBloans

### Impact Assessment (IA) of the Blueprint - SWD/2012/382<sup>3</sup>

#### • Impact Assessment report (Part I)

#### 2.4 Problem definition for the Blueprint (pg. 18)

##### 2.4.2. Lack of policy integration in support to specific measures

Even if a proper implementation of economic and communication instruments can help for a further uptake of measures that can provide a cost-efficient response to water resource problems, there are cases for which additional support from policy and funding instruments is needed:

...

- The lack of common EU **standards for water re-use** for agriculture and industrial uses limits a potentially important alternative water source - especially for water stressed areas where this option could be cheaper than desalination or transfers<sup>19</sup>. The lack of common health/environmental standards threatens farmers using re-used water to irrigate crops for export within the single market and prevents industry from making long-term investment decisions. It also constitutes a barrier for innovation.

#### 2.7 The need to act at EU level (pg. 29, 31)

Lack of integration of water issues into other policies (pg. 31)

<sup>3</sup> <http://eur-lex.europa.eu/legal-content/fr/TXT/?uri=CELEX:52012SC0382>



- The main barrier to expansion of **water re-use** is the lack of common standards at EU level, in particular in agriculture. While guidelines for agricultural water re-use have been defined by the World Health Organisation<sup>36</sup>, and by different countries, such as the USA<sup>37</sup> and Australia, a uniform solution for Europe is lacking. Establishing standards for the functional operation of the single market is an appropriate EU level response, taking into account EU Health, Agriculture and Energy policies.

#### **4. Policy options (pg. 36)**

##### **4.7 Water re-use (pg. 39)**

The problem analysis highlighted that a critical problem to address in the Blueprint is that there are no common standards for waste water reuse. Taking account of the detailed problem analysis and baseline, the following options were identified to be assessed within the Impact Assessment:

- develop CIS guidance on certification schemes for water re-use (Option 7a1),
- the Comité Européen de Normalisation (CEN) to adopt standards water re-use (Option 7a2),
- an EU Regulation establishing standards for water re-use (option 7b), and
- provision of funding through Cohesion Funds and/or EIB loans (Option 7d).

#### **5. Analysis of the impacts of the options (pg. 41)**

##### **5.7 Water re-use (pg. 44)**

The options concerned with water re-use all seek to stimulate the re-use of waste water in agriculture as a means of providing an alternative water supply and so reduce the pressure on surface and ground water sources and provide a stable supply to users in times of scarcity and drought. The impacts of water re-use are, therefore, common to all of the options and largely only differ to the extent that the options would be effective at stimulating water re-use.

The primary economic benefits of water re-use are to the agriculture sector and water industry sector. Water re-use ensures to farmers and horticulturalists a more reliable water supply, less dependant on precipitations, as it benefits from the priority given to drinking water in periods of drought, leading to more certainty in economic investment. Furthermore, farmers can benefit from nutrients contained in waste water, so reducing their costs for the use of fertilisers. The water industry sector benefits from alternative water treatment requirements, which can be less stringent and, therefore, less costly than requirements for treatment for discharge to surface waters.

The economic benefits translate into social benefits. Security of the agricultural producers enables jobs to be secured, providing benefits to local communities. Furthermore, it can enable traditional agricultural production to continue in water stressed areas that would otherwise be under threat from water scarcity and so maintain cultural traditions. However, health concerns do arise from the re-use of water for agricultural products. Therefore, the standards proposed to be adopted for options 7a, 7b1 and 7b2 would all be required to meet the necessary health standards. Furthermore, funding (option 7d) should only be provided to schemes which guarantee health standards are to be complied with.

The environmental benefits are proportional to the reduction in pressure on surface and ground waters from supply of re-used water as an alternative to abstraction. Ecological flows are more likely to be maintained, protecting aquatic ecosystems and, therefore, helping to meet WFD requirements. Furthermore, diversion of waste water to agriculture may result in less discharge of nutrients, etc., to surface waters.

The extent of these impacts is proportional to the effectiveness of the options. The primary problem facing water re-use is the lack of EU-level standards which could result in different standards across the Member States, leading to barriers in the trade of agricultural products. Voluntary standards (option 7a1) developed at EU level would provide a basis for a common approach, but the option cannot prevent Member States adopting a different approach and, therefore, cannot prevent barriers in the internal market. CEN standards (option 7a2) might be more likely to be adopted by Member States, but they suffer the same flaw as option 7a1. A Regulation (option 7b) does not have this problem and would guarantee that internal market barriers would not arise. The development of each of these options has similar costs, although the direct applicability of a Regulation would have lower burdens on Member States as it would not require transposition. The public consultation and stakeholder views all show more support for a binding Regulation as the effective means to overcome the problem compared to the other options. The option would be fully coherent with other EU water law and policy.

Option 7d (funding) is not an alternative to the other options, but can accompany any of the other options. Given public and private expenditure constraints, investment in water treatment and distribution for irrigation is constrained in some regions. Areas eligible for Cohesion Funds and EIB loans can benefit from additional investment support. The effectiveness of this option (and the resulting economic, social and environmental impacts) would be directly proportional to the level of available investment.

## **6. Identifying the preferred options package and its impacts (pg. 48)**

### **6.1 Proposed package (pg. 49)**

- Regarding **water re-use** there is a need to ensure the effective operation of the internal market to support investment and use of re-used water. The assessment, including stakeholder consultation, found that this can only be achieved through the development of new regulatory standards at EU level. Therefore, the preferred option is for the Commission to pursue appropriate health/environment protection standards for re-use of water and, subsequently, to propose a new Regulation containing these subject to a specific impact assessment.

## **• Annex to the Impact Assessment report (Part II)**

### **2.2. Measures improving water availability (pg. 35)**

#### *2.2.1. Description*

**Desalination** is the specialised treatment method used to remove dissolved minerals and mineral salts (demineralisation) from the feed-water (fresh water, brackish water, saline water, but mainly from sea water) and thus to convert it to fresh water mainly for domestic, irrigation or industrial use. In Europe, several countries have turned to desalination technologies, especially in the southern more water scarce areas. Several Member States use desalination as an **alternative water supply** source to remedy water stress situations. In 2008 Spain had the largest desalination capacity in the EU with up to 713 Mm<sup>3</sup>/day. Malta had a desalination capacity of 14 Mm<sup>3</sup>/day (more than 45% of its total water needs), while Italy reached around 0,75 Mm<sup>3</sup>/day, and Cyprus around 0,093 Mm<sup>3</sup>/day (TYPISA 2012). More and

more Northern European Countries also use this option. For example, in the UK, the company Thames Water has built a desalination plant for meeting the future water demands of the London metropolitan area.

**Water transfers** – are used to transfer water from one river basin where water is considered abundant to another one where water is scarce. The interbasin transfer of water, when implemented on a large scale, is one of the most significant human interventions in natural environmental processes. Water transfer has potential for substantial beneficial effects through alleviation of water shortages that impede continuing development of regions without adequate local water supplies. But transfer also has potential to limit future development of the area of the transfer's origin and to produce other negative effects.

**Groundwater recharge** is a hydrologic process where water moves downward from the soil surface towards groundwater. Recharge occurs both naturally (through the water cycle) and man-induced (i.e. artificial groundwater recharge), where rainwater, surface water and/or reclaimed water is routed to the subsurface. Artificial groundwater recharge aims at the increase of the groundwater potential. This is done by artificially inducing large quantities of surface water (from streams or reservoirs) to infiltrate the ground. It is commonly done at rates and in quantities many times in excess of natural recharge. The number of aquifer recharge and re-use schemes in Europe, and around the world, has expanded in recent years. The primary driver for this expansion has been the increasing demand for water to meet agricultural, industrial, environmental, and municipal needs. In southern Europe, the uptake is predominantly motivated by agricultural and municipal water needs, whereas in Northern Europe groundwater recharge is mostly found in densely populated areas for use in households (e.g. Berlin, The Netherlands).

Dams and reservoirs for **water storage** can be potentially used in most water scarce areas, where water efficiency measures can't fully resolve the problem. A dam is a barrier that produces changes in the hydro-morphological and physico-chemical conditions of the impounded river. River damming is one of the most ancient techniques used for water supply. Large dams have long been promoted as providing "cheap" hydropower and water supply, reducing also flood impacts to populated floodplains. A reservoir is natural or artificial pond or lake used for the storage and regulation of water. Reservoirs may be created in river valleys by the construction of a dam or may be built by excavation in the ground or by conventional construction techniques. These measures, in general, are considered more expensive and might have significant negative impacts to the environment.

There are two types of **water re-use**: direct and indirect. Direct wastewater re-use is treated wastewater that is piped into a water supply system without first being incorporated in a natural stream or lake or in groundwater. Indirect wastewater re-use involves the mixing of reclaimed wastewater with another water supply source before re-use. The mixing occurs for example when the groundwater is too saline and needs to be improved by the treated waste water. Re-use of treated wastewater is a valuable resource for water supply in areas where water is limited. It has the potential to become an alternative source of water after relevant treatment. It could be used for irrigation in agriculture, industrial uses and specific uses in buildings provided that all relevant safety standards are respected. Re-use of treated wastewater is an accepted practice in several European countries with limited rainfall and very limited water resources, where it has become already an integral effective component of long term water resources management. However, only a few countries developed comprehensive reuse standards. Strict quality controls to minimise the risk of environmental

contamination and human health problems due to water re-use. In addition, proper household metering and water pricing strategies are important drivers for the implementation of water reuse systems.

**Rainwater harvesting** is the process of collecting, diverting and storing rainwater from an area (usually roofs or another surface catchment area) for direct or future use. This is a technology that can be used to supply water to agriculture, households and industry.

### *2.2.2. Key information on the cost-effectiveness (risks and benefits)*

In theory alternative water supply options, especially desalination, can deliver unlimited amount of water. In practice all the options have a lot of limitations in terms of costs and negative economic, environmental and social impacts. Cost-effectiveness of the options is as follow:

Desalination plants involve high capital costs, maintenance and operational costs and recurrent costs, because of its reliance on high energy requirements and if its location is far from urban areas a distribution network needs to be installed to transfer desalinated water to the mains water supply. It affects the cost-effectiveness of desalination bringing high desalination costs (0,21 – 1,06 Euro/m<sup>3</sup>). Distribution costs of desalinated water: to transport 1 m<sup>3</sup> of water is estimated at 0.037 € per 100 m of vertical transport and 0.043 € per 100 km of horizontal transport. Other costs, related to the pre-treatment and the concentrate disposal, has to be also considered within the desalination process. Miller (2003) estimates pre-treatment costs to account for up to 30% of O&M costs while Younos (2004) estimates the costs of brine disposal between 5 to 33% of total desalination costs (Ecologic, 2008).

Development of the water transfer infrastructure involves very high costs. Example from England: the capital cost of water transfer infrastructure (to meet demand for water in south east England) is estimated to be between £8 million to £14 million per megaliter, which is 4 times more than developing new resources in south east. To transport 1 m<sup>3</sup> of water is estimated at 0.037 € per 100 m of vertical transport and 0.043 € per 100 km of horizontal transport (EA 2006).

Concerning water recharge costs of water supply are lower than in the case of desalination or water transfers. It is mainly owing to lower investment, treatment and distribution costs. In the Belgian case study cost of producing water from ground water recharge was estimated to be 0.5 €/m<sup>3</sup>, which was cheaper than transferred water from outside the region (0.77 €/m<sup>3</sup>) (in 2007) (TYPISA 2012). There is no need of large storage structures to store water. Structures required are mostly small and cost-effective and less evaporation losses are produced. An extensive and expensive tertiary treatment is required for using waste water to recharge ground waters (although in most situations in the EU these are in place in any case). Strict quality controls to minimise the risk of environmental contamination and human health problems are needed, what entails costs, which should be taken into consideration.

Costs effectiveness of storage reservoirs seems to be the most expensive water supply option. In UK costs of winter storage reservoirs are calculated as follows: lay-lined reservoirs: €3.20/m<sup>3</sup> to 6,70 EUR/m<sup>3</sup>, Reservoirs with a synthetic liner: 4,90 EUR/m<sup>3</sup> to 15,80 EUR/m<sup>3</sup>, including energy (CO<sub>2</sub>) from pumping twice (from borehole/river to reservoir; and from reservoir to field) (BIO 2012). In Australia case study expanding reservoir capacity costs were estimated on AUD 2,40/ kL (OECD 2011). However overall benefit (to farmers) of moving to

irrigation reservoirs is estimated at 14 EUR/m<sup>3</sup> to 27 EUR/m<sup>3</sup> as well as additional (non-monetised) benefits associated with improved security and flexibility of supply (case study from UK) (BIO 2012). Those benefits should be taken into account while considering water supply alternatives.

One of the most cost promising water supply alternatives is water recycling. The capital costs are low to medium for most wastewater re-use systems and are recoverable in a very short time. Experience from Australia: cost of recycling urban storm water (for non potable) – AUD 1,20-2,00 /kL; (for potable) – AUD 1,30-1,70 /kL; recycling treated sewage water – non-potable AUD 1,90/kL; potable AUD 2,50/kL (OECD 2011). Costs of waste water irrigation even tend to be lower than for groundwater irrigation, because the pumping effort needed is lower. However wastewater re-use may not be economically feasible if it requires an additional distribution network and storage facilities. Strict quality controls to minimise the risk of environmental contamination and human health problems are needed, what entails costs, which should be taken into consideration.

Total treated wastewater life cycle cost converted into €/m<sup>3</sup> (TYP SA 2012):

Reuse alternative	Recommended treatment process	Annual costs (€/m <sup>3</sup> )a, b
Agriculture	Activated sludge <sup>4</sup>	0.16-0.44
Livestock	Trickling filter	0.17-0.46
Industry and power generation	Rotating biological contactors	0.25-0.47
Urban irrigation – landscape	Activated sludge, filtration of secondary effluent	0.19-0.59
Groundwater recharge – spreading basins	Infiltration – percolation	0.07-0.17
Groundwater recharge – injection wells	Activated sludge, filtration of secondary effluent, carbon adsorption, reverse osmosis of advanced wastewater treatment effluent	0.76-2.12

Cost effectiveness of rain water harvesting is related to the need of financing the capital investments and operation/maintenance costs for relatively large storage tanks in situations where there is a poor rainfall distribution. These cost are relatively high as presents experiences from different countries: Australia - cost of rain water tanks – AUD 3,75/kL (OECD 2011); in Belgium a RWHS for private households requires a large investment and the price reaches the value of around €1.8 to 4/m<sup>3</sup> of RW used. The regulation specifies minimum requirements that aim at a cost-efficient introduction of RWHS. On the other hand, the savings amount to €1.7/m<sup>3</sup> for avoided use of mains water. As with current regulations, the costs for sewage and sewage treatment are recovered on the basis of m<sup>3</sup> of mains water used, the RW user benefits from an additional €2/m<sup>3</sup> for avoided costs for sewage and sewage treatment; in Malta the estimated cost of using the water produced by a RWH system reaches the value of €5 to 11/m<sup>3</sup> depending on the varying construction costs.

<sup>4</sup> Could also be natural low-cost treatment systems such as stabilisation ponds, constructed wetlands, or other like trickling filter, rotating biological contactor (footnote 16 in the IA of the Blueprint).

According to expertise the water saving potential for measures which are associated with rain water harvesting (rain water flowing from a roof is transferred via a pipe to a container in order to be used, for example, for gardening or car wash activities) is expected to meet up to 80% and 50% of households needs in France and UK, respectively (ACTeon et al., 2012). Concerning water harvesting in agriculture the overall benefit (to farmers) of moving to irrigation reservoirs can be estimated at 14 EUR/m<sup>3</sup> to 27 EUR/m<sup>3</sup> (discounted over 25 years at 4%), or annualised benefits of 0,80 EUR/m<sup>3</sup> to 1,55 EUR/m<sup>3</sup> per year (BIO 2011).

### **Economic impacts**

- Provision of adequate and reliable water supply in urban areas encourages general economic development;
- Guarantee of water supply during peak water demand periods (e.g. the tourist season), and because of its reliability it can support other and new economic activities;
- High investment and O&M costs related to treatment and distribution.
- In case of water storage reservoirs the need to devote a land, which otherwise could be used for some economic activities should be considered. The location of desalination plants also implies land-use planning issues: they are mostly located in coastal zones (already densely populated), and have impact on the value of land – “not in my back yard”.
- In case of water reuse there are some additional positive economic impacts:
  - Reusing the total volume of treated wastewater in Europe could cover nearly 44.14% of the agricultural irrigation demand and avoid 13.3% of abstraction from natural sources (Defra 2011). In Israel of all sewage that is treated, 75.5% (358 Mm<sup>3</sup>) is used for irrigation, representing 40% of the total water use in agricultural irrigation. Recently assessments point that the percentage had risen to 87% by 2007 and the objective is to reach 95% of reclaimed water by the end of the decade (Defra 2011).
  - use of the nutrients of the wastewater (e.g. nitrogen and phosphate) resulting to the reduction of the use of synthetic fertilizer and, reduction of treatment costs (reclaimed water, can be used for agricultural irrigation, landscape irrigation, industry, and non-potable urban uses). However there are some technological restraints related to crop type, presence of chemicals/nutrients not synchronized with crop requirements in using treated wastewater.

The potential of the water reuse source hasn't been exploited so far in Europe: by 2006 the total volume of reused treated wastewater in Europe was 964 Mm<sup>3</sup>/yr, which accounted for 2.4% of the treated effluent. The treated wastewater reuse rate was high in Cyprus (100%) and Malta (just under 60%), whereas in Greece, Italy and Spain treated wastewater reuse was only between 5 % and 12 % of their effluents. Nevertheless, the amount of treated wastewater reused was mostly very small (less than 1%) when compared with a country's total water abstraction (TYPESA 2012).

Water reuse and desalination require a continue enhancement of technologies in order to lower the use of energy and minimize environmental impacts on the aquatic environment. This is, therefore, an area for investment in innovation to ensure the cost-effectiveness of measures. Unlike water transfers, that increase water supply in one basin, at the expense of other basins, desalination has the advantage of decoupling water production from the hydrometeorological cycle.

Rainwater harvesting can have strong economic impact by reducing water costs paid by households, agriculture or industry to pay for mains water supply. The economic potential of this supply option is estimated very high. Rainwater harvesting could save 20 to 50% of the total potable water use in a standard home, whereas grey water recycling could save 5 to 35%, as seen in the UK experience (Bio Intelligence et al., 2012). In Bedfordshire, one of the drier parts of England, the MAAF study showed that one hectare of roof area might theoretically provide sufficient water to irrigate 2,5 hectares of potatoes (at 80% efficiency).

### **Environmental impacts**

All alternative sources of water supply reduce the demand on mains water supplies and reduce pressure on environment.

Most of alternative supply options are related to the intensive use of energy. Among them the most energy consuming is desalination. If the energy is from using the use of fossil fuels, this will increase GHG emissions. This is linked to the higher amounts of energy needed to desalt water (between 3.5 and 24 kWh/m<sup>3</sup> according to the technology), especially with thermal processes. On the basis of an average European fuel mix for power generation, it has been estimated that a revers osmosis plant produces 1.78 kg of CO<sub>2</sub> per m<sup>3</sup> of water, while thermal multi stage flash leads to 23.41 kg CO<sub>2</sub>/m<sup>3</sup> and multiple effect distillation to 18.05 kg CO<sub>2</sub>/m<sup>3</sup> (Ecologic 2008).

Example from Spain: it was estimated the desalination installation at Carboneras – Europe’s largest RO plant - uses one third of the electricity supplied to Almeria province. The more than 700 Spanish desalination plants produce about 1.6 million m<sup>3</sup> of water per day. According to the estimates (1.78 kg of CO<sub>2</sub> per m<sup>3</sup> of water) on CO<sub>2</sub> production from desalination, this translates into about 2.8 million kg CO<sub>2</sub> per day. It can be argued therefore that desalination is contributing significantly to Spain’s overall GHG emissions, which have been skyrocketing to +52.3% in 2005 compared to 1990 levels – moving Spain well beyond its European burden sharing target of +15%. This may be a foretaste of the dilemmas that will face other Member States in future years as the impacts of climate change are felt increasingly widely (Ecologic 2008).

Other environmental impacts of desalination varying severity depending on local conditions are on the aquifer and on the marine environment as a result of the concentrated brine management and water treatment and plant maintenance activities, water intake activities, and noise.

Water transfers and water supply projects, such as the construction of reservoirs and dams or irrigation schemes have significant negative environmental impacts in terms of biodiversity, wetlands, water availability and environmental flow. There are big uncertainties regarding how much water will be able to be transferred in the future.

Additionally construction of reservoirs and dams or irrigation schemes, can have negative consequences on biodiversity, especially in water scarce areas. As an example, planned irrigation schemes in the water poor Ebro basin in Spain were linked to significant declines in bird distribution (ACTeon et al., 2012). It is contributing as well to the discontinuity along the river, impeding fish species to reach their spawning grounds and is responsible for blocking of sediment transport to the sea is the main responsible of deltas and beaches regression.

Groundwater recharge reduces the threat of over-exploitation of existing aquifers, and decreases the risks of seawater intrusion into aquifers at or near the coast. It guarantees available for both the economy and the environment surface and groundwater resources during summer and drought periods. Fewer evaporation losses are produced, contrary to dam or impoundment alternatives, that in southern countries could reach levels up to 1m/year (TYPISA 2012). In the contrary it reduces pressure on water bodies from reduction in summer abstractions.

Waste water reuse not only reduces the demands of freshwater, but can also reduce the pollution of rivers and groundwater by nutrients. From another side if there is no strict quality controls, there could be the risk of environmental contamination and human health problems (water-borne diseases and skin irritations).

The direct waste water reuse in households results in increased GHG emissions in existing homes, whereas its installation in new homes, alongside with other water efficiency measures, shows net carbon benefits. Different biological and bio-mechanical systems apply to single residential dwellings, commercial buildings or multi-use buildings. These systems have different operational energy and carbon intensities. For grey water reuse, the latter range from 0.6 kWh/m<sup>3</sup> for short-retention to 3.5 kWh/m<sup>3</sup> for small membrane bioreactors (Bio Intelligence et al., 2012).

The same environmental impact concerns rain water harvesting. The need of construction and maintenance of the necessary infrastructure may lead to negative energy/treatment/GHG impacts. The retrofitting of household rainwater harvesting results in increased GHG emissions in existing homes, whereas its installation in new homes, alongside with other water efficiency measures, shows net carbon benefits. Different biological and biomechanical systems apply to single residential dwellings, commercial buildings or multi-use buildings. These systems have different operational energy and carbon intensities. For rainwater harvesting, the latter range from 1.0 kWh/m<sup>3</sup> for direct feed to 1.5 kWh/m<sup>3</sup> for header tank (Bio Intelligence et al., 2012). For water harvesting in agriculture the same negative effects should be taken as those identified for water storage (dams and reservoirs).

The positive environmental impact of rain water harvesting is the reduction of the amount of urban storm runoff due to its buffering effect on storm events, which in turn reduces the amount of pollutants being washed into surface waters that are used to recharge shallow groundwaters.

### **Social impacts**

In general alternative water supply alternatives provide adequate and reliable water supply in urban areas and encourage general economic development and job creation.

Water transfers provide right distribution of benefits between the area of transfer origination and area of water delivery. However by contributing to the development of regions without adequate local water supplies it may limit future development (economic productivity) in the area of the transfer's origin. It can cause problems of inter-regional or international fights for water rights, as drought extreme events are complex to manage.

Water storage change land use in the region, which can lead to low social acceptance.



The general public or specific groups may refuse to consume products that are associated with the waste water re-use – the so called “yuk” factor.

There is the potential for impacts on health arising from these options (which would be stronger with a regulatory approach). These impacts would depend on whether building standards included requirements for re-use of water within the buildings (which would, therefore, need to be subject to subsequent IA if this were proposed). Reduced water flows can result stagnate in pipes, leading to microbial growth, although this concern is largely theoretical at present and currently design and control have reduced this problem. With regard to rainwater harvesting and to grey water reuse health issues are linked especially to installation, maintenance and operation of these sources. Stored rainwater can be contaminated with Enterococci (EUREAU 2011b). Also, back-wash systems (as part of the design of a reuse system for maintenance and cleaning) could contaminate drinking water supplies.

Having said this, public perceptions of possible health impacts are a barrier. Actions to control water quality include health codes, procedures for approval of service, regulations governing design and construction specifications, inspections, and operation and maintenance (US EPA, 2004) and standards have been adopted in national law (e.g. France, Spain and UK) for rainwater harvesting and grey water re-use to address this issue.

Poorer families will not have the financial resources to invest in the technology of water harvesting, and reap the benefits of lower water costs. The same concerns tenants who will not have the opportunity to reap the benefits of lower household water costs, as landlords do not benefit from this type of investment.

### *2.2.3. Barriers for implementation*

#### *Market failures, regulatory and policy support*

There is the lack of the application of best practices in integrated water management by water managers at a national or basin level to produce RBMPs that are coherent and cost effective. In general at a national or basin level the institutional or administrative structures are not in place. It causes problems in the development and implementation of an integrated water resource management plan for the administration, management, protection and sustainable development of the raw water resources at a basin and water body level.

The existing RBMPs hardly apply the principles of: polluter pays, cost recovery, cost effectiveness and disproportionate costs. It means that they do not meet society’s overall water objectives for quality and quantity i.e. a RBMP that is harmonized with socioeconomic development objectives resulting in water bodies that will achieve good ecological status.

There is the lack of coherence between the RBMPs and other sectorial plans resulting in inability of basin managers to fully evaluate the costs and benefits between measures in order to select the most cost effective ones for society. For example: there is lack of sufficient linkage with related policies such as CAP, land-use planning; artificial water storage very often is not in line with rural development rules and existing legislation (too strict existing standards).

There is a general lack of clear institutional roles between water resource managers (responsible for quantity and quality) and competent authorities for environment whose focus is on water quality and the environment. The efficient and cost effective management of water resources requires the management and implementation of measures that are for the common and cost effective good of multiple users and are not solely linked to one user or user group. This requires an institutional framework with the capacity to administrate, evaluate, select and manage the implementation of common water resource.

Lack of full cost recovery of water services, including financial, environmental and resource costs makes difficult to take economically and environmentally sound decisions on the choice of best water supply option.

There is lack of guidelines or criteria for water reuse taking into account regional characteristics. The absence of an EU regulatory framework presents a significant barrier as standards commonly agreed terminology are the basis for the success of water reuse projects.

The lack of standards has caused administrations to take a rather conservative approach and has led to mistrust and misunderstandings regarding users who do not have of trust, credibility and confidence, especially in the agricultural sector. In some countries the governing standards put unnecessary limits on the use of the treated waste water or led to illegal uses.

Lack of financing is considered the single most significant barrier to wider use of reclaimed wastewater.

Reclaimed water is not the only source available for groundwater recharge, also water excess due to floods or wet periods are available to be naturally (ponds) or artificially (wells) injected. When treated wastewater (expensive tertiary treatment is needed) is used for groundwater recharging there is a need to have strict controls to ensure that no pollution problems to the groundwater bodies appear.

#### *Financing sources*

Lack of financial incentives and of sufficient information on the available techniques, best practices and the benefits of using treated waste water or harvested rain water put limits to the use of these alternative water sources.

Important barrier to the implementation of alternative water sources are the high costs associated with them. When current water supply is provided from cheap local sources (groundwater or surface water), water produced by desalination or ground water recharge are likely to be more costly. In these cases it is not financially obvious to introduce these water supply options, especially if the current water prices do not reflect all the economic costs, nor the environmental and resource costs. Costs per m<sup>3</sup> water produced may be very different for similar technologies or supply options in the different Member States that implies that the barriers for implementation vary country by country.

#### *Lack of implementation and coordination*

There is a need of a high quality monitoring system and quality assurance for consumer's acceptance (concerns especially water reuse, water recharge and rain water harvesting).

Desalination can be a replacement for potable water supply purposes, although its supply regime is rigid and inflexible, and so is best suited for supplying a fixed amount of water (according to its design specifications). There are, particular environmental and economic concerns about the high energy requirements of the desalination process, meaning that mitigation measures are needed to either improve efficiency or incorporate the use of renewable energy resources. In addition, there are also concerns about the impact on the environment of disposing brine – meaning that adequate mitigation measures have to be incorporated to deal with brine disposal. These concerns are an opportunity to develop new technologies, that more efficient, with less environmental impact.

There are problems to find available land for construction of big desalination plants.

### *Knowledge base*

In the context of river basin planning, water reuse options tend to be excluded or forgotten as stakeholders are not well informed about the link between water supply and wastewater treatment. As such, research results from feasibility studies on water use have not been taken up in practice, especially in areas where water supply and wastewater are managed by different companies or agencies.

Interbasin water transfer proposals needs thorough evaluation to determine if they are justified considering all associated impacts. There are uncertainties concerning water availability in the future (how much water will be available to be transferred).

Investments in artificial water storage and the creation of new resources should be based on economic analysis. They usually bore high investment, maintenance and operation costs, long investment procedures and significant potential impacts on the environment that have to be taken into consideration. They should be considered as an option when other options to improve water efficiency, including the application of economic instruments have been implemented.

#### *2.2.4. Degree of implementation as reflected by the RBMPs*

The development or upgrade of reservoirs or other water regulation works is included in about 30% of the RBMPs, development or upgrade of water transfer schemes in 23%. Measures to foster aquifer recharge are included in 33% of the plans.

The development or upgrade of desalination plants (in about 1% of the plans) and the establishment of water rights markets or schemes to facilitate water reallocation (in about 2% of the plans) are the least considered.

There is little quantitative information on the waste water reuse. While at EU level water reuse amounts to less than 1% of the countries' total water abstraction, in Cyprus and Malta the treated wastewater reuse rate of their effluents is high (respectively 100% and 60%) (TYPISA 2012). This currently under-exploited measure has a high potential. Nevertheless treated waste water reuse and rainwater harvesting are not identified as main measures in the RBMPs. According to the preliminary analysis of RBMPs there were no measures related to WWR and RWH included in almost 50% of the assessed RBMPs.

#### *2.2.5. Key EU policy instruments that would unlock / guide the implementation*

### *EU Policy instruments related to use of economic instruments*

Economic incentives could help in "unlocking" the measures. This supposes the proper implementation of the WFD economic principles of polluter-pays principle, the principle of cost recovery, including environmental and resource costs. Alternative water supply is more costly than conventional sources, especially if water prices do not cover all costs. It may be difficult to introduce the measures without **economic incentives** such as temporarily applied subsidies.

While choosing the best water supply option economic analysis taking into account full cost recovery of water services, including financial, environmental and resource costs should be the base to take economically and environmentally sound decision.

### *EU Policy instruments related to governance and integration*

To strengthen the "quantitative dimension" of the WFD implementation by establishment of systematic water balance assessment/water accounts at sub-catchment level and the dynamic modelling of water resources for the preparation of next RBMP. This will provide information on where and how water efficiency can be improved and which alternative water supply sources should be developed in a cost-effective way.

#### **Water reuse:**

The key recommendation of the Mediterranean Component of the EU Water Initiative (MED EUWI) Wastewater Reuse Working Group is to develop a commonly agreed European and Mediterranean guidance framework for treated wastewater reuse planning, water quality recommendations, and applications.

Awareness raising campaigns and advisory services could improve the public and user awareness and acceptance of the water reuse. Improve implementation of cost recovery and provision of economic incentives to promote and make water reuse cost effective.

#### **Other sources:**

The application of desalination and artificial recharge could be facilitated by improving the political and public acceptance. Prior to starting such type of new investment an awareness raising campaign and extensive consultation with the stakeholders and public should be carried out. This should be combined with a high quality monitoring system for ensuring their safe use and improving consumers' acceptance.

