# Final Publishable Summary Report

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## Acronyms

AMF – Amiad microfiber filtration

CAD - Centro de Alianzas para el Desarrollo

CBA - Costs-benefits analysis

CIP – Cleaning-in-place

CTM - Fundació CTM Centre Tecnològic

CUF – Capacity usage factor

DGENV - Directorate General Environment

DO – Dissolved oxygen

EDR – Electrodialysis reversal

EIP - European Innovation Partnership

FHNW - Fachhochschule Nordwestschweiz

FCM - Flow Cytometry

FR – Flow reversal

GAC – Granulated activated carbon

GC – Gas chromatography

DCI – Dow Chemical Iberia S.L.

HRMS - High Resolution Mass Spectrometers

HRT – Hydraulic retention time

IPR – Indirect potable reuse

IRSA-CNR Istituto di Ricerca sulle Acque-Consiglio Nazionale delle Ricerche

IRTA - Institut de Recerca i Tecnologia Agroalimentàries

JRC - Joint Research Centre

IWVA - Intercommunale Waterleidingsmaatschappij van Veurne-Ambach

KWB Kompetenzzentrum Wasser Berlin

LC - liquid chromatography

LCA- Life-cycle Analysis

LUR – Logarithmic units removal UF- Ultrafiltration

MBBR – Moving bed biofilm reactor

PFA – Performic acid

QMRA - Quantitative Microbial Risk Assessment

qPCR - Quantitative Real Time Polymerase Chain Reaction

RA – Risk Assessment

RO – Reverse Osmosis

RW - Reclaimed water

sAnMBR – Submerged anaerobic membrane bioreactor

SAT – Soil aquifer treatment

SME – Small and medium enterprises

UV – Ultraviolet

VERI - Veolia Environnement Research and Innovation

WWTP – Wastewater treatment plant

WRE – Water Reuse Europe

# 1 Executive summary

The ability of Europe's communities to respond to increasing water stress by taking advantage of water reuse opportunities is restricted by low public confidence in solutions, inconsistent approaches to evaluating costs and benefits of reuse schemes, and poor coordination of the professionals and organisations who design, implement and manage them.

Innovation-demonstration for a competitive and innovative European water reuse sector (DEMOWARE) is a research project funded by the European Union's Seventh Framework Programme for research, technological development and demonstration (FP7 619040). DEMOWARE aims to rectify these shortcomings by executing a highly collaborative programme of demonstration and exploitation of innovations in the water reuse sector.

The project brought together public authorities, regulators, water utilities and companies, the research community and the public to generate and share knowledge on innovative water reuse schemes technologies, not only to increase water use efficiency, but to position Europe ahead of the world market for water reuse. The project is guided by SME & industry priorities and has two central ambitions; to enhance the availability and reliability of innovative water reuse solutions, and to create a unified professional identity for the European Water Reuse sector.

Using nine existing and one greenfield innovation demonstration sites distributed all over Europe and Israel, the project was structured in nine work packages dealing with treatment processes and reuse schemes (WP1), process monitoring and performance control (WP2), risk and environmental benefit analysis (WP3), business models and pricing strategies (WP4) and governance and stakeholder collaboration (WP5). Specific work packages for dissemination (WP7) and exploitation (WP8) are also included in the project. Project outcomes will guide the development of a live in-development water reuse scheme in the Vendée greenfield site (WP6).

For three years (January 2014 – December 2017) DEMOWARE consortium performed a series of activities focused on mitigating the main barriers to water reuse implementation by:

- Deepening the evidence base around innovative treatment processes performance and reuse schemes,
- Testing new tools for process monitoring and performance control,
- Providing strategies for the risk management and quantifying the environmental benefit of water reuse.
- Advancing the quality and usefulness of business models and pricing strategies,
- Generating regulatory regime specific guidance on appropriate governance, public involvement and stakeholder collaboration processes and,
- Establishing of a European water reuse association (www.water-reuse.eu) to shape market opportunities for European solution providers.

The multidisciplinary approach of DEMOWARE activities has produced a series of outcomes that should boost the implementation of water reuse schemes all over Europe by enhancing their performance, ensuring their safety, demonstrating how the benefits overcome the risks, helping on the development of a correct governance strategy and providing a single identity for the whole sector.

For more information regarding the activities within DEMOWARE you can visit www.demoware.eu or follow its Twitter profile @DemowareFP7.

# 2 Project Context and Objectives

## 2.1 General context

Europe's water resources are increasingly under stress, characterised by a mismatch of demand for, and availability of, water resources across time and geographical space (European Environment Agency (EEA), 2009). Poor or unsuitable water quality often further reduces availability, restricts uses, and increases the costs of supply. Regions with low rainfall and high population density are prone to water stress as well as areas with intense agricultural, industrial or tourism activities. Global climate change is already exacerbating these problems with projections indicating significant and widespread impacts over the medium to long term ( (Intergovernmental Panel on Climate Change (IPCC), 2012)). These developments will inevitably lead to growing competition between different water use sectors, with high quality resources being protected and reserved for drinking water production.

These pressures have encouraged more active consideration of alternative water sources as a strategic option to supplement water supplies and protect natural resources. Recognition of the potential role of water reuse in such a strategy is now well embedded within both European and national policy communities. Indeed recent years has seen a sense of urgency in calls for water reuse to become more widespread. It is, in fact, the top listed priority area in the Strategic Implementation Plan of the European Innovation Partnership Water (European Innovation Partnership Water, 2015) which drew attention to 'limited institutional capacity to formulate and institutionalize recycling and reuse measures, a lack of financial incentives for reuse schemes, and poor public perceptions towards water reuse'. In a similar vein, maximisation of water reuse is a specific objective of the European Blueprint for Water (European Commission, 2012) with a proposal for development of a regulatory instrument on standards for water re-use anticipated by 2015.

There is a substantial range of water reuse practices already applied worldwide, many of these in Europe (Bixio & Wintgens, 2006). Although data on the overall water reuse situation in the member states is of limited reliability (BIO by Deloitte, 2015) the freshwater replacement potential through water reuse was estimated to vary between 1-17% in European countries with even higher effects on local and regional scale (Hochstrat, Wintgens, Melin, & Jeffrey, 2006)

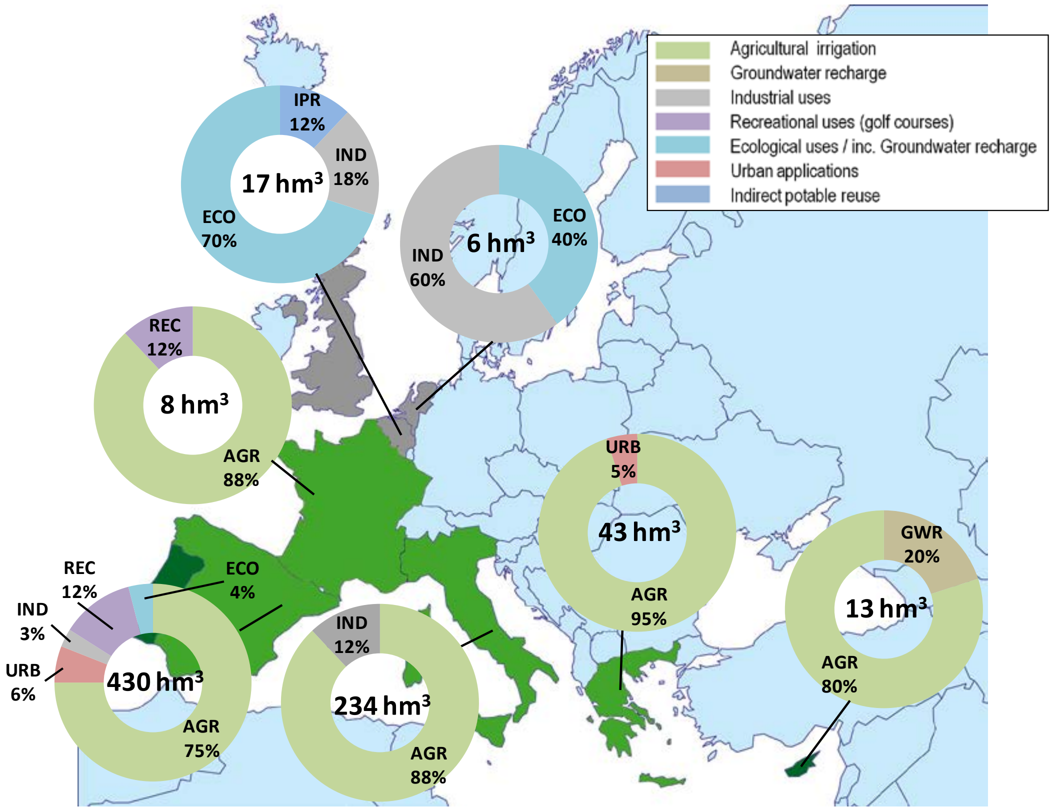


Figure 1 Status of water reuse in Europe
Source: (Hochstrat, Wintgens, Melin, & Jeffrey, 2006) Data from EUREAU survey and AQUAREC results www.aquarec.org)

However, there remain a number of barriers to more widespread development of water reuse and to the exploitation of the significant eco-innovation potential associated with it. The following barriers were already identified by Joint Research Centre (2014), members of DEMOWARE consortium:

- Inconsistent or inadequate water reuse regulation/guidelines
- Inconsistent and unreliable methods for identification and optimization of appropriate wastewater treatment technologies for reuse applications which are able to balance the competing demands of sustainable processes.
- Difficulties in specifying and selecting effective whole system monitoring techniques and technologies.
- Significant challenges in reliably assessing the environmental and public health risk / benefit of water reuse across a range of geographical application scales.
- Poorly developed business models for water reuse schemes and markets for recycled water.
- Low levels of public and government enthusiasm for water reuse.
- Lack of a unifying identity and professional image for the European water reuse sector.

The DEMOWARE initiative has as main objective to remedy all these shortcomings by stimulating innovation and improving cohesion within the evolving European water reuse sector. Guided by the priorities of SMEs and industry, it aimed to shape market opportunities for European solution providers and provided an environment for the validation and benchmark of technologies and tools. Importantly, DEMOWARE had also to deliver the mechanisms needed for the water reuse sector to mature and become the unified, assertive, and high-reliability industry that our communities demand.