Since desalination facilities might have significant negative impact on the environment the inclusion of these facilities under the scope of the IED (2010/75/EU) and EIA (85/337/EEC) Directives should be considered.

### *EU Policy instruments related to funding*

Implementation of alternative water supply measures requires high investment costs, so potentially they can enter to the scope of EU funds financing. As they can trigger substantial economic, environment and social impacts, there should be introduced strict assessment procedures to allow their implementation and financing, only while efficiency measures are fully addressed and can't resolve water shortage problems.

*EU Policy instruments related to knowledge base*

Further research and innovation activities:

- To get cost efficient and more environmental friendly techniques and technologies available for desalination technologies.
- To develop available techniques, best practices and the benefits of using treated waste water or harvested rain water.
- To adapt water markets.

## Annex 2 - Synopsis report on consultation activities

### I. Introduction

The consultation process for a possible new EU initiative on water reuse began in 2012 and continued until July 2017 in various forms, both organised and ad hoc. The implementation of the consultation strategy involved collecting and analysing input from a wide range of stakeholders as well as two online public consultations with the aim to:

- (1) Provide an opportunity to express views on the present and potential development of water reuse in the EU, on the opportunity to further promote water reuse in different kinds of sectors and on possible/desirable actions that could be taken at EU level;
- (2) Gather specialised input (data and factual information, expert views) on specific aspects of the benefits and barriers affecting the development of water reuse (e.g. available treatment techniques and related costs, existing and planned legislation in Member States, risk management approaches etc.) with the aim of filling the data and information gaps in view of refining the policy options and preparing the impact assessment.

The following identified stakeholders' categories have been targeted in consultation activities:

- Scientific Committees [[European Food Safety Agency \(EFSA\)](#) and [Scientific Committees Scientific Committee on Health, Environmental and Emerging Risks \(SCHEER\)](#)]
- EU Member States and public authorities responsible for water management
- Water users, in particular representatives of the farming sector
- Water industry, both water supply and sanitation and suppliers of technology
- NGOs active in the water area
- Academia and experts, research and innovation organisations
- Citizens and the general public;
- As well as other EU institutions

This document summarises the various contributions received<sup>5</sup> and, based on the analysis of this input, identifies issues that stakeholders regard as priorities when further developing water reuse at EU level. These findings have been used in the preparation of the impact assessment and the updating of the scientific basis of the proposal (the JRC report in Annex 7) and will further be used to inform the decision-making process in view of a new instrument to regulate specific aspects of water reuse at EU level (agricultural irrigation and aquifer recharge).

In the consultation process, stakeholders also put forward a number of suggestions going beyond the current scope of a possible instrument on water reuse at EU level and these will be taken into consideration in future exercises addressing other aspects of water reuse.

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<sup>5</sup> <http://ec.europa.eu/environment/water/reuse.htm>

## II. Consultation results by activities and stakeholder group

### *Scientific Committees*

To ensure the proposal will be based on up-to-date scientific knowledge and will provide the appropriate level of safety as regards human health and the environment, EFSA and SCHEER were consulted on the penultimate version of the technical report developed by the JRC (December 2016) which is mentioned above.

EFSA approved its technical report on 22 May 2017. It reviewed whether the methodology used was appropriate, the defined food crop categories were appropriate, the proposed minimum quality requirements were sufficient, and any risks had been overlooked. Following its analysis, EFSA issued recommendations<sup>6</sup>.

SCHEER delivered its scientific advice on 9 June 2017. It examined four questions: Is the methodology used by the JRC considered appropriate? Do the proposed minimum quality requirements provide sufficient protection against environmental risks that may be associated with water reuse for agricultural irrigation and aquifer recharge? Do the proposed minimum quality requirements provide sufficient protection against human health risks that may be associated with water reuse for aquifer recharge? And have any risks been overlooked? The SCHEER concluded that, while the methodology chosen was appropriate and the report considers many important elements, the document is deficient in key details<sup>7</sup>.

The opinions of the two scientific Committees have been duly taken into account in the finalisation of the technical content of the proposal and its assessment in terms of health and environmental impacts.

### *Consultation of experts in Member States and stakeholder organisations*

Consultation took place in the framework of the Common Implementation Strategy (CIS) for the implementation of the Water Framework Directive (WFD). Water reuse was discussed in 6 meetings of the former Working Group on the Programmes of Measures (September and November 2013, March and October 2014, March and October 2015). A dedicated activity on water reuse and an Ad-hoc Task Group (ATG) was included in the CIS work programme for 2016-2018 to accompany the development of related actions.<sup>8</sup>

### *EU Member States and public authorities responsible for water management*

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<sup>6</sup> The EFSA opinion published on 10 July 2017 is available at <http://onlinelibrary.wiley.com/doi/10.2903/sp.efsa.2017.EN-1247/epdf>

<sup>7</sup> [https://ec.europa.eu/health/sites/health/files/scientific\\_committees/scheer/docs/scheer\\_o\\_010.pdf](https://ec.europa.eu/health/sites/health/files/scientific_committees/scheer/docs/scheer_o_010.pdf)

<sup>8</sup> Information on the status of water reuse in EU Member States was collected and participants were invited to feedback on draft versions of the IA support studies elaborated by consultants. A technical workshop on possible minimum quality requirements on water reuse at EU level was organised by DG ENV and JRC in June 2015. Meetings were held in March 2016, October 2016 and June 2017 and specifically discussed draft versions of the JRC technical report. Draft elements of the impact assessment were also presented in order to collect feedback and gather additional information. Expert Groups on the Groundwater Directive, the EQS Directive, the UWWTD and on the Drinking Water Directive were also consulted.

During the detailed discussions held with Member States' experts, broad support for the concept of water reuse was overall apparent, with some notable exceptions. Representatives of those Member States currently already practicing water reuse in the relevant areas (agricultural irrigation and aquifer recharge) have generally been more in favor. These include notably Spain<sup>9</sup> and Italy<sup>10</sup> but also others (Cyprus, Malta, Portugal, and Bulgaria). France has also expressed its support for an EU legal instrument.

Despite the political support expressed by the Council (see above), some Member State representatives at technical level have expressed certain reservations about the initiative. These include Germany<sup>11</sup>, Austria<sup>12</sup> and the Netherlands<sup>13</sup>. At the latest meeting of the CIS ATG on Water reuse, broad support for the EU initiative on water reuse was expressed. Support for a legal instrument was particularly strong from Member States currently already facing water scarcity and severe impacts of droughts and climate change. There were also some positions expressed concerning the type of EU instrument, and a few Member States seemed to prefer a Guidance document to an EU legal instrument as a starting point.

#### *Consultation of water users (in particular farmers)*

The farmers' association at EU level (COPA-COGECA) participated in the expert group exchanges and issued a position in writing and participated in various conferences. They were overall appreciative of the concept, stating that it will contribute to a more resilient farming sector, help overcome pressures deriving from climate change and, in upcoming years, be not only an alternative supply option but rather the most important source of clean water. Challenges highlighted were the need to identify the right quality of water, whereby the minimum quality requirements must take into account specific local needs and give flexibilities to the regions and Member States. Reclaimed water for irrigation should be nutrient-free as well as particle-free. Affordability of the proposed water reuse schemes should be carefully considered. COPA-COGECA further indicated that the compliance should be at the point where reclaimed water is discharged by the treatment plant. Finally, any new

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<sup>9</sup> Spain indicated its support and noted that as the objective is to promote rather than to prevent water reuse, the legislation should be safe but also practical and manageable; in particular, there is a need to properly reflect on the feasibility of the proposed minimum quality requirements. According to the Spanish experience setting limit values for chemicals is challenging, also for those which can be crop nutrients. This should not prevent but incentivise their recycling. The validation requirement proposed by the JRC for quality class A is considered unrealistic; the proposed parameter is not technically appropriate and would also strongly disincentive existing water reuse practices in ES.

<sup>10</sup> Italy expressed support while indicating that the final instrument has to be realistic. Italy informed that there is currently no practice with aquifer recharge, however a strong interest for the future. In relation to minimum quality requirements for this purpose, parameters for chemicals (CECs) should be introduced as there is a risk of contamination. The JRC report was considered a very good basis for a potential EU instrument on water reuse.

<sup>11</sup> Germany indicated that water reuse is currently not an important issue in Germany (there are as of yet only 2 sites where water reuse for irrigation is practiced) and considers there is no need for a binding instrument on risk management at this stage. The practical implementation of the instrument on water reuse was unclear. For aquifer recharge a guidance document would be sufficient. For agricultural irrigation, the current minimum standards proposed by JRC were not stringent enough.

<sup>12</sup> Austria felt that for obvious reasons water reuse is not high on the agenda in Austria and it is considered that the existing water acquis is currently sufficient to address this issue. Concerning the risk management framework, a guidance document was considered as the most appropriate response and in relation to CECs, Austria supported very much a holistic approach beyond the specific issue of water reuse.

<sup>13</sup> The Netherlands referred to existing legislation being sufficient enough to address the problem; the EC initiative not fully complying with the Better regulation principles and finally the scope of the initiative being too narrow, whereas the Netherlands would rather appreciate a focus on integrated water management.



instrument should be light and not inflict administrative burden. It should only apply to those practicing reuse.

*Water industry, both operators of water services (water supply and sanitation) and suppliers of technology for water treatment*

The initiative is of interest to both operators of water services (water supply and sanitation) and suppliers of technology for water treatment – e.g. European federation of national associations of drinking water suppliers and waste water services (EUREAU), Water supply and sanitation technology platform (WSSTP), European Centre of Employers and Enterprises providing Public services (CEEP), European Irrigation Association (EIA), European Water Association (EWA);

Positions taken by industry representatives have generally been supportive; they were aware of the potential of harmonizing quality standards on water reuse for technological and economic development. Water reuse is already happening in many countries and the demand for reused water will continue growing due to climate change. Technologies exist to provide safe reused water and scientific evidence shows that potential negative impacts can be mitigated. In this respect, proper risk assessment and monitoring are key tools to ensure water reuse safety. Private companies were by far the most positive across types of stakeholders about the safety of water reused compared to other sources of freshwater (groundwater or water from rivers).

The industry has, however, also highlighted a number of challenges, particularly potential legal constraints and administrative burden related to the development of water reuse, as well as the cost of implementation. They also mentioned the low price of freshwater compared to reused water. For example, EUREAU, while overall supportive of the work on water reuse, felt that possible EU requirements cannot be a “one size fits all” solution and must not be imposed on Member States. In particular, they must reflect different water quality levels depending on the intended use of treated water. It must remain economically viable on top of protecting human health and the environment. Industry has also requested that the issue of liability be clarified in a possible new instrument.

*NGOs active in the water area (including European Environmental Bureau; WWF)*

NGOs were generally supportive of the concept and work. They were, however, concerned with the safety of reclaimed water and felt that a possible new EU instrument would need to set minimum criteria that are stringent enough to ensure the needed protection of the environment, as well as human health.

*Consultation of academia and experts, research and innovation organisations*

Within the [European Innovation Partnership \(EIP\) on Water](#), several action groups set up in recent years address water reuse, such as: [Industrial Water Reuse and Recycling \(InDuRe\)](#), [Water & Irrigated agriculture Resilient Europe \(WIRE\)](#), [Real Time Water Quality Monitoring \(RTWQM\)](#), [Verdygo - modular & sustainable wastewater treatment](#). The European Technology Platform for Water (WssTP) initiated by the Commission is also very active on water reuse with a dedicated multi-stakeholders working group on water reuse. These groups have been regularly informed about the initiative and invited to provide feedback on the technical development of the proposal.

Representatives of academia and experts were strongly in favour of EU action for water reuse for agricultural irrigation; however an EU action on aquifer recharge has not been supported by all. They demonstrated particular interest in the approach that would be chosen concerning risk perception and the proper protection of public health and the environment. A preference for a risk-based approach as a key element to build trust and confidence was also voiced. Other important elements were management practices, transparency and involvement of the public.

Representatives of the research and innovation community had a preference for mandatory EU minimum quality requirements which were seen as innovation-friendly if certain conditions, such as the balanced scope of water quality parameters and stringency of limit values, are met. They would boost R&I at all phases driven by the needs to demonstrate technical performance, efficiency and reliability of conventional and new technologies (filtration, disinfection, membranes, advanced oxidation, etc.), economic viability of water reuse projects, and social and environmental benefits. In addition, new and innovative ways of monitoring would be stimulated.

### *EU institutions*

The Commission communicated to the Council and the Parliament its intention to address water reuse with a new initiative in two Communications (COM(2012)673) and COM(2015)614). The **Council** provided feedback in its conclusions on these two Communications. It further elaborated on its expectations as regards the proposal in its Conclusions on Sustainable Water Management (11902/16) under the Slovak Presidency (17 October 2016) which state that the Council

"EMPHASISES that water re-use, in addition to other water saving and efficiency measures, can be an important instrument to address water scarcity and to adapt to climate change as part of integrated water management; CALLS ON the Members States to take measures to promote water re-use practices, taking into account regional conditions where appropriate and whilst ensuring a high level of protection for human health and the environment, as water re-use can also deliver benefits in terms of economic savings, environmental protection, stimulating investments in new technologies and creating green jobs; STRESSES that well-treated urban waste water can be re-used for a variety of purposes in the agricultural sector, industrial applications, sustainable urban development and protection of ecosystems; and NOTES with interest the intention of the Commission to present in 2017 a proposal on minimum quality requirements for reused water in the EU;"

The **Parliament** expressed expectations as regards the initiative in its resolution<sup>14</sup> on the follow-up to the European Citizens' Initiative Right2Water of 8 September 2015. Like the Council, it expressed overall support to the concept of water reuse and the Commission's intention to develop a dedicated instrument; the Parliament notably "72. Encourages the Commission to draw up a European legislative framework for the reuse of treated effluent in order, in particular, to protect sensitive activities and areas". A number of events were also organised in the European Parliament by Members to discuss water reuse and the opportunity of a new EU legislation<sup>15</sup>.

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<sup>14</sup> <http://www.europarl.europa.eu/sides/getDoc.do?type=REPORT&reference=A8-2015-0228&language=EN>

<sup>15</sup> e.g.: Breakfast meeting "The contribution of Water to Circular Economy – Practices of reuse across Europe" in January 2016 by the EP Intergroup on "Climate Change, Biodiversity and Sustainable Development"; EP

The initiative was also considered by the *Committee of the Regions*, which, in its opinion<sup>16</sup> on "Effective water management system: an approach to innovative solutions" of February 2017, states that it " supports the Commission's intention to put forward, in 2017 – as part of the implementation of the Action Plan for the Circular Economy – a proposal for minimum requirements regarding the reuse of water [...], ensuring that there are no disproportionate negative effects on other sectors, such as agriculture; The Committee of the Regions also stressed that differences between regions in terms of water availability must be taken into account. There should be no obligation to reuse water unless this can be justified."*Communication on the development of the initiative*

A [roadmap on the initial initiative "Maximisation of water reuse in the EU"](#) was published in September 2015 which was further elaborated and focussed in an [inception impact assessment](#) published in April 2016. Both documents were provided with an on-line mechanism inviting to provide feedback, but none has been received.

Dedicated Internet pages have been developed on DG ENV's Website providing information on the [policy context](#) and the [implementation of the action plan](#) to promote water reuse in the EU. Both pages reference all available information (e.g. IA support studies) and are regularly updated. A functional mailbox [ENV-WATERREUSE@ec.europa.eu](mailto:ENV-WATERREUSE@ec.europa.eu) was created and has been used to communicate with citizens and stakeholders.

A public relations campaign was launched in January 2017 with the aim to effectively inform about, explain, promote and increase awareness and support of the EU initiative on water reuse as part of the circular economy (CE) package. This campaign was targeted to a few EU Member States selected for their interest (countries already practicing water reuse) and influence (countries that are active in the process of defining an EU action on water reuse with regard to the initiative, tentatively: Belgium, Cyprus, France, Germany, Greece, Italy, Malta, the Netherlands, Portugal and Spain. The target audiences are policy-makers and key stakeholders (water service operators, farmers and operators in the food supply chain, water intensive industries, NGOs etc.).

A [Green Week session on Water Reuse](#) took place on 5 June 2014 with the aim to present the Commission work on water reuse, the US Guidelines on water reuse, the agricultural sector's view on water reuse and the innovation potential of water reuse practices. Water reuse was showcased again in the Green Week 2017 in a session focusing on green jobs and skills in the water sector, with the objective to demonstrate how development and implementation of EU environmental policies benefits people and the economy by creating green jobs.

### **III. Horizontal assessment**

This section is a horizontal assessment of the views of those consulted on the need for EU action and the scope and level of ambition of a potential new EU-level instrument, mainly based on the results of the two online public consultations.

A [first internet-based public consultation ran from 30 July to 7 November 2014](#) to gather wider feedback from the interested public and the expert practitioners across the EU. In total, 506 respondents participated in the consultation. This included: 224 individual respondents,

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Water Group Plenary Session 'Water in the Circular Economy' in January 2016; EP Water Group meeting "Water Reuse Models" in October 2013

<sup>16</sup> <http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52016IR3691&from=EN>

222 companies and organisations, 43 public authorities and 17 other respondents. Twelve stakeholders uploaded additional documents and eight sent more detailed responses or position papers via email. Participation was particularly high in four Member States (France, Spain, Italy and Germany), which together made up more than 65% of total responses. About 95% of total answers were obtained from Member States' organisations, 3% from EU-level organisations and 2% from other countries. Among private companies, nearly equal share of respondents represented large companies and Small and Medium Enterprises (SMEs).

A [second internet-based public consultation ran from 28 October 2016 to 27 January 2017](#) and focused on the more detailed policy options to set minimum requirements for reused water for irrigation and groundwater recharge.

In total, 344 respondents participated in the consultation. Responses were received on-line from 103 individuals (30% of respondents) and 239 stakeholders or experts (70% of respondents). Respondents represented a variety of stakeholders groups, economic sectors and countries:

- **Type of stakeholders:** Private companies, water utilities and providers and industry or trade associations represented more than a third of total respondents, a similar proportion to citizens. Public authorities represented 12% of respondents, respondents from academic/scientific/research field represented 9% and NGOs and international bodies represented less than 5% of respondents.
- **Economic sector:** Organisations involved in sanitation and/or drinking water sectors represented half of the respondents. About 20% of respondents reported to be involved in the environment and climate sectors, while only 10% represented the agriculture sector. Food industry, health and economics sector had even lower response rates compared to previous categories (each less than 5% of respondents),
- **Countries:** The large majority of responses were received from within the EU (98%). Half of the responses were provided by three Member States: Spain, France and Germany with particularly high contribution from Spain (more than one quarter of all participants). Twenty countries provided ten answers or fewer.

After both online consultations a dedicated stakeholder meeting was held (on 4 December 2014 and in March 2017); draft results of the analysis were discussed with stakeholders and additional contributions were collected. The reports on the public consultations are available at the Website of the initiative mentioned above.

## ***A. The need for EU action***

### *Perceived benefits of water reuse*

There is a wide perception among respondents of the benefits of reusing water for irrigation or aquifer recharge purposes with regards to the availability of water resources, in the context of water stress or scarcity, unsustainable abstractions and climate change (perception from more than 70% of respondents across and within different categories of respondents). The potential contribution of water reuse to the quality of water bodies, through preserving groundwater from salinization and reducing pollution discharge from urban waste water treatment plants, into rivers, is perceived by a large number of respondents as well. Furthermore, water reuse is also perceived by a number of respondents as a means to increase resource efficiency, foster

innovation and contribute to soil fertilisation, although these benefits were considered more moderate compared to the former ones. Several respondents - in particular from the health, environment and agriculture sectors - expressed their concern about the difficulty for water users (in particular farmers) to accurately estimate the amounts of nutrients present in the reused water to fully benefit from nutrient recycling and prevent risks of environmental contamination.

On the other hand, respondents are much less inclined to perceive cost savings for authorities, increased revenues, or energy and carbon savings as benefits of water reuse.

The analysis per category of respondents shows in particular that:

- countries regularly exposed to water stress and countries from Southern EU perceive significantly more and higher benefits than other categories of respondents,
- large consensus is found about these benefits within the respondents from the sanitation, drinking water, environment and economics sectors.

### *Perceived barriers*

The main barriers to water reuse as identified by respondents are similar for water reuse in irrigation and aquifer recharge. They primarily include:

- the negative connotation of water reuse (perceived as a high or medium barrier by about 80% of respondents), including lack of awareness of costs and benefits of reuse schemes
- barriers related to policy or governance, including insufficient clarity in the regulatory framework to manage risks associated with water reuse or insufficient consideration for water reuse in integrated water management (nearly 90% of respondents perceived them as high or medium regarding irrigation and over 80% regarding aquifer recharge),
- economic barriers, including the low price of freshwater compared to that of reused water (especially in countries not affected by water scarcity) and the high cost of treatment for production of reused water (perceived as a high or medium barrier by about 80% of respondents) and fear of potential trade barriers in the case of irrigation.

In the specific case of irrigation, the distance between waste water treatment plants and irrigation fields is also seen as a key barrier (2<sup>nd</sup> most pointed out by respondents). In addition to recognising different barriers listed in the consultation, some respondents or participants to the Stakeholder meeting also expressed their concerns regarding potential risks for the environment of reusing water for irrigation, through the perturbation of environmental flows (e.g. limitation of river flows in regions affected by water scarcity) and the potential salinization through the reuse of waste water. In the case of aquifer recharge, additional concerns were expressed regarding risks of contamination of the aquifers and its irreversibility, due to the difficulty to remove pollutants from this water body.

On the other hand, significantly fewer respondents perceive awareness and availability of technical solutions to produce safe water as barriers, except in Eastern EU Member States.

Most barriers are perceived by respondents from Southern EU Member States and countries facing regular water stress, which practically experienced water reuse and often have stringent water reuse schemes in place.

### *Perceived safety of treated water reuse*

There is an overall consensus amongst respondents about the safety of reused water compared to water from rivers, as nearly 70% of respondents (amongst those who had an opinion) consider reused water as at least as safe, both for irrigation and for aquifer recharge. In comparison, the safety of reused water compared to groundwater is more controversial, as 50% of respondents consider it less safe for irrigation and 44% for aquifer recharge.

These overall statistics hide in reality very different perceptions from specific categories of respondents. Some categories of respondents have a particularly positive or negative perception of reused water depending on their economic sector, type of organisations, situation of water stress or EU regions:

- respondents from Southern EU Member States and countries facing regular water stress are significantly more inclined to consider reused water for both irrigation and aquifer recharge as being at least as safe as alternative sources (rivers or groundwater) than respondents from Eastern and Northern countries, which tend to consider reused water as less safe in the same proportions;
- respondents from some economic sectors also have a particular negative perception of reused water safety, such as the health sector, for which 70% of respondents perceive reused water as less safe than groundwater for irrigation purposes;
- on the contrary, respondents from private companies show by far the most positive perception of reused water safety compared to other types of organisations, keeping in mind that they are involved at 68% in drinking and sanitation sectors.

The perception of reused water safety may also significantly differ within categories of respondents, as it is the case within the agriculture, food and environment sectors, for which no clear position could be seen based on the public consultation.

### *Justification of EU-level instrument*

Although in the online public consultations in 2016 and 2014 over 60% to 80% of all respondents were in favour of an EU regulatory framework, there is no clear consensus across all types of respondents on the most suitable type of EU instrument - as listed in the questionnaire - to promote water reuse in irrigation and in aquifer recharge. In addition, more than 80% of respondents to the online public consultation held in 2014 considered legally binding EU minimum standards as effective to ensure the environmental and health safety of water reuse practices.

The respondents which are mostly in favour of the instrument of an EU regulation, in both cases, are representatives from private companies, from the sanitation, drinking water, food industry and environment sectors, and/or from Southern countries. Respondents from agriculture and economics sectors<sup>17</sup> as well as industry or trade associations show less consensus on supporting this policy option.

Overall, the option of the instrument of a Commission recommendation is the 2<sup>nd</sup> preferred policy option within and across most categories of respondents, although CEN standards are generally preferred by respondents from agriculture, food and health sectors for water reuse in irrigation. The highest level of support for the use of Commission recommendations comes from water providers/utilities and public authorities as well as respondents from Eastern EU Member States.

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<sup>17</sup> i.e. any industrial sectors other than food, drinking water and sanitation

These results should be considered with caution, as many comments - from respondents who selected the EU regulation or Commission recommendations - pointed to the preference for an EU Directive, which was perceived to provide both sufficient level of protection to reach its objectives and adaptability to be relevant to local contexts and needs. However, this was not listed in the closed list of policy options from the public consultation and also the impact assessment did not consider a Directive as an option as it would impose requirements also on Member States which otherwise don't intend to reuse water.

### ***B. Scope and level of ambition***

#### *Objectives of the EU minimum quality requirements for water reuse*

Respondents to the public consultation identify in their vast majority (>70%) the following objectives as key for the EU minimum quality requirements for water reuse:

- For irrigation, the protection of human health of consumers through the safety of agricultural products placed on the EU market, of human health of public directly exposed to reused water, of water resources and dependent ecosystems, and of the wider environment.
- For aquifer recharge, the protection of water resources and dependent ecosystems, of human health of the public directly exposed to reused water and of future users of water abstracted from the aquifer.

These objectives are largely supported by the civil society and public authorities and are shared within and across economic sectors. They are also mostly shared within and across EU regions, except for the protection of human health of public directly exposed to water reuse in the case of irrigation, which was recognised as an objective by a lower share of Eastern EU Member States compared to other EU regions (50% vs. 70% for other EU regions).

In comparison, in the specific case of irrigation, the protection of agricultural productivity is not given as much importance (40% of respondents only think it should be covered). Yet, a large majority of respondents from the agriculture sector still considers it as an objective to be addressed by EU minimum quality requirements for irrigation (75% of respondents). A significantly higher share of respondents from Eastern EU Member States also identified it as an objective compared to other EU regions.

#### *Specific aspects to be covered by minimum quality requirements for water reuse*

Priority aspects to be covered by minimum quality requirements for water reuse in irrigation include: microbiological contaminants, monitoring, and other chemicals addressed by EU legislation, both for irrigation and groundwater recharge purposes. While these aspects are generally subject to large consensus within and across key categories of respondents (economic sectors, types of organisation), the following differences can be noted:

- Respondents from the agricultural sector are less favourable to including aspects related to monitoring, while there is strong support from most other sectors,
- Respondents from the food, drinking water and sanitation sectors are also the least inclined to identify additional chemicals as aspects as needing to be included.

Other aspects are more controversial within and across categories of respondents, such as risk-based management or the question of nutrients. Risk-based management approaches were considered by many respondents and participants as relevant to ensure adequate protection of health and the environment, but their practical implementation was subject to extensive discussions. They can be perceived as costly, time-consuming and requiring specific expertise. The question of nutrients is considered as a priority aspect to be covered when

reusing water for aquifer recharge while interest for such an aspect is more moderate for irrigation purposes. There, it can be seen both as a benefit from a recycling perspective and a key barrier for ends-users like farmers, with high risks of environmental contamination (nutrient surplus and leakage to the aquifer, eutrophication). Yet, this aspect is, in both cases, of very high interest to the health sector (73% in the case of irrigation and 79% in the case of aquifer recharge). Some respondents were concerned that water reuse, if not well regulated, may contribute to pollution of aquifers and soils, although to a lesser extent.

*Other uses which are out of the scope of this initiative*

A large majority of respondents considers the possibility or even the need for other types of uses than irrigation and aquifer recharge to be covered by EU minimum quality requirements. The limitation of the scope is described in section 1.2.1 of the IA report.

In particular, there is a large consensus, namely half of the respondents (and in particular within the health and the environment sectors) on the possibility or need to expand EU minimum requirements beyond agricultural irrigation to the irrigation of sport fields and urban green spaces.

The idea to expand EU minimum requirements particularly to industrial uses as well as to other urban uses is slightly more debated across respondents. Twenty percent and fifteen percent (respectively) of respondents would not like these uses to be covered by EU requirements (compared to 10% for both other uses), while 40% of respondents think they should be included. Comments from some respondents on industrial uses highlighted a possible confusion with regards to the scope of the water reuse initiative for irrigation and aquifer recharge: they put forward initiatives from the industry in terms of recycling and reuse of their own waste water, while the waste water considered in this initiative must be covered by the UWWTD.



### **Annex 3 - Who is affected by the initiative and how**

This Annex sets out how the new legal instrument would function in practice in the Member States.

As indicated in the description of the policy options, the legislative instrument will require that **any water reuse scheme is subject to a permit** delivered by competent authorities in Member States; EU minimum quality requirements will apply to those permits. It will in no case be imposed on Member States to develop or promote water reuse in their territory.

The key principles of a risk management framework would be compulsory as part of the authorisation procedures and conditions of granting permits to any water reuse project in the EU (as described in section 4.2). The key principles would cover the different steps and operators of the water reuse system (urban waste water collection and treatment, additional treatment if any, distribution, storage if any and irrigation at farm). In practice, the legal instrument would foresee that, before such a permit can be authorised, the applicant of the permit has to perform a thorough identification and assessment of risks specific to the project and its environment. Key requirements for this risk assessment would be laid down based on description of the risk management framework in Annex 7 and would cover:

- **description** of the water reuse system;
- **identification of hazards** and risk assessment, in particular:
  - o additional characterisation and monitoring of pollutants in raw effluent (source control);
  - o characterisation of human exposure and of the local environment vulnerability;
- **determination of preventive measures** to limit risks, e.g. including requirements on wastewater treatment, restrictions on crops and irrigation techniques, access to fields, buffer zones etc.
- **operational procedures** to ensure the system will deliver the appropriate safety, including verification of water quality and management of incidents and emergencies, need for advanced additional mitigation measures regarding treatment, access to fields, buffer zones etc.

Reflecting the outcome of the risk assessment, the permit to be delivered by competent authorities in the Member States would include additional conditions to the minimum requirements ensuring safety of agricultural products, in terms of:

- additional quality criteria (parameters and limit values) to be complied with, at the outlet of the (advanced) treatment plant or in more appropriate location in the system;
- monitoring frequencies for these quality criteria;
- additional preventive measures conditions;
- management plan and procedures to be followed when operating the water reuse system.

A water reuse scheme involves a number of operators, respectively in charge of collection and treatment of urban waste water, additional treatment for achieving the required quality for reuse (as necessary), possible storage, distribution to farms and to irrigated fields, application to crops etc. Designs of water reuse schemes are very diverse in Member States and distributions of roles and responsibilities differ widely; as a result holders of existing permits for water reuse may be any of the above operators, or any association of those.

#### ***Application of the "fit-for-purpose" approach***

The legislative proposal requires different levels of quality depending on the crops and irrigation techniques. As a result, in the design of a water reuse scheme, a quality class will be targeted, and the treatment technology will be installed and operated accordingly. When this

quality is lower than the most stringent one in the legislative proposal (class A) irrigation will be allowed only for certain crops and with certain irrigation techniques, as detailed in the legislation proposal. The "fit-for-purpose" requirements allow for certain flexibility in adapting the level of treatment to the actual use in irrigation:

- in farming areas where only crops with low sensitivity are grown with irrigation technique that prevent contact with edible part of the crop, a less stringent water quality will be allowed, thus saving treatment costs;
- where crops with different sensitivities are grown in different periods, the level of treatment can be adapted and changed between periods, e.g. by turning off or by-passing the most advanced disinfection treatment
- when crops with different sensitivities are grown in different areas with separated distributions systems, the level of treatment and the quality of reclaimed water can be adapted and different in the different distribution systems.

#### ***Application to existing water reuse schemes***

Existing legislations in Member States already require water reuse schemes to be subject to an authorisation. Existing legislations and authorisations will need to be reviewed and possibly revised to comply with the new EU legislation. The legal instrument would set a transition period [2 years] for existing legislations and water reuse schemes to be made compliant.

As regards quality criteria, in many cases the ones imposed by existing legislations in Member States, are more comprehensive and more stringent than the ones required by the future legislative proposal. In a few cases where existing legislations and authorisations impose less stringent quality criteria, these will need revision, e.g. microbiological criteria for validation of the most stringent quality class (irrigation of crops consumed raw which edible part are in direct contact with reclaimed water) in Spain. This will impact on both the competent authorities (revision of legislation and existing permits) and holders of permits (adaptation of the level of treatment, with possible increase in treatment cost).

In many cases quality criteria in the new EU legislation will be less stringent than required by the national legislation. As the EU legislation will set only minimum requirements, Member States will not be obliged to change their legislation to align with the EU standards. However it is expected that this EU legislation will trigger discussion in Member States regarding the evidence base and relevance of national legislation. This would lead to some revision of existing national legislation, and be reflected in less costly treatment requirements.

Additionally existing authorisations in Member States are usually granted on the basis of an ex ante assessment of impacts; permit conditions are set to mitigate identified risks and impacts. This process (ex ante impact assessment and mitigation measures) fulfils to a certain extent the risk management framework required by the future legislative proposal. However in most cases part of this risk assessment will be missing, e.g. as regards accumulation of pollutants in soils. In those cases additional assessment and possibly additional conditions to the permit will be needed to comply with the new legislative instrument. Additional conditions will mostly consist of additional monitoring, and additional treatments. Depending on the decision by competent authorities in Member States this additional assessment and additional measures is likely to be at the expenses of the permit holder. As this additional risk assessment will further ascertain and quantify risks, it is expected that it will also contribute to fit existing conditions to actual risks, and in particular allow for less costly monitoring and treatment requirements.

Beyond possible specific changes to the treatment facility, it is expected that the new EU Legislation will not require any further change into the existing infrastructure, in particular as regards storage and conveyance of reclaimed water to farms, and a farm level.

#### ***Application to new water reuse schemes***

Any new water reuse scheme shall be subject to a permit delivered by competent authorities in Member States and complying with the EU minimum quality requirements. This permit will be granted on the basis of a risk assessment by the applicant complying with the EU requirements. Permit conditions will include at least the minimum quality criteria of the new EU legislation and additional conditions as deemed necessary to manage the identified risks.

In Member States with no legislation in place, no new and specific legislation will be needed to regulate new projects as the EU legal instrument will provide a full-fledged legislative framework that can be directly implemented by competent authorities and applicants of permits.

In Member States where existing legislation already regulate water reuse, revision will be required within a transition period, on aspects for which the EU requirements are more stringent. For aspects where the EU legislation is less stringent, no revision will be legally required but some can be expected as result of discussion triggered by the new EU legislation.

When a new water reuse scheme is developed in an area where irrigation does not exist and/or when this project will convey water to farms or fields which were not irrigated before, investment will be necessary to develop the infrastructure downstream of the urban waste water treatment plant, both off-farm (facilities for additional water treatment, storage, distribution) and on-farm (distribution to field, irrigation material). The impact of the project is likely to increase the abstraction pressure on water resources. In those cases, it will be the responsibility of the competent authorities in Member States to check that this new / increased pressure will not impair the status of the water body, as required by the WFD, before issuing any such permit.

When a new water reuse scheme is developed to bring reclaimed water to farms which were already practicing irrigation before with individual access to water, investment will be necessary to develop an off-farm infrastructure downstream of the urban waste water treatment plant, both off-farm (facilities for additional water treatment, storage, distribution) but it is expected that on-farm equipment will not require significant additional investment. In cases where the farming area depends on a collective access to irrigation, it is expected that most of the distribution and storage infrastructure can also be used for reclaimed water; new investment will be limited to the additional treatment (if necessary) and conveyance from the urban waste treatment plant to the collective distribution system. In both cases the new water supply can be used either to substitute or to increase the volume of irrigation water. It will be the responsibility of the competent authorities in Member States to check that the project will not impair the status of the water body, as required by the WFD, before issuing any such permit. It is expected that, for most projects developed in water scarce areas, the volume of reclaimed water will result in a full or partial substitution of existing abstractions on over-exploited resources (and revision of existing abstraction permits accordingly), with a positive impact on those resources. However it could also result in the opposite impact with increased irrigation and increased negative impact on water resources, similarly to the "rebound effect" of water saving technologies which tends to increase (rather than decrease) the rate of water consumption (cf. Blueprint). The actual impact on water resources will ultimately depend on the decision of the competent authority that will have the possibility to condition the permit for a new water reuse scheme to a reduction of existing abstraction permits.

### *Coherence with other EU legislation*

Quality requirements would complement, but not decrease, the ones laid down by the UWWTD and relevant European Case-Law<sup>18</sup> in particular as regards the quality of discharge effluents. When complying with the new legal instrument, reclaimed water at the outlet of the treatment plant would need to respect the criteria of the "clean water" as defined by the Regulation on the Hygiene of Foodstuffs (852/2004). Hence consistency with other relevant legislation is ensured in either approach. It is to be noted that this "clean water" definition pertains to its envisaged use in primary production and regarding the safety of foodstuffs. It does not prejudice its possible impact on water resources and ecosystems<sup>19</sup>. In practice the proposed legal instrument would foresee that whenever reclaimed water is used for agricultural irrigation in an EU Member State, this is subject to a permit. In any case the urban waste water treatment plant would still be subject to the application of the UWWTD, taking into account the nature of the area where the irrigation will take place, and farmers would retain the responsibility to maintain this status of clean water and of other duties laid by Regulation 852/2004 (as for any other irrigation sources). Member States competent authorities would be responsible for enforcing the permit and carrying out inspections as necessary.

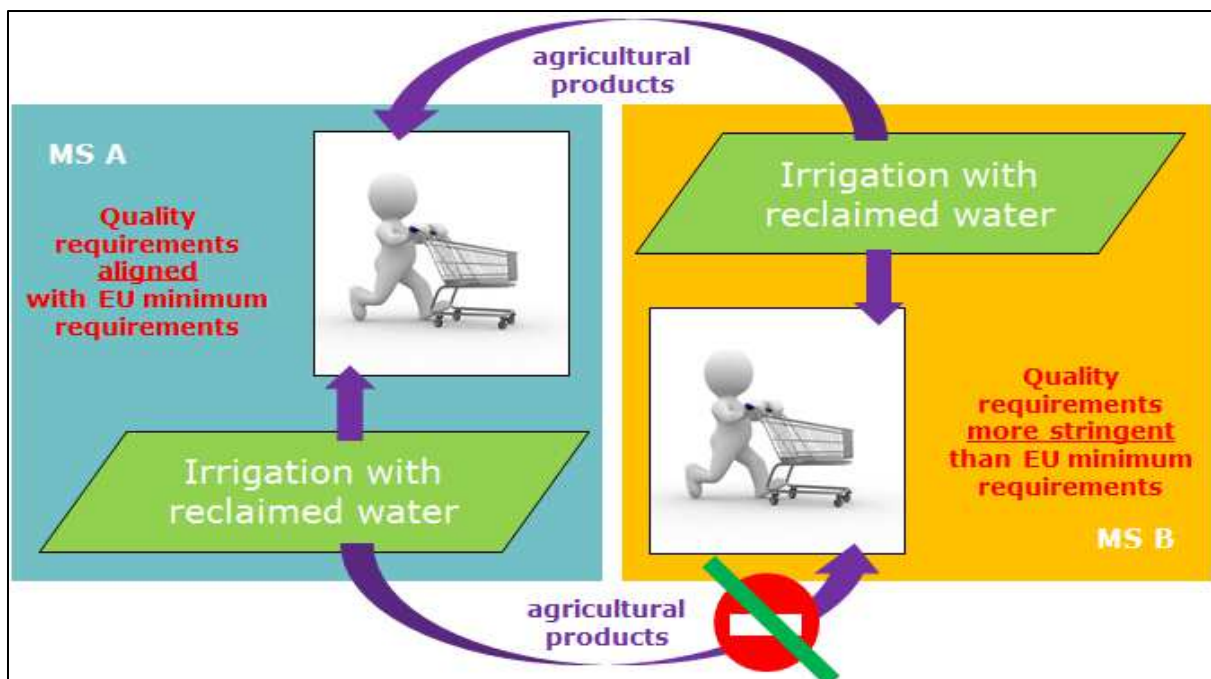
As depicted in Figure 10 (see section 4.3.3 above), the legal instrument would set minimum requirements, and any Member State (Member State B in the Figure) could still adopt or retain more stringent legislation for water reuse in its territory. However, no Member State could ban imports of food products irrigated with reclaimed water in another Member State (Member State A in the Figure) enforcing the legal instrument.

*Figure 10: trade of agricultural products irrigated with reclaimed water within the EU*

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<sup>18</sup> ECJ Judgement cases C-119/2002, and C-335/07

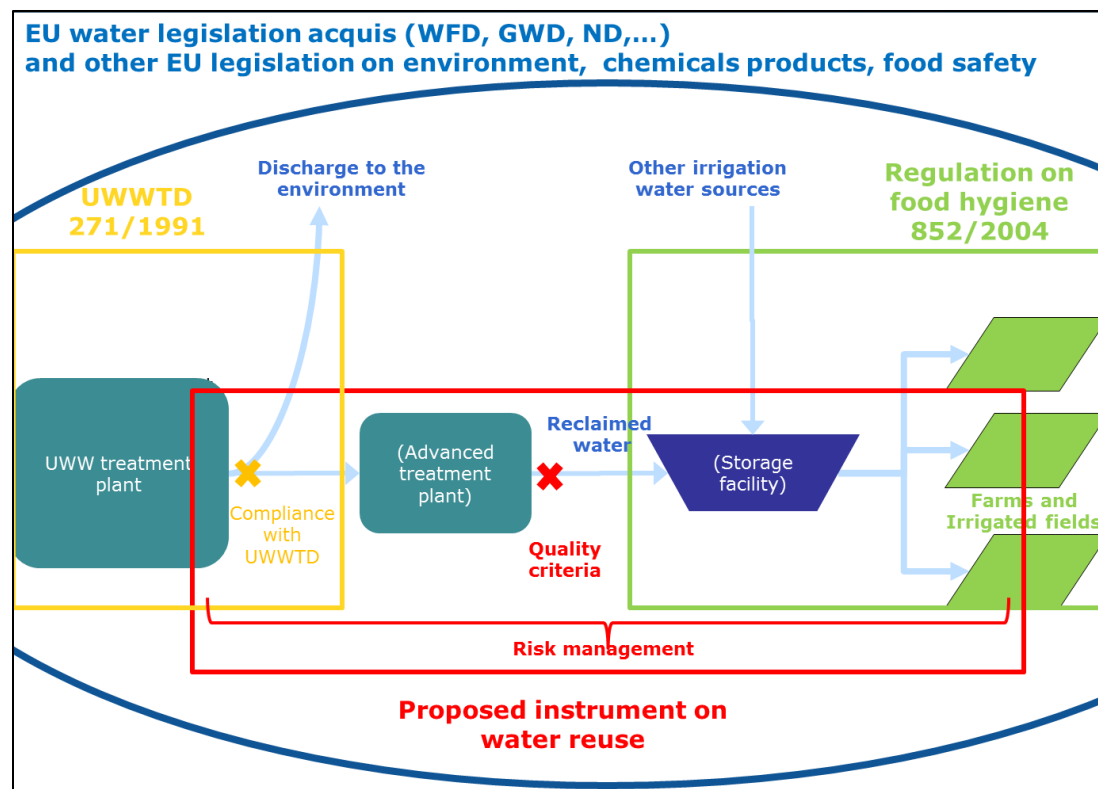
<sup>19</sup> E.g. nutrient content of reclaimed water is not specifically addressed in these requirements because of their safety to foodstuffs, while they may negatively affect the trophic status of receiving waters.



As illustrated by Figure 10, the proposed instrument would complement existing legislation and address specific risks in the context of water reuse projects typically composed of:

- an urban waste water treatment plant
- a possible advanced treatment plant
- infrastructure conveying reclaimed water from the (advanced) treatment plant to farms irrigated fields, possibly with intermediary storage facilities.

*Figure 23: Existing EU legislation and proposed instrument for water reuse*



In this system, all impacts on surface waters, ground waters and dependent ecosystems are subject to provisions of existing water law, in particular the WFD, the Groundwater Directive and the Environment Quality Standards Directive. The UWWTD also sets requirements on the collection and treatment of urban wastewater and on the quality of effluent discharged to the environment, including specific requirements for discharges into sensitive areas and/or their catchments, nutrients removal and other treatments such as disinfection. These requirements also apply to water that will be reused. Given its nutrient content, reclaimed water is to be considered as a fertilizer and its application on agricultural land is subject to the provisions of the Nitrates Directive (91/676/EEC), in particular as regards periods when the land application of fertilizers is prohibited and balanced fertilization measures, such as the inclusion in fertilizer plans and in the records of fertiliser use, and also of the UWWTD if the irrigated lands are sensitive areas or their catchments, which require nutrients removal. Detailed interpretation of these requirements is provided in the “*Guidelines on Integrating Water Reuse into Water Planning and Management in the context of the WFD*”.

On the other hand, as mentioned above, the use of reclaimed water in irrigation for primary production of food products is subject to the requirements of the Regulation on the Hygiene of Foodstuffs. According to its Annex I / Part A setting hygiene provisions for primary production and associated operations:

2. As far as possible, food business operators are to ensure that primary products are protected against contamination, having regard to any processing that primary products will subsequently undergo. [...]

4. Food business operators rearing, harvesting or hunting animals or producing primary products of animal origin are to take adequate measures, as appropriate: [...]

(d) to use potable water, or clean water, whenever necessary to prevent contamination; [...]

Therefore as any other irrigation water source, reclaimed water for irrigation should comply with the definition of "clean water" at the point of use, i.e. water "that does not contain micro-organisms, harmful substances in quantities capable of directly or indirectly affecting the health quality of food" according to article 2 of Regulation 852/2004. This "clean water"

requirement is not translated into a set of quality standards in the Regulation. Further details on implementation on grounds of this requirement are given in the Commission Notice on "Guidance document on addressing microbiological risks in fresh fruits and vegetables at primary production through good hygiene" (2017/C 163/01 of 23 May 2017).

Figure 24: Overview of benefits and costs

I. Overview of Benefits (total for all provisions) – Preferred Option(s)		
Description	Amount	Comments
<b>Direct benefits</b>		
Reduction of water stress	more than 5%, corresponding to a benefit of about EUR 3 billion/year for the whole EU assuming a willingness to pay of about EUR 0.5/m <sup>3</sup> for preserving natural flows in rivers and aquifers.	Ir2 would enable reusing more than 50% of the total volume theoretically allocated for irrigation; the total available volume would enable a water stress reduction of ca.10%, Ir2 would enable a reduction of more than 5% (see section 5.2.1)
Reduction of nutrient pollution	more than 5% of agricultural mineral fertilizers	Ir2 would enable reusing more than 50% of the total volume that can be theoretically allocated for irrigation; as the total volume would enable reducing the use of mineral fertilizers in agriculture by about 10%, Ir2 would enable a reduction of more than 5% (see section 5.2.1)
<b>Indirect benefits</b>		
Increased reliability of water supply for agricultural irrigation and therefore more sustainable production of agricultural products.	Not quantified at EU scale, but in the order of 1 billion/drought year. In the Po plain, Italy, costs were quantified in EUR 500-1000 million during a drought year. <sup>20</sup>	Reuse would enable farmers to depend less on freshwater resources, whose use may be more severely restricted during droughts.

II. Overview of costs – Preferred option(s)						
	Citizens/consumers		Businesses		Administrations	
	One-off	Recurrent	One-off	Recurrent	One-off	Recurrent

<sup>20</sup> In a paper on the Po plain in Italy, Musolino et al. (2017) quantify an impact of droughts on the overall welfare (farmers+consumers) in the order of EUR 500-1000 million/year during droughts. The affected population is more than 16 million persons. This may suggest a cost of about 30-60 Euro/person during drought years and is in fact in line with the figures on the willingness to pay provided above. The authors stress that farmers alone benefitted from drought as the price increase was stronger than the production loss in the area. As reuse contributes to water stress reduction in the order of 10%, we may assume an indirect benefit of 50-100 million Euro during drought years, for the Po plain alone. Considering a drought that simultaneously affects an area 10 times as big as the Po plain in Europe, the indirect benefits for the whole of Europe would go back to 500-1000 million Euro during a drought year. Source: Dario Musolino, Alessandro de Carli, Antonio Massarutto, Evaluation of the socioeconomic impacts of the drought events: The case of the po river basin. Europ. Countrys. · 1 · 2017 · p. 163-176 DOI: 10.1515/euco-2017-0010.

Water reuse development <sup>21</sup>	Direct costs	-	Top-up of farmers' payment for reused water: EUR 0.25 /m3	Investment for reuse system infrastructure (treatment+ transport): EUR 700 million <sup>22</sup>	Farmers' payment for reused water EUR 0.25 /m3; Monitoring by the reclaimed water provider <sup>23</sup>		Monitoring results review, inspections
	Indirect costs						
Risk assessment <sup>24</sup>	Direct costs			Studies to support risk quantification		Administrative procedure for risk assessment technical work for risk quantification review	
	Indirect costs						Managing public access to information

<sup>21</sup> For the sake of this Impact Assessment, and without prejudice for future specific assessments in other contexts, the calculations assume a total levelized cost of reused water of EUR 0.5 /m3, of which approximately 50% is paid by the farmer and 50% by the citizens in exchange of the corresponding environmental benefits.

<sup>22</sup> These costs are part of the estimated recurrent costs.

<sup>23</sup> The total costs of water reuse are assumed to correspond to 0.5 Eur/m3. In principle, these costs should be covered by the water user, but in many cases there may be a more general interest in water reuse because of the broad benefits it may bring for water stress reduction. Consequently, it is possible that part of the costs be subsidized through taxpayers' money or passed on to consumers through increases in prices. In this table, exclusively for the sake of providing a first quantification, we assume that the cost of reused water be equally shared between farmers and taxpayers (or consumers), 0.25 Eur/m3 each

<sup>24</sup> Costs not quantified



## Annex 3a –SME test

### **(1) Preliminary assessment of businesses likely to be affected**

A total of roughly 11 million farms operated in the EU-28 in 2013. All the farms of the European Union are micro or small following the definition of the EU enterprises. Very few farms are small and the wide majority are micro enterprises<sup>25</sup>.

The total number of jobs in agriculture is 8.7 million jobs in terms of Annual Working Units (AWU) when in irrigated farms is 20% according to Eurostat. The production value is 26% in irrigated farms on the total Standard Output. The number of irrigated farms is in total 1.7 million, 16% of total farms.

In 2013 the total irrigated area in the EU was 10.2 million hectares, accounting for 5.9% of the total Utilised Agricultural Area (UAA). Southern European countries like Spain, France, Italy, Greece and Portugal show the highest amounts of irrigated land. Indeed, in Southern Europe agriculture accounts for more than 50% of water abstractions: Spain (60%), Greece (88%). Together, these countries account for 86% of the total. On the other side, in Denmark and the Netherlands irrigated UAA makes up less than 3% of the total UAA.

### **(2) Consultation with micro and small enterprises representatives**

The farmers' association at EU level (COPA-COGECA) was overall appreciative of the concept, stating that it will contribute to a more resilient farming sector, help overcome pressures deriving from climate change and, in upcoming years, be not only an alternative supply option but rather the most important source of clean water. Challenges highlighted were the need to identify the right quality of water, whereby the minimum quality requirements must take into account specific local needs and give flexibilities to the regions and Member States. Reclaimed water for irrigation should be nutrient-free as well as particle-free. Affordability of the proposed water reuse schemes should be carefully considered. COPA-COGECA further indicated that the compliance should be at the point where reclaimed water is discharged by the treatment plant. Finally, any new instrument should be light and not inflict administrative burden. It should only apply to those practicing reuse.

### **(3) Measurement of the impact on SMEs**

Farmers are affected in proportion to the volume used of reclaimed water and therefore micro enterprises are not affected differently than bigger farms. Moreover, it is by crop type grown that requirements in stringency differ, for instance for so called energy crops the minimum requirements are much lower than for fruit and vegetables. Therefore fruit and vegetable growers are more significantly affected in case they irrigate with reclaimed water than farmers growing energy crops.

<sup>25</sup> [http://ec.europa.eu/growth/smes/business-friendly-environment/sme-definition\\_en](http://ec.europa.eu/growth/smes/business-friendly-environment/sme-definition_en)

As regards water costs for irrigation paid by farmers in 2013, on the basis of FADN (Farm Accountancy Data Network) for agriculture, the ratio of water costs for irrigation on total intermediate consumption (specific costs and farming overheads), the situation by Member State is the following:

MS	In % 2013	MS	In % 2013
Belgium	0,32	Lithuania	0,44
Bulgaria	0,70	Luxembourg	2,13
Cyprus	2,72	Latvia	0,08
Czech Republic	0,46	Malta	0,71
Denmark	0,32	Netherlands	0,24
Germany	0,71	Austria	0,24
Greece	3,08	Poland	0,51
Spain	4,42	Portugal	0,27
Estonia	0,07	Romania	0,99
France	0,94	Finland	0,42
Croatia	1,11	Sweden	0,25
Hungary	0,51	Slovakia	0,26
Ireland	0,48	Slovenia	0,94
Italy	1,53	United Kingdom	0,79

The incidence of costs for irrigation is generally low in comparison with the total intermediate consumption. It appears to be more important in Spain, Greece, Cyprus, Italy, Luxembourg and Croatia. In Spain the incidence of water cost on the output per group of crops is measured at 4.1% for field crops, 4.2% for horticulture and 4.9% for permanent crops. The same indicator amounts to 1.2% on field crops, 0.3% for horticulture, 0.9% for permanent crops in Italy, while in Greece the water costs paid compared to output are at 2.7% for field crops, 1.5% for horticulture and 1.9% for permanent crops.

However these prices paid for water do not reflect the real water costs of irrigation as often these prices are subsidised and are therefore borne by society and the environment.

The impact assessment calculates the amount of reclaimed water which could be made available to farmers at the cost of 0.5 €/m<sup>3</sup>. In water scarce areas 0.5 €/m<sup>3</sup> is a competitive price given the fact that prices for conventional water are in the same order of magnitude in areas of severe water stress and would not raise irrigation costs significantly compared to

total intermediate consumption. For instance according to Custodio (2015) common prices for groundwater in Spain range between 0.3 and 0.5 €/m<sup>3</sup> (and can be higher depending on conjoint use and the cost of energy for pumping). In the Canary Islands usual prices are around 0.5 €/m<sup>3</sup> though during peak demand they can go beyond 1 €/m<sup>3</sup>. Existing irrigation freshwater tariffs range significantly across Greece (0.02-0.70 €/m<sup>3</sup>)<sup>26</sup>. (For more information please see in Annex 4 the sections for some selected MS.)

Moreover estimations of the Commission show that by 2030 important spring and summer droughts are expected in Southern and Centre of Europe to a degree that competition among sectors for water is expected to raise water prices. Under these conditions reclaimed water becomes progressively more competitive compared to other water sources used for irrigation.

Reclaimed water can be of major interest for farmers when urgent irrigation interventions in water stress conditions for crops is necessary (e.g. the case of summer 2017 when some of the crops' production was lost due to drought). Farmers could be interested to pay a higher price to save crops at risk of total or partial loss. Moreover farmers can benefit from a secure water supply if relying on reclaimed water for irrigation purposes, compared to the risk of unavailability of freshwater for irrigation purposes in case of water bans in water scarce areas in periods of severe water shortages. Increased reliability of water supply for agricultural irrigation and therefore more sustainable production of agricultural products could add up to benefits of EUR 500-1000 million during a drought year. Under these circumstances the cost of reclaimed water would be offset by these indirect benefits<sup>27</sup>. While this estimation is very rough, it at least shows that, in areas where droughts are (or are likely to become) common, water reuse is clearly also beneficial from an economic point of view.

Therefore farmers are motivated to substitute freshwater sources with reused water in areas with water stress, so areas where freshwater and other sources of water become unavailable (e.g. droughts and potentially resulting bans to use the available water for irrigation purposes) or too costly (e.g. increasing energy costs for pumping of the groundwater due to lowering of groundwater levels).

Willingness to pay for reused water will differ across regions depending on differences in water stress, availability of other conventional water sources and their price. Studies on

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<sup>26</sup> (Pinios case study, Annex 4)

<sup>27</sup> In a paper on the Po plain in Italy, Musolino et al. (2017) quantify an impact of droughts on the overall welfare (farmers+consumers) in the order of EUR 500-1000 million/year during droughts. The affected population is more than 16 million persons. This may suggest a cost of about 30-60 Euro/person during drought years and is in fact in line with the figures on the willingness to pay provided in Annex 4. The authors stress that farmers alone benefitted from drought as the price increase was stronger than the production loss in the area. As reuse contributes to water stress reduction in the order of 10%, we may assume an indirect benefit of 50-100 million Euro during drought years, for the Po plain alone. Considering a drought that simultaneously affects an area 10 times as big as the Po plain in Europe, the indirect benefits for the whole of Europe would go back to 500-1000 million Euro during a drought year. Source: Dario Musolino, Alessandro de Carli, Antonio Massarutto, Evaluation of the socioeconomic impacts of the drought events: The case of the po river basin. Europ. Countrys. · 1 · 2017 · p. 163-176 DOI: 10.1515/euco-2017-0010.

willingness to pay (see Annex 4 for more details) show that willingness to pay is extremely variable (for instance, Birol et al., 2007<sup>28</sup> estimate a willingness to pay higher than EUR 0.6 /m<sup>3</sup> in Cyprus, while Tziakis et al., 2009<sup>29</sup>, indicate less than EUR 0.1/m<sup>3</sup> for Crete), see Annex 4 for further details on the range of different studies and estimations for the value of 1 m<sup>3</sup> of water. These examples in the Annex highlight the large variability in valuation of water used to reduce water stress, and the uncertainty due to their high case-specificity. In this assessment, we adopt a benefit of water reuse of EUR 0.5 /m<sup>3</sup>, which is in the mid-lower end of the cases examined above, and may be argued to represent as a first approximation of the combined market and non-market value of water reuse in Europe, provided it contributes to reducing water stress. Therefore it can be concluded that in areas of high water stress it is a reasonable assumption that there would be an overall willingness to pay by farmers and society for the set 0,5 €/m<sup>3</sup> cost of reclaimed water, for which this impact assessment calculates the uptake of water reuse at this given cost.

#### **4) Assess alternative options and mitigating measures**

There are no mitigating measures necessary given the fact that micro enterprises and SMEs are not disproportionately affected.

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<sup>28</sup> Birol, E., P. Koundouri, and Y. Kountouris (2007), Farmers' demand for recycled water in Cyprus: A contingent valuation approach, in *Wastewater Reuse—Risk Assessment, Decision-Making and Environmental Security*, edited by M. K. Zaidi, pp. 267–278, Springer, Dordrecht, Netherlands.

<sup>29</sup> Tziakis, I., I. Pachiadakis, M. Moraitakis, K. Xideas, G. Theologis and K. P. Tsagarakis (2009), Valuing benefits from wastewater treatment and reuse using contingent valuation methodology, *Desalination*, 237, 117–125.

#### **Annex 4 - Analytical models used in preparing the impact assessment**

This annex provides a description of the models used for certain aspects of this impact assessment:

- The model developer and nature (public/private/open source) of the model;
- Model structure and modelling approach with any key assumptions, limitations and simplifications;
- Intended field of application and appropriateness for the specific impact assessment study presented;
- Model validation and peer review with relevant references;
- The extent to which the content of the model and input data have been discussed with external experts;
- Explanation of the likely uncertainty in the model results and the likely robustness of model results to changes in underlying assumptions or data inputs;
- Explanation as to how uncertainty has been addressed or minimised in the modelling exercise with respect to the policy conclusions; and
- The steps taken to assure the quality of the modelling results presented in the IA.

We make use of a hydro-economic model to estimate the demand of water for irrigation, and the costs of treating and deploying reclaimed water to agricultural land within a distance of 10 km from existing wastewater treatment plants. On this basis, we conduct the analysis of volumes and costs of reclaimed water under the two policy options “one size fits all” (Ir1) and “fit for purpose” (Ir2) considered in the Impact Assessment.

The key elements of the models are summarized in Table 1. In the following, we first introduce the models in more details, and then describe the main assumptions and sources of data used for the assessment. The material presented here is based on Pistocchi et al., 2018<sup>30</sup>.

In addition to describing the models used in this assessment, we provide details on (1) the quantification of the benefits from water reuse; and (2) the calculation of the administrative burden of the proposed instrument.

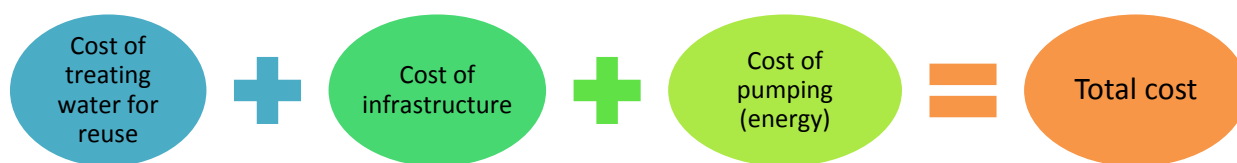
#### **General aspects of the models used in the Impact assessment**

The key assumptions and data sources are described in this Annex. The assessment refers to a conventional baseline where reuse is a negligible source of water for irrigation in Europe in the absence of specific policies, because of the lack of a clear legal framework enabling steady investment in this area. For the rest, we assume the water legislation (and particularly the Urban Wastewater Treatment Directive) to be correctly implemented across Europe.

The most critical aspect of the assessment is the evaluation of costs of reclaimed water. The cost of wastewater reuse is computed as the sum of the cost of: 1) treatment of water for reuse; 2) building infrastructures for water storage and distribution (pipelines and pumps); and 3) energy for reclaimed water pumping from the wastewater treatment plant to the neighboring agricultural areas (Figure 1).

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<sup>30</sup> Pistocchi, A., Aloe, A., Dorati, C., Alcalde Sanz, L., Bouraoui, F., Gawlik, B., Grizzetti, B., Pastori, M., Vigiak, O., The potential of water reuse for agricultural irrigation in the EU. A Hydro-Economic Analysis, EUR 28980 EN, Publications Office of the European Union, Luxembourg, 2018, ISBN 978-92-79-77210-8, doi 10.2760/263713



*Figure 1 – scheme of the costs considered in this assessment.*

Although both investment and operation costs of water reuse are highly dependent on conditions such as the level of treatment already existing at a plant and the size of the plant, mean levelized treatment costs<sup>31</sup> are pragmatically assumed to be constant across Europe. This assumption still enables analyzing the difference of the two policy options considered in the Impact Assessment, without the need for a representation of the variability of wastewater treatment plant conditions at European scale. Such representation would be anyway rather challenging to develop, due to the extreme sensitivity of investment and operation costs to local conditions. At the same time, while variable, the impact of treatment cost variability is attenuated by the variability of water transport costs that is, on the contrary, more predictable as it depends on distance, elevation differences and other relatively simple parameters (as also shown in the global sensitivity analysis exercise reported below). Therefore, in this assessment we refer to the mid-range of treatment costs provided by Iglesias et al., 2010. We assume option Ir2 to correspond to an intermediate treatment requirement corresponding to disinfection and depth filtration, and Ir1 to an advanced treatment with membrane filtration and disinfection.