## 2.2 Specific Objectives

The central objective of the DEMOWARE project has been to mitigate the main barriers to water reuse implementation by stimulating innovation and improving cohesion within the evolving European water reuse sector. DEMOWARE has the following specific objectives:

**Objective 1. To demonstrate the technical feasibility of innovative technologies for wastewater reclamation and reuse.** Although there are many readily available current technologies highly effective for water recycling, depending on the water quality requirement it is necessary to explore new technologies and approaches that meet not only technical but also economical, environmental and social criteria. Five main issues, currently regarded as technical barriers for widespread implementation of water reuse have been tackled in the project: capital and operational costs of advanced membrane technologies, technical feasibility of soil aquifer treatment not only as water low cost reclamation technology but also as a storage system, low-cost and reliable disinfection strategies, innovative water reuse schemes in the agricultural sector and revalorization of wastewater and concentrate brines as a source of valuable compounds.

**Objective 2. To demonstrate advanced monitoring and control options for the assurance of desired routes/fate of water contaminants in various water recycling schemes.** The inherent risk in water recycling systems from the wide range and potential negative impact of contaminants in wastewater is one of the main barriers for the widespread implementation of water reuse. The project aimed at demonstrating the feasibility of advanced monitoring and control options for critical contaminants from both biological and chemical origin in reuse schemes, test advanced technologies to control the integrity of treatment barriers and provide end-user specific recommendations on process monitoring and performance control of water reuse schemes.

**Objective 3. To demonstrate how through the assessment and management of environmental and human health risks the socio-economic and environmental benefits of water reuse schemes can be maximized while negative health and environmental impacts are kept to a minimum**. The knowledge level of risks associated to water reuse has to be increased in order to favour the overall public acceptance towards water reuse. DEMOWARE wanted to show how, by combining methods for risk assessment, life cycle assessment and water footprinting the benefits, the socio-economic benefits of water reuse schemes can be maximized while negative health and environmental impacts are kept to an acceptable level.

**Objective 4. To increase and promote the marketability of water reuse schemes.** The lack of sustainable business models to commercialize properly water reuse schemes and pricing properly reclaimed water (RW) while taking into account other economic factors is one of the global barriers that water reuse faces. DEMOWARE aimed to overcome these barriers through the following main points: design business models and strategies promoting water reuse technologies, provide simplified tools to perform Cost Benefit Analysis (CBA) of water reuse schemes and provide guidance on developing of the correct pricing strategy for water reuse schemes.

**Objective 5. To improve the ability of reuse scheme operators to deliver socially acceptable projects within collaborative and effective governance regimes.** Water reuse practices face daily governance barriers related to the absence of supportive policies and regulatory frameworks, low public engagement and stakeholder collaboration. DEMOWARE intended to demonstrate response strategies that stakeholders involved have developed or could potentially develop in order to deal with these barriers. Three governance dimensions were to specifically be considered: policies and regulatory frameworks, public engagement and stakeholder collaboration.

**Objective 6. To promote a wider understanding and awareness of water reuse practices among public administrations and end-users** through the development of an integrated communication strategy of project outputs. DEMOWARE project aimed to promote the inclusion of water reuse practices on water related policies at EU level, influence the nascent European water reuse legislation framework with the results of the project, promote the science-policy dialogue across Europe on water reuse and increase the public related awareness and understanding of water reuse.

**Objective 7. Demonstrate the applicability of the results obtained in a real-case scenario.** One of the main objectives of DEMOWARE was to demonstrate how the knowledge obtained during the execution of the project can be effectively used to promote the implementation of water reuse. This was to be achieved by implementing the methodologies developed and lessons learnt in a green field site where is planned to implement an indirect potable water reuse scheme.

**Objective 8. To create and nurture an identity and knowledge base for the nascent European water reuse sector.** This had to be achieved through the establishment of an European water reuse association of reuse professionals with the mission to share good practices, knowledge, techniques, research, and experiences on water reuse to promote the safe and effective use of recycled water in Europe.

# 3 Main S&T results/foregrounds

## 3.1 Project structure

The DEMOWARE project has brought together ten representative water reuse sites from across Europe and Israel. They were mostly located in water stressed areas or regions that suffer structural or seasonal water scarcity and have been selected to depict the range of water reuse applications: from different agricultural irrigation applications, industrial, urban and recreational uses through to indirect potable reuse. The sites also reflect the variety of water reclamation technologies used to achieve appropriate water quality, from extensive treatments to high-tech schemes.

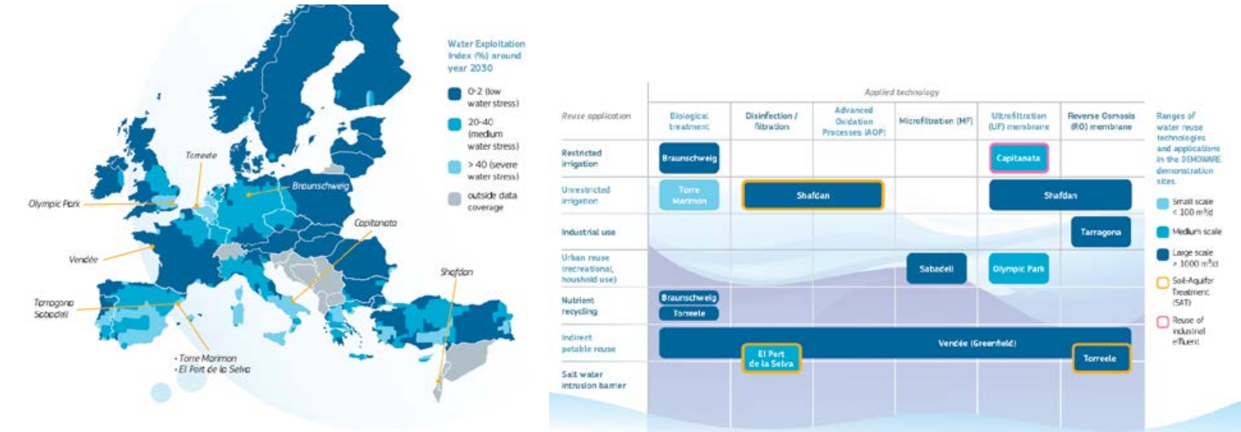


Figure 2 Demoware demonstration sites location (left) and technologies applied (right)

The activities performed within these ten demonstration sites have been structured in nine work packages dealing with both technological and non technological barriers. Technological barriers include treatment processes and reuse scheme operations (WP1) and process monitoring and performance control (WP2). Non-technological barriers are related to risk management and environmental benefit analysis (WP3), business models and pricing strategies (WP4) and governance for water reuse (WP5).

The knowledge acquired in WP1 to WP5 has been used in WP6. In this WP, water reuse will be implemented in a "new" site, for an area which requires water reuse but as of yet, there have not been any actions implemented. This WP will take into account all the knowledge gained in the previous WPs and therefore will show how this site can start to overcome the main constraints to water reuse implementation. Dissemination (WP7) and Exploitation (WP8) activities, including the establishment of Water Reuse Europe, ensured that DEMOWARE results outlive the timelife of the project.

## 3.2 Innovations in treatment processes and reuse schemes

Although current technology and reclamation schemes are capable of reaching the quality requirements of all water reuse regulations, operational and capital costs still remain one of the main barriers that limit the widespread implementation of water reuse schemes. DEMOWARE has evaluated and demonstrated the feasibility of innovative technologies and water reclamation schemes to decrease the overall costs of water reuse by innovative filtration technologies, improve performance of SAT treatments, innovative strategies for partial disinfection, identifying innovative reuse schemes in the agricultural sector and developing strategies for nutrient management and recovery in water reuse schemes.

### 3.2.1 Innovations in filtration technologies

Membranes are one of the most used technologies for water reclamation. However, the costs caused by fouling, chemical demand and high-energy consumption still remain the main barrier that prevents their implementation in water reuse schemes. DEMOWARE demonstrated how innovative technologies and treatment schemes can help in decreasing the overall economic and environmental costs associated with this technology in the water reuse sector.

Dow Chemical Ibérica S.L. (DCI), in their Global Water Technology Center (GWTC) in Tarragona has been working on demonstrating the improved performance of the next generation ultrafiltration (UF) and reverse osmosis (RO) membranes for water reclamation and how these technologies can provide a water of enough quality for cooling purposes in the petrochemical industry.

Regarding UF technology, the next generation membranes developed by DCI showed up 30% more permeability when compared with conventional membranes treating secondary effluent from an urban wastewater treatment plant. A new specific cleaning strategy for urban wastewater reclamation based on short-CIP has also been developed offering higher efficiencies, recoveries and availabilities but especially lower reagent consumptions than standard cleaning procedures.

On the other side, the new RO membranes developed by DCI showed up to 30% more operating time than reference elements before reaching the established maximum differential pressure and cleaning trigger, while showing the same or even better salt rejection than conventional membranes.

DCI activities also included the demonstration of water reuse at full scale in its petrochemical complex with product water from the Camp de Tarragona Advanced Water Reclamation Plant. In a full-scale set-up from the Tarragona site (Spain), DCI demonstrated the techno-economic feasibility of reusing water in its ethylene steam cracker facility including a challenging cooling water circuit of about 25.000 $m^3$/hr of water recirculation flow and a water make-up flow ranging from 350 to 500 $m^3$/hr. The operating mode (40% of RO permeate feed) allowed the cooling tower to be operated at 7 cycles of concentration in summer when ambient temperatures allow high evaporation rates, compared to 4 concentration cycles with 100% freshwater as make-up, with no significant effect on pipes regarding corrosion and biofouling and an estimated savings up to 120,000 €/yr.