In order to evaluate the potential of reusing reclaimed water, we estimate the cost of treatment and the cost of transport of water, which requires defining a source and a destination of reclaimed water in order to quantify a transport distance and an elevation difference for pumping. We assume that water sources coincide with wastewater treatment plants as depicted in the WaterBase – Wastewater v. 4.0 dataset made available at the European Environment Agency<sup>32</sup>. Moreover, we distribute in space the estimated irrigation demand assuming that all agricultural land excluding pastures is potentially irrigated, thus neglecting the actual distribution of irrigation infrastructure. We conduct appropriately aggregated calculations using the elementary sub-basins of the CCM2 database<sup>33</sup> as a mapping unit, without disaggregating results therein. A major source of uncertainty is represented by the spatial scale and resolution of the analysis. The assumptions made and the data used as input do not enable any conclusion on specific situations, but suggest only general trends valid at European scale. All conclusions of this assessment must be considered indicative at a broad strategic level, and can by no means serve the purposes of case-specific assessments. Particularly, the assessment cannot be regarded as a pointwise evaluation of the potential of a specific wastewater treatment plant, but as yielding representative frequency distributions of

<sup>31</sup> In analogy with the case of energy, the levelized cost is the net present value of the unit-cost of water over the lifetime of a generating asset.

<sup>32</sup> <https://www.eea.europa.eu/data-and-maps/data/waterbase-uwtd-urban-waste-water-treatment-directive-4>

<sup>33</sup> <http://inspire-geoportal.ec.europa.eu/demos/ccm/>

costs at a regional scale, such as EU NUTS2 level or river basins. Results are consistently presented at resolutions not finer than these.

The results of the EPIC model, while uncertain, have less critical implications for the conclusions of the study and were not subjected to specific uncertainty analysis. Their uncertainties are discussed on a qualitative basis, when necessary, in the specific sections of this document. EPIC has been calibrated using data publicly available from EUROSTAT and EEA.

This assessment is based on the current wastewater treatment plant system in the EU, as well as on current estimated irrigation requirements and fertilizer use. We do not make assumptions on other macroeconomic, socio-economic conditions nor policies and measures, as the scope is limited to quantifying a possible cost distribution for reuse of wastewater. Information on wastewater treatment plants in Europe is derived from the European Environment Agency’s Waterbase dataset, v. 4. Additional details on models, data, and the estimation of water quantity and quality at wastewater treatment plants are given in a JRC report accompanying this Impact Assessment.

<b>Model and model type</b>	<b>Developer</b>	<b>Intended field of application/appropriateness</b>	<b>Validation and peer review</b>	<b>Discussed with external experts</b>	<b>Quality control and uncertainty</b>
EPIC agronomic model	USDA (open source)	Simulation of crop yields, nutrient and water requirements; appropriate for irrigation demand estimation and the corresponding yields	Illustrated in this annex	EPIC model included in JRC Blueprint study. No specific discussion.	Illustrated in this annex
Hydro-economic model	JRC	Calculation of costs of water treatment and distribution; appropriate to extend simple cost calculations to the various contexts in Europe based on the spatial relationships of wastewater treatment plants and agriculture	FEASIBLE model equations endorsed by OECD. No specific validation.	FEASIBLE model used for other EC studies. No specific discussion.	Informal checks on compatibility of the results of equations with common experience; global sensitivity analysis

*Table 1 – models used in the assessment*

### **Hydro-economic model**

The equations used for the assessment of costs were developed specifically for the present assessment, following engineering assumptions widely adopted in practice, and are presented in a specific section of this report. The cost appraisal equations used for the assessment derive from the literature, and particularly from the FEASIBLE model (OECD, 2004) for what

concerns the cost of pipelines and pumping stations these were already used in previous assessments at the European Commission (e.g. European Commission, 2010); for the costs of storage, we follow the assumptions made in Maton et al., 2010.

For the cost calculations, apart from the sensitivity analysis conducted on purpose to address uncertainties, comparisons have been drawn with costs reported from experts referring to real cases in Europe or comparable contexts. For the purposes of this assessment, we assume the costs indicated by Iglesias et al., 2010, to be representative of the whole European context. It must be stressed that the costs considered here are additional to those required anyway to comply with the legislation on urban wastewater treatment.

For policy option Ir2 (“fit-for-purpose”), we assume treatment costs for a reference condition where effluent standards for reclaimed water can be obtained by a treatment consisting of depth filtration and disinfection, for which Iglesias et al., 2010, report a mean investment cost in the range of 28-48 €/m<sup>3</sup>/day) and an operation cost in the range 0.06-0.09 €/m<sup>3</sup>. Under option Ir2, in fact, it is possible that water is reused with lower treatment costs as well as higher treatment costs (the latter only for the share of water volumes requiring the highest standards). As it is currently impossible to assume how much of the water volume available for reuse will be treated at which level of quality, adopting a lower-middle level of treatment costs appears a reasonable pragmatic assumption. The range of levelized costs of treatment (LCOWt) is computed assuming a discount rate of 5% and a depreciation period of 20 years, as:

$$LCOWt = (LCOW_{t, \min} + LCOW_{t, \max})/2$$

with

$$LCOW_{t, \min} = 0.06 + 28 / pva(0.05, 20)/365$$

$$LCOW_{t, \max} = 0.09 + 48 / pva(0.05, 20)/365$$

and with  $pva(r, n)$ , representing the present value of investment cost annuity, defined in Equation 15 below. For policy option Ir1, we consider that membrane filtration and disinfection are required to achieve the quality standards. For this case, Iglesias et al., 2010, provide a mean investment cost in the range of 185-398 €/m<sup>3</sup>/day) and an operation cost in the range 0.14-0.20 €/m<sup>3</sup>. We compute the levelized costs of treatment as:

$$LCOW_{t, \min} = 0.14 + 185 / pva(0.05, 20)/365$$

$$LCOW_{t, \max} = 0.20 + 398 / pva(0.05, 20)/365$$

Table 7 summarizes the adopted levelized costs.

Option	LCOWt cost (min)	LCOWt(max)	LCOWt
Ir1	€ 0.18	€ 0.29	€ 0.23
Ir2	€ 0.07	€ 0.10	€ 0.08

Table 7 – water treatment costs assumed for the two policy options

The treatment costs are the only difference between the two policy options considered in this assessment. On the contrary, it is assumed that the infrastructure to distribute reclaimed water from wastewater treatment plants does not presently exist and needs to be developed.



The model adopted to calculate the cost of water distribution refers to the spatial support represented by the sub-basins of the CCM2 dataset<sup>34</sup>. Table 8 summarizes the attributes of sub-basins considered for model calculations.

Symbol	Description	Source
$i$	Sub-basin identifier	-
$(x_{p,i}, y_{p,i}, z_{p,i})$	Coordinates of the center of mass of WWTPs present in the SB	Computed with Equation 1 using the capacity of WWTPs (PE) as masses; coincides with WWTP coordinates if only one WWPT is present
$(x_i, y_i, z_i)$	Coordinates of the center of mass of agricultural areas present in the SB	Computed with Equation 2. Agricultural areas are all pixels in CLC2012 with level 1 code=2, excluding level 3 code 231 (pastures)
$A_i$	Extent of agricultural area in the SB	See above
$R_i$	Radius of inertia (dispersion) of the agricultural area in the SB	Computed with Equation 3. See above
$\varphi_i$	Porosity (share of the SB accessible for pipelines)	Computed with Equation 4 using Open Street Map roads layer, agricultural land (including pastures) and slope from SRTM 100 m DEM
$\tau_i$	Tortuosity	Computed from porosity using Equation 5
$Q_i$	output discharge of the WWTPs present in the SB	From EEA UWWTP database v.4 as revised by Vigiak et al., 2017
$\alpha_i$	fraction of discharge $Q_i$ that is reclaimed	Set to default of 1
LCOWt	Cost of water treatment at the WWTPs present in the SB	See § 6.2
$I_i$	irrigation demand in the SB	Estimated from EPIC under the “baseline” scenario, and from EPIC results with Equation 28 under the “potential” scenario
$T_i$	Duration of the irrigation period in the SB	Set to a default value of 4 months (120 days).
$\psi_i$	Cost of energy in the SB	Set to default of 0.10 €/kWh

Table 8 – summary of attributes of each sub-basin used in the calculation (SB=sub-basin)

For the generic  $i$ -th sub-basin, we define an equivalent WWTP with coordinates of the centre of mass of all WWTPs in the sub-basin, computed as:

$$\begin{aligned}
 x_{p,i} &= \frac{\sum_{k=1}^{m_i} P_k \xi_{pk}}{\sum_{k=1}^{m_i} P_k} \\
 y_{p,i} &= \frac{\sum_{k=1}^{m_i} P_k \eta_{pk}}{\sum_{k=1}^{m_i} P_k} \\
 z_{p,i} &= \frac{\sum_{k=1}^{m_i} P_k \zeta_{pk}}{\sum_{k=1}^{m_i} P_k}
 \end{aligned}
 \tag{Equation 1}$$

where  $m_i$  is the number of WWTPs in the  $i$ -th sub-basin,  $P_k$  the capacity (PE) of the  $k$ -th WWTP in the sub-basin, and  $(\xi_{pk}, \eta_{pk}, \zeta_{pk})$  its coordinates along the horizontal axes and elevation, respectively. We define an equivalent agricultural area in the sub-basin, with an extent equal to the total agricultural area  $A_i$  within the sub-basin, with coordinates of the centre of mass computed as

$$x_i = \frac{\sum_{k=1}^{n_i} \xi_k}{n_i}
 \tag{Equation 2}$$

<sup>34</sup> <http://inspire-geoportal.ec.europa.eu/demos/ccm/>

$$y_i = \frac{\sum_{k=1}^{n_i} \eta_k}{n_i}$$

$$z_i = \frac{\sum_{k=1}^{n_i} \zeta_k}{n_i}$$

where  $n_i$  is the number of agricultural pixels in the  $i$ -th sub-basin, and  $(\xi_k, \eta_k, \zeta_k)$  the coordinates of the  $k$ -th pixel along the horizontal axes and elevation, respectively. The dispersion of agricultural pixels around their center of mass is represented by the radius of inertia computed as:

$$R_i = \frac{\sum_{k=1}^{n_i} \sqrt{(\xi_k - x_i)^2 + (\eta_k - y_i)^2 + (\zeta_k - z_i)^2}}{n_i} \quad \text{Equation 3}$$

Each sub-basin is characterized by a porosity, meant as the share of its area where water can be in principle transported through pipelines. The latter is assumed to coincide with the ensemble of:

- A buffer of 100 m around all road infrastructure
- Agricultural land with terrain slope below 35°.

Porosity is defined as:

$$\varphi_i = \frac{\text{accessible area in sub-basin } i}{\text{total area in sub-basin } i} \quad \text{Equation 4}$$

In the analysis of costs of water reuse, we compute the length of pipelines assuming a Euclidean distance, hence a homogeneously accessible sub-basin, while in reality the actual length will tend to be higher depending on the tortuosity of its trail. We quantify the tortuosity using the theoretical model of Bruggeman (1935; see also Tjaden et al., 2016) for two-dimensional porosity:

$$\tau_i = \left( \frac{1}{\varphi_i^a} \right) \quad \text{Equation 5}$$

Where  $a$  is a parameter depending on the geometry of the pores. For a space filled by cylinders,  $a=1$  while, for a space filled by spheres,  $a=0.5$ . The higher  $a$ , the higher the tortuosity for a given porosity. In practice,  $a$  needs to be fitted to the specific case. In this exercise, we set  $a=0.5$  by default. Moreover, we do not allow  $\tau_i$  to exceed the value of 3.

Water potentially reclaimed at a given wastewater treatment plant may be transported for reuse within the plant's sub-basin (i.e. "at the source"), or towards other "receptor" sub-basins. In this exercise, we assume that water cannot be conveniently transported to sub-basins more than 10 km away (on a straight line) nor to sub-basins with elevation differences representing an excessive pumping requirement. For the latter, we assume that sub-basins featuring an elevation range above 200 m would require excessive pumping efforts and we regard them as "inaccessible". We exclude from this set those sub-basins corresponding to the valleys of relatively large rivers (those with Strahler order  $> 4$  in the CCM2 database), where it is assumed that the valley bottoms may still host infrastructure despite the potentially high elevation ranges on the hillsides.

Within a “source” sub-basin, the flow of reclaimed water to agriculture (m<sup>3</sup>/day) is computed as:

$$F_{i,i} = \min(\alpha_i Q_i, I_i) \quad \text{Equation 6}$$

where  $Q_i$  (m<sup>3</sup>/day) is the output discharge of the WWTP,  $\alpha_i$  (-) is the fraction of this discharge that is reclaimed (by default,  $\alpha_i=1$ ), and  $I_i$  (m<sup>3</sup>/day) is the irrigation demand in the sub-basin.

The length of the pipeline required to transport this flow to the agricultural area in the sub-basin is given by:

$$L_{i,i} = \sqrt{(x_i - x_{p,i})^2 + (y_i - y_{p,i})^2 + (z_i - z_{p,i})^2} \quad \text{Equation 7}$$

while the diameter of the pipeline (m) is computed using the Hazen-Williams formula as:

$$D_{i,i} = \left( \frac{10.675 \left( \frac{F_{i,i}}{C} \right)^{1.852}}{J} \right)^{\frac{1}{4.8704}} \quad \text{Equation 8}$$

where  $J$  is the friction loss rate and  $C$  is a friction coefficient. We assume  $C=120$  (-), valid for steel pipes, and  $J=0.005$  (-). Under these assumptions, with  $F_{i,i}$  in m<sup>3</sup>/day, Equation 8 can be written as:

$$D_{i,i} = 0.0104 F_{i,i}^{0.3803}$$

In addition to the transport of reclaimed water to the agricultural area, we account for the distribution of this water within the agricultural area itself. The radius of inertia  $R_i$  represents the average distance of agricultural areas from their centre of mass. We assume the investment in the infrastructure for distribution to the farms to be independent of the water reuse investment, while we compute the energy cost of distributing the reused water within the agricultural area of a sub-basin, as this contributes directly to the levelized cost of water.

The expenditure for a pipeline with diameter  $\Delta$  is given in €/m by<sup>35</sup>:

$$E(\Delta) = \begin{cases} 0.088433 \Delta^{1.29} + 65.8 & \text{if } \Delta \leq 0.8 \text{ m} \\ 0.0040115 \Delta^{1.785} + 68.1 & \text{if } \Delta > 0.8 \text{ m} \end{cases} \quad \text{Equation 9}$$

as from the FEASIBLE model (OECD, 2004). This expenditure function is used to compute  $E(D_{i,i})$ .

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<sup>35</sup> The functions are provided by OECD (2004) in US\$/m. In 2004, the exchange rate of € against US \$ was about 0.83. However, given the indicative value of the functions and the relative stability of the prices, we assume a unit exchange rate. This applies to all expenditure functions from the FEASIBLE model when values are given in US\$.

The energy required to transport and distribute the reclaimed water within the sub-basin (kWh/year) is computed as:

$$\Psi_{i,i} = \frac{F_{i,i}}{86400\eta} (365 * 24)g(\max(0, z_i - z_{p,i}) + J(\tau_i L_{i,i} + R_i)) \quad \text{Equation 10}$$

where  $g$  is the acceleration of gravity (9.81 m/s<sup>2</sup>) and  $\eta$  is the efficiency of pumping. We assume  $\eta=0.75$ . The power installation requirement (kW) of an equivalent pumping station for the transport and distribution of the reclaimed water flow is:

$$S_{i,i} = \frac{365 \Psi_{i,i}}{(365 * 24)T_i} \quad \text{Equation 11}$$

where  $T_i$  (days) is the duration of the irrigation period in the sub-basin. The expenditure for a pumping station of power  $S$  (€) is computed from the FEASIBLE model as:

$$E'(S) = 33140 S^{0.559} \quad \text{Equation 12}$$

The storage volume required for use of water in irrigation is computed as:

$$W_{i,i} = 365F_{i,i} \left(1 - \frac{T_i}{365}\right) \quad \text{Equation 13}$$

The cost of the storage volume is:

$$E(W_{i,i}) = \omega_i W_i \quad \text{Equation 14}$$

with  $\omega_i$  set to default of 5 €/m<sup>3</sup> in line with Maton et al., 2010. Cost of storage is extremely variable. For natural storage (e.g. in floodplains), Grygoruk et al., 2013 report a value above 8 €/m<sup>3</sup>.

The expenditure for an investment can be converted into an equivalent annual cost by the “present value of annuity” factor:

$$pva(r, n) = \frac{1 - \left(\frac{1}{1+r}\right)^n}{r} \quad \text{Equation 15}$$

where  $r$  is the annual interest rate and  $n$  is the number of years of useful life (or depreciation period) of the investment. We assume  $n=50$  years for pipelines and storage, and  $n=15$  for pumping stations, while  $r=0.05$  (5%).

The total equivalent annual cost of water transport and distribution (€/year) is given by:

$$E_{i,i} = \frac{E(D_{i,i})\tau_i L_{i,i} + E(W_{i,i})}{pva(0.05, 50)} + \frac{E'(S_{i,i})}{pva(0.05, 15)} + \psi_i \Psi_{i,i} \quad \text{Equation 16}$$

Where  $\psi_i$  is the cost of energy (€/kWh) in the sub-basin. In this exercise, we assume a constant value  $\psi_i = 0.10$  €/kWh. The cost of energy for industrial use reported by EUROSTAT is provided in Table 9, suggesting the assumed value to be plausible for large industrial users across Europe.

Country	Consumption (MWh/year)						
	20	500	2000	20000	70000	150000	>150000
Belgium	€ 0.18	€ 0.15	€ 0.11	€ 0.10	€ 0.08	€ 0.07	€ 0.06
Bulgaria	€ 0.10	€ 0.10	€ 0.08	€ 0.07	€ 0.06	€ 0.06	€ 0.06
Czech Republic	€ 0.16	€ 0.12	€ 0.08	€ 0.07	€ 0.07	€ 0.07	
Denmark	€ 0.18	€ 0.10	€ 0.09	€ 0.09	€ 0.08	€ 0.08	
Germany	€ 0.22	€ 0.18	€ 0.15	€ 0.13	€ 0.11	€ 0.10	
Estonia	€ 0.11	€ 0.10	€ 0.09	€ 0.08	€ 0.07	€ 0.07	
Ireland	€ 0.20	€ 0.16	€ 0.13	€ 0.11	€ 0.09	€ 0.09	
Greece	€ 0.21	€ 0.17	€ 0.12	€ 0.10	€ 0.08	€ 0.05	
Spain	€ 0.27	€ 0.15	€ 0.11	€ 0.10	€ 0.08	€ 0.07	€ 0.06
France	€ 0.15	€ 0.12	€ 0.10	€ 0.08	€ 0.07	€ 0.06	
Croatia	€ 0.13	€ 0.11	€ 0.09	€ 0.08	€ 0.06	€ 0.06	
Italy	€ 0.27	€ 0.19	€ 0.16	€ 0.15	€ 0.13	€ 0.10	€ 0.08
Cyprus	€ 0.18	€ 0.17	€ 0.15	€ 0.13	€ 0.13	€ 0.12	
Latvia	€ 0.16	€ 0.13	€ 0.12	€ 0.11	€ 0.10	€ 0.09	
Lithuania	€ 0.13	€ 0.11	€ 0.10	€ 0.10	€ 0.09	€ 0.08	
Luxembourg	€ 0.17	€ 0.11	€ 0.09	€ 0.06	€ 0.05		
Hungary	€ 0.11	€ 0.10	€ 0.09	€ 0.08	€ 0.08	€ 0.08	€ 0.08
Malta	€ 0.22	€ 0.17	€ 0.16	€ 0.14	€ 0.12	€ 0.11	
Netherlands	€ 0.16	€ 0.12	€ 0.09	€ 0.08	€ 0.07	€ 0.07	€ 0.06
Austria	€ 0.16	€ 0.13	€ 0.10	€ 0.09	€ 0.08	€ 0.07	€ 0.06
Poland	€ 0.15	€ 0.11	€ 0.08	€ 0.07	€ 0.07	€ 0.06	€ 0.06
Portugal	€ 0.19	€ 0.15	€ 0.12	€ 0.10	€ 0.09	€ 0.08	
Romania	€ 0.11	€ 0.10	€ 0.08	€ 0.07	€ 0.06	€ 0.06	
Slovenia	€ 0.14	€ 0.10	€ 0.08	€ 0.07	€ 0.07	€ 0.06	
Slovakia	€ 0.20	€ 0.14	€ 0.11	€ 0.10	€ 0.09	€ 0.09	€ 0.07
Finland	€ 0.09	€ 0.08	€ 0.07	€ 0.07	€ 0.05	€ 0.05	
Sweden	€ 0.14	€ 0.07	€ 0.06	€ 0.06	€ 0.05	€ 0.04	
United Kingdom	€ 0.17	€ 0.15	€ 0.14	€ 0.13	€ 0.12	€ 0.12	€ 0.12

Table 9 – Electricity prices per kWh, for industrial consumers, excluding VAT and other recoverable taxes and levies – average of bi-annual data 2014-16 (source: EUROSTAT)

The levelized cost of reclaimed water within the sub-basin (€/m3) is:

$$LCoW_{i,i} = \frac{E_{i,i}}{365F_{i,i}} + LCOWt \quad \text{Equation 17}$$

The flow of reclaimed water potentially supplied from the i-th source sub-basin to the j-th receptor sub-basin (m3/day) is computed in a similar way. First of all, the shortest path connecting the i-th source to the j-th receptor is identified. If a receptor is not adjacent to the source but there are one or more sub-basins in between, the path is forced to pass through the center of mass of agriculture in each of these sub-basins. When a sub-basin does not contain agriculture, its centroid is considered instead. Each receptor sub-basin can be therefore characterized with the shortest path length to reach it from the i-th source ( $L_{ij}$ ), and in addition with the shortest path length to reach its neighbor immediately closer to the source ( $\Lambda_{i,j}$ ). The shortest-path lengths between two generic nodes are computed as the Euclidean distances,

multiplied by the tortuosity factor of the origin node. On a par, each receptor sub-basin can be characterized by the potential flow from the i-th source basin:

$$F_{i,j} = \min \left( \max(0, -\alpha_i Q_i F_{i,i}), \max(0, I_j - F_{j,j}) \right). \quad \text{Equation 18}$$

as well as the flow to its neighbor immediately closer to the source, which we denote as  $\Phi_{i,j}$ . The pipeline connecting the i-th source to the j-th receptor requires a diameter to convey  $F_{i,j}$  for the length  $L_{i,j} - \Lambda_{i,j}$ . In addition it needs the infrastructure, already sized to convey flow to its neighbors closer to the source, to be appropriately upsized. In this exercise, we assume that costs of pumping stations are additive (i.e., for each receptor basin there may be a dedicated pumping station in line with the modularity principles often adopted in design). The upsizing costs of pipelines are estimated as if the whole length  $\Lambda_{i,j}$  were designed for flow  $\Phi_{i,j}$ , and need to be adjusted now to the total flow  $F_{i,j} - \Phi_{i,j}$ . The cost of transport of water between the i-th source and the j-th receptor can be then computed, in analogy with what outlined above, as:

$$E_{i,j} = \frac{E(D_{i,j})(L_{i,j} - \Lambda_{i,j}) + (E(D_{i,j}^{cum}) - E(D_{i,j}^{base}))\Lambda_{i,j} + E(W_{i,j})}{pva(0.05, 50)} + \frac{E'(S_{i,j})}{pva(0.05, 15)} + \psi_i \Psi_{i,j} \quad \text{Equation 19}$$

Where we posit:

$$\begin{aligned} D_{i,j}^{cum} &= 0.0104 (F_{i,j} + \Phi_{i,j})^{0.3803} \\ D_{i,j}^{base} &= 0.0104 \Phi_{i,j}^{0.3803} \\ D_{i,j} &= 0.0104 F_{i,j}^{0.3803} \end{aligned} \quad \text{Equation 20}$$

And where  $E(*)$  is the expenditure function introduced before (Equation 9). Moreover, we have:

$$\Psi_{i,j} = \frac{F_{i,j}}{86400\eta} (365 * 24)g(\max(0, z_{obst\ i,j} - z_{p,i}, z_j - z_{p,i}) + J(\tau_i L_{i,j} + R_j)) \quad \text{Equation 21}$$

Where now  $z_{obst\ i,j}$  is the height of the expected obstacle to be met when crossing sub-basin divides between the i-th and j-th sub-basins. We consider the 75<sup>th</sup> percentile of catchment elevation for each sub-basin on the shortest path between the i-th and j-th sub-basins, and we assume that  $z_{obst\ i,j}$  is the maximum of these elevations.

$$S_{i,j} = \frac{365 \Psi_{i,j}}{(365 * 24)T_j} \quad \text{Equation 22}$$

$$W_{i,j} = 365 F_{i,j} \left( 1 - \frac{T_j}{365} \right) \quad \text{Equation 23}$$

The levelized cost of water from the i-th source sub-basin potentially used in the j-th sub-basin is then given by:

$$LCoW_{i,j} = \frac{E_{i,j}}{365 F_{i,j}} + LCOWt \quad \text{Equation 24}$$

Table 10 summarizes the attributes computed for each sub-basin, related to the transfer of reclaimed water from the  $i$ -th to the  $j$ -th sub-basin.

Symbol	Description	Calculation
$F_{i,j}$	Potential Flow of reclaimed water within the SB	Equation 6, Equation 18
$L_{i,j}$	Length of the pipeline for transport to the SB's agricultural area	Equation 7
$D_{i,j}$	Diameter of the pipeline for transport to the SB's agricultural area	Equation 8, Equation 20
$E(D_{i,j})$	Cost per unit length of the pipeline for transport to the SB's agricultural area	Equation 9
$W_{i,i}$	Storage volume	Equation 13, Equation 23
$E(W_{i,i})$	Cost of storage volume	Equation 14
$\Psi_{i,j}$	Energy required for transport and distribution of reclaimed water	Equation 10, Equation 21
$S_{i,j}$	Power requirement for pumping	Equation 11, Equation 22
$E(S_{i,j})$	Cost of pumping stations for distribution within the SB	Equation 12
$E_{i,j}$	Cost of water distribution within the SB	Equation 16, Equation 19
$LCoW_{i,j}$	Levelized cost of water within the SB	Equation 17, Equation 24

*Table 10 – summary of computed attributes of each pair of related sub-basin (SB=sub-basin).*

The above equations allow calculating the levelized cost of water for each potential source-receptor link. In order to allocate a given water availability at a source, receptors need to be ranked on the basis of cost criteria. The levelized cost as a function of the cumulative volume of reclaimed water potentially allocated from a source is the so called source's water-marginal cost curve (WMCC). The WMCC is a tool used for investment strategy decision support in the field of water infrastructure (McKinsey, 2009).

The actual volume of potentially reclaimed water at a source sub-basin that can be allocated to the receptor sub-basins is the minimum between reclaimed water availability at the source and irrigation demand in its neighborhood. The difference of these two terms represents the local surplus or deficit of reclaimed water with respect to irrigation requirements. Demands of receptors entailing a cost above a given threshold can be excluded.

The amount allocated from a source to any of its cost-ranked receptors is computed as the potential flow, if the sum of all potential flows up to the receptor's rank does not exceed availability, else it is calculated as the difference between availability and the sum of potential flows for all receptors featuring lower cost.

A receptor sub-basin may belong to the neighborhood of, hence be allocated water from, more than one source sub-basin. In this case, a surplus may result from the sum of allocations. A surplus may occur also when restricting potential flows with a cost threshold.

In this assessment, we refer to three cost scenarios:

- (1) case when reuse requires developing all infrastructure from scratch (pipelines, pumping stations and water storage);

(2) case when pipelines and pumping stations must be built, but storage can be made using existing infrastructure;

(3) case when all infrastructure exists, and the costs are limited to treatment and energy.

For each of the above cases, we rank receptors based on the corresponding costs. For each source sub-basin considered in the EU, the calculation yields the demand in the neighbourhood that can be met under no restriction on costs, and with costs not exceeding a threshold of 0.25, 0.50, 0.75, 1.00 Euro/m<sup>3</sup>, in addition to the corresponding local surplus or deficit.

Based on the above assumptions, we compute the variables summarized in Table 12.

Cost scenario #	costs included	target	variable	meaning
1	total costs	source	demand	demand in the neighborhood
1	total costs	source	Cost1demand25	demand that can be met with costs <=0.25Euro/m3
1	total costs	source	Cost1demand50	demand that can be met with costs <=0.5Euro/m3
1	total costs	source	Cost1demand75	demand that can be met with costs <=0.75Euro/m3
1	total costs	source	Cost1demand100	demand that can be met with costs <=1Euro/m3
1	total costs	receptor	Cost1alloc	supply that can be allocated
1	total costs	receptor	Cost1alloc25	supply that can be allocated with costs <=0.25Euro/m3
1	total costs	receptor	Cost1alloc50	supply that can be allocated with costs <=0.5Euro/m3
1	total costs	receptor	Cost1alloc75	supply that can be allocated with costs <=0.75Euro/m3
1	total costs	receptor	Cost1alloc100	supply that can be allocated with costs <=1Euro/m3
1	total costs	receptor	Cost1surplus	surplus of receptor after allocation at 1 Euro/m
2	total costs - storage	source	Cost2demand25	demand that can be met with costs <=0.25Euro/m3
2	total costs - storage	source	Cost2demand50	demand that can be met with costs <=0.5Euro/m3
2	total costs - storage	source	Cost2demand75	demand that can be met with costs <=0.75Euro/m3
2	total costs - storage	source	Cost2demand100	demand that can be met with costs <=1Euro/m3
2	total costs - storage	receptor	Cost2alloc	supply that can be allocated
2	total costs - storage	receptor	Cost2alloc25	supply that can be allocated with costs <=0.25Euro/m3
2	total costs - storage	receptor	Cost2alloc50	supply that can be allocated with costs <=0.5Euro/m3
2	total costs - storage	receptor	Cost2alloc75	supply that can be allocated with costs <=0.75Euro/m3
2	total costs - storage	receptor	Cost2alloc100	supply that can be allocated with costs <=1Euro/m3
2	total costs - storage	receptor	Cost2surplus	surplus of receptor after allocation at 1 Euro/m
3	only energy and treatment	receptor	Cost3demand25	demand that can be met with costs <=0.25Euro/m3
3	only energy and treatment	receptor	Cost3demand50	demand that can be met with costs <=0.5Euro/m3
3	only energy and treatment	receptor	Cost3demand75	demand that can be met with costs <=0.75Euro/m3
3	only energy and treatment	receptor	Cost3demand100	demand that can be met with costs <=1Euro/m3
3	only energy and treatment	receptor	Cost3alloc	supply that can be allocated
3	only energy and treatment	receptor	Cost3alloc25	supply that can be allocated with costs <=0.25Euro/m3
3	only energy and treatment	receptor	Cost3alloc50	supply that can be allocated with costs <=0.5Euro/m3
3	only energy and treatment	receptor	Cost3alloc75	supply that can be allocated with costs <=0.75Euro/m3
3	only energy and treatment	receptor	Cost3alloc100	supply that can be allocated with costs <=1Euro/m3
3	only energy and treatment	receptor	Cost3surplus	surplus of receptor after allocation at 1 Euro/m

Table 12 – variables considered in the assessment of reuse costs.

The above cost model makes assumptions on the following parameters:



- Cost of energy
- Cost of storage
- Duration of the irrigation period
- Discount rate
- Depreciation period of pipelines
- Depreciation period of storage
- Depreciation period of pumping stations
- Incidence of O&M costs of pipelines
- Incidence of O&M costs of storage
- Incidence of O&M costs of pumping stations.

In addition, the model assumes a roughness coefficient and an energy gradient in the Hazen-Williams formula used for the sizing of pipes. As these are typical, and largely conventional, engineering assumptions, we ignore these two parameters in the sensitivity analysis. In order to estimate a plausible upper and lower range for the computed levelized costs of water, we consider two scenarios, which we label as “more favorable” and “less favorable” respectively. In the former, we change the parameters from the base assumptions to values which systematically reduce costs; in the latter, on the contrary, we alter the base values so to increase the costs. Table 11 shows the values considered in the exercise.

<b>Parameter</b>	<b>Units</b>	<b>Base value</b>	<b>More favorable</b>	<b>Less favorable</b>
Cost of energy	€/kWh	0.1	0.05	0.15
Cost of storage	€/m <sup>3</sup>	5	2	8
Duration of the irrigation period	Days	120	180	70
Discount rate	%	5	2	7
Depreciation period of pipelines	Years	50	75	25
Depreciation period of storage	Years	50	75	25
Depreciation period of pumping stations	Years	15	20	10
Incidence of O&M costs of pipelines	%	3	1	5
Incidence of O&M costs of storage	%	1	0.5	1.5
Incidence of O&M costs of pumping stations.	%	1.5	0.5	2.5

*Table 11 – alteration of model parameters in the global sensitivity analysis.*

With reference to the two scenarios, we conducted a simplified global sensitivity analysis of the cost model by computing the levelized costs of water for each source-receptor link identified as detailed above. Figure 7, Figure 8 and Figure 9 show the scatter plots of costs under base and altered conditions, including all costs (Figure 7), all costs excluding storage (Figure 8) and only energy and treatment costs (Figure 9). From the plots, it is apparent that

the overall ranking of source-receptor links does not change appreciably, the dispersion of points being always very narrow. This indicates that the cost analysis is sufficiently robust with respect to the identification of priorities for water allocation.

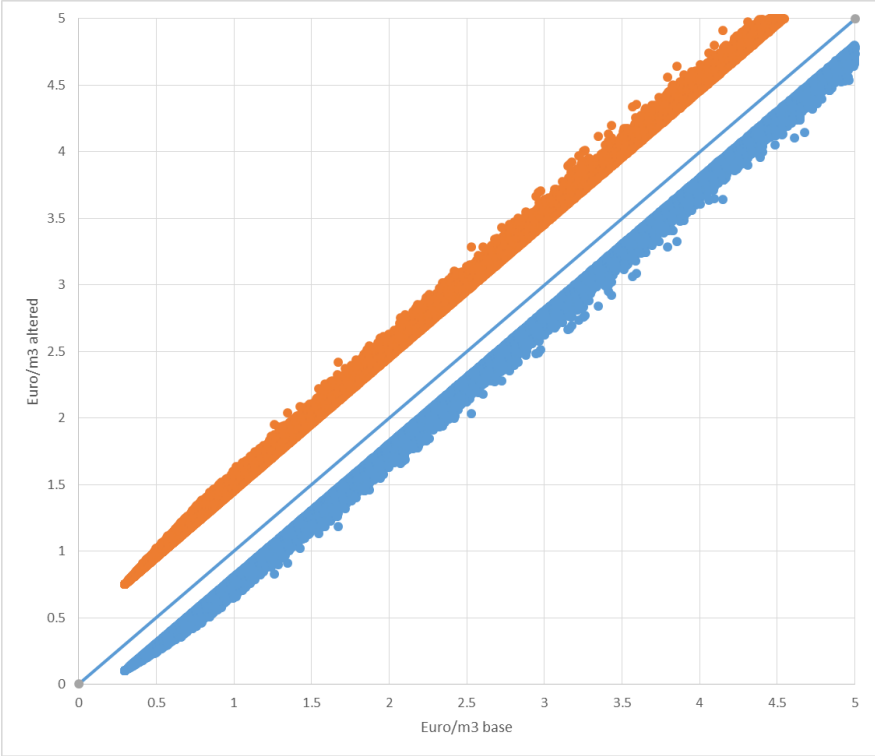


Figure 3 – Levelized costs including pipelines, pumping stations, storage, energy and treatment: comparison of the base case and altered values (orange=less favorable ; blue=more favorable), using parameters as per Table 11.

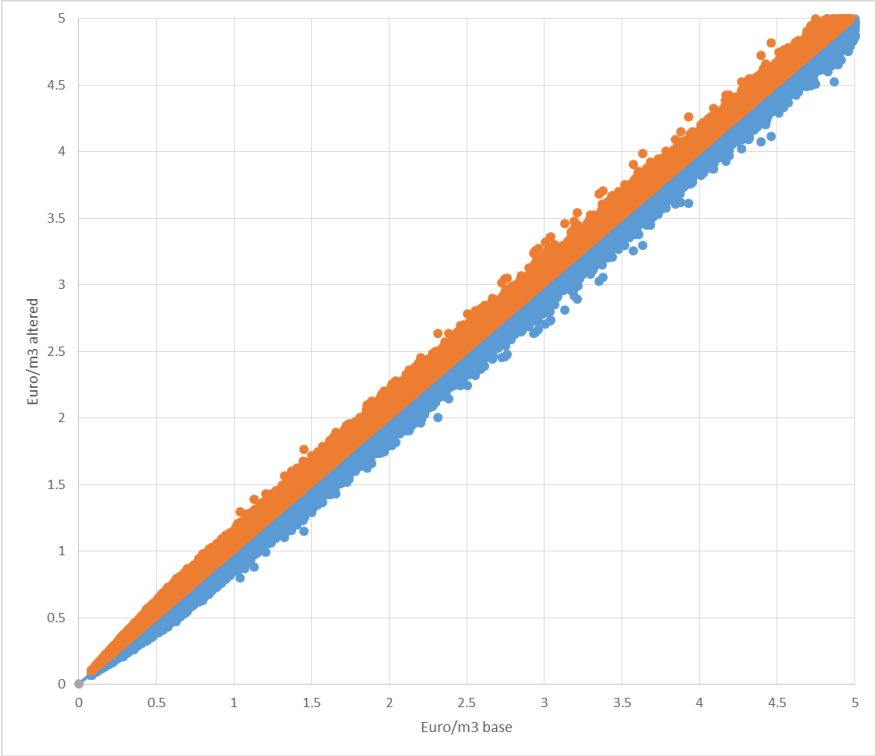


Figure 4 – Levelized costs including pipelines, pumping stations, energy and treatment: comparison of the base case and altered values (orange=less favorable; blue=more favorable), using parameters as per Table 11.

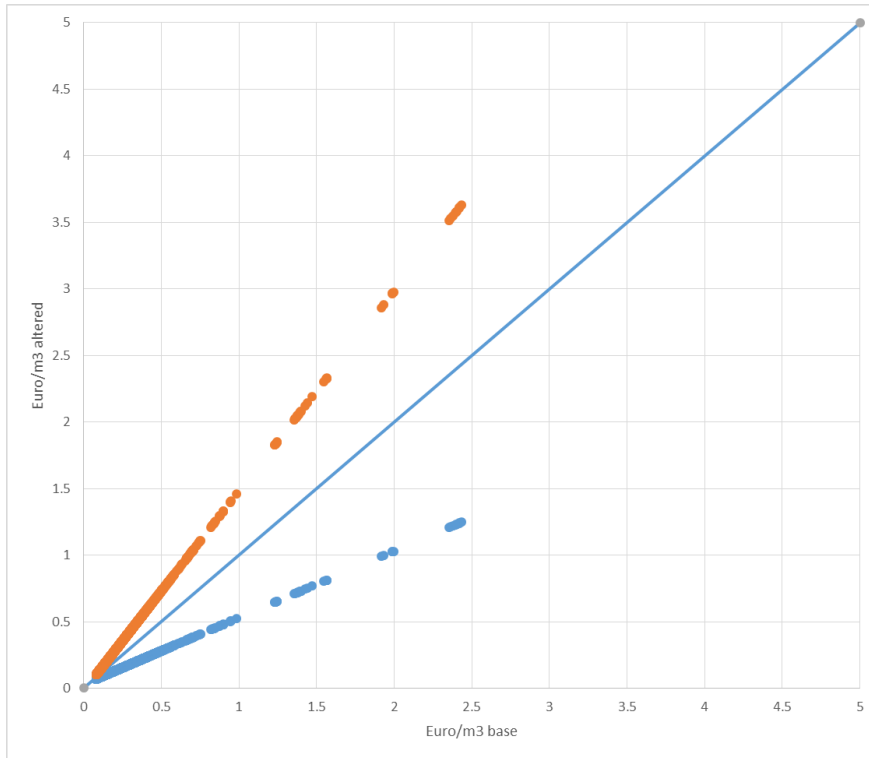


Figure 5 – Levelized costs including energy and treatment: comparison of the base case and altered values (orange=less favorable; blue=more favorable), using parameters as per Table 11.

Absolute costs may change significantly (especially when energy and treatment costs are considered alone) but in a very predictable way as per the narrow scattering. When total costs are considered, considering a more favorable alteration is practically equivalent to reducing costs of about 0.25 Euro/m<sup>3</sup> while a less favorable alteration increases costs of about 0.5 Euro/m<sup>3</sup> (Figure 7). The alteration of energy and treatment costs alone is practically equivalent to halving (for more favorable conditions) or multiplying by 1.5 (for less favorable conditions) the levelized costs (Figure 9). When total costs excluding storage are considered, the alterations have much less apparent effects (Figure 8).

### Crop model

The EPIC model (Sharpley and Williams, 1990) was originally developed by the US Department of Agriculture, and is now maintained and developed by the Texas A&M University. It is an open-source code extensively used worldwide for crop simulations. The model has been widely used for the simulation of crop yields, nitrogen and phosphorus balances, and water requirements. The existing EPIC setup is used by the JRC in the context of other European scale assessments. The EPIC model has been validated against independent yield data (see § 4). EPIC model simulations have been used extensively in the last years for a

number of assessments by the JRC, including a study supporting the Impact Assessment of the Water Blueprint in 2012 (de Roo et al., 2012).

Demand is estimated on the basis of calculated irrigation water requirements. We selected the biophysical model EPIC because it simulates crop production under different farming practices and operations including fertilization and irrigation application rates and timing and because it considers nutrient losses to the environment (N leaching and runoff) (Figure 3). In addition, it has been thoroughly evaluated and applied from local to continental scale (Gassman et al. 2005) and used in global assessments (Liu et al. 2007). The model has been applied for irrigation scheduling assessment (Wriedt et al. 2009), and biofuels production (Van der Velde et al. 2009).

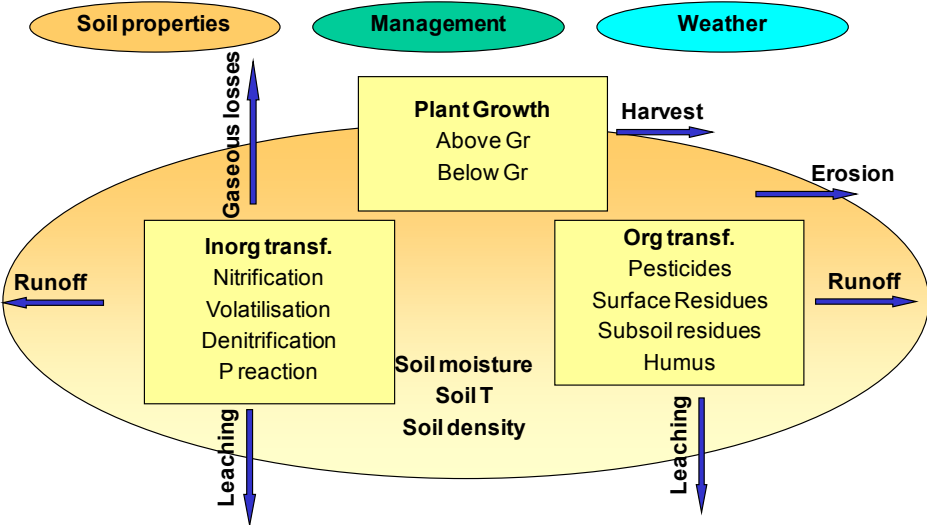


Figure 6. The EPIC model structure.

Furthermore the model is already integrated in a GIS system working at European scale (Bouraoui et al. 2007). The GIS system includes all the data required for EPIC modelling (meteorological daily data, soil profile data, landuse data with crop distribution and agriculture management data) and all necessary sets of attributes required to simulate different strategies, management and scenarios.

Wheat, barley, maize, rapeseed, oats, rye are major crops grown in Europe, while other crops are more important in specific regions such as olive and fruit trees in southern Europe or potatoes and sugar beet in Central and Northern Europe. There are many different cultivars adapted to different climate and environments and characterized by peculiar growth properties and productivity. Specific information on crop cultivars are not easily available at European scale but these information are important in order to represent this spatial variability in the model.

In this assessment, we make use of the results of the EPIC model setup at European scale available at the JRC corresponding to “baseline” conditions, i.e. supposed to reflect the actual

current levels of irrigation. Under this scenario, crop water requirements (m<sup>3</sup>/year) were estimated at the cells of a regular 5km x 5 km grid across Europe.

The model setup used to estimate the average irrigation requirements is based on crop distribution statistics defined at 5km resolution derived from the combination of CAPRI (Britz, 2004), SAGE (Monfreda et al., 2008) and GLC (Bartholomé and Belward, 2005). The amount of manure and mineral fertilization applied were retrieved from the Common Agricultural Policy Regionalized Impact (CAPRI) agro-economic model (Britz and Witzke, 2008) and crop production optimized according to EUROSTAT statistics at NUTS2 level (EUROSTAT, 2010a). Extension of irrigated land by crop was derived according to MIRCA dataset (Portmann, 2011) and applied irrigated volume were validated at country level by using EUROSTAT 2010 statistics (EUROSTAT, 2010b). Landuse and crop management is assumed constant for the whole period of simulation.

First we identified 4 main regions in Europe, by performing a Cluster Analysis considering the main parameters potentially influencing crop growth, such as climate (precipitation, temperature, evapotranspiration, etc.), soil type (texture, organic matter content, drainage, water storage capacity, etc. ) landuse and crop management (irrigation, fertilization plans, etc.). The initial cluster included 9 regions (Figure 4) that were reduced to four macro regions. The crop parameters were adapted for these four macro-regions.

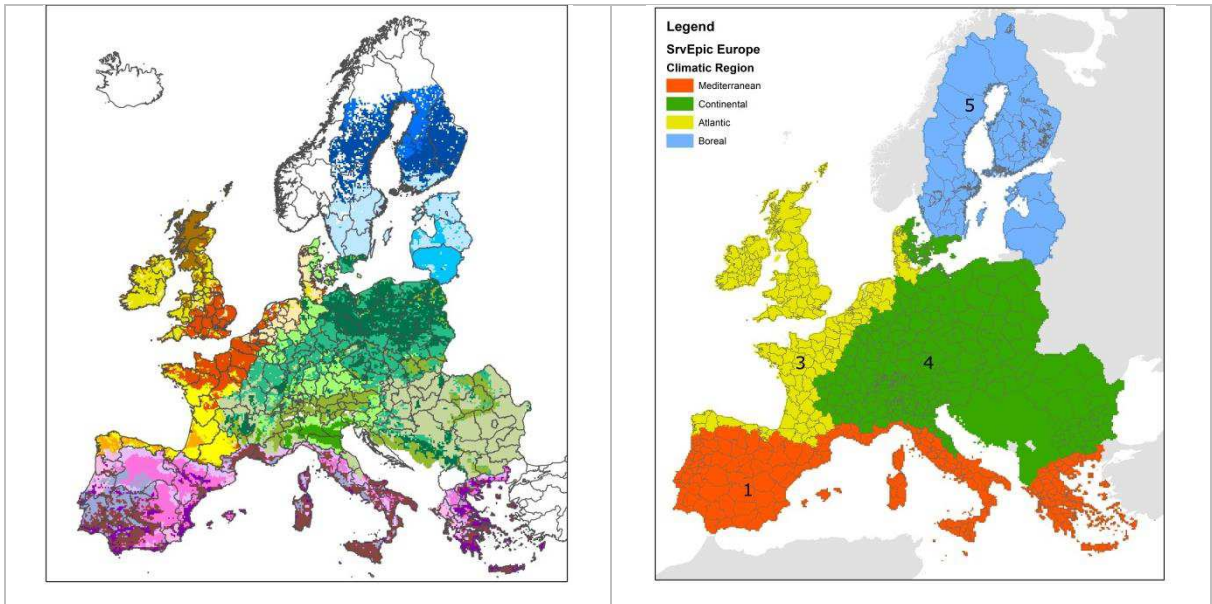


Figure 7 . Main clusters and selected regions for Europe detailed (left) and simplified (right).

The parameters affecting crop growth that were modified to customize EPIC to specific regional conditions included the optimal and base temperatures, the biomass growth rate parameter and the harvest index.

In our approach the optimization aimed at minimizing the differences between simulated and reported yields (EUROSTAT data) in different macro regions. We used the Multi Objective Genetic Algorithm (MOEA) library by Udías (2011) to optimize the selected set of parameters controlling the crop growth and productivity.

A comparison between simulated and reported annual yields (for last reporting period) aggregated at NUTS 2 level for all Europe is presented in Figure 5. The simulated yields compare well with the reported ones for all major crops, keeping in mind that the reported statistical data are not available for all the years considered (2008-2011) and that in some cases only data at country level is available. This analysis demonstrated the capability of the model to capture the spatial and annual variability of yields.

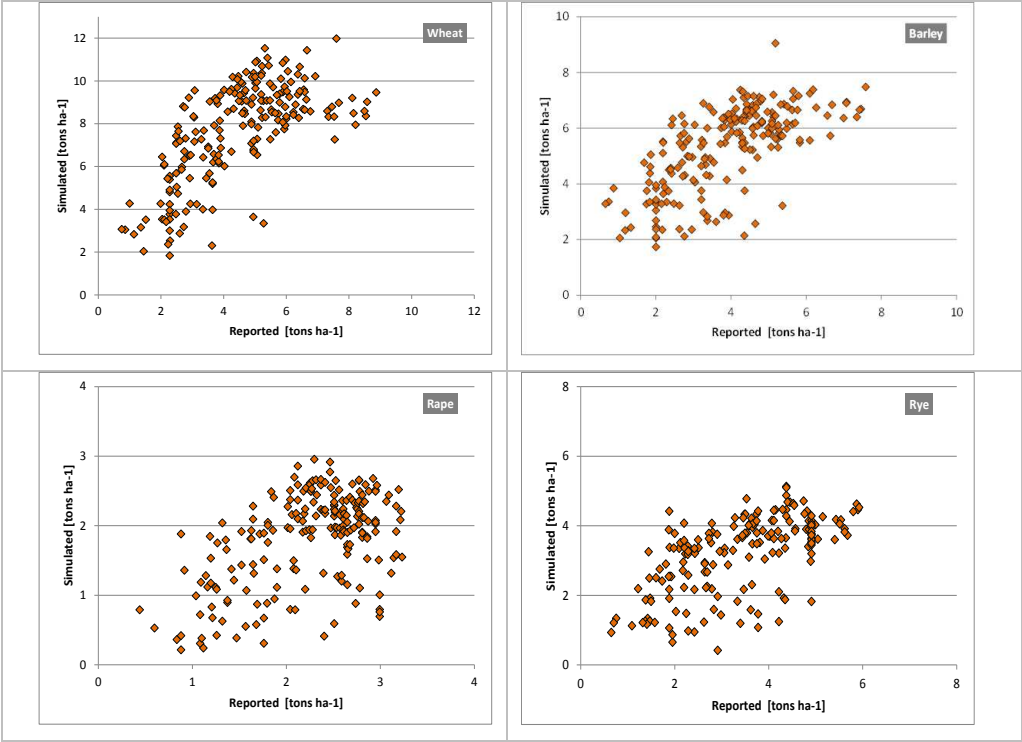


Figure 8. Scatter plots with means simulated yields versus reported regional crop yields for some major cereals, forage crops in Europe.

The EPIC model calculates annual crop water requirements, expressed in m<sup>3</sup> per grid cell of 25 km<sup>2</sup> (Figure 9). For each grid cell, we computed the hectares of agricultural land as the number of pixels of the 100 m x 100 m CLC 2012 map classified as “agricultural” (CLC 2012 level 1 code =2, with exclusion of level 3 code 231 – pastures) falling within the cell. Dividing the crop water requirements by the number of hectares allowed estimating a crop water requirement per unit area (unit requirement). Each sub-basin was attributed the unit requirement from the grid cells intersecting it, in proportion to the area of the grid cells on a sub-basin. The crop water requirement per sub-basin,  $I_i$ , was finally estimated as the unit requirement multiplied by the number of 100 m x 100 m agricultural CLC 2012 pixels falling within the sub-basin.

It should be stressed that we consider irrigation demand merely as the water required by crops. In reality, more water may be required for irrigation than what is actually used by crops. This water includes the losses along canals and pipelines, as well as the water evaporating or leaching below the root zone during field applications. We do not make a distinction here between crop water requirements and the actual amount required for irrigation. The latter is assumed to coincide with the former, i.e. we assume irrigation

efficiency to be 100%, compatibly with the objective of this work which is an indicative comparison between requirements and availability. This aspect should be considered particularly when interpreting the results with reference to highly inefficient irrigation systems.

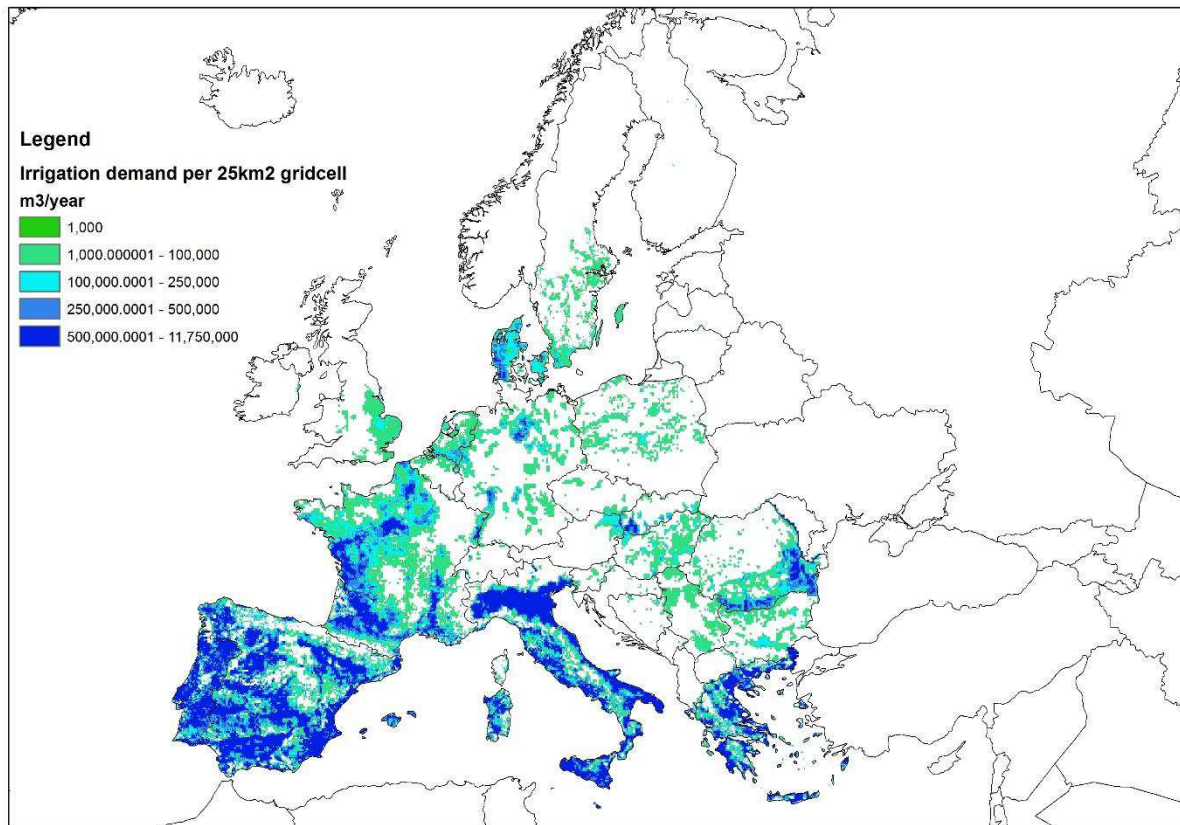


Figure 9- average irrigation water requirement used in this assessment, as computed with the EPIC model.

### Quantification of the benefits from reuse.

Valuing the benefits that may stem from water reuse is overwhelmingly complex in general terms. One proxy of benefits is the willingness to pay of farmers for reclaimed water, which is extremely variable (for instance, Birol et al., 2007<sup>[1]</sup> estimate a willingness to pay higher than 0.6 Euro/m<sup>3</sup> in Cyprus, while Tziakis et al., 2009<sup>[2]</sup>, indicate less than 0.1 Euro/m<sup>3</sup> for Crete).

Mattheiss and Zayas, 2016<sup>[3]</sup> analyse a case study in Braunschweig, Germany and another one in Sabadell, Spain. In Braunschweig, a survey has identified a willingness to pay of about 3 to 5 million euro/year for about 7 million m<sup>3</sup>/year of water reused to recharge aquifers, which

<sup>[1]</sup> Birol, E., P. Koundouri, and Y. Kountouris (2007), Farmers' demand for recycled water in Cyprus: A contingent valuation approach, in *Wastewater Reuse—Risk Assessment, Decision-Making and Environmental Security*, edited by M. K. Zaidi, pp. 267–278, Springer, Dordrecht, Netherlands.

<sup>[2]</sup> Tziakis, I., I. Pachiadakis, M. Moraitakis, K. Xideas, G. Theologis and K. P. Tsagarakis (2009), Valuing benefits from wastewater treatment and reuse using contingent valuation methodology, *Desalination*, 237, 117–125.

<sup>[3]</sup> Mattheiss, V., Zayas, I., Social and environmental Benefits of water reuse schemes – economic considerations for two case studies. DEMOWARE project deliverable 4.4, 2016. <http://demoware.eu>

could be interpreted as a valuation of water to improve flow regimes between 0.4 and 0.7 Euro/m<sup>3</sup>. In Sabadell, the willingness to pay of households for irrigation of green areas and street cleaning is estimated to exceed 5.5 million Euro/year, and the water demand for these activities is estimated at 1.1 million m<sup>3</sup>/year, indicating a value of water in the order of 5 Euro/m<sup>3</sup>.

Arborea et al., 2017, quantify the benefits of reusing water for irrigation in Puglia in the order of slightly less than 0.5 Euro/m<sup>3</sup>, including the direct and option benefits for the farmers and the benefits of maintaining good groundwater status.

Molinos\_Senante et al., 2011<sup>[4]</sup>, quantify the benefits of reuse using shadow prices of pollutants (suspended solids, nutrients and Chemical Oxygen Demand) not being discharged to rivers (therefore assuming the impact of such pollutants through irrigation would be negligible). In addition, they consider a sale price of reclaimed water of 0.9 Euro/m<sup>3</sup>. The total net benefits summing these components are estimated at a mean value of 1.22 Euro/m<sup>3</sup> for 13 wastewater treatment plants in Spain.

Maton et al., 2010, conduct a cost-benefit analysis for water reuse in western Crete, and show that net benefits of reuse depend significantly on the level of stress on water resources; for cases of high water stress, net benefits range between 0.35 and 1.92 Euro/m<sup>3</sup>. Alcon et al., 2010<sup>[5]</sup>, estimate the Segura river basin population's willingness to pay for irrigation reuse at about 0.3 Euro/m<sup>3</sup>, which is presented as the non-market value of reused water. This should be summed to the willingness to pay of farmers or market value of reclaimed water, so that the overall value of reclaimed water can be arguably around 0.5 Euro/m<sup>3</sup>. Birol et al., 2009<sup>[6]</sup> present an estimate of the willingness to pay for aquifer recharge by local residents in Cyprus of about 1.3 Euro/m<sup>3</sup>.

In the context of the AQUAMONEY EU-funded project<sup>[1]</sup>, the willingness to pay of the public has been assessed for different actions improving water quality, safety and security in a few case studies across Europe (Table below – case studies). The case studies highlight a significant willingness to pay of households for a more sustainable management of water resources. This may support the idea that a part of the costs of water reuse could be borne by society/taxpayers and not only by the farmers alone, since water reuse generates additional benefits to society.

Case	Motivation	Willingness to pay
Vienna (AT)	Reduce flooding frequency and improve water quality	About 52 to 78 €/household/year
Hungary	Reduce flooding frequency and improve water quality	About 35 to 54 €/household/year

<sup>[4]</sup> Molinos-Senante, M., Hernandez Sancho, F., Sala Garrido, R., Cost-benefit analysis of water reuse projects for environmental purposes: a case study for Spanish wastewater treatment plants. *Journal of Environmental Management*, 92 (2011) 3091-3097. DOI: 10.1016/j.jenvman.2011.07.023

<sup>[5]</sup> F. Alcon, F. Pedrero, J. Martin-Ortega, N. Arcas, J. J. Alarcon, and M. D. de Miguel, The non-market value of reclaimed wastewater for use in agriculture: a contingent valuation approach *Spanish Journal of Agricultural Research* 2010 8(S2), S187-S196. URL: [www.inia.es/sjar](http://www.inia.es/sjar)

<sup>[6]</sup> Birol, E., P. Koundouri and Y. Kountouris (2009), Assessing the economic viability of alternative water resources in water scarce regions: The roles of economic valuation, cost-benefit analysis and discounting, paper presented at 27th International Association of Agricultural Economists Conference, Beijing, 16–22 Aug.

<sup>[1]</sup> <http://www.ivm.vu.nl/en/research-new/environmental-economics/projects/aquamoney/project-deliverables/index.aspx>



Braila (RO)	Reduce flooding frequency and improve water quality	About 9 to 22 €/household/year
Odense (DK)	Reduce flooding frequency and improve water quality	About 57 to 192 €/household/year
Po and Reno river basins (IT)	Ensure water availability for different sectors (agriculture, industry, energy,...) and the environment	About 10 to 40 €/household/year
Serpis (Jucar) river basin (ES)	Ensure domestic water supply and improve/maintain ecological status	297 €/household/year for supply; 64 to 104 for ecological status
Lesvos (EL)	Ensure domestic water supply and improve/maintain ecological status	287 €/household/year for supply; 44 to 253 for ecological status

These examples highlight the large variability in valuation of water used to reduce water stress, and the uncertainty due to their high case-specificity. If a benefit of water reuse of 0.5 Euro/m<sup>3</sup> was assumed, which is in the mid-lower end of the cases examined above, and may be argued to represent as a first approximation the combined market and non-market value of water reuse in Europe, provided it contributes to water stress reduction, there would be willingness to pay the assumed costs of water reuse.

Calculation of administrative burden for policy options for water reuse for agricultural irrigation (Ir1, Ir2 and Ir3, if followed) and aquifer recharge (Re1, if followed and Re2).