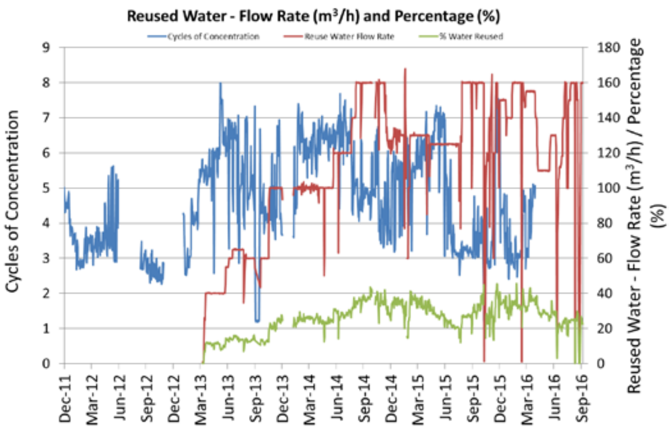


Figure 3 Picture (left) and reused water (right) at Tarragona site

On the other side, Mekorot and Rotec worked in the Shafdan site (Irsael) on demonstrating the benefits of flow reversal RO (FR-RO) technology developed by Rotec, in which the saline stream in RO pressure vessel arrays is periodically switched, avoiding the scale formation on membrane surfaces. FR allowed operating RO at 90% recovery on UF treated secondary effluent at higher pH (90% lower acid consumption) or 50% less antiscalant at moderate supersaturation of phosphate salts. Future work may show that further savings in antiscalant may be possible if flow reversal frequency is increased.

Mekorot has also demonstrated the technical feasibility of an innovative pre-treatment technology for RO based on innovative self-cleaning microfiber filtration (AMF). Compared to UF, AMF seems to cause less biofouling from extracellular polymeric systems as determined by the smaller drop in pure water permeability of RO membranes fed from AMF treatment as compared to RO membranes operating on UF permeate.

Finally, an innovative reuse scheme for the rural sector showing the potential benefits of coupling anaerobic digestion with submerged membrane technology (sAnMBR) allowing waste management, water reuse and biogas valorisation from organic wastes has been evaluated. Although the biological part of the process showed good performance, there is still significant room for improvement in order to control fouling and achieve a good membrane performance compared to external membrane configurations. Biological and inorganic fouling (phosphate salts) remain the main factors to be addressed in order to achieve the performance to make this technology competitive.

### 3.2.2 Innovation in soil-aquifer treatment recharge (SAT)

Managed Aquifer Recharge (MAR) comprises a variety of systems in which water is intentionally introduced into an aquifer. Schemes using the favourable characteristics of soil, subsoil and aquifer for further (advanced) treatment of the infiltrated water are called SAT (Soil Aquifer Treatment). SAT is becoming one of the most promising technologies for water reuse, especially in those schemes intending a potable use of the RW.

Figure 4 Infiltration basins at Yavne, Dan Region (Shafdan site)

Mekorot demonstrated, in the Shafdan site, how a pretreatment to SAT based on a biofiter followed by ozonation, allows significantly better performance in a short HRT (~22 days of short SAT). The addition of ozonation to the existing biofiltration pretreatment succeeded in effectively maintain good SAT product quality including removal of organic matter, microorganisms and micropollutants, while controlling $Mn^{2+}$ dissolution and maintaining high infiltration rate (~4-6 m/d).

SAT has also been the principal technology evaluated in El Port de la Selva site (Spain). Water reclamation by SAT was intended to counteract seasonal mismatch between demand and availability while improving groundwater availability for potable reuse. The innovation and importance of this study was to demonstrate SAT for IPR without the need for advanced treatment such as ozonation or reverse osmosis, relying on natural treatment capacity of the soil and aquifer only.

Figure 5 Infiltration basins at El Port de la Selva site

Altogether, the results obtained by KWB and Veolia Water Systems Iberia, demonstrated the case of infiltration of treated effluent copying with the Spanish regulation for aquifer recharge for indirect potable reuse.

UV proved to be effective against indicator bacteria. A slight increase on the path from tertiary effluent to the pond sample was attributed to potential contamination by animals that can access the ponds. Substantial removal of viruses was observed in tertiary treatment; however, sub-surface passage showed no clear trend. A possible reason could be the analytical method based on quantitative polymerase chain reaction (qPCR) that cannot differentiate between infectious and inactivated virus particles. The scheme was implemented without advanced treatment such as ozonation or reverse osmosis. It was found that in order to be on the safe side, an addition of GAC filtration following media filtration would be required in the future for micropollutants and other organic residues removal.

Using a flow and transport model, the migration of the plume of infiltrate in the aquifer was simulated by Amphos21 to analyse the sensitivity of travel times and dilution factors related to different scenarios. In the most conservative scenario (high rainfall), the model predicted arrival of RW at concentration of 5% after 350 days. In all scenarios, concentration of RW in water supply wells was below 14%. However, the numerical model was not capable to determine travel time and dilution rate with acceptable reliability.

Monitoring will thus be continued by the site operator to validate subsurface travel times and degradation and dilution rates from filed observations at the point of recovery.

### 3.2.3 Innovations in partial disinfection strategies

Some reuse schemes do not require full disinfection (>>99.9% pathogen removal) of the secondary effluents to guaranty a good level of risk management with regards to infection hazard, enabling to resort lower cost disinfection techniques. Partial disinfection shall reduce the energy or chemical consumption of the disinfection process and thus reduce costs and the environmental footprint.

Based on the literature review performed by KWB, UV disinfection and performic acid were chosen for a 3-month pilot test in Braunschweig site (Germany), both tested technologies were suitable to achieve the goal of 1.5 log virus removal (assessed indirectly via indicator organisms). The net present value analysis revealed that the planned lifetime and as well the capacity usage factor (CUF: average flow/max flow) are the key drivers which make the one or the other technology more economic. UV disinfection has a lower economic impact for longer lifetime of investment and/or for high CUF, while performic acid is more economic for shorter project life time and/or low CUF.

### 3.2.4 Innovative water reuse schemes in the agricultural sector

The agricultural sector remains one of the most water consumer sectors in most parts of the world. Within the agricultural sector, the most popular water reuse scheme is the use of reclaimed urban wastewater for the irrigation of food crops, pastures, and industrial non-food crops. However, variability on water quality and sources and distance between urban zones where wastewater is generated and agricultural zones where wastewater can be consumed still remains a barrier to increase the water reuse in the rural areas. By two demonstration activities, DEMOWARE studied the feasibility of two new water reuse schemes to promote the implementation of water reuse schemes in the agricultural sector.

A study performed by Institut de Recerca i Tecnologia Agroalimentàries (IRTA) and CTM in Torre Marimon site (Spain) confirmed that water quality determines palatability and acceptability of water by animals, and consequently animal performance in terms of feed consumption and body weight gain in livestock production. The *in-vivo* experiments showed that RW, which has higher content of dissolved salts than tap water, was less preferred by animals and probably this is the reason that these same animals had slightly lower feed consumptions and weight gains. In contrast, intestinal cells incubated with chlorinated waters in the *in-vitro* experiments showed greater expressions of genes indicating cell damage and stress than the other cells incubated with not-chlorinated RW, probably associated to the presence of toxic disinfection by-products from the chlorination process.

Figure 6 Feeding reclaimed water to calves

The use of reclaimed wastewater for livestock drinking and farming cleaning does not pose an acute risk for animal health. Water reuse for livestock production represents a feasible option in case of water shortages or lack of water availability and, depending on the achieved water quality, blending options could be considered.

The second demonstration activity took place in Capitanata site (Italy) and was leaded by Istituto di Ricerca sulle Acque-Consiglio Nazionale delle Ricerche (IRSA-CNR) and Fiordelisi, an agro-food industry located in

Apulia (Southern Italy). Due to the progressive decreasing of water availability, the company decided to install a full-scale tertiary treatment including UF and UV to reclaim the secondary effluent from the industrial process for irrigating its own fields.

Figure 7 Capitanata site

Two years of monitoring of the WWTP operation at full-scale demonstrated the feasibility of this reuse scheme with no significant effects on the productivity of the crops. The reuse of treated WW provided a considerable contribution as potassium and a small, but still relevant, contribution as nitrogen. Most important barrier to overcome is maintaining the tertiary effluent performance against variations on the wastewater quality due to modifications of the industrial process. The overall cost of the tertiary treatment was higher than the price of the water actually paid by the company for the conventional source of water (well). However, the availability of the well water is limited and during part of the year (summer) the maximum volume of water available for pumping is easily reached. The additional water available from WW reclamation would decrease the water stress for crops cultivation and ensure the sustainability of the industrial activity of Fiordelisi while promoting water reuse among farmers of the region.

### 3.2.5 Innovative approaches for nutrient recovery and recycling

Wastewater contains considerable amounts of nutrients (nitrogen and phosphorous) that need to be removed prior to discharge to avoid the eutrophication of receiving waters but can be valuable constituents of the reclaimed wastewater for crop production.

KWB has studied in Braunschweig site (Germany) the benefits derived from decoupling nutrient and water management. The optimization potential was especially high for nitrogen management, since the simultaneous supply via the Braunschweig wastewater treatment plant and additional conventional nitrogen fertilizer application by farmers result in an oversupply of nitrogen, losses to environment and a low efficient reuse compared to the total potential of renewable nitrogen in wastewater or sludge.

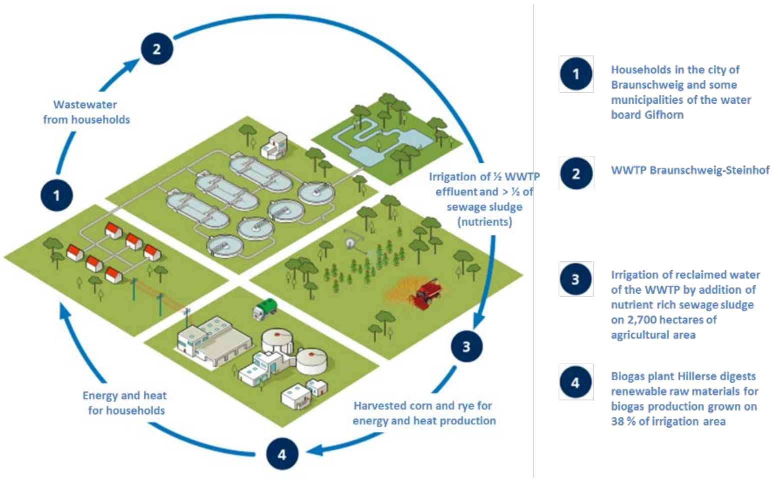


Figure 8 The Braunschweig model of local water and nutrient recycling (simplified)
(Abwasserverband Braunschweig 2016)

Concluding from the investigated scenarios, a decoupling of water and nutrients management is reasonable to achieve a demand orientated supply of both water and nutrients. An adapted management strategy (e.g. according to the fertigation concept) within existing reuse and recycling schemes can improve the net efficiency in nitrogen recycling, but this approach will demand precise application of nutrient doses per field area and hence a close cooperation between farmers and operators of the reuse system.