Minimum quality requirements for water reuse for irrigation and aquifer recharge						Tariff (€ per hour)	Time (minutes)	Price (per action)	Freq (per year)	Nbr of entities	Total number of actions	Equipment costs (per entity & per year)	Outsourcing costs (per entity & per year)	Total Administrative Costs	Business As Usual Costs (% of AC)	Total Administrative Burdens (AC - BAU)
No.	Art.	Orig. Art.	Type of obligation	Description of required action(s)	Target group											
1			Application for individual authorisation or exemption for water reuse for <b>agricultural irrigation</b>	Producing new data	water operators would need to perform risk assessment and adjust/ issue permits at UWWTP level for water reuse for agricultural irrigation	32	1.200,00	641	1	3.500 <sup>36</sup>	3.500			2.244.176	0%	2.244.176
2			Application for individual authorisation or exemption for water reuse for <b>aquifer recharge</b>	Producing new data	water operators would be required to perform risk assessment for water reuse for the 220 sites of aquifers which could be potentially recharged with reclaimed water	32	1.200,00	641	1	220 <sup>37</sup>	220			141.063	0%	141.063

<sup>36</sup> The number of UWWTPs estimated as a percentage similar to the ratio of volume that can be allocated at costs <0.5 euro/m<sup>3</sup>, divided by total volume available at WWTPs (see Figure 10 in Section 5 of the Impact assessment report). This is about 13%, therefore 0.13 x 25,000 = 3250.

<sup>37</sup> The estimated number of aquifers in the EU (see Annex 6)

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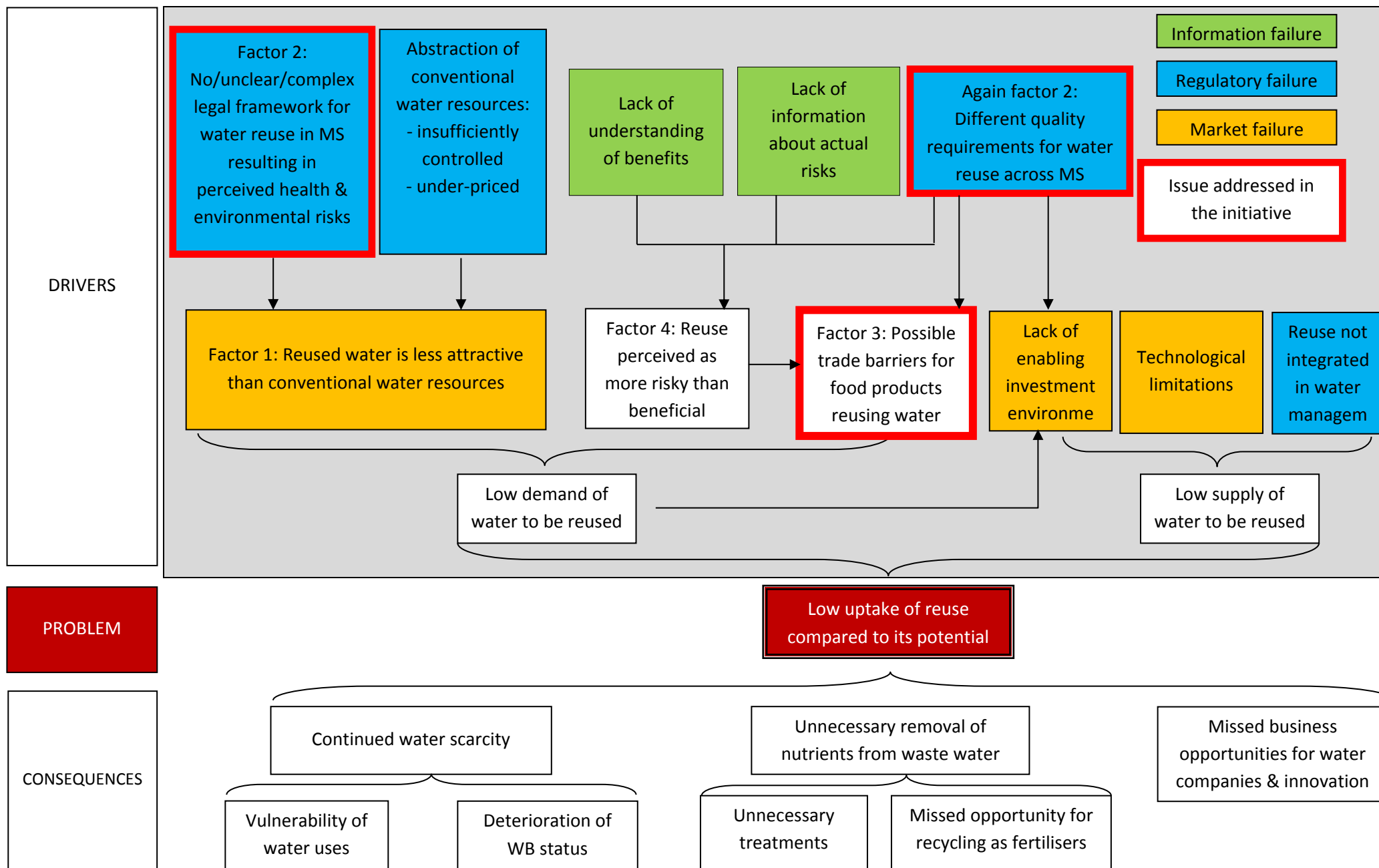
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## Annex 5 - Problem tree



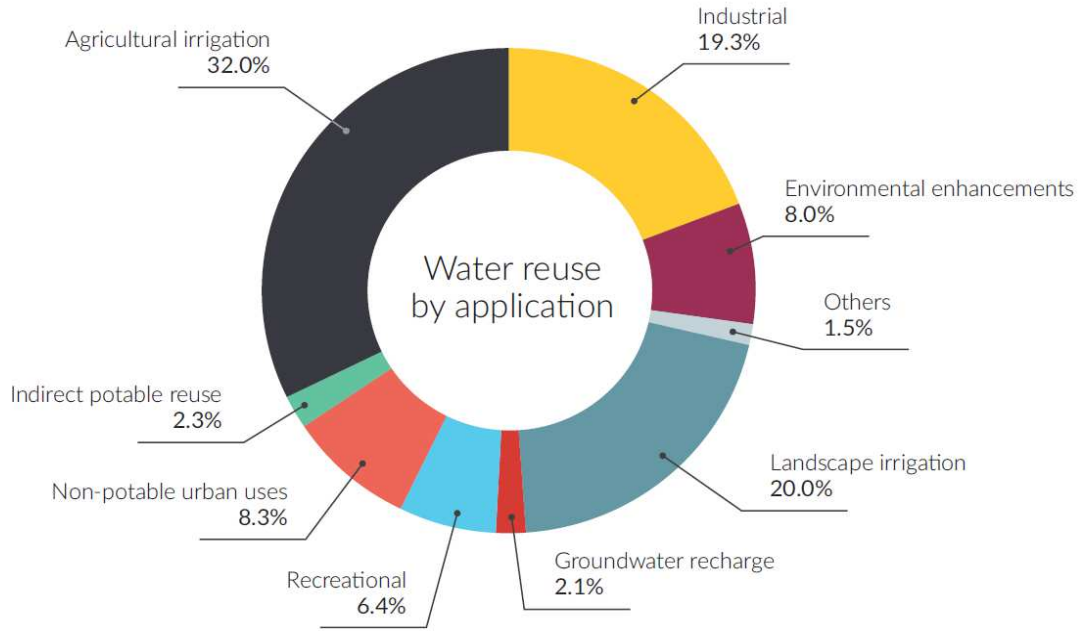
## **Annex 6 - The purposes and benefits of reusing water - situation in selected Member States**

In this report, the term "water reuse" is used interchangeably with the terms "reuse of treated wastewater" and "use of reclaimed water". They all stand for the use of water which is generated from wastewater and which, after the necessary treatment, achieves a quality that is appropriate for its intended uses (taking account of the health and environment risks and local and EU legislation). Unless it is specified otherwise, the source of reclaimed water is urban wastewater in accordance with the Urban Waste Water Directive. "Water reuse" refers to planned or intended water reuse, namely water reuse schemes that are developed with the goal of beneficially reusing a recycled water supply. Water reuse for irrigation typically allows substituting abstractions from depleted aquifers with reclaimed water which would otherwise be discharged to rivers. In contrast, unplanned water reuse refers to uncontrolled reuse of treated wastewater after discharge. An example of unplanned reuse of wastewater is when effluents from a wastewater treatment plant are discharged upstream in a river while river water is abstracted downstream for the production of drinking water or for irrigation.

Treated wastewater may be used for a wide variety of purposes, and there is continuing innovation in potential uses. These include:

- Contributing to environmental objectives/making water available for future uses such as aquatic ecosystem restoration or creation of new aquatic environments, stream augmentation (especially in dry seasons), aquifer recharge (e.g. for saline intrusion control or later abstraction for use such as the further uses below).
- Agricultural/horticulture uses such as irrigation of crops (food and non-food), orchards and pastures.
- Industrial uses such as cooling water, process water, aggregate washing, concrete making, soil compaction, dust control etc.
- Municipal/landscape uses such as irrigation of public parks, recreational and sporting facilities, private gardens, road sides, street cleaning, fire protection systems, vehicle washing, toilet flushing, dust control.

Figure 25. Global water reuse after advanced (tertiary) treatment: Market share by application



Source: Lautze et al. (2014, Figure 2, p. 5, based on Global Water Intelligence data).

### Reusing water for aquifer recharge

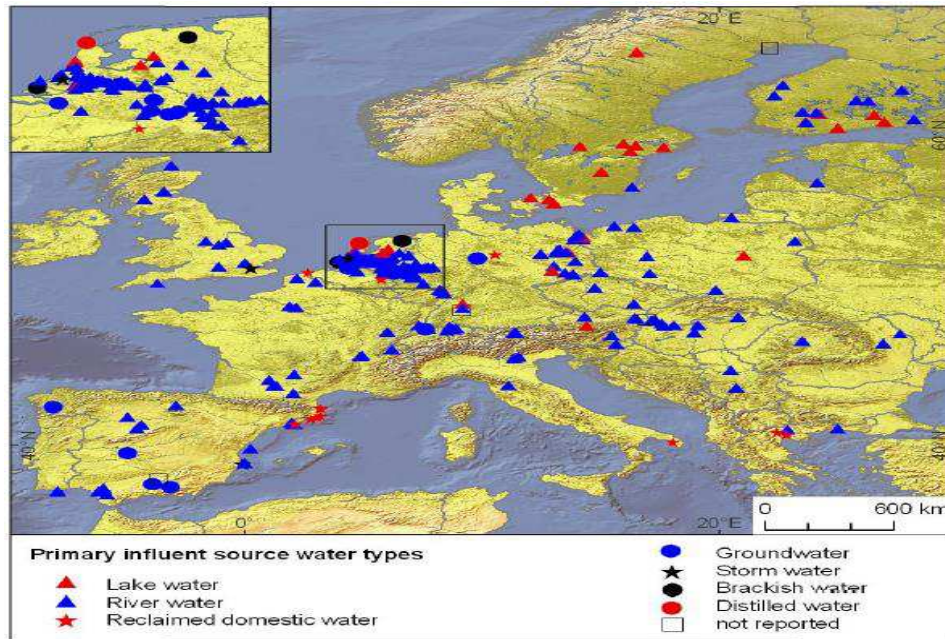
Aquifer recharge is a hydrological process where water moves downward from the soil surface towards groundwater. Recharge occurs both naturally (through the water cycle) and man-induced (i.e. artificial aquifer recharge), where rainwater, surface water and/or reclaimed water is routed to the subsurface. Artificial groundwater recharge aims at increasing the groundwater potential and it can effectively help preventing saline intrusion in depleted coastal aquifers. The lack of scientific and technical knowledge (including lack of clarity of ownership and liability), coupled with low perception of this kind of technique being an important water management instrument, contribute to the low uptake at present (Escalante, 2014). The barriers identified for aquifer recharge specifically include: the limited knowledge on the receiving waters, in particular the impacts on water quality due to the mixing; technical problems associated with the design and choice of the recharge technique; poor quality of water used for the recharge (often of lesser quality than potable water or with presence of emerging pollutants -pharmaceuticals, industrial chemicals, pesticides and degradation products) resulting in a potential to degrade the receiving groundwater; downstream impacts on environment and other users; and socio-economic challenges (Escalante, 2014). The risks to health and the environment from pollutants such as bacteria, viruses and emerging pollutants and priority substances such as those already detected occasionally in discharges from water treatment plants (and in high concentrations) are also perceived as an obstacle (Estévez et al., 2016; Estévez et al., 2012). However, in the first public consultation, aquifer recharge was one of the most often mentioned additional appropriate uses, in particular in order to prevent saline intrusion.

As illustrated in Figure 26, managed aquifer recharge (MAR) is a practice relatively widespread in Europe. In a comprehensive but non-exhaustive review FP7 project DEMAU



could identify about 270 sites (220 being still active), with a spatial distribution covering most of the European countries. Different water sources can be used for MAR. River and lake water and groundwater have been the most commonly used influent so far, while treated waste water has remained rather limited (12 sites out of 270 in the DEMEAU catalogue, in Belgium, Germany, Italy, Greece and Spain). In most case recharge with reclaimed water is done via surface spreading and more limitedly injection (4 sites).

Figure 26: spatial distribution of MAR sites in Europe and primary source of water (Hannappel et.al, 2014)



In addition to the benefits in terms of freshwater availability, there is a wide range of environmental benefits associated with reuse schemes, in particular:

- Reducing pressure on water bodies, maintaining ecological flows and protecting aquatic ecosystems;
- Preserving high-quality groundwater for more sensitive uses (e.g. drinking water production);
- Decreasing the nutrient pollution load directly discharged to rivers or other waterbodies, and the associated risks of eutrophication;
- Improving the quality of irrigation water and bathing waters. Currently, irrigation water sources should comply with the definition of "clean water" at the point of use, i.e. water "that does not contain micro-organisms, harmful substances in quantities capable of directly or indirectly affecting the health quality of food" according to Article 2 of Regulation 852/2004. Further details on implementation of this requirement are given in the Commission Notice 2017/C 163/01<sup>38</sup> "Guidance document on addressing microbiological risks in fresh fruits and vegetables at primary production through good hygiene";

<sup>38</sup> [2017/C 163/01](http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ%3AC%3A2017%3A163%3ATOC) - <http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ%3AC%3A2017%3A163%3ATOC>

- Restoring or enhancing biodiversity and the various ecosystem services associated with wetlands;
- Protecting groundwater resources from saline intrusion, particularly in islands and coastal areas (through groundwater recharge);
- Reducing the amount of organic fertilisers applied to irrigated fields, thereby contributing to conserving natural resources of phosphorus and reducing environmental impacts associated with fertilisers' manufacture;
- Decreasing the level of purification/treatment necessary for discharging wastewater, thereby reducing energy consumption associated with water treatment, while guaranteeing compliance with all the relevant legislation.

In the second open public consultation, a majority of respondents (more than 70% across and within different categories of respondents) perceive the environmental benefits of reusing water for agricultural irrigation for:

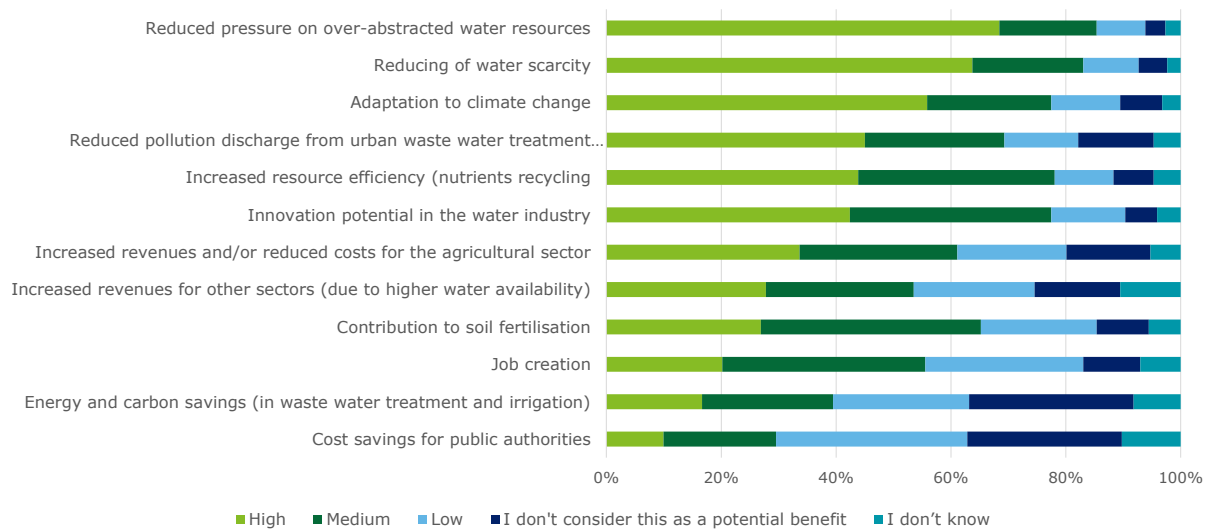
- **reducing pressure on resources** that are over-abstracted,
- **reducing water scarcity**, and
- **thereby adapting to climate change.**

These potential benefits are particularly highlighted by respondents from the sanitation, drinking water and environment/climate sectors as well as respondents from countries in regular situation of water stress or more generally from Southern EU (over 80% of respondents within each of these categories).

A large number of respondents (more than 70% of all respondents) also identify the following environmental benefits:

- **increased resource efficiency**,
- **enhanced innovation potential** in the water industry, and
- **reduced pollution discharge** from urban wastewater treatment plants into rivers. In this respect, a utility provider recognised that capture of effluents currently discharged in coastal areas would benefit the environment. An academic representative noted that the increased stringency on water treatment plants to produce high quality reused water would indirectly benefit the environment by enhancing the global quality of water discharged.

Figure 27: Overview on potential benefits of water reuse in agricultural irrigation, for all respondents



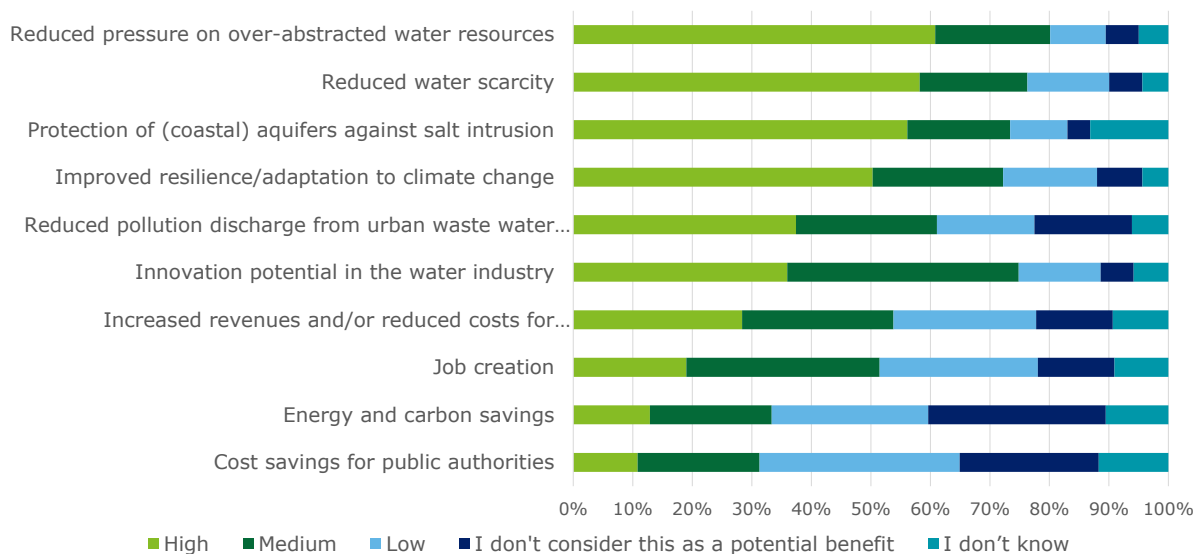
A large share of respondents (more than 70%) perceive the environmental benefits of reusing water in aquifer recharge for:

- reducing pressure on resources that are over-abstracted: an industry association representing French water companies highlighted in particular the benefits of the limited evaporation allowed by water storage in the aquifer,
- reducing water scarcity, and
- protecting coastal aquifers against salt intrusion.

In addition, water reuse is perceived by a significant number of respondents across all sectors (over 70%) to contribute to fostering the innovation potential in the water industry.

A large proportion of respondents also considers adaptation to climate change and reduced pollution discharge into rivers as benefits of reusing water for aquifer recharge, although they are considered slightly more moderate than the first ones and appear less consensual across sectors and categories of stakeholders. Several respondents commented on the benefits of aquifer recharge to reduce pollution discharge, e.g. by reducing water exposure to various contaminations and eutrophication occurring at the surface of the earth and through filtering services from the soils.

Figure 28: Views on potential benefits of water reuse in aquifer recharge



Because the uptake of water reuse solutions will remain very limited at the EU level in the baseline scenario, these other benefits are unlikely to materialise at a wide scale across the EU.

On the other hand, environmental risks potentially associated with treated wastewater reuse, such as chemical contaminants from inorganic salts, nutrients, heavy metals and micro pollutants, e.g. detergents, would also remain minimal. Emerging pollutants, such as pharmaceutical products and their metabolites, personal care products, household chemicals, food additives, etc., in particular, represent a growing environmental concern. At the moment, however, there is not yet full scientific consensus on the actual level of risks associated with many of these various substances and further research is thus required.

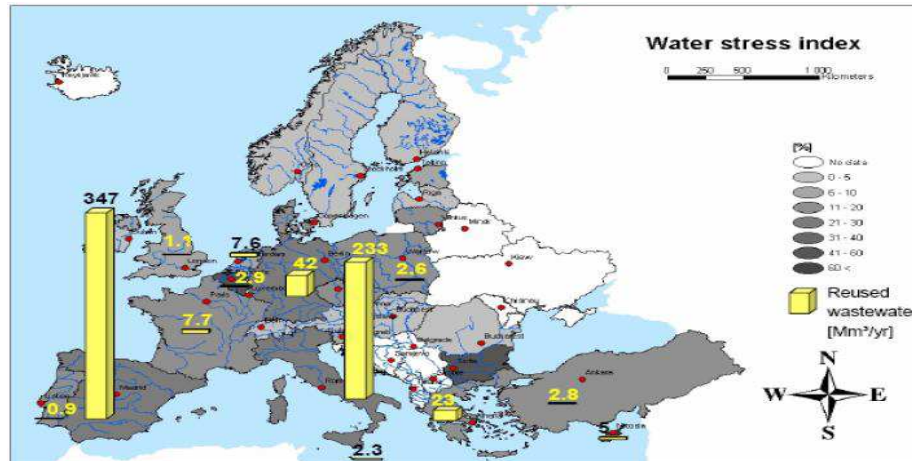
### Current status of water reuse in the EU – selected Member States

In 2006, the total volume of reused treated wastewater in the EU amounted to 964 million m<sup>3</sup>/year, accounting for 2.4% of the treated urban wastewater or less than 0.5% of annual EU freshwater abstraction (Hochstrat et al., 2006). No complete and harmonised data are available on the current volume of treated wastewater being reused in the EU; however **the current volume of reused treated wastewater in the EU can be estimated at 1,100 million m<sup>3</sup>/year** or 0.4% of annual EU freshwater abstractions (BIO, 2015).

In 2006, Spain and Italy jointly accounted for about 60% of the total EU treated wastewater reuse volume, predominantly for agricultural irrigation and for urban or environmental applications. Other countries are reusing much less, and the reuse figures broadly decline the further north one goes. In relative terms (i.e. in comparison to treated wastewater volume generated in each of the Member States), reuse was considered significant in Cyprus and Malta where 89% and about 60% of treated wastewater treatment plant effluents are being re-used respectively for various purposes. In other countries, such as Greece, Italy and Spain reuse of treated wastewater constituted between 5% and 12% of total treated effluent from wastewater treatment plants. Figure 29 below presents the amount of reused treated

wastewater in European countries, as estimated by FP5 project AQUAREC in 2006, relative to the spatial distribution of water stress.

Figure 29: Reuse of reclaimed water in Europe (Hochstrat et al., 2006)

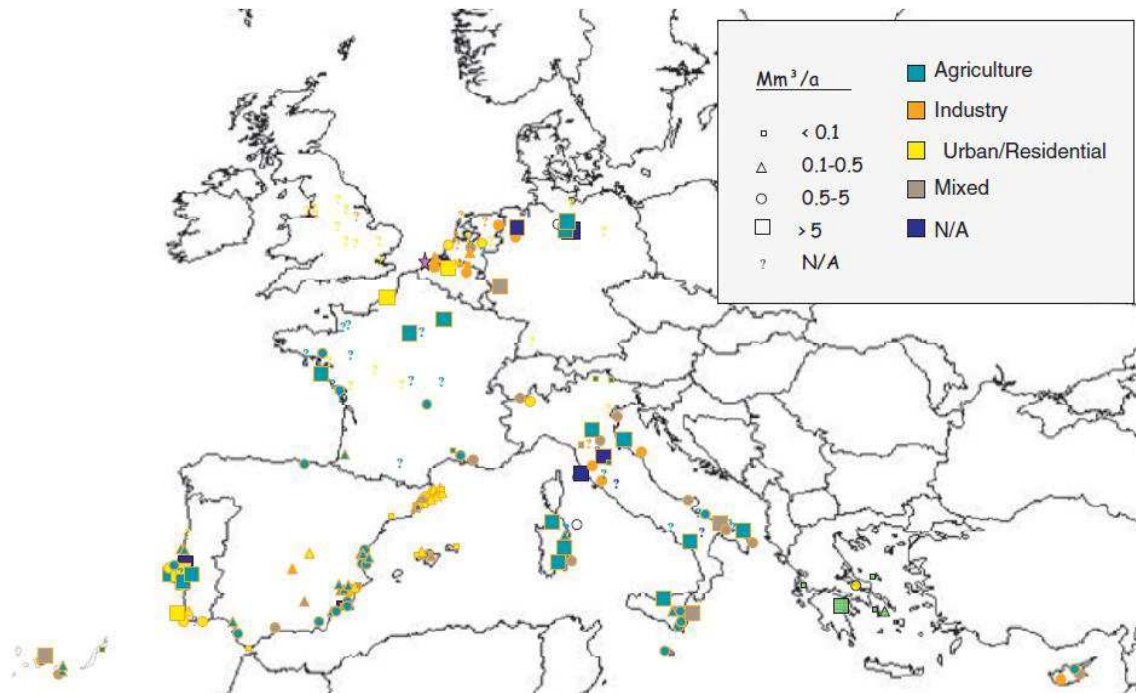


The literature suggests that some countries have little or no evidence of any water reuse schemes; this is understandably the case in countries with high water availability and low drought risk, such as Ireland or Finland. However, some Member States that have experienced severe water stress recently are also in this situation, including some Baltic countries (e.g. Latvia and Lithuania), as well as Eastern European countries (Romania, Bulgaria, Slovakia, Slovenia, and Hungary). It is important to highlight that the southern and Baltic states usually have efficient urban waste water treatment plants, hence there is potential for reusing reclaimed water. Such potential is more limited in Eastern European states, where many treatment plants are not yet equipped with appropriate treatment technologies at present. However the need for upgrade and refurbishment of these treatment plants to comply with the UWWTD also provides an opportunity for considering water reuse as a possible solution at lesser costs than would be needed to integrate water reuse at a later stage.

Member States in which water reuse is being practiced include Scandinavian countries (Sweden, Denmark), southern European states (Spain, Cyprus, Malta, Italy, Greece, Portugal) as well as North-Western countries (France, Belgium, UK, Luxembourg, the Netherlands). In Luxembourg, Sweden and Denmark, water reuse is driven by high water prices and ecological concerns, especially during the summer. For instance, several Danish industries recycle wastewater, while in Sweden treated wastewater is used for irrigation purposes. Reuse of water for agricultural activities is also very widespread in southern European countries, although it must also be highlighted that water reuse in these countries is also driven by tourism, for example for irrigation of golf courses and parks. In European regions that are not water-scarce but experience episodic drought events, water recycling is becoming much more widespread and being implemented in the agricultural, urban and industrial sectors. This is the case for countries such as the UK and France, where competition for increasingly limited water resources during peak demand periods is driving interest in alternative sources. Even short dry spells in humid or temperate countries can trigger temporary restrictions in freshwater abstraction.

Furthermore, interest in water reuse implementation can be evaluated by considering the number and geographical spread of projects in Europe. Such an analysis was conducted in 2005 during the AQUAREC project (Figure 30). In the course of this Impact Assessment updated and consistent data on water reuse projects in Europe has been collected, in particular as concerns information already reported by Member States to Eurostat and to the Commission under the WFD and UWWTD. Given the relatively recent interest for these technologies in a number of Member States only very limited data is available at this stage and suggests the possible need for adapting existing reporting tools in the future for monitoring and evaluation of this policy area (Chapter 7).

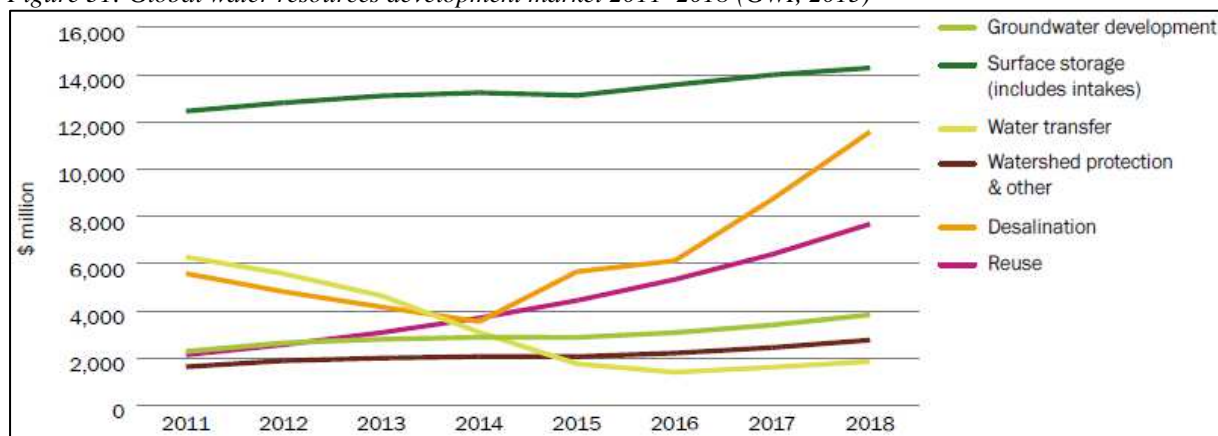
Figure 30: Identified water reuse projects in Europe, incl. their size and intended use (Bixio et al., 2005)



All information sources agree on the significant potential for further development of water reuse projects in the EU. Climate change pressures are likely to increase the level of interest in such solutions for both mitigating wastewater disposal impacts and episodic drought effects (Falloon et al., 2010). Moreover, a number of countries are developing the policy and – for those that do not possess suitable wastewater treatment technology – technical capacities needed to promote the uptake of water reuse solutions.

The global market for water reuse is expected (Global Water Intelligence, 2015) to be fast-growing in the coming years. Between 2011 and 2018 capital expenditure on advanced water re-use was expected to have grown at a compound annual rate of 20% (cf. Figure 31 as the global installed capacity of high quality water re-use plants grows from 7 km<sup>3</sup>/yr to 26 km<sup>3</sup>/yr.

Figure 31: Global water resources development market 2011–2018 (GWI, 2015)



As confirmed by the number of projects funded by the EU on this topic in the last decade and by experts in a dedicated workshop (cf. Annex 8) water reuse is an active field for research and innovation.

Details on the current state of water resources and treated wastewater reuse in agricultural irrigation and aquifer recharge in selected Member States are presented in the section below. The selection covers Spain, Italy, Greece, Cyprus, France and Romania representing a wide range of Member States including countries with and without existing national standards on treated wastewater reuse, major and small users of treated wastewater in the EU as well as Member States where significant share of treated effluent from wastewater treatment plants is being reused.