If agricultural valorisation of sludge is not an option, stand-alone technical options for nutrient extraction or phosphorus recovery from ash can improve the net efficiency in nitrogen recycling and mitigate reduced net efficiency in phosphorus recycling.

On the other side, Intercommunale Waterleidingsmaatschappij van Veurne-Ambach (IWVA) has investigated the possibility of taking advantage of the nutrients present in the concentrate effluents from the existing RO system in the historical IPR scheme in Torreele (Belgium). DEMOWARE activities demonstrated how the use of willows to treat RO concentrate and produce biomass is technically feasible. Two specimens of *Salix x rubens* var. *Basfordiana*, were salt tolerant and proved the best to re-sprout and grow. Based on the experiences with the test and other related experiences, a production of 20 tonnes of dry matter per hectare and year seems feasible while removing a minimum 30% of the total phosphorous and nitrogen from the concentrate. An economic evaluation of the technology showed that installing and operating a full-scale willow field for the treatment of RO concentrate is economically feasible mainly due to the reduced discharge cost (up to 30,000 euro yearly).

Figure 9 Picture of the willow field installed in IWVA facilities in Torreele site

In parallel, a denitrification pilot plant based on moving-bed biofilm reactor technology (MBBR) was constructed by ASIO and operated by IWVA in order to evaluate this post-denitrification technology as final treatment of concentrates after the willow field. The test with post-denitrification MBBR showed that the variable and mainly low nitrate content of the concentrate in combination with high salinity limits the performance and contrary to willows, energy and chemicals are needed to run the MBBR. Further research is required to apply this technology for the removal of nutrients from RO concentrates

## 3.3 Process monitoring and performance control

The inherent risk in water recycling stems from the wide range and potential negative impact of contaminants in wastewater. Treatment technologies and appropriate use practices are able to mitigate those risks. Based on a better understanding of contaminant occurrence and fate operators should be enabled to monitor and maintain their water recycling processes effectively.

Across a number of demonstration sites various advanced monitoring and control options were tested including flow cytometry and qPCR, disinfection for biofilm control, on-line particle detection for membrane integrity monitoring and advanced analytical methods and effect-based assays for chemicals' detection and fate characterisation.

### 3.3.1 Assessing disinfection effectiveness and effects

In reuse water reuse schemes microbial contamination may pose health risks to workers, end-user and the public (see also section 3.4). Hence disinfection is applied to inactivate and/or remove pathogens. Chlorination and ultraviolet irradiation are common processes, but also membrane filtration contributes to this purpose. Water utilities routinely monitor microbiological parameters through time consuming cultivation methods (i.e. plate counts) at a frequency that would not provide early warning of a contamination event.

DEMOWARE assessed new fluorescence-based devices and techniques in the evaluation of the effectiveness of multi-barrier treatment water reuse schemes and disinfection technologies: flow cytometry (FCM) and a molecular indicator system quantitative real time polymerase chain reaction (qPCR).

The application of FCM to monitor multi-barrier treatment process was found to achieve consistent results which indicated a change in water quality following physical treatment, disinfection and storage periods.

The results generated provided a baseline profile for the treatment process within each scheme thereby enabling determination of performance deterioration and maintenance requirements through deviations within the baseline values. Results acquired through FCM could be associated to surrogate parameters including suspended solids (irrigation application) and disinfectant residual (non-potable network), enabling the determination of a bespoke disinfectant residual to limit cell viability and regrowth during distribution and assist with maintenance activities. Limitations in the technique were concluded regarding the limit of detection, with highly concentrated samples requiring pre-sample preparation and whilst dilute samples contributed to biased estimations of efficacy. In addition, the technique was found to be most appropriate in the determination of an intact/alive cell concentrations following chemical disinfection, due to the method of cell compromisation targeted through the double staining methodology (i.e. cell membrane damage), in comparison to non-chemical processes such as UV.

Unlike FCM, qPCR was possible for highly enriched bio-film samples and could detect non-cultivable yet hygienically relevant microorganisms. Furthermore, sample preparation could be standardized via existing DNA extraction protocols and in combination with a DNA stain can distinguish between viable and membrane-compromised cells. However, the data to date is not sufficient to draw final conclusions regarding specific treatment processes and maintenance regimes similar to FCM with future results enabling the possibility to understand the impact of specific treatment on the population dynamics of different wastewater treatment plants, and identification of critical and hygienically relevant organisms.

### 3.3.2 Managing biofilm formation in distribution networks

Quality of distributed water will inevitably influence the biofilm formation in pipes by providing microbial biomass and nutrients. Particularly in irrigation network this can lead to clogging of drippers. In a long-term study at an experimental (agricultural) irrigation network it was investigated whether this is a pronounced problems when using reclaimed water (here: non-disinfected secondary effluent) compared to groundwater and how it can be mitigated. During almost 2 years of operation no marked biofilm growth was observed. Results indicated that the use of reclaimed wastewater even led to a better drip irrigation performance, in terms of clogging and drip uniformity, and less scaling formation compared to groundwater. Moreover, prior treatment of reclaimed water with nitric acid and $CO_2$ reduces the scaling formation and inactivates microbial pathogens.

It was also observed that the microbiological community undergoes changes from the storage reservoir through the pipes, in which high temperatures and redox conditions in stagnant water select for specific strains. High temperature (>37 °C) inside the pipes/drippers seemed to promote the selective enrichment of thermophilic microbiota outcompeting the enrichment of pathogenic microbes. $CO_2$ and $HNO_3$ treatments reduced considerably the presence of the phytopathogen *Cladosporium spp.* and active human pathogens such as *Legionella* and *Mycobacterium* in acidified reclaimed water. In conclusion, treatments based on $CO_2$ or $HNO_3$ applied on reclaimed water turned out to be supportive factors in managing the presence of microbial pathogens in water.

### 3.3.3 New approaches in Membrane integrity testing

In order to push detection of particles as water quality indicator into the sub-micron size range, a new particle monitoring device provided by partner PML was tested. The work primarily aimed at the development and the assessment of a membrane integrity testing protocol for a "Dark Laser Beam" device "Pola 100X". The device was operated by partners Fachhochschule Nordwestschweiz (FHNW) and CTM in pilot and full-scale (Sabadell) membrane bioreactors respectively.

Figure 10 Sabadell demonstration site

In permeate of intact membranes the "Dark Laser Beam" device measured particles in size ranges between 0.2 and 21 µm in UF and MF membrane permeate and secondary treated effluent. Overall particles counts were low compared to other particles detections devices and flow cytometry. This is largely related to the measuring principle of the device which is not presenting a complete analysis of all particles present in a sample.

In the pilot plant the membrane was damaged mechanically, in this set-up the sensitivity of the device was found to be good (detection of changes in LRV of the membrane, defect size detection) but a correlation with increase in particle is not strong (statistically weak basis of counts or signals). Whilst plate counting and flow cytometry detect sharp increases of bacteria in the permeate with membrane damage the relevant size fraction in the PML measurement (supposedly 0.8 - 1.5 µm) did not reflect this.

Effect of chemical membrane cleaning on membrane integrity, or more precise on the permeate quality, could be observed in both the full-scale plant and pilot plant. Removal of foulants and cake layer at the membrane apparently resulted in an increased number of particles in the permeate (5 times more). In the pilot plant this effect was only temporary, with water quality restoring within a few days. The reduced retention of the membrane after cleaning was also verified by flow cytometry analysis. Results also showed that at a relative larger share of bigger particles passes through a cleaned membrane, assuming a correct and non-discriminating particle size detection by the POLA X100, and provided that particles are actually stemming from the feed side.

There were several handling issues related to the representative sampling and continuous in-line monitoring of the permeate. However, based on the application in the full-scale plant, the operator identified the potential to use the information for adapting the post-disinfection to actual needs. Yet, in order to better tailor the dosage to the actual need, a more profound correlation of particles counts of the "Dark Laser Beam" device with hygienically relevant parameters needs to be established.

Monitoring and evaluation of membrane integrity of dense membranes (nanofiltration and reverse osmosis membranes) was investigated by DCI. They successfully implemented an integrity testing procedure for full-scale reverse osmosis modules which allows identifying the type of damage being the cause for reduced performance. Feed solutions of defined ion compositions are filtered through the membrane under specified pressure and other boundary conditions. The change in composition of the generated permeate over time then allows to conclude which type of damage the membrane has suffered. This analysis is based on an adapted solution diffusion model from which the leakage factor and the salt permeability of a membrane are derived. Those values take different values depending on damage. Analysis of past and adaptation of future operational conditions may then avoid such damages and increase membrane performance and life-time and risk of non-compliant / not-to-spec permeate characteristics.

### 3.3.4 Chemical fingerprinting

Chemical analysis is a powerful approach to characterise water quality yet only covering a limited amount of known compounds. More global screening approaches can provide a broader picture of chemical contamination. Such non-target screening is enabled by high throughput instrumentations such as gas chromatography (GC) and liquid chromatography (LC) coupled to high resolution mass spectrometers (HRMS).

Within the DEMOWARE project partner Veolia Environnement Research and Innovation (VERI) developed a tool for data processing, data interpretation and assessment of micropollutants levels derived from non-target screening of environmental and other water samples. The data processing has been automated and the time needed to identify compounds from raw data is now dramatically decreased (from 1 week down to 3 days). A complete procedure is proposed from the establishment of a compound database allowing for identification and classification of detected compounds. This also encompasses a protocol of semi-quantification of compounds in samples. It is now possible to semi-quantify 60 and 58 compounds in surface water and wastewater respectively. This quantitative information allows assessing the compliance of samples with existing regulations. In order to compare level of micropollutants with usual levels of contamination described in the literature or to check the compliance of samples to the corresponding regulations, a list of regulations and reference bibliography has been established.

This approach can be used in monitoring the effects on the environment of (indirect) water reuse schemes. It has then been applied for the “La Bultière” case study in the Vendée Eau Greenfield site (see section 3.7).

### 3.3.5 Effect-based bio-assays

Whilst chemical analyses provide info on the presence (and concentration) of specific compounds, bioassays may indicate acute detrimental (toxic) effects that are not necessarily detectable by standard water quality monitoring procedures. They thus can indicate malfunctioning or failures in treatment or operation.  The sensitivity and responsiveness of such a test system using bio-luminescent bacteria was verified in the Shafdan and the Torreele demonstration sites. It was able to reflect the progressed purification along the treatment trains and to detect deviation from this performance. As for the Shafdan demonstration site, the major findings indicated that the toxicity test were able to follow the gradual removal of effluent toxicity through the different stages of the treatment trains. It highlighted the efficiency of the RO stage, as well as of the biofiltration and recharge steps. In the case of the RO stage at the Torreele site, the test was found to be useful in pointing at an unknown contamination problem in one of the skids

The bioassay was also found to be responsive and sensitive enough to detect the presence of residual cleaning agents dosed into reverse osmosis water at concentrations that were lower than those used for routine cleaning of membranes and filters

In summary, this approach showed potential for application as early warning system and could improve detection and assessment of failures during operation.

### 3.4 Risk management and environmental benefit analysis

KWB, KWR and CTM have applied and adapted quantitative methods for microbial and chemical risk assessment (RA) for the specific needs of the water reuse systems from the different sites (El Port de la Selva, Braunschweig, Old Ford, Sabadell and Shafdan).

In general, microbial risks can be kept below the WHO benchmark of 1 additional µDALY per person and year as an acceptable risk level for water reuse. Multi-barrier approaches with several physical (e.g. filtration, membrane, UV) or chemical (e.g. chlorination, performic acid) barriers for pathogens are typically used to guarantee an adequate removal of bacteria, viruses and parasites from secondary effluent. In addition, natural systems such as aquifer recharge or soil-aquifer-treatment contribute to the removal of pathogens and can provide a very effective barrier depending on their specific operation conditions (e.g. travel time, soil characteristics). For all disinfection systems, a careful operation within defined conditions is required to avoid the bypass of untreated water or ineffective treatment of water. QMRA results for agricultural reuse show that a single disinfection stage for secondary effluent has to be properly designed (e.g. UV dose, residence time of performic acid) to maintain risk levels for field workers below the WHO benchmark. However, the strict WHO benchmark originally derived from drinking water standards may also be challenged as being too restrictive if applied for field workers in direct contact with reclaimed water in agricultural systems.

Figure 11 Old Ford water reclamation plant

Chemical risk assessment identified some potential substances of concern if reclaimed water is used for indirect potable reuse (i.e. direct consumption of humans via drinking water). While inorganic substances such as heavy metals do not pose major risks in the current reuse schemes, organic micropollutants may pass through multiple barriers if they are biologically stable and not removed in tertiary treatment or drinking water production. Hence, dedicated barriers for organic micropollutants (e.g. ozonation, activated carbon, NF/RO membranes) could be required in IPR systems to eliminate specific substances below threshold levels of concern. However, it has to be noted that health-based thresholds are not established for all organic micropollutants, while existing guideline values for those substances are derived with precautionary approaches due to lack of suitable toxicity data. Hence, regulators have to decide for adequate guideline values for those substances which are not addressed in national regulations to give clear and transparent requirements for the operators of IPR reuse systems. Overall, risk assessment for the different case studies showed that water reuse can be operated without unacceptable risks for human health from chemical substances or microbial pathogens if suitable measures for risk reduction are applied in a multi-barrier approach.

High uncertainty due to lack of data has been identified as a major challenge in risk assessment for water reuse systems. If only a small number of samples and a limited set of water quality parameters is available to be used for the assessment, numerical modelling of expected concentrations in reclaimed water and relevant exposure pathways is difficult and affected by high uncertainties, increasing potential risk of threshold exceedance. Usually, prior knowledge of expected water quality and system performance from literature and experts has to be combined with real monitoring data of the investigated reuse site in a transparent and reproducible way to enable proper risk characterisation.

Using the Life-cycle Analysis (LCA) method for assessing global environmental impacts, major benefits and drawbacks of water reuse could be identified from an environmental perspective. As secondary effluent is used as water source, a major benefit of water reuse is the decrease in nutrient and pollutant loads to receiving waters (e.g. rivers, lakes, ocean) by diverting effluent discharge to other uses. However, polishing of secondary effluent may also lead to concentrated waste streams (e.g. RO brine) which should be further treated before discharge to minimize the negative effects of those substances. Overall, water quality is mostly improved by water reuse, as tertiary treatment of reclaimed water eliminates residual pollutants and nutrients to a higher extent.

From an energy point of view, water reuse requires the investment of a specific amount of additional energy in form of electricity and chemicals for tertiary treatment. Hence, water reuse is often more energy intensive than the traditional way of water supply (e.g. groundwater pumping and treatment) and wastewater treatment. However, water reuse is often applied in regions where the natural water resources are already heavily exploited, with rising water stress leading to the search for alternative water resources. In that case, water reuse is often competitive or even superior in energy demand to other options for alternative water supply, e.g. the import of water via pipeline from other regions, or seawater desalination. Here, water reuse can form a valuable alternative to complex and expensive options, having a smaller energy footprint and lower associated emission of greenhouse gases. Finally, the environmental profile of water reuse can only be assessed in site-specific studies in comparison to other local alternatives of water supply to decide whether the additional efforts for water treatment are reasonable in that particular case. Water footprinting shows that the use of reclaimed water can indeed mitigate additional pressure on local freshwater resources and provide an alternative water resource in regions of high water scarcity. From a global perspective, indirect use of water for electricity and chemicals production is marginal compared to the local benefits of water reuse for the water balance.

Eventually, key messages and approaches related to risk assessment, environmental and process performance, as well as need for creating acceptance were compiled in a suggestion for a Water Reuse Safety Plan.

## 3.5 Business models and pricing strategies

Water reuse faces numerous global barriers, including lack of sustainable business models to commercialise properly its products and pricing properly the resource while taking into account other economic factors. DEMOWARE aimed to overcome these barriers by:

- Helping companies define what new markets show opportunities for the services which have been identified and how to best capture such opportunities for future frameworks for reused water
- Providing business model strategies that promote technologies linked to water reuse.
- Demonstrating the full benefit of water reuse schemes based on Cost-Benefits Analysis (CBA) and assessment of externalities.
- Identifying financing mechanisms and provide guidance on how to access them to the companies from the water reuse sector.

- Analysing current water pricing strategies and provide insight on how to improve them.

In this sense, Centro de Alianzas para el Desarrollo (CAD) has selected and analysed seven technologies within the most relevant used for water reclamation considering the technological profile, the market overview and their future perspectives. The results from this activity can provide assistance to water operators wanting to implement a new reuse scheme but are unsure of which of the current leading technologies can give them the best value for money. It can also act as a guide to technology suppliers requiring a better understanding of the current water reuse market in terms of the opportunities, trends and constraints for their technologies in the water reuse sector in European as well as in the global markets.

CAD has also leaded an analysis of current business models in the water reuse sector in order to help companies define what new markets show opportunities and how to best capture such opportunities for future frameworks for reused water. Based on this analysis, a series of recommendations to improve the business model of the water reuse schemes were produced.

Using specific valuation techniques such as choice-experiment, ACTeon has applied cost-benefit analysis CBA methodology in two case studies from DEMOWARE (Braunschweig and Sabadell), demonstrating how including environmental or societal externalities stemming from water reuse, can significantly change the overall outcome in terms of social welfare generated by water reuse projects or schemes. ACTeon also developed an on-line CBA Tool (available in http://demoware.acteon-environment.eu/) in order to help stakeholders valuate external costs and benefits of water reuse schemes.

ACTeon has also performed a deep insight on the available funding mechanisms to improve financial feasibility of reuse schemes. Results have been compiled in a database including available funding sources for water reuse projects, such as for example EU Funds or private funds. Furthermore, a specific document in order to guide SMEs on available financing opportunities in the EU and on how to access these.

DEMOWARE also provided insight on the current pricing strategies of water reuse schemes. Through the analysis of four demonstration sites (Braunschweig, Sabadell, Capitanata and Tarragona), ACTeon draw different outcomes: overall, it can be seen that different tariff structures and levels can work in different contexts. A suitable pricing strategy for water reuse will depend on the specific characteristics of the site and the cost-profile, as well as on decisions on who will recover the costs of water reuse.

With the aim of strengthening SMEs and supporting them in the process of addressing the numerous global challenges they are normally facing, one of the outcomes of DEMOWARE was the design and development of an online knowledge platform tool for SMEs involved in the water reuse sector. The platform was developed by CAD to help SMEs incubating new projects and/or diversify current ones, managing more effectively their business areas, as well as promoting and accelerating the impact of their activities.

In order to design the online tool platform for SMEs, CAD performed an in-depth survey to understand the needs from the potential target audiences (SMEs and corporations). The specific tools designed in each of the four key areas of the value chain have been programmed to be used in an interactive way through an online platform (http://www.knowledgeonlineplatform.com) that programmes automatic aggregation of results in visual format to ease the decision making process of SMEs. The way the platform adopts a continuous learning approach depending on how SMEs use the tools means that the number of tools as well as their structure and contents will self-improve overtime.

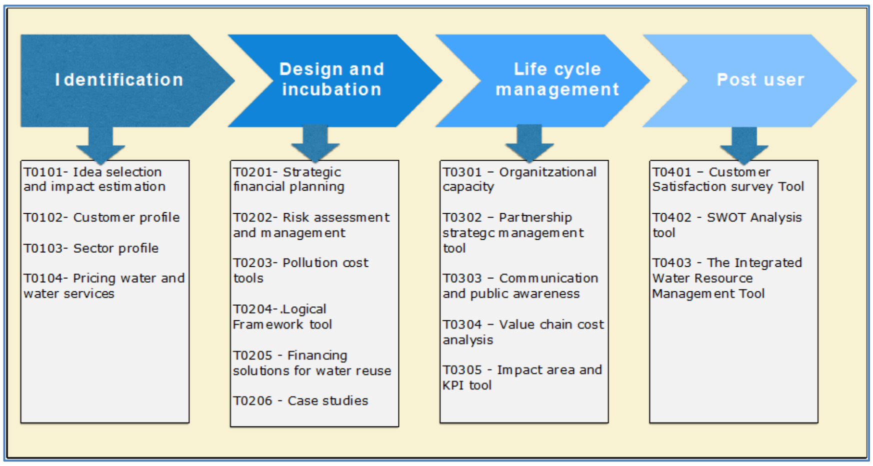


Figure 12 Tools of the online knowledge platform

## 3.6 Governance

Governance issues, such as policies and regulatory frameworks, public involvement and stakeholder collaboration are both enabling and constraining factors in water reuse practices. Through a baseline assessment at several water reuse sites (Torreele, Shafdan, Olympic Park, Sabadell, Torre Marimon and Capitanata) KWR and Cranfield University explored the importance of the different governance issues at each site. From these assessments, an overall issues map was composed that highlights the key enabling (*in green*) and constraining (*in red*) governance issues in water reuse.