## Spain

In terms of water reuse, all of RBDs in Spain already consider water reuse in their RBMPs. Current data from the second cycle of RBMPs (all River Basin Districts included except Catalonia and Canary Islands, where the most updated data from the river basin authority have been used) shows that reclaimed water in Spain reached 413 hm<sup>3</sup>/yr in 2013. Their estimations at the plan submission date approached 520 hm<sup>3</sup>/yr for 2015 with extended projections in 2021. Should these projections and regional plans for water reuse – e.g. Madrid and Catalonia, be factored in, the total estimated volume would soar up to 1,150 hm<sup>3</sup>/yr,<sup>39</sup> showing what actually a potential upper bound is if all planned investments are in fact implemented.

Total volumes disclosed in the Survey of Water Supply and Sanitation, according to official data from the Office for National Statistics (INE, 2015a) differ from the RBMPs data, with a total volume of water reuse of 531 hm<sup>3</sup> per annum in 2013. Disparities may be due to differing criteria on the year used as a “current reference” within RBMPs. The total amount of reclaimed wastewater was 11% of the total volume of wastewater treated in 2013. This share remained steady (10-12%) from 2007, when the Spanish water reuse regulation came into force. Before 2007, the average value was lower than 8%. Again, the situation was

<sup>39</sup> According to the draft National Plan for Water Reuse (MARM 2010a), which was not further developed and implemented as such

especially remarkable in SE Spain (including Segura and Júcar River Basin Districts, plus the Balearic Islands), where 62%, 55% and 48% of wastewater treated was reused in 2013, respectively (INE, 2015a).

Additional information is available from non-official sources. AEAS (Spanish Association of Water Supply and Sanitation Services) (2014) reported that the use of reclaimed wastewater in 2012 was around 9.7% of treated wastewater. 77.3%, as above, were reused in agriculture, 10.2% in other forms of irrigation (leisure areas), 9.7% to undetermined uses, 2.2% in manufacturing, and 0.6% for cleaning. Updated information produced by AEAS and reported by iAgua (2016) shows significant changes in these shares: irrigated agriculture (41%), other irrigation uses (31%), industrial (12%) and other undetermined uses (16%).

In turn, FENACORE (National Federation of Irrigation Districts) have recently projected water reuse in Spain in 2016 on the basis of information reported to the Commission in the second cycle of river basin management plans. This yields a rough estimate of 400 million m<sup>3</sup>/year of reused water out of a total urban wastewater volume of 3,500 million m<sup>3</sup>/year.

The cost of water reuse treatments are asymmetric depending on the treatment used to meet legal water quality requirements: the upfront investment cost can vary from 5 €/m<sup>3</sup> produced/day (filtration) to 736 €/m<sup>3</sup> produced/day (chemical treatment with a lamella settling system, ultrafiltration, reverse osmosis) and operational and maintenance costs may vary from 0.04 €/m<sup>3</sup> (filtration, and disinfection or depth filtration) to 0.35-0.45 €/m<sup>3</sup>/day (with lamella/double depth chemical precipitation, ultrafiltration, RO/EDR desalination and disinfection). A specific example of costing in a region with a consolidated capacity of reclaimed wastewater reuse (Valencia, see Molinos-Senante et al., 2013) shows an average opex for secondary treatment of 0.26 €/m<sup>3</sup>, 0.32 €/m<sup>3</sup> for tertiary treatment, and 0.57 €/m<sup>3</sup> for advanced treatments such as osmosis or ultrafiltration.

The legal framework for water reuse is quite an advanced one at EU level. Nationwide, water reuse is regulated by Royal Decree 1620/2007 (December 7<sup>th</sup>), which establishes quality criteria (maximum acceptable values, presence-absence for certain parameters according to the type of water use) as well as risk management measures including inter alia both for reuse of treated wastewater in agricultural irrigation and aquifer recharge.

The Decree expressly forbids reclaimed water for the following uses:

- Human consumption, with the exception of a catastrophic event;
- Food industry, except process and cleaning waters, as in Art 2.1b) of Royal Decree 140/2003;
- Hospitals and alike;
- Filter-feeding molluscs aquaculture;
- Bathing waters (recreational uses);
- Cooling towers and evaporation condensers, with exemption criteria for some industrial uses;
- Fountains and ornamental plates in public or interior spaces of public buildings; and
- Any other use public health or environmental authorities may consider as a risk, whatever the time when the risk or the damage are perceived.



Hence, allowed uses are urban irrigation or other uses (section 1), agricultural irrigation (section 2), industrial uses (section 3), recreational uses (section 4), and environmental uses (i.e. aquifer recharge inter alia) (section 5).

Additional related regulations / guidelines / planning instruments include a) the already mentioned water reuse planning instrument, still in a stagnant, draft stage (the National Water Reuse Plan, MARM, 2010a); b) all the 2<sup>nd</sup> River Basin Management Plans already adopted (i.e. main RBDs, Balearic Islands, Galicia Coast and Andalusian RBDs (see BOE 2016a; 2016b) as they contemplate water reuse measures, and c) an official specific document containing guidelines for the application of Royal Decree 1620/2007 (MAGRAMA, 2010b).

As per water reuse in agriculture, Appendix I.A. of the Decree sets up water quality criteria for intestinal nematodes, *Escherichia coli*, suspended solids, turbidity, and additional criteria such as *Legionella spp.*, *Taenia*, and complying with Environmental Quality Standards regarding several pollutants. Regarding water reuse for aquifer recharge, similar criteria are defined and others are added, such as nitrogen and NO<sub>3</sub>, both for recharge through surface infiltration (indirect recharge) or injection (direct recharge). In terms of monitoring, Appendix I.B of the Royal Decree 1620/2007 in turn establishes the minimum sampling and testing frequencies for each quality parameter.

### *Agricultural irrigation*

Conventional agriculture, dominated by extensive crops with low returns per hectare (cereals yield in 2012 amounted 2,843 kg/ha, average for both rain-fed and irrigated fields) (MAGRAMA, 2014), dependent on public infrastructure and EU subsidies (i.e. CAP) contrasts with a dynamic, intensive and highly productive agriculture driven by market stimulus and competitive advantages, with limited financial support either from the local government or the EU (if at all). The largest examples can be found in the Castile and León region, in central Spain, with an average size of 57.7 ha, while those in the southeast are amongst the smallest, with an average size between 5.07 and 11.72 ha (INE, 2014).

The overriding traditional model of agriculture requires limited labour and manufactured inputs; management practices do not demand sophisticated commercial and financial services; and output does not feed complex industrial processes or supply chains. In contrast, the relatively modern and thriving agriculture that dominates water-scarce Mediterranean basins requires increasingly more sophisticated inputs and labour skills, follows modern entrepreneurial practices, and supplies basic commodities for a complex and competitive agro-food manufacturing and logistics industry.

Whereas apparent productivity in the regions of Castile and León (central Spain) and Andalusia (southern Spain) is the same (0.56 €/m<sup>403</sup>), indirect water productivity in Andalusia is actually larger (1.75 €/m<sup>3</sup>) than that of Castile and León (1.65 €/m<sup>3</sup>), showing that the

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<sup>40</sup> Value of agricultural output (EUR) per m<sup>3</sup> of water added

Andalusian agriculture has more relevant forward linkages with the rest of the economy (Pérez et al., 2010).

In regions like Andalusia and Murcia the direct contribution of agriculture to the regional output and employment (4.2% and 4.5%, respectively) might be low (although higher than average), but its indirect and induced impact over the whole production chain makes it the central piece of the existing income and employment opportunities.

According to de Stefano et al. (2015), estimated water demand (surface and groundwater sources) for agriculture amounts to approximately 25,000 million m<sup>3</sup>/year (or 79% of total water demand). Groundwater abstraction is estimated at circa 6,125-6,925 million m<sup>3</sup>/year (19-22% of Spain's total water demand) out of which 70-72% (4,300-5,000 million m<sup>3</sup>/year) is used for around one third of irrigated land (0.9 million hectares, on the basis of 3.3 million of irrigated ha). Following INE (2015), available water for irrigation in Spain comes from surface sources (77%), groundwater (21%), and desalination or reuse (2%). Arable crops account for 56% of water for irrigation whereas 16% is for fruit trees, 10% for olive trees and vineyards, 9% for other crops and 8% for potatoes and vegetables. Irrigation techniques have moved away from gravity (still 37%) towards drop irrigation (37% also) and sprinkler (26%).

It is of paramount importance to highlight groundwater prices in areas of the country with high water scarcity, since this is critical to understanding some of the variables for further penetration of water reuse for agriculture. According to Custodio (2015) common prices for groundwater in SE Spain range between 0.3 and 0.5 €/m<sup>3</sup> (and can be higher depending on conjoint use and the cost of energy for pumping). In the Canary Islands usual prices are around 0.5 €/m<sup>3</sup> though during peak demand they can go beyond 1 €/m<sup>3</sup>.

### *Aquifer recharge*

According to the last implementation report of the WFD (EC, 2015), the number of delineated groundwater bodies (GWB) in Spain is 748, with an average size of 482 km<sup>2</sup> and a total area of more than 355,564 km<sup>2</sup>. De Stefano et al. (2015) estimated that groundwater abstraction is around 6,125-6,925 million m<sup>3</sup>/year i.e. around 22% of the total water demand. Agriculture is the main groundwater user (70-72%), followed by domestic supply (23-22%) and industry (6-5%) and, to a lesser extent, recreational uses (0.4%). The chemical status of GWB (% by number of bodies) was good for 66.0%, poor for 32.9% and unknown for 1.1%. On quantitative grounds, the status was good for almost three quarters (71.3%), poor for 27.3% and unknown for 1.5%.

Estimates from the DINA-MAR Research Project (Escalante, 2014) show that managed aquifer recharge (MAR) in Spain hits 380 million m<sup>3</sup>/year. According to the DEMAU Project (Hannappel et al., 2014), 25 out of the 270 European known MAR sites (9%) are in Spain, most of them (López-Vera, 2012) in Mediterranean regions.

At European scale, Spain is the European country where MAR for irrigation is most common. Environmental uses (e.g. to restore the hydraulic gradient to mitigate seawater intrusion at the Llobregat aquifer in Barcelona – by means of injection wells/ infiltration through infiltration

ponds, and Marbella) are also common (as in other European countries such as Germany and the Netherlands). In Spain, in practice all MAR schemes are implemented in fluvial deposits. Main types of MAR are Aquifer Storage and Recovery (ASR) and Aquifer Storage Transfer and Recovery (ASTR) and infiltration ponds, followed by flooding and, to a lesser extent, by others such as pits and excess irrigation, riverbed scarification, and ditch and furrow.

There is no information available within the second cycle of RBMPs about specific volumes of treated wastewater used for aquifer recharge.

The mean investment cost ratio (€/m<sup>3</sup>) differs according to the implemented MAR technique. Escalante (2014) provides examples on the basis of implemented projects: 9.75 €/m<sup>3</sup> for ponds; 0.80 €/m<sup>3</sup> for dams; 0.23–0.58 €/m<sup>3</sup> for deep boreholes (deep injection); 0.36 €/m<sup>3</sup> for medium-deep boreholes and 0.21 €/m<sup>3</sup> for surface MAR facilities (ponds, channels). 16% of the analysed area in the country (Iberian Peninsula and Balearic Islands, Canary Islands excluded: *circa* 500,000 km<sup>2</sup>) has the potential for being used for MAR (i.e. 134,000 million m<sup>3</sup>, i.e. 2 million m<sup>3</sup>/km<sup>2</sup>).

## Cyprus

Cyprus, as far as natural water resources are concerned, depends solely on rainfall. The total annual water supply is 3030 million m<sup>3</sup>/year, 89% of which is lost in evapotranspiration, leaving 321 million m<sup>3</sup>/year as useable water. Historically, droughts occur every two-to-three years due to the decline in rainfall. In the last fifty years, however, drought incidences have increased both in magnitude and frequency. Reuse of treated wastewater (known in Cyprus as “recycled water”) provides additional drought-proof water supply.

In terms of water stress, Cyprus is the most affected country of the European Union, with a water stress index of approximately 66%<sup>41</sup>. Domestic water use and agricultural irrigation are the two main sources of water demand in Cyprus.

In Cyprus, water reuse provides additional drought-proof water supply, favours a more local sourcing of water and avoids the use of drinking water quality water where such high quality is not needed. The potential for water reuse depends on the availability and accessibility of wastewater (i.e. the wastewater infrastructure) and the acceptability by potential end-users and consumers. Cyprus has adopted a ‘Not a Drop of Water to the Sea’ policy encouraging the maximum capture of run-off by dam construction and handling of wastewater.

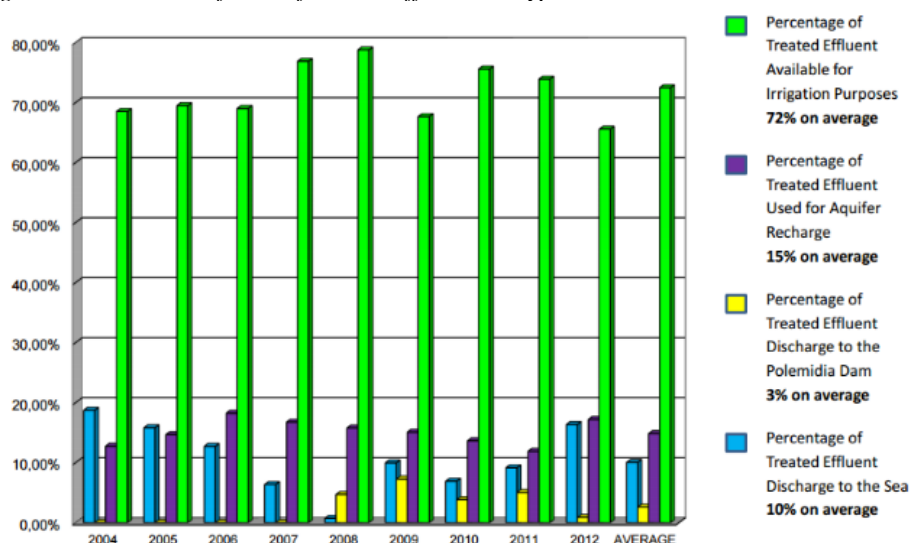
Almost 90<sup>42</sup>% of treated wastewater is reused, primarily for the irrigation of agricultural land, parks, gardens and public greens. In 2011, 12 million m<sup>3</sup>/year of recycled water is given for irrigation and about 2,2 million m<sup>3</sup>/year for artificial recharge of aquifers.

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<sup>41</sup> Eurostat tsdnr310 | Publication date: 19 February 2016, CET (Water Exploitation Index - Percentage)

<sup>42</sup> For 2004-2013 – 89.32% according to competent authority communication

Figure 32: Overview of uses of treated effluent in Cyprus



Source: Ministry of Agriculture, Natural Resources and Environment Water Development Department River Basin Management Plan, April 2011

However, a significant increase in the amounts of treated wastewater available in the future is expected. The capacity of the new Waste Water Treatment Plants was expected to reach up to 85 million m<sup>3</sup>/year for long term (2025)<sup>43</sup>.

Cyprus is one of the Member States where water reuse provisions are fully integrated into the legislation on urban wastewater treatment and discharge (State Law N.106(I)/2002, as amended). Quality criteria for the treated wastewater take the specific conditions of Cyprus into account. In particular, conventional secondary treatment has been preferred to stabilisation ponds in some areas because of the high cost of land (coastal areas) or for protection of environmental and aesthetic amenities for tourism. Different uses of treated wastewater require different levels of treatment and, by extension, costs.

#### *Agricultural irrigation*

In Cyprus, the use of recycled water has mostly been for irrigation and to mitigate the overdependence of agriculture on groundwater<sup>44,45</sup>. In Cyprus about 25 million m<sup>3</sup>/year of wastewater is collected and used for irrigation after tertiary treatment. It is anticipated that most of the recycled water, about 55 to 60%, is used for amenity purposes such as hotel gardens, parks and golf courses. Most treated wastewater (12 million m<sup>3</sup>/year) is used directly

<sup>43</sup> Ministry of Agriculture, Natural Resources and Environment Water Development Department River Basin Management Plan, April 2011

<sup>44</sup> Pashiardis, S. Trends of precipitation in Cyprus rainfall analysis for agricultural planning. In Proceedings of the 1st Technical Workshop of the Mediterranean Component of CLIMAGRI Project on Climate Change and Agriculture, Rome, Italy, 25–27 September 2002

<sup>45</sup> Eighth Report on the Implementation Status and the Programmes for Implementation (as required by Article 17) of Council Directive 91/271/EEC concerning urban waste water treatment

for irrigation with orchards being the most irrigated crops, such as citrus and olive trees, but water is also used for fodder crops.

According to information made available by the Water Development Department (WDD), the acceptance of using recycled water from farmers was initially slow (period 2002-2005) but in time it has increased significantly.

Separate regulation, i.e. Cyprus Regulation K.D.269/2005 specifies the reclaimed water quality criteria for treated wastewater produced from agglomerations with less than 2,000 population equivalent. For agglomerations of more than 2,000 population equivalent (p.e.), the quality characteristics that must be met for the use of the treated effluent are specified within Wastewater Discharge Permits, issued by the Ministry of Agriculture for the Sewerage Boards and the Water Development Department.

The prevailing treatment technology was, until recently, conventional activated sludge treatment with secondary clarifiers followed by sand filtration and chlorination. However, most new projects under planning (new wastewater treatment plants as well as extension of existing ones) are considering advanced technologies such as membrane application, e.g. bioreactor technology (Larnaca, Limassol, and Nicosia) or reverse osmosis.

Cyprus adopted water quality standards for wastewater reuse in 2005 and is prohibiting the irrigation of treated wastewater for vegetables that are consumed raw, crops for exporting, and ornamental plants.

Yearly water needs of irrigation amounts to an average of 178.5 million m<sup>3</sup>/year; however, as this demand is rarely satisfied, the actual water consumption in agriculture fluctuates around 150 million m<sup>3</sup>/year. Irrigated agriculture accounts for 88% of this amount (or 132 million m<sup>3</sup> of water per year) while accounting for only 28% of the total area under crops. Agricultural sector accounts for around 60% of total Cyprus' water consumption<sup>46</sup>.

In Cyprus, the current nationally set objective is to replace 40% of agricultural freshwater requirements by reclaimed water.

Costs for construction and operation of municipal wastewater collection and treatment infrastructure are funded by the local communities through the sewerage rates. Tertiary treatment and reclaimed water distribution networks are financed and operated by the government, through the Water Development Department. Customers are charged different prices for reclaimed water depending on the end use.

Reused water tariffs in Cyprus range from 33%-44% of freshwater rates, ratios which appear typical for the EU Mediterranean islands<sup>47</sup>. The price reflects the application of substantial subsidies to reclaimed water supplies to encourage wider uptake, which may be at odds with the need for greater cost recovery in water treatment and management (BIO, 2015). Although such subsidised price structures have been in place for many years to incentivise take-up, price rates are usually based on intuitive judgements by utilities of the level of willingness to accept reclaimed supplies amongst different groups rather than empirical evidence of the

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<sup>46</sup> Arcadis, et al. (2012). The Role of Water Pricing and Water Allocation in Agriculture in Delivering Sustainable Water Use in Agriculture.

<sup>47</sup> Hidalgo & Irusta, 2005

price at which users would begin to accept these supplies over conventional freshwater. (BIO, 2015)

Research focused on irrigation of forage and citrus revealed no adverse impacts on using treated wastewater on either soil physicochemical properties or heavy metal content, nor on the heavy metal content of agricultural products. Similarly, research results concerning wastewater irrigation of tomato crops showed no accumulation of heavy metals in tomatoes, whereas total coliforms and faecal coliforms were not quantified in tomato flesh or peel; and E.coli, Salmonella spp and Listeria spp were not detected in tomato homogenates. Research on pharmaceutical compounds detected traces of these compounds in treated effluent but further research is on-going to assess whether they are being taken up by plants under field conditions. (Appendix D of AMEC study- case study for Cyprus)

### *Aquifer recharge*

In Cyprus almost all the aquifers are over-exploited and, for many of them, water quality has deteriorated due to seawater intrusion. In particular, characterising water bodies according to requirements of the WFD, around 80% of the groundwater bodies had been assessed as being at risk of failing to achieve a "good status" by 2015. This is mainly due to over-pumping, saltwater intrusion, high nitrate concentrations caused by agricultural activities<sup>48</sup>.

Further action, therefore, is required for reducing aquifer extraction to a level which will allow the aquifers to recover. This can be achieved with very careful management that is focused mainly in two methods: first with the drastic reduction of pumping to sustainable levels and second with the increase of their recharge with natural and artificial methods. Managed Aquifer Recharge (MAR) is becoming an increasingly attractive water management option, especially in semi-arid areas. Artificial recharge using treated wastewater in depleted aquifers, via deep boreholes, is an internationally acceptable practice, which is compatible with Directive 2000/60/EC and may contribute to cover a part of irrigation needs, as well as the sustainable water resources management in many areas<sup>49</sup>. It does, however, have a number of limitations; with the degradation of subsurface environment and groundwater due to the transport of pathogenic viruses with the recycled water being the main environmental issue associated with artificial recharge. Furthermore, the clogging effect of boreholes caused by suspended solids, bacterial and recharge water is a phenomenon that limits the viability of artificial recharge.

In Cyprus, the lack of suitable site selection is one of the limiting factors in applying groundwater recharge. The process of selecting suitable locations includes: hydrogeological conditions, availability and quality of wastewater, possible benefits, economic evaluation and environmental considerations<sup>27</sup>. The wastewater should be pre-treated to improve its physico-chemical characteristics. The pre-treatment includes ultrafiltration and/or inverse osmosis. Membrane techniques are successful in producing wastewater with low values of TDS and nutrient content. The lack of field studies on the fate and transport of priority substances, heavy metals and pharmaceutical products within the recharged aquifer is also an important consideration.

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<sup>48</sup> MANRE,2005

<sup>49</sup> Voudouris, K.; Diamantopoulou, P.; Giannatos, G.; Zannis, P. Groundwater recharge via deep boreholes in Patras industrial area aquifer system (NW Peloponnesus, Greece). Bull. Eng. Geol. Environ. 2006, 65, 297-308.

On the other hand, important advantages of aquifer recharge include:

- Seawater intrusion being controlled;
- Provision of storage of effluent water for subsequent retrieval and reuse;
- The aquifer serving as an eventual natural distribution system;
- Further purification of effluent water (reduced biological load); and
- Saving of equal quantities of fresh water for domestic use.

In Cyprus, four candidate regions have been selected on the basis of water scarcity/ shortage or deficiency and aridity of the area, social and economic characteristics and the complexity of the water system. Recycled water is used to recharge depleted aquifers and reduce seawater intrusion. This is the method used in Paphos, where the Ezousa aquifer is recharged artificially with 2–3 million m<sup>3</sup> treated wastewater per year, which is then re-abstracted for irrigation<sup>50, 51</sup>.

## France

Although France does not experience serious water stress (with its Water Exploitation Index being around 15.5% for the period 2008-2012 (Eurostat)), the analysis of natural flows in France shows that low water periods are getting more frequent and more serious in the last 40 years (1970-2010), particularly affecting the South of France (ONEMA, 2011). The consumption of water for farming is growing particularly strongly in South-Western France and in the Paris region (TYPESA, 2013).

In addition to the growing demand for water for agricultural purposes, some irrigated crops (such as corn) have become more widespread and periodic droughts have occurred. Over the last 20 years droughts events affected the regions traditionally considered to be the wettest, in Western and North-Western France. In more than one-third of the country, water tables are falling as the autumn and winter rains are no longer making up for the amounts drawn up in spring and summer. Faced with this situation, the authorities have occasionally imposed restrictions on water use, a very unusual practice in France. It is also worth recalling that around fifteen French departments are situated in an area with a Mediterranean climate similar to that of Northern Spain and Italy, well-suited to market gardening, fruit farming and mass tourism.

In France, water reuse systems are already in place, and legally binding standards for reuse are in place for the agricultural sector and water reuse for green and recreational areas.

There are no recent data on the total volume of reused water in France but the latest data from a 2007 report indicate that water reuse was 19,200 m<sup>3</sup>/day corresponding to about 7 million m<sup>3</sup>/year (according to Jimenez et al.<sup>52</sup>). At present, there are about 40 reuse schemes in France, most of which are dedicated to irrigation (agriculture, public areas, golf courses and

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<sup>50</sup> Water Scarcity in Cyprus: A Review and Call for Integrated Policy, Anastasia Sofroniou and Steven Bishop

<sup>51</sup> Eighth Report on the Implementation Status and the Programmes for Implementation (as required by Article 17) of Council Directive 91/271/EEC concerning urban waste water treatment

<sup>52</sup> However, the yearly estimate must be taken as indicative (or as a maximum potential yearly production), as it is calculated taking the daily production and multiplying it by 365. However, it must be noted that reused water is used mostly during the summer period.

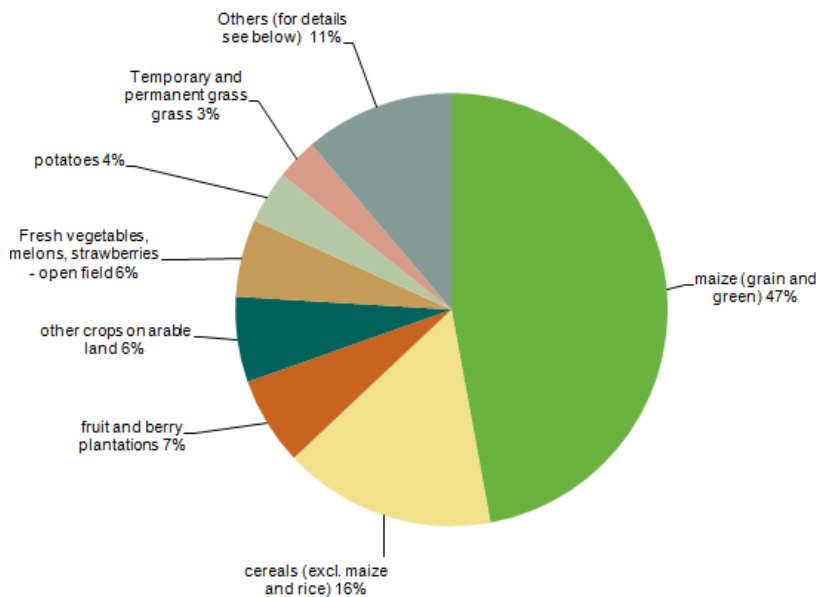
racecourses) (SYNTEAU, 2014). Latest available data indicate that around 55 reuse schemes are now in place in the country<sup>53</sup>.

### *Agricultural irrigation*

Agriculture is the main user of water in France (48% of the water used in 2004<sup>54</sup>). The total agricultural area equipped for irrigation amounts to 27.7 million hectares; however, in 2010, it was reported that irrigation actually occurred on 1.6 million hectares, corresponding to a total water use of 2.7 billion m<sup>3</sup> per year.

The irrigated area by type of crop is illustrated in the Figure below<sup>55</sup>.

*Figure 33: Irrigated area by type of crop (2010)*



The reuse of wastewater for irrigation purposes is still little developed in France. On the one hand, France is hardly facing water scarcity issues – and when it does, scarcity events unfold at the local scale. In fact, water reuse for irrigation is limited to particular regions, such as islands or areas with a high water demand and uses possibly conflicting with potable use. On the other hand, the price of reused water is higher than the price of conventional water, so there is no economic incentive to switch to reused water. In particular, in France, both volumetric and mixed tariffs are applied to the provision of irrigation water. The EEA (2013) reports flat tariffs ranging between 38 and 157 EUR/year, combined with volumetric rates ranging between 0.06 and 0.09 EUR/m<sup>3</sup>. Tariffs paid by farmers cover 100% of operation and

<sup>53</sup> Communication from French competent authority

<sup>54</sup> France Nature Environnement, 2008.

<sup>55</sup> France Nature Environnement, 2008.



maintenance costs, but they do not fully cover investment costs: depending on the area, revenues from tariffs cover from 15% to 95% of investments costs (55% on average)<sup>56</sup>.

At the end of the 1990s, only around twenty water reuse projects could be found in France; all projects were set up for irrigation of crops, green spaces and golf courses. The largest water recycling project provides irrigation water to 2,300 ha<sup>57</sup>. More updated data are not available, although it seems that few additional projects have been set up since then. According to an ongoing study by CEREMA, the number of operating water reuse projects has more than doubled since 2010<sup>58</sup>.

The French population already eats fruits and vegetables imported from countries where water reuse for irrigation is frequent (e.g. Spain). Despite this, a third of the French population declared themselves not ready to eat fruits and vegetables irrigated with recycled water (CGDD, May 2014).

### *Aquifer recharge*

The volume of groundwater in France is estimated at 2000 billion m<sup>3</sup> per year, of which 100 billion m<sup>3</sup> per year flow through springs and water courses. About 7 billion m<sup>3</sup> per year are extracted from groundwater through the exploitation of springs, wells and drillings. Half of the water is used for drinking water<sup>59</sup>, covering two thirds of the demand for drinking water (BRGM, 2016).

Of the 646 groundwater bodies in France, 90.6% were in a good quantitative status in 2013. Water bodies with less than good status are mainly situated in the South-East and the centre, the Mediterranean region as well as the islands Réunion and Mayotte. The main reasons for not reaching good status are overexploitation of the aquifers compared to their recharge, but also salt water intrusion (Réunion, Mediterranean region).

There are no official statistics on artificial groundwater recharge in France. An inventory from the year 2013 (Casanova et al., 2013) listed 75 sites of artificial groundwater recharge on the French national territory. The status of 48 out of them is known with certainty, without certainty for 8 and unknown for 19. Two-thirds of the sites for which the status is known are situated in the (former) regions Nord-Pas-de-Calais, Midi-Pyrénées and PACA. Only about 20 of them are still active today (Casanova et al., 2013). The techniques applied are either indirect injection (infiltration basins) or direct injection (via drilling) (BRGM, 2016).

In most of the known cases of artificial groundwater recharge in France, the primary objective is to support an overexploited groundwater body. The second objective is the improvement of the quality of the groundwater bodies through significantly diminishing the concentrations of certain chemicals by dilution (e.g. nitrates, pesticides). The latter allows for

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<sup>56</sup> EEA, 2013. Assessment of cost recovery through pricing of water. Technical report No 16/2013.

<http://www.eea.europa.eu/publications/assessment-of-full-cost-recovery>

<sup>57</sup> <http://www.ecoumenegolf.org/XEauXLAZAROVA.pdf>

<sup>58</sup> The ongoing CEREMA study aims to establish an assessment of reuse in France and the relevant places to develop the reuse. Information on the original study could not be found, this information was provided by French Competent Authority (personal communication).

<sup>59</sup> <http://www.eaufrance.fr/comprendre/les-milieux-aquatiques/eaux-souterraines>

the application of simpler and more economic final treatments to make the water suitable for drinking water purposes (Casanova et al., 2013).

In almost all cases which are currently active in France, surface water is the source of water used for artificial recharge. This is mainly due to the availability of the resource. Artificial recharge with treated wastewater is not prohibited. However, this is not regulated by existing legislation, as quality requirements and allowed uses of treated wastewater are only regulated for irrigation of crops and green areas<sup>60</sup>.

While direct injection of treated wastewater in the aquifer has never taken place in France, two research projects on indirect infiltration of treated effluent have been carried out by BRGM – the public service provider for the quantitative groundwater management in France – and the company Veolia until 2011 (REGAL and RECHARGE) (BRGM, 2016).

## Greece

In Greece the theoretical long-term annual freshwater availability is 72,000 million m<sup>3</sup>/year<sup>61</sup>. Due to a range of technical and economic reasons the amount of freshwater which is readily available for abstraction and use is much lower. The annual freshwater abstractions constitute only 13% of the theoretical availability and are estimated at 9,539 million m<sup>3</sup>/year<sup>1</sup>. The major water user in Greece is irrigated agriculture, which accounts for 84% of the total water use.