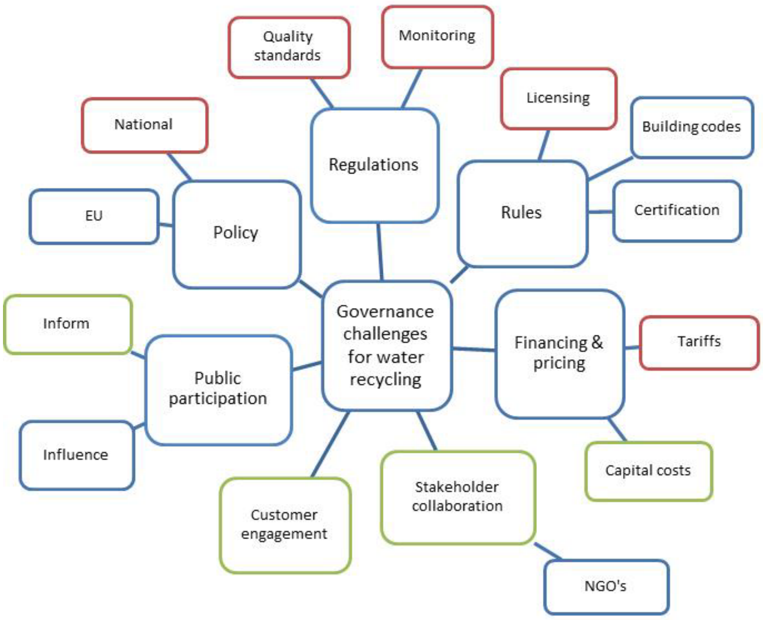


Figure 13 Overall governance challenges map in water reuse

Next to drawing on the experience from these DEMOWARE demonstration sites, international examples were evaluated. One of the key results of the review of public involvement in international water reuse practices is that public support and opposition to water reuse is fundamentally influenced by trust, including trust in the technical process and regulation, trust in the water reuse organisation itself, and ultimately, trust in the quality and safety of the final product: reused water.

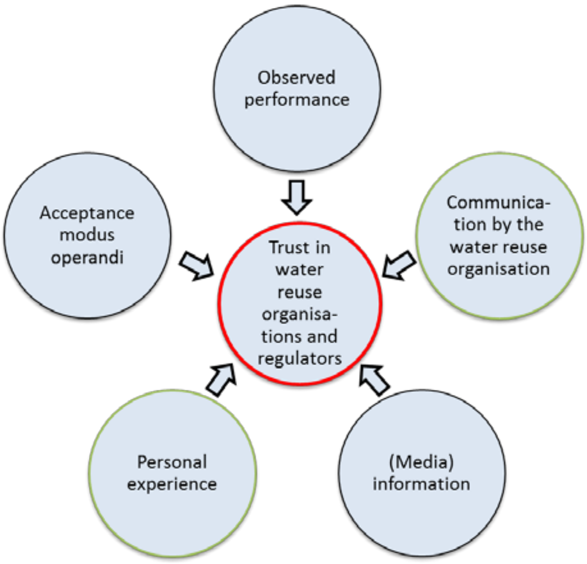


Figure 14 Main factors influencing trust in water reuse

Public and stakeholder involvement and information provision are all opportunities within the action perspective of water reuse organisations themselves, and are thus emphasised in the tailored advice DEMOWARE developed for the Capitanata and Sabadell schemes. The tailored advice was centred around the organisation of focus group meetings, as these are a good means for consultation with stakeholders. A methodological outline of a focus group meeting was prepared and applied in the tailored advice (Table 1).

Table 1 Main conclusions for the tailored advice to Sabadell and Capitanata sites

| Sabadell | Capitanata |
|---|---|
| • Raising public awareness of water reuse<br>o risks (health) and benefits (cost saving, environment)<br>• More active forms of engagement<br>o focus groups with community; public outreach programmes<br>• Communication and educational material on water reuse<br>o multiple channels<br>• Building public confidence<br>o independent water reuse advisory group | • Don't sell, but truly educate and inform the public<br>o address solution (reuse) and problem (scarcity), sense of urgency<br>• Demonstrate and explain the advantages<br>o compared to other options<br>• Invest in building public trust and systems of monitoring<br>o regulations and control<br>• Organise active forms of engagement<br>o focus groups with farmers and consumers |

KWR organised two water reuse governance workshops with stakeholders of the Capitanata (with the collaboration of IRSA-CNR and ARTI) and Sabadell (with the collaboration of CASSA) schemes. The objectives were to discuss the governance challenges of the water reuse schemes, learn from the experiences of other sites, and derive water reuse policy recommendations. Stakeholders at these workshops felt that most EU support would be needed to determine and regulate quality standards and provide access to capital financing.

A policy relevant summary of the DEMOWARE research findings on water reuse governance, has been published in a policy brief in the form of 'good practice' guidance that may inform water managers and policymakers within and outside of Europe.

An effective legal framework is fundamental to ensuring the sound and safe implementation and management of water reuse schemes. There is need for regulations that find a balance between protecting public health and the environment, and setting a realistic standard for the reuse sector in order to help promote its growth and viability.

- Good practice 1: Establish realistic water quality standards
- Good practice 2: Establish clear institutional roles and responsibilities

In addition to supportive legal frameworks, greater access to capital investment and competitive tariffs are needed to support the economic viability of (new) water reuse schemes.

- Good practice 3: Facilitate access to capital financing
- Good practice 4: Set competitive recycled water tariffs

Public acceptance of, or opposition to, water reuse is largely based on (the lack of) public trust in regulation and monitoring, the technical process, the water reuse organisation, and ultimately, the quality and safety of the reused water itself. Different approaches, including stakeholder collaboration, public engagement and information provision, are needed to build trust in water reuse.

- Good practice 5: Promote stakeholder and public collaboration and involvement
- Good practice 6: Inform, raise awareness and educate

These good practices may contribute to the successful integration of the different steps outlined in the EU CIS Guidelines on integrating water reuse into water planning and management. As such, the good governance practices presented in the policy brief can serve to facilitate wider adoption of water reuse schemes.

## 3.7 Green field site

The Vendée site comprises a region in France with seasonal water stress which is planning to implement water reuse. Vendée Eau, as the main water utility in the region, has used the knowledge gained in DEMOWARE to draw a strategy in order overcome the possible barriers that this site can face in the future.

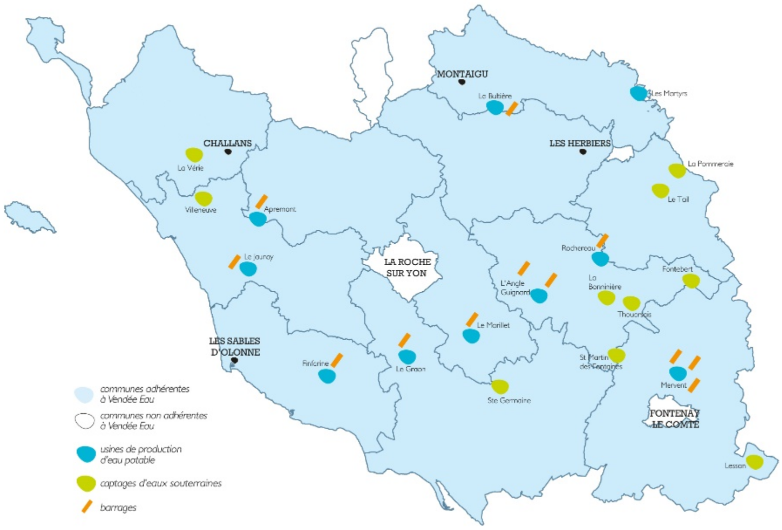


Figure 15 Vendée region, greenfield demonstration site

To design a planned IPR scheme involving a wastewater treatment plant supplying a reservoir (CCO WWTP-Le Jaunay reservoir), a similar system located 50 km away was studied by Veolia Environnement Research (VERI) and Innovation and Vendée Eau in the project: Les Herbiers WWTP-La Bultière reservoir. This two-year study showed:

- For main nutrients (nitrogen, phosphorus and total organic carbon), the pollution load from run-off or non-treated wastewater is higher than the load from Les Herbiers WWTP - the same trend is observed for metals;
- The monitoring of the microbiological indexes shows a self-purification in the aquatic environment;
- For most of the organic micropollutants, self-purification occurs as their concentration at la Bultière DWTP intake are similar to the concentrations observed upstream of the WWTP;
- Carbamazepine, Oxazepam and Sulfamethoxazole were found in measurable concentrations in La Bultière DWTP intake: Carbamazepine, Oxazepam and Sulfamethoxazole.

The aquatic environment in la Grande Maine river and in La Bultière reservoir seems to be degraded according to the assessment of aquatic environment quality. Thus, before implementing the reuse scheme, assessment of the initial state of the reservoir is recommended. It will also be necessary to assess the pollutants loads to the reservoir, their origin and their fate, as part of this initial state.

The characteristics of the CCO WWTP treated water and the Jaunay reservoir water quality were also assessed with a large analytical campaign. Results have been used to design the reuse scheme to be implemented in Vendée and to assess the potential impact of the Reuse on the reservoir.

Two tertiary treatment processes were identified as relevant for the planned IPR scheme: UF/RO and µGAC/EDR/UV process. The water quality expected after the tertiary treatments (RO or EDR) is in accordance with the health quality standards for raw water intended for human consumption and/or drinking water standards. The environmental impact of the discharged water on the Jaunay reservoir water quality is more difficult to assess. The Jaunay reservoir has a good water quality for micropollutants (including pharmaceuticals compounds) and is sensitive to eutrophication. The real impact of the discharge cannot be precisely assessed with the existing data and the simplified flow dispersion model in the Jaunay reservoir. An additional modelling is needed for accurate results, and new in situ measurement campaigns including sediments samplings, will help to have a better knowledge of the Jaunay reservoir and its characteristics. To confirm all the project assumptions, the implementation of a demonstrator and additional studies (in situ measurement campaigns, flow dispersion model…) will be done in the coming years.

Quantitative microbial risk assessment showed that no unacceptable risks for human health are associated with the IPR scheme, given the multiple barriers for microbial contaminants in tertiary treatment and drinking water production. Chemical risk assessment revealed that health risks from the monitored 138 individual substances are below most guideline values for drinking water quality, however, several substances in reclaimed water may pose an additional risk for ecosystems, which should also be further investigated.

LCA showed that water reuse is competitive in energy demand and associated greenhouse gas emissions when compared to water import from another reservoir or seasonal water storage in a mining quarry. Seawater desalination requires twice as much energy and +40% greenhouse gas emissions than water reuse. Water reuse can also alleviate the local water stress by providing additional drinking water without exploiting the local freshwater resources, which is represented by a low water footprint of IPR compared to existing drinking water supply or water import. Additional benefits of IPR include the reduction of emissions into the marine environment with secondary effluent, but IPR may also cause an increased risk of eutrophication in the reservoir which has to be analysed during the demonstrator phase.

The IPR project in Vendée is an innovative approach toward integrated water resources management. Yet, it is not covered by the current French regulation on reuse of treated urban wastewater which only authorizes uses for irrigation purposes. DEMOWARE tasks enabled identifying the regulatory constraints and gaps in the current French legislation related to such an undertaking. With the help of worldwide regulations and/or approaches and lessons learned from existing (direct and indirect potable) reuse schemes, legal procedure to follow and recommendations to be implemented were addressed.

Finally, ACTeon investigated the social acceptability challenges linked to the development and implementation of a wastewater reuse pilot for the Vendee greenfield. Social acceptability dynamics, and the factors that influence these in the Vendee site, have been studied via stakeholders' semi-structured interviews. In general terms, the recommendations stress the need for a collective development of the justification and general interest character of wastewater reuse at the scale of the Vendée territory; and, the need for joined ownership by all stakeholders of the proposed pilot project. At a more operational level, the recommendations address the ten factors separately, stressing however the need to work on the different factors simultaneously. Thus, efforts will be required to continuously understand social acceptability, and to propose solutions for new social acceptability factors that might have emerged during the experimentation process.

## 3.8 Water reuse association

One of the main objectives of DEMOWARE was to develop and launch an association of companies and professionals involved in the European water reuse sector with the aim of sharing good practices, knowledge, techniques, research and experiences on water reuse.

The creation of this association has been leaded by Cranfield University. Water Reuse Europe (WRE) was officially incorporated at Companies House, the United Kingdom's registrar of companies, on the 10th February 2016. The legal basis of the association is described in its main constitutional document, the so-called Articles of Association (https://beta.companieshouse.gov.uk/company/09998708/filing-history). Seven directors rom five different European member states and a range of professional backgrounds (public and private sector) are constituting the WRE Board of directors.


Figure 16 WRE governing structure

One of the main outcomes was the development and launch of the association's website (http://www.water-reuse.eu) and associated social media accounts (Twitter, LinkedIn, and YouTube). Through its online platform WRE processes applications for membership from companies and organisations from the water reuse sector and offers a range of services for its members who are involved in the design, operation and maintenance of water reuse schemes as well as the regulation and governance of reuse schemes.

A multi-component impact strategy to target potential members for WRE has allowed the identification of 500 organisations and companies including detailed information on each potential/actual member. An email marketing strategy also permitted an effective advertising of WRE's launch in various online media sources such as Utility Week, Water and Wastewater Treatment, EIP-Water, SEMIDE-EMWIS and the Ends Report.

The development of an event based marketing strategy allowed presenting WRE to large audiences at various world-class events of the water reuse sector. Finally, in terms of events, WRE will be organising its first annual conference on water reuse in Bruges, Belgium in October 2017.

# 4 Potential Impact

The DEMOWARE project is due to have a profound and lasting impact on overcoming the barriers to a more widespread implementation of water reuse in Europe. It is expected that the results from DEMOWARE have strong impacts on technological, academic, economic, environmental and above all social dimensions while ensuring market opportunities for the water related industry, specifically SMEs, which will in turn promote innovation, growth and job creation leading to Europe becoming a global leader in water reuse technologies and implementation.

European citizens will benefit from the project outcomes in three main ways. The results of DEMOWARE should serve to the design and operation of more reliable and (energy and cost) efficient water reuse schemes, thus delivering water to end-users at affordable costs, thereby enhancing sustainable water management practices and reducing the vulnerability of European communities to climate change and drought through. Secondly, the project will improve the ability of the European water reuse sector to present and sell its services both internally and outside of Europe thereby boosting the value of the sector to the European economy. Finally, Europeans will realise value from the project through its support for efficient resource use protecting environmental water flows and more appropriately matching water supply quality to use.

DEMOWARE dissemination and exploitation activities included actions to bring the emerging European water reuse sector together to plan and implement training and knowledge sharing schemes and consulting on benchmarking and regulation, as well as lobbing for the resources needed to deliver a highly trained generation of technicians and engineers for the sector.

As an example of the potential impact of DEMOWARE it is worth mentioning the specific impact that the project results are already having in the Vendée region. The work carried out in the different tasks allowed assessment of the feasibility of the reuse scheme in the greenfield site of Vendée which could provide around 10,000 $m^3$/d as an additional resource of drinking water in an area where water scarcity is increasing, thus ensuring the sustainable development of the region. As mentioned, the IPR scheme proposed it is not considered in the current French legislation so, DEMOWARE results could catalyse the improvement of French legislation to promote the implementation of water reuse schemes, specifically those involving IPR.

## 4.1 Technological impact

### 4.1.1 Decreasing costs of reclamation technologies and reuse schemes

DEMOWARE activities and results will have an important positive impact from the technological point of view. One of the main barriers that hamper the implementation of water reuse schemes is the cost associated with the treatment, storage and distribution of reclaimed wastewater to reuse it. DEMOWARE activities have demonstrated the benefits of several technologies and reuse schemes which should improve the overall feasibility of water reuse and thus, its implementation all over Europe.

Membrane technologies, thanks to their ability to selectively remove non-desirable compounds from wastewater, still remain one of the most common technologies in water reclamation schemes. DEMOWARE has demonstrated in real-case scenarios (TRL 7 and higher) the benefits of next generation of elements, operational strategies and pre-treatments for membrane-based processes.

Implementation of these developments must significantly decrease the costs associated with this membrane processes and so, the overall costs of reuse schemes. Moreover, membrane treatments are not exclusively used in water reclamation so the results of DEMOWARE should have a positive impact in other fields of the water and industrial sectors.

DEMOWARE results should also foster the development of innovative water reuse schemes in those industrial sectors with a high water demand. A very interesting example of this is the full-scale urban-to-industrial reuse scheme that has been demonstrated in Tarragona site where membranes are the core technology to provide high-quality water for the petrochemical industry. Cooling is by far the industrial process which consumes, in absolute terms, the most quantity of water so the results of DEMOWARE should have a very positive impact in decreasing the overall water consumption of the industrial sector.

IPR has received, in the last years, a lot of attention and efforts to overcome the barriers that hamper its implementation. DEMOWARE results have demonstrated how the appropriate pre-treatment can increase the overall performance of a SAT system, thus providing a high-quality water with an overall decrease of costs associated. If the results obtained are further confirmed, the impact on the overall water reuse sector can be enormous as using SAT for IPR without any membrane pre-treatment would significantly improve the economic feasibility of these schemes thus providing a solution to the mismatch between wastewater production and demand seasonality, especially in coastal areas.

Disinfection is also a key aspect in water reclamation and reuse. DEMOWARE has demonstrated how the partial disinfection approach has technical and economic benefits. The use of innovative low-cost reagents to achieve <3 LVR can result in a good level of risk management in non-potable water uses while decreasing the cost related to disinfection and so, lowering the costs and promoting the use of reclaimed water in those uses where the presence of microorganisms is not critical, such as irrigation of non-food crops.

In fact, agriculture is the sector where, traditionally, water reuse had a higher presence. DEMOWARE results also demonstrated the feasibility of innovative water reuse schemes in the agriculture which should promote the adoption of water reuse in this sector. DEMOWARE results demonstrated the feasibility of reclaiming the water used in the industrial process for irrigation of the crops located nearby which should help increase the water efficiency and thus the competitiveness of the food and drink industrial sector.

At the same time, DEMOWARE demonstrated how water reuse for livestock production can be a feasible option, if the appropriate treatments are adopted, to deal with water scarcity and, particularly, with water shortages. This reuse application, which is already considered in countries with a long water reuse tradition such as Australia, is not considered in the current legislation of member states.

Finally, DEMOWARE have also provided very interesting results on how take advantage of nutrients while reclaiming wastewater. This not only will have a positive impact on water reuse, but also in promoting the implementation of strategies to recover valuable resources from wastewater, thus fostering the change of the water treatment paradigm from the point of view of eliminating contaminants to a circular model that considers WWTP factories of valuable resources.

### 4.1.2 Ensuring water quality by advanced control and monitoring strategies

With respect to process monitoring and performance control DEMOWARE findings enhanced insights into how barriers in treatment flowsheets (disinfection, membranes) and downstream handling (storage, distribution) alter the microbial community. Flow cytometry was successfully demonstrated to support the characterisation of microbial spatial and temporal distribution in treated water reuse network, as well as the assessment of water reuse treatment train microbial removal efficiency.

Whilst flow cytometry is a mature technique, the tailored indicator kit based on qPCR methods will require further development and validation. Yet the potential of these techniques may lead to re-consideration of monitoring routines in water reuse. In any case they provide the operator with a more comprehensive understanding of the performance of its reuse scheme.

Also effect-based assays were able to confirm effectiveness of treatment processes and even more important, to reveal otherwise undetected operational malfunctions.

The tested particle monitoring device proved to be superior to commercially available particle counters in the market as for the monitoring of membrane integrity. It was more sensitive and could detect changes in permeate particle concentration related to different membrane damages. However the current state of its development is not yet suited for a daily routine application.