Half of the Greek RBDs (7 out of 14) face water scarcity issues (Water Exploitation Index (WEI<sup>62</sup>)+>20%) with these 7 RBDs being among the twenty most water-scarce RBDs of Europe<sup>63</sup>.

Wastewater reuse in Greece is being regulated by JMD 145116/2011 (GG B 354) and JMD 191002/2013 (GG B 2220), which aims to promote wastewater reuse and protect public health by establishing criteria and standards on its practice. Their scope extends to urban and conventional industrial wastewater (included in JMD 5673/400/97), for restricted and unrestricted irrigation in agriculture, urban and peri-urban use, aquifer recharge (including protected aquifers) and industrial use.

The reported estimates for the current and potential volumes of reused wastewater differ significantly. The average daily wastewater reuse is estimated at 28,000 m<sup>3</sup>/day (or 10.2

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<sup>60</sup> Arrêté du 2 août 2010 relatif à l'utilisation d'eaux issues du traitement d'épuration des eaux résiduaires urbaines pour l'irrigation de cultures ou d'espaces verts  
<https://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000022753522&dateTexte=&categorieLien=id>

<sup>61</sup> Eurostat data, Water statistics, Agricultural statistics, Crop statistics, Agri-environmental indicators, Agricultural Census in Greece.

<sup>62</sup> The water exploitation index (WEI) in a country is the mean annual total demand for freshwater divided by the long-term average freshwater resources. The following threshold values/ranges for the water exploitation index have been used to indicate levels of water stress: (a) non-stressed countries < 10%; (b) low stress 10 to < 20%; (c) stressed 20% to < 40%; and (d) severe water stress ≥ 40%. (EEA, 2015.  
<http://www.eea.europa.eu/data-and-maps/indicators/water-exploitation-index>)

<sup>63</sup> ETC/ICM, 2016. Use of freshwater resources in Europe 2002–2012. Supplementary document to the European Environment Agency's core set indicator 018. ETC/ICM Technical Report 1/2016, Magdeburg: European Topic Centre on inland, coastal and marine waters, 62 pp

million m<sup>3</sup>/year)<sup>64</sup>, while in the AQUAREC project the average annual wastewater reuse was estimated at 23 million m<sup>3</sup>/year<sup>65</sup>. The future potential for wastewater reuse in Greece (2025) was modelled at 57 million m<sup>3</sup>/year<sup>66</sup> in the AQUAREC project, while another study estimated it at 242 million m<sup>3</sup>/year<sup>67</sup>.

When compared to the total water use in the country, wastewater reuse in Greece accounts for less than 1%). Furthermore, the share of reclaimed wastewater, when compared to the total treated effluent is below 5%<sup>68</sup>. In addition, a water balance analysis has revealed that over 83% of the treated effluent from wastewater treatment plants are produced in regions with a water deficit. Furthermore, over 88% of the effluents from WWTP are discharged at less than 5 km from available farmland, which implies that the additional cost for wastewater reuse in irrigation could possibly be technically and economically affordable<sup>69</sup>.

### *Agricultural irrigation*

The reuse of treated urban wastewater for agricultural irrigation may require differentiation depending on the type of crops (e.g. food crops to be eaten raw, food crops to be cooked or processed, non-food crops, ornamental flowers), the irrigation equipment (sprinklers used or not) and the status of access for the public and for animals (restricted or unrestricted).

It is estimated that 84% of the total water use in Greece is taken up by irrigated agriculture (3,897 million m<sup>3</sup>/year). The average irrigation intensity is 3,800 m<sup>3</sup>/ha, which is the 6th highest in Europe<sup>70</sup>.

Irrigation water in Greece is billed in a number of ways with the average price ranging between 0.02-0.70 €/m<sup>3</sup><sup>71</sup> for volumetric billing, 73-286.3 €/ha<sup>72</sup> for flat rates by crop type and 45-243.1 €/ha for flat rates by irrigation system<sup>73</sup>. There are no abstraction or pollution charges. The price of self-abstracted groundwater can be roughly approximated using the electricity consumption for pumping. For an expected range of depths it could range between 0.02-0.03 €/m<sup>3</sup><sup>3</sup>. The price of desalination water is 0.3-0.7 €/m<sup>3</sup><sup>74</sup>. Since the monetary cost of (usually illegal) self-abstracted on-farm surface water and groundwater is very low (<0.03 €/m<sup>3</sup>), these users are unlikely to be interested in using reclaimed water. At least 32% of the

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<sup>64</sup> Kellis M., Kalavrouziotis, I.K., and Gikas, P., 2013. Review of wastewater reuse in the Mediterranean countries, focusing on regulations and policies for municipal and industrial applications. *Global NEST Journal*, Vol. 15, No. 3, pp. 333-350.

<sup>65</sup> Hochstrat et al., 2006. Report on integrated water reuse concepts. Deliverable D19, AQUAREC project.

<sup>66</sup> Hochstrat et al., 2006. Report on integrated water reuse concepts. Deliverable D19, AQUAREC project

<sup>67</sup> Tsagarakis, K.P., Tsoumanis, P., Chartzoulakis, K., Angelakis A.N., 2001. Water resources status including wastewater treatment and reuse in Greece: Related problems and prospectives. *Water International*, 26, 2, pp. 252–258

<sup>68</sup> TYPESA, 2012. Wastewater reuse in the European Union. Service contract for the support to the follow-up of the Communication on Water Scarcity and Droughts, Report for DG ENV.

<sup>69</sup> BIO by Deloitte, 2015. Optimising water reuse in the EU, Final report prepared for the European Commission (DG ENV), Part I. In collaboration with ICF and Cranfield University

<sup>70</sup> Eurostat data, Agri-environmental indicators

<sup>71</sup> Kalligaros, D., 2004. *The cost of irrigation water in Greece*, Postgraduate Thesis, Environmental Studies Department, University of the Aegean.

<sup>72</sup> OECD, 2010. *Agricultural Water Pricing: EU and Mexico*, <http://www.oecd.org/eu/45015101.pdf>

<sup>73</sup> OECD, 2010. *Agricultural Water Pricing: EU and Mexico*, <http://www.oecd.org/eu/45015101.pdf>

<sup>74</sup> Zotalis, K., Dialynas, E., Mamassis, N., and Angelakis, A.N., 2014. Desalination Technologies: Hellenic Experience, *Water*, 6, 1134-1150; doi:10.3390/w6051134

total holdings rely on self-abstracted groundwater. Taking into account the price of desalination water (0.3-0.7 €/m<sup>3</sup>) it is concluded that wastewater reuse might be more cost-efficient than desalination in coastal areas and islands with existing WWTPs. It is also expected that reclaimed water would be appealing to users of off-farm water supply, which account for nearly 63% of the total irrigation water users. Given that the existing irrigation freshwater tariffs range significantly across the country (0.02-0.70 €/m<sup>3</sup>) and reported price of reclaimed water ranges from 0 (Salonica case study) to 0.12-0.30 €/m<sup>3</sup> (Pinios case study), there is not sufficient data to make the comparison between the two types of water.

Over recent years at least 9 wastewater reuse projects for crop irrigation have been implemented in Greece with EYATH in Salonica (2,500 ha; corn, cotton, sugarbeet, rice, alfalfa) being the most important project<sup>75</sup>.

Overall, technical, economic and social reasons will continue to block faster uptake of wastewater reuse for agricultural irrigation in the baseline. Additional wastewater reuse might come from the WWTPs where it is already implemented and potentially from some more new sites in Crete<sup>76</sup>. A conservative estimate is that wastewater reuse in irrigated agriculture would increase by 10-20% up to 2025 (Appendix D of AMEC study - case study for Greece).

### *Aquifer recharge*

In Greece, the average annual groundwater availability for abstraction is reported at 3,550 million m<sup>3</sup>/year<sup>77</sup>. When considering actual water abstraction in Greece, groundwater resources account for 38% of the total water abstraction. Groundwater is a primary source for drinking water in rural areas and for the industrial sector. It is also a significant source of water for irrigated agriculture, which covers 84% of total water use. Almost 80% of the Greek groundwater bodies are in a good state. Only 17% of them are in bad quantitative state<sup>78</sup>.

The reuse of treated urban wastewater for aquifer recharge is differentiated depending on the type of aquifer (potable or non-potable water resources) and the applied method (direct injection in boreholes and wells or surface spreading and infiltration). It should be highlighted that direct injection of reclaimed water is not allowed for aquifers with potable water resources. Additionally, a hydrogeological study is required in all cases.

Reported data on aquifer recharge were not found in Eurostat or in the “National Program for the Management and Protection of Water Resources”<sup>79</sup>. After communication with the

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<sup>75</sup> Ilias, A., Panoras, A., and Angelakis, A., 2014. Wastewater Recycling in Greece: The Case of Thessaloniki. *Sustainability*, 6, pp. 2876-2892; doi:10.3390/su6052876

<sup>76</sup> Agrafioti, E., Diamadopoulou, E., 2012. A strategic plan for reuse of treated municipal wastewater for crop irrigation on the Island of Crete, *Agricultural Water Management*, 105, 57-64

<sup>77</sup> Eurostat data, Water statistics, Agricultural statistics, Crop statistics, Agri-environmental indicators, Agricultural Census in Greece.

<sup>78</sup> COM, 2015. *WFD implementation report on River Basin Management Plans, MS: Greece*, Commission Staff Working Document accompanying the document Communication from the Commission to the European Parliament and the Council: "The Water Framework Directive (WFD) and the Floods Directive (FD): Actions towards the ‘good status’ of EU water and to reduce flood risks", European Commission, Brussels.

<sup>79</sup> Koutsoyiannis, D., Andreadakis, A., Mavrodimitou, R., Christofides, A., Mamassis, N., Efstratiadis, A., Koukouvinos, A., Karavokiros, G., Kozanis, S., Mamais, D., and Noutsopoulos, K., 2008. *National Program for the Management and Protection of Water Resources*. Support to the development of the national program for

Special Secretariat for Water, the Greek authorities could not provide additional information on similar projects. Literature review revealed only two cases of aquifer recharge in Greece. Both were/are conducted in the context of research projects and serve as pilot sites. It is interesting that both of them are actually wastewater reuse projects.

For a WWTP of 4,000 m<sup>3</sup>/day the estimated cost for aquifer recharge is at least 0.17 €/m<sup>3</sup> to 2.12 €/m<sup>3</sup>. When using treatment with microfiltration or reverse osmosis, the cost of electricity could be 0.15 €/m<sup>3</sup>. A newer abstraction from the recharged aquifer for indirect use would require an additional cost for pumping. Hence, the whole chain of costs would increase further. On the other hand, wastewater reuse in agricultural irrigation could cost 0.44 €/m<sup>3</sup> <sup>36</sup> (a range of 0.123-0.304 €/m<sup>3</sup> is reported at one of the sites (see Appendix for the Greek case study). Generally there is a lack of concrete economic data, but reuse for aquifer recharge seems to be less mature and less competitive than reuse for agricultural irrigation in Greece.

Overall, very limited expansion is expected for aquifer recharge using reclaimed water under the baseline.

## Italy

Despite an average annual rainfall of 1 000 mm/year, well above the European average, average freshwater availability for the population (2 900 m<sup>3</sup>/capita) is one of the lowest among OECD countries, due to high evapotranspiration, rapid run-off and limited storage capacity (OECD, 2013). In addition, available resources are distributed very unevenly across the national territory: 59.1% are in fact in the North, whereas the rest is shared by the Centre (18.2%), the South (18.2%) and the islands (4.5%).

With annual water abstraction making up 31% of available water resources, Italy is classified as a medium-high water-stressed country (OECD, 2013).

Under the Law-decree n. 152, a new legislative set of rules was promulgated on June 12th, 2003 (Ministry Decree, D.M. no 185/03) under which recycled water can be used for (APAT, 2008):

- Irrigation of crops for human and animal consumption, as well as non-food crops. Irrigation of green and sport areas;
- Urban uses: street washing, heating and cooling systems, toilet flushing; and
- Industrial uses: fire control, processing, washing, thermal cycles of industrial processes (recycled water must not get in contact with food, pharmaceutical products or cosmetics).
- Treated wastewater is used mainly for agricultural irrigation. However, the controlled reuse of municipal wastewater in agriculture is not yet developed in most Italian regions and has decreased due to the low quality of water.

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the management and conservation of water resources, 748 pages, Department of Water Resources and Environmental Engineering, National Technical University of Athens, Athens.

Average costs, as calculated by ISPRA in a survey of several Italian recycling plants (different plants for different uses: urban, industrial, agriculture) range between 0.083 and 0.48 EUR/m<sup>3</sup>. As a comparison, the costs of abstracting water from rivers and groundwater bodies is estimated at 0.015-0.2 EUR/m<sup>3</sup>. The high cost of recycled water is generally indicated as one of the main barriers to water reuse<sup>80</sup>.

### *Agricultural irrigation*

Nearly 50% of water abstraction is attributed to the agricultural sector.

Irrigated areas are unevenly distributed across the country: 66% of irrigated area is, in fact, concentrated in the relatively water-abundant North, whereas the rest is shared between the Centre (6%) and the South (28%). The three major irrigated crops are maize, rice and vegetables (ISTAT, 2010). Although the irrigated agricultural area only accounts for 19% of the total Utilised Agricultural Area (UAA) (ISTAT, 2010), in terms of production, irrigated agriculture accounts for 50% of total production and 60% of total value added of the agricultural sector, and its products constitute 80% of agricultural exports (Althesys, 2013).

The use of untreated wastewater has been practiced in Italy at least since the beginning of this century, especially on the outskirts of small towns and near Milan. Reuse of untreated wastewater is prohibited in Italy: the legislation requires that all discharges comply with normative standards. Therefore, the reuse of untreated wastewater is illegal and, as such, subject to penal and administrative sanctions. Treated wastewater is used mainly for agricultural irrigation. However, the controlled reuse of municipal wastewater in agriculture is not yet developed in most Italian regions.

### *Aquifer recharge*

Groundwater makes up almost 50% of water abstracted for domestic water supplies (ISTAT, 2012b). Overexploitation has been reported in the North, in the lower reaches of the Po plain and around Venice, due to industrial and agricultural uses as well as gas and oil extraction.

Water availability differs significantly from Northern to Southern Italy. In the North, water is relatively abundant, due to stable and abundant flows in water courses throughout the year. In addition, out of 13 billion m<sup>3</sup> of groundwater available annually, over 70% is located in the North, and particularly in the Po river plain. In contrast, the South of Italy is often subject to long periods without precipitation, resulting in droughts and water rationing (OECD, 2013).

Over 52% of GWBs are assessed as having good quantitative status, according to Italy's reporting; however, the status is unknown for almost 32%.

At present, artificial aquifer recharge interventions are not common in Italy, and current practice focuses mainly on pilot experimental sites (Regione Emilia Romagna, 2008<sup>81</sup>; confirmed by other sources up to 2015.). Existing examples of artificial aquifer recharge are being implemented thanks to EU LIFE and FP7 funding:

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<sup>80</sup> ISPRA, 2009. L'ottimizzazione del servizio di scarico urbano: massimizzazione dei recuperi di risorsa (acque e fanghi) e riduzione dei consumi energetici. Rapporto 93/2009. <http://www.isprambiente.gov.it/it/pubblicazioni/rapporti/12019ottimizzazione-del-servizio-di-depurazione>

<sup>81</sup> <http://ambiente.regione.emilia-romagna.it/acque/informazioni/documenti/studio-sulla-ricarica-artificiale-delle-falde-in-emilia-romagna/view>

LIFE+ AQUOR (ended in May 15): implementation of artificial aquifer recharge in the Province of Vicenza - <http://www.lifeaquor.org/en> ;

LIFE+ TRUST (ended in December 2011): research in the aquifer recharge area in the Veneto plain (rivers Isonzo, Tagliamento, Livenza, Piave, Brenta and Bacchiglione) <http://www.lifetrust.it/cms/> ;

LIFE+ WARBO (ended in March 2015): testing of artificial aquifer recharge methods (from rainwater) in the Po Delta and in the Pordenone province - <http://www.warbo-life.eu/it> ; and

MARSOL – FP7 (on-going): Demonstrating Managed Aquifer Recharge as a Solution to Water Scarcity and Drought – Pilot sites in Italy: Brenta (Veneto) and Serchio (Liguria) - <http://www.marsol.eu/6-0-Home.html> .

A recent modification to the Environmental Act – Art. 24, comma 1, Law 97/2013 – clarified some important technical and permitting aspects of aquifer recharge. In particular, these interventions can be authorised provided that they are executed in compliance with the criteria to be established by the Ministry of Environment through a specific Decree – Ministerial Decree 2 May 2016, n.100.

According to Legislative Decree 152/06, wastewater discharge into groundwater bodies is forbidden with some exceptions. Such exceptions include artificial aquifer recharge, provided that this does not compromise the achievement of the environmental objectives established for the specific groundwater body. Aquifer recharge is established and regulated by the RBMPs and the Water Protection plan.

Artificial aquifer recharge is also subject to Environmental Impact Assessment (LIFE AQUOR, 2015<sup>82</sup>).

Artificial aquifer recharge was also included in the National Operational Programme “Governance and systemic actions – European Social Fund 2007-2013 – Axis E Institutional Capacity, Specific Objective 5.5 Reinforce and Integrate the environmental governance system, Action 7A Horizontal actions for environmental integration”, as part of models and tools for water resource management (natural water retention measures, aquifer recharge and participatory systems)<sup>83</sup>.

At present, no testing of artificial groundwater recharge with treated effluents has been reported: this practice is forbidden in Italy<sup>84</sup>.

## **Romania**

Romania's water resources are relatively poor and unevenly distributed in time and space with about 40 billion m<sup>3</sup> being available for use per year. Water demand in Romania in 2014 was 7.21 billion m<sup>3</sup>/year.

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<sup>82</sup> [http://www.lifeaquor.it/file/649-A6\\_linee\\_guida\\_tecnico\\_operative\\_I.pdf](http://www.lifeaquor.it/file/649-A6_linee_guida_tecnico_operative_I.pdf)

<sup>83</sup> <http://www.pongas.minambiente.it/pubblicazioni/misura-7a/pubblicazioni/news/studio-di-settore-modelli-e-strumenti-di-gestione-e-conservazione-delle-risorse-idriche-sistemi-naturali-di-ritenzione-idrica-ricarica-artificiale-delle-falde-e-processi-partecipativi>

<sup>84</sup> The Ministerial Decree 2 May 2016, n.100 indicates the sources for groundwater recharge, which do not include wastewater.

In 2013, the Water Exploitation Index was 15.2 (Eurostat), which is below the EEA's threshold of 20% for water stress<sup>85</sup>.

The balance between water availability and the expected trends for water demand shows no deficit at state level or in the 11 sub-basins; there are only a few river sections with deficits in the Prut - Bârlad basin that should be carefully considered in the future<sup>86</sup>.

Currently treated wastewater reuse is not being practiced in Romania for either irrigation or aquifer recharge. Wastewater reuse in irrigation was launched experimentally as part of research projects, but it is not a mainstream practice. In regard to aquifer recharge, this is currently a prohibited practice, as the Waters Law prohibits injections of wastewater into groundwater.

Furthermore, given decreasing water consumption, lack of irrigated agriculture and adequate natural recharge of the most aquifers in Romania, there is low demand for the use of treated wastewater overall.

### *Agricultural irrigation*

The total irrigated area in Romania is 2.99 million ha with 85% of the area being irrigated from the River Danube. In reality, (functional) irrigated land accounted for less than 300,000 ha (less than 1% of the total arable land) in the last 5 years (2011-2015), consuming about 1 million m<sup>3</sup> per year.

Although Romanian legislation does not forbid the use of treated wastewater in irrigation, there are no specific regulations and standards that govern water reuse. Additionally, the low number of users that are connected to the irrigation system and the relatively low water volume that is used for irrigations at national level does not currently act as an incentive to invest in further technologies.

In the long run, the interest in treated water reuse for irrigation might increase, as forecasts predict a significant increase of the number of users connected to the irrigation system, while research has begun to study the conditions under which treated wastewater could be used in agriculture at experimental level.

### *Aquifer recharge*

The groundwater potential in Romania is estimated at 9.6 billion m<sup>3</sup>/year. In general terms, groundwater is not overexploited in Romania. In fact, data for 2014 showed that surface water abstraction accounted for around 10 times the volume of water abstracted from groundwater resources.

Furthermore, aquifer recharge using treated wastewater is currently a prohibited practice in Romania with the Waters Law explicitly prohibiting injections of wastewater into

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<sup>85</sup> The water exploitation index (WEI) in a country is the mean annual total demand for freshwater divided by the long-term average freshwater resources. The following threshold values/ranges for the water exploitation index have been used to indicate levels of water stress: (a) non-stressed countries < 10%; (b) low stress 10 to < 20%; (c) stressed 20% to < 40%; and (d) severe water stress  $\geq$  40%. (EEA, 2015.

<http://www.eea.europa.eu/data-and-maps/indicators/water-exploitation-index>)

<sup>86</sup> Romanian Waters



groundwater. The current potential for treated wastewater reuse in aquifer recharge, therefore, is effectively non-existent.

### Comparison of MS regulations/guidelines on water reuse for agriculture and the proposed minimum quality requirements

The minimum quality requirements for water reuse in agricultural irrigation are compared with the national regulations from MS that have the most comprehensive standards developed specifically for water reuse practices including agricultural uses: Cyprus, France, Greece, Italy, Portugal and Spain. The regulations of Cyprus, France, Greece, Italy and Spain are included as regulations in the national legislation. In Portugal, the standards on water reuse are guidelines, but they are taken into consideration by the national government when issuing any water reuse permits in the country.

This comparison is not exhaustive but includes the following points:

- Parameters (microbiological and physico-chemical) and limit values
- Category of crops
- Irrigation method
- Risk management framework

The following tables (Table 1, 2, 3, 4 and 5) show different quality categories included in the minimum quality requirements and the MS standards for the reclaimed water quality.

**Table 1.** Category of reclaimed water quality for agricultural irrigation in MS standards and the minimum quality requirements proposed by JRC.

Analytical parameters/ Category of use	JRC	Cyprus	France	Greece	Italy	Portugal	Spain
<b>CATEGORY A</b>							
<b>Verification monitoring</b>							
<i>Escherichia coli</i> (cfu/100ml)	≤10; ≤100	≤5	≤250	≤5; ≤50	≤10; ≤100		≤100; ≤1,000
Fecal coliforms (cfu/100ml)						≤100	
<i>Legionella sp.</i> (cfu/l) <sup>(a)</sup>	≤1,000						≤1,000
<i>Salmonella sp.</i>					absence		absence (c)
Intestinal helminth eggs (eggs/l)	≤1 <sup>(b)</sup>	absence				≤0.1	≤0.1
TSS (mg/l)	≤10	≤10	≤15	≤10	≤10	≤60	≤20
BOD <sub>5</sub> (mg/l)	≤10	≤10		≤10	≤20		
COD (mg/l)		≤70	≤60		≤100		
Turbidity (NTU)	≤5			≤2 median			≤10
<b>Validation monitoring</b>							
<i>Escherichia coli</i> (log <sub>10</sub> reduction)	≥5						

Analytical parameters/ Category of use	JRC	Cyprus	France	Greece	Italy	Portugal	Spain
<b>Total coliphages/F-specific coliphages/somatic coliphages (log<sub>10</sub> reduction)</b>	≥6						
<b><i>Clostridium perfringens</i> spores/Sulphite-reducing bacteria spores (log<sub>10</sub> reduction)</b>	≥5						
<b>Fecal enterococci (log<sub>10</sub> reduction)</b>			≥4				
<b>F-specific RNA bacteriophages (log<sub>10</sub> reduction)</b>			≥4				
<b>Sulphite-reducing bacteria spores (log<sub>10</sub> reduction)</b>			≥4				

More stringent than JRC      more stringent than JRC

(a): Only if there is risk of aerosolization. (b): When irrigation of pastures or fodder for livestock. (c): after certain monitoring results is compulsory to conduct analysis of *Salmonella*.

JRC: 90% samples, maximum value in 10% samples. Cyprus: 80% of the samples. Greece: 80% samples and 95% samples. Italy: 80% samples, maximum value in 20% samples. Spain: 90% samples, maximum value in 10% samples.

The requirements of this Category 1 (Table 1) are to be applied for the irrigation of all types of crops, including food crops consumed raw with reclaimed water in direct contact with edible parts of the crop, and using any irrigation method. The only exceptions are described by Cyprus which indicates that it is forbidden the irrigation of leafy vegetables and bulbs consumed raw, and by Portugal that allows irrigation of vegetables consumed raw only by drip irrigation.

**Table 2.** Category of reclaimed water quality for agricultural irrigation in MS standards and the minimum quality requirements proposed by JRC.

Analytical parameters/ Category of use	JRC	Cyprus	France	Greece	Portugal	Spain
<b>CATEGORY B</b>						
<b>Verification monitoring</b>						
<b><i>Escherichia coli</i> (cfu/100ml)</b>	≤100; ≤1,000	≤50	≤10,000	≤200		≤1,000; ≤10,000
<b>Fecal coliforms (cfu/100ml)</b>					≤1,000	
<b><i>Legionella</i> sp. (cfu/l)<sup>(a)</sup></b>	≤1,000					
<b><i>Salmonella</i> sp.</b>						absence <sup>(d)</sup>
<b>Intestinal helminth eggs (eggs/l)</b>	≤1 <sup>(b)</sup>	absence			≤0.1	≤0.1
<b><i>Taenia saginata</i> and <i>Taenia solium</i> (egg/l)</b>						≤1 <sup>(b)</sup>
<b>TSS (mg/l)</b>	(c)	≤10	(c)	(c)	≤60	≤35
<b>BOD<sub>5</sub> (mg/l)</b>	(c)	≤10	(c)	(c)		
<b>COD (mg/l)</b>		≤70				
<b>Validation monitoring</b>						
<b>Fecal enterococci (log<sub>10</sub> reduction)</b>			≥3			
<b>F-specific RNA bacteriophages (log<sub>10</sub> reduction)</b>			≥3			

Analytical parameters/ Category of use	JRC	Cyprus	France	Greece	Portugal	Spain
<b>Sulphite-reducing bacteria spores (log<sub>10</sub> reduction)</b>			≥3			

Less stringent than JRC more stringent than JRC

(a): Only if there is risk of aerosolization. (b): When irrigation of pastures or fodder for livestock. (c): According to Directive 91/271/EEC. (d): after certain monitoring results is compulsory to conduct analysis of *Salmonella*.

JRC: 90% samples, maximum value in 10% samples. Cyprus: 80% of the samples. Greece: median. Italy: 80% samples. Spain: 90% samples, maximum value in 10% samples.

The requirements of this Category 2 (Table 2) are to be applied for the irrigation of food crops consumed raw where the edible portion is produced above ground and is not in direct contact with reclaimed water, processed food crops, and non-food crops including crops to feed milk-or meat-producing animals. All irrigation methods are allowed. The exceptions are the following: Greece does not allow the use of sprinkler irrigation for this category, France only allows irrigation of cut flowers by drip irrigation within this category.

**Table 3.** Category of reclaimed water quality for agricultural irrigation in MS standards and the minimum quality requirements proposed by JRC.

Analytical parameters/ Category of use	JRC	Cyprus	France	Portugal	Spain
<b>CATEGORY C</b>					
<b>Verification monitoring</b>					
<i>Escherichia coli</i> (cfu/100ml)	≤1,000; ≤10,000	≤200	≤100,000		≤10,000; ≤100,000
Fecal coliforms (cfu/100ml)				≤10,000	
<i>Legionella sp.</i> (cfu/l) <sup>(a)</sup>	≤1,000				≤100
Intestinal helminth eggs (eggs/l)	≤1 <sup>(b)</sup>	absence		≤0.1	≤0.1
TSS (mg/l)	(c)	≤35	(c)	≤60	≤35
BOD <sub>5</sub> (mg/l)	(c)	≤25	(c)		
COD (mg/l)		≤125			
<b>Validation monitoring</b>					
Fecal enterococci (log <sub>10</sub> reduction)			≥2		
F-specific RNA bacteriophages (log <sub>10</sub> reduction)			≥2		
<b>Sulphite-reducing bacteria spores (log<sub>10</sub> reduction)</b>			≥2		

Less stringent than JRC more stringent than JRC

(a): Only if there is risk of aerosolization. (b): When irrigation of pastures or fodder for livestock. (c): According to Directive 91/271/EEC.

JRC: 90% samples, maximum value in 10% samples. Cyprus: 80% of the samples. Greece: median. Italy: 80% samples; maximum value.

Spain: 90% samples, maximum value in 10% samples.

The requirements of this Category 3 (Table 3) are to be applied for the irrigation of processed food crops and non-food crops using only drip irrigation, and industrial, energy and seeded crops using all irrigation methods. It has to be noticed that Cyprus and Portugal allow all type of irrigation methods, while France only allows the irrigation of orchards, ornamental flowers, fodder, and cereals but all these food crops have to be irrigated only by drip irrigation. Spain allows the irrigation of orchards, ornamental flowers, nurseries and greenhouses only by drip irrigation.

**Table 4.** Category of the minimum quality requirements for agricultural irrigation proposed by JRC.

Analytical parameters/ Category of use	JRC
<b>CATEGORY D</b>	
<i>Escherichia coli</i> (cfu/100ml)	≤10,000
<i>Legionella</i> sp. (cfu/l) <sup>(a)</sup>	≤1,000
Sulphite-reducing bacteria spores (log <sub>10</sub> reduction)	
Intestinal helminth eggs (eggs/l)	≤1 <sup>(b)</sup>
F-specific RNA bacteriophages (log <sub>10</sub> reduction)	
TSS (mg/l)	(b)
BOD <sub>5</sub> (mg/l)	(b)
COD (mg/l)	

(a): Only if there is risk of aerosolization. (b): According to Directive 91/271/EEC.

JRC: 90% samples, maximum 100,000 in 10% samples.

The requirements of this Category 4 (Table 4) are to be applied for the irrigation of industrial, energy and seeded crops with all irrigation methods allowed.

The risk management framework is not mentioned in the MS regulations as a tool to be applied by MS. But some elements of the RMF are sometimes included (Table 5). Supplementary physico-chemical parameters appear in some MS regulations, mainly agronomic parameters, while the minimum quality requirements proposed are recommending the application of a risk assessment according to local conditions to derived additional requirements for monitoring (Table 5).

Justification for the selected minimum quality requirements with references to MS regulations/guidelines are provided in the technical report (section 4.4).

**Table 5.** Additional requirements included in MS standards and in the proposed minimum requirements for water reuse in agricultural irrigation.

	JRC	Cyprus	France	Greece	Italy	Portugal	Spain
<b>ALL CATEGORIES</b>							
<b>Application of elements from a risk management framework</b>	<b>Yes</b>	<b>Yes</b>	<b>Yes</b>	<b>Yes</b>	<b>No</b>	<b>Yes</b>	<b>Yes</b>
<b>Elements applied</b>	All elements	Multiple barrier	Multiple barrier, validation monitoring	Multiple barrier		Multiple barrier	Multiple barrier
<b>Additional physico-chemical parameters and limit values</b>	Depending on risk assessment results	<b>Yes</b>	<b>No</b>	<b>Yes</b>	<b>Yes</b>	<b>Yes</b>	<b>Yes</b>
<b>Parameters</b>		Heavy metals, nutrients		Heavy metals, nutrients, organic substances	Heavy metals, nutrients, organic substances	Heavy metals, nutrients, organic substances	Heavy metals, nutrients