Though most of the monitoring approaches were actually performed off-line and discontinuously they complement already established site monitoring based on water sampling and lab analysis. This will strengthen the evidence basis on which e.g. risk assessments are done and risk management procedures are designed and thus deriving in a higher safety when implementing water reuse schemes.

## 4.2 Non-technological impact

As stated previously, overcoming non-technological barriers is also crucial to further implementing water reuse in Europe. Assessing benefits versus risks, applying more sustainable business models and pricing strategies, improving governance related to water reuse and creating an unified identity for the European water reuse sector are activities performed in DEMOWARE that would enable the widespread application of water reuse.

### 4.2.1 Improved understanding of risks and benefits

The comprehensive assessment of potential risks and environmental benefits of water reuse systems will facilitate the implementation of water reuse systems in Europe and beyond. RA and resulting information can be used by operators to promote the concept of water reuse and its safe operation, but also to address concerns of regulators or public stakeholders towards a suitable risk management. In addition, RA illustrates the state of knowledge about the reuse system and can help the operator and regulators to design a suitable monitoring strategy to ensure safe operation and decrease uncertainty about crucial parameters.

The global assessment of environmental impacts and benefits with LCA helps to promote water reuse as a sustainable strategy to augment existing water supply without putting additional stress on local water resources. Comparing water reuse with other alternatives of water supply, the efforts for operating a reuse system (e.g. electricity, chemicals, or infrastructure) can often be justified from an environmental point of view. Other alternatives such as water import from other regions or seawater desalination also come with a high impact on energy demand and associated environmental impacts such as greenhouse gas emissions. Hence, LCA can be used to illustrate and also quantify the global environmental benefits of water reuse compared to other options of water supply, which could form a major driver for wider implementation of water reuse throughout Europe.

Risk-based assessments of water reuse systems, in combination with LCA, can also play a major role in elaborating the regulatory context of water reuse in Europe, as they provides scientifically sound information on required risk reduction and suitable, i.e. justified requirements on the regulatory side. This could prevent regulators from taking a very conservative approach on future legal frameworks for the implementation of water reuse systems, which could prevent widespread uptake of this innovative concept throughout Europe.

### 4.2.2 Overcoming the governance barriers in water reuse

DEMOWARE also provided insight into the governance challenges at stake and the possible response strategies in real life demonstration sites. This improves the ability of reuse scheme operators to deliver socially acceptable projects within collaborative and effective governance regimes. Governance 'issues maps' have been developed that help the water reuse industry to anticipate and make more informed decisions in addressing governance challenges. DEMOWARE results are already used in the development of the planned indirect reuse scheme of the Vendée (e.g. related to regulations and public acceptance).

DEMOWARE explored ways to strengthen public engagement and stakeholder participation, among others by producing a review report on international experiences in public involvement and stakeholder collaboration. We gained understanding how to engage the public and other stakeholders in long-term dialogue about the potential risks and benefits of reuse. A focus group methodology was applied to support such dialogue. And actual focus group meetings and stakeholder workshops increased the understanding and awareness of water reuse practices among the public, local administrations and end-users. From these meetings, recommendations were derived for awareness raising and communication strategies.

DEMOWARE's governance assessment at the demonstration sites provided input to policy recommendations that can facilitate the effective development of European water reuse policy. A policy relevant summary on water reuse governance has been published in a policy brief in the form of 'good practice' guidance that may inform water managers and policymakers within and outside of Europe. We have also promoted the science – policy dialogue, among others through the public consultation on EU policy for water reuse, participation in EU stakeholders meetings, and involvement of the JRC in the CIS Guidelines and the development of minimum quality requirements.

### 4.2.3 Assistance and guide to business development in the water reuse sector

DEMOWARE activities should also have a very positive impact into EU economy. As stated previously, one of the main barriers that hamper the implementation of water reuse schemes is related to the business models of technologies and schemes for water reuse. Results obtained should help companies, and specially SMEs, from the water reuse sector on defining more successful business models and identifying new market opportunities for their products.

The online platform to support SMEs in the development of business exploitation plans aims to become a reference in the training of SMEs in the water reuse sector in Europe. Its main mission is to cover the critical aspects of the development of a business in the water reuse sector and its management before and after it is started up in order to become a useful toolkit for those SMEs and entrepreneurs that aim to set up a business or improve an existing one. The tool platform should boost the number of SMEs operating in the water reuse sector, as it should help them overcome the main barriers associated with the development of their business in this market.

Water reuse operators should also benefit from DEMOWARE results as they provide guidance on how to account for environmental and social benefits of water reuse schemes and monetizing them. Guidance on better pricing strategies is also very important to improve the economic feasibility of water reuse schemes. DEMOWARE results should also help water utilities on developing improved pricing strategies that help increase the overall sustainability of water reuse schemes.

### 4.2.4 Steps towards unifying and enforcing the European Water Reuse Sector

The water reuse sector in Europe currently lacked, before DEMOWARE, a unifying identity or direction, is often parochial in its outlook, and is poorly coordinated as a body of knowledge and action. Its ability to deliver sustainable water services to European communities, make best use of each-other's experiences and knowledge, grow new business, and export its competencies and expertise to other regions of the world is hampered by this lack of cohesiveness.

The creation of WRE will serve to these objective as it will provide a managed forum for business and career development based on the principles of reciprocity and professionalism which will drive both improvements in both the quality of delivered reuse schemes and the ability of the sector to promote its expertise. The overarching ambition of WRE is to become the collective identity for the European water reuse sector and promote an innovative and dynamic industry. To stimulate the growth and competitiveness of the European water reuse sector WRE seeks to raise public awareness and understanding of water reuse practices; facilitate the sharing of knowledge, techniques, research and experiences on water reuse amongst public and private entities involved in water reuse; promote European products, services and expertise in water reuse to communities around the world; support European companies, and particularly small and medium-sized enterprises, in their efforts to commercialise safe and innovative water reuse solutions; and promote research and innovation on water reuse.

WRE activities will have an impact, not only in the water reuse sector, but into the whole European society as they should also promote the knowledge and awareness of the benefits associated with water reuse among the general public. One of its main objectives will also be to help improve public understanding of, and trust in, water reuse. Furthermore, its activities will raise awareness in Asia, North America and elsewhere of European competences in this increasingly important area of water management with subsequent benefits to both European business and society.

# 5 Main dissemination activities and exploitation of results

A specific dissemination strategy plan was established at the beginning of the project with specific dissemination actions to be performed by the whole consortium.

The project website (www.demoware.eu) it has been a very important part of the dissemination strategy of the DEMOWARE project. It served as first source of information to the public, as concerns objectives, structure and partners involved but particularly about activities, news and public project results including public deliverables. It had more than 600 visits per month on average from countries all over the world, especially Spain (where 4 out of 10 demo-sites were located) but also United States, France, Germany, United Kingdom, Brazil or Russia.

Regarding social media, Twitter has also been a very important digital media to promote DEMOWARE activities. The Twitter account served to publish instant news on activities and events organized by DEMOWARE. The account currently has a total of 293 followers and the total tweet impressions have reached a total of 32,823 (nearly 1,000 per month) which is a significant number for a research project.

A generic brochure of the project was also produced and 2,000 copies were printed and distributed among all beneficiaries. This has been also a very important way to disseminate the existence and main objectives of the project on all events that partners attended (conferences, workshops, exhibitions, commercial visits, etc.). A video with interviews from the work package leaders and footage from selected demosites was also produced and it is publicly available at Youtube (https://youtu.be/fAnpZb30ecA).

A very important part of dissemination actions has been focused on the dissemination of the project results to policy-makers. The presence of JRC in the consortium has been very important to involve European policy-making or policy-supporting institutions (e.g. DG Environment, DG Agriculture, DG Research, EEA) and other institutions at national level to enhance their capacity to integrate water reuse in future policies JRC organized presentations of key results of the DEMOWARE project and discussions with high-level European policy-makers.

Specific actions were taken to involve European policy-making institutions to convey DEMOWARE's consortium inputs in the policy initiatives on water reuse, as well as the results from the project to be considered as future instruments for guidance and standards for water reuse at EU level. Following the initiatives from the EC on water reuse, one workshop and one meeting were organized where some results from DEMOWARE demosites were presented: "Water reuse in agricultural irrigation and aquifer recharge – Towards minimum quality requirements at EU level" (DG Environment 25-26 June 2016); and the 2$^{nd}$ meeting of the CIS Ad-hoc Task group on water reuse (Madrid 17-18 of October 2016).

The DEMOWARE project provided a joint input for the Public Consultation, organized by the EC, on Policy Options to optimize water reuse in the EU and the development of the *Guidelines on Integrating Water Reuse in Water Planning and Management in the context of the Water Framework Directive (WFD)*.

At the same time, several face-to-face meetings with the responsible for the water reuse initiatives in the EC Directorate General Environment (DGENV), Mr. Thomas Petitiguyot, were taking place along the development of the guidelines, and the DEMOWARE project results have been closely followed by him.

In parallel to the above activities, two workshops on water reuse governance was organized at Sabadell and Capitanata sites 15 September 2016 to exchange and transfer knowledge on governance barriers in water reuse practices to stakeholders and policy-makers involved.

Regarding stakeholder workshops, four major events were organized and hosted by DEMOWARE partners.

- "Water Reuse Conference. Innovation Demonstration for a Competitive and Innovative European Water Reuse Sector" Barcelona, 13-14 June 2016

- “Benefits and opportunities of water reuse in agriculture in Puglia” Bari, 13 September 2016
- “The DEMOWARE project and water reuse in agriculture in Puglia”. Capitanata, 20 September 2016
- “Faire de l’eau une ressource inépuisable”, Puy-du-Fou, 25 November 2016

DEMOWARE partners have been very active on the dissemination of project results through networking and other dissemination activities. More than 250 dissemination activities have been identified including press releases to both technical and generic media (technical not peer-reviewed journals, generic press, local and national TV stations, etc.). Oral presentations in scientific events have also been a very important part of the dissemination activities performed by partners with a total of 47 including regional conferences but also in most important international conferences on water reuse held in Europe, USA, China, etc.

A very large number of site-specific presentations and visits have also been performed by the site owners and coordinators. This has also been a very important face-to-face way to disseminate specific project results from demonstration sites to a broader audience.

The partners of DEMOWARE are members of a number of national and European associations, networks, platforms etc. Through these mediums the partners have also disseminated the project results at platforms in Europe such as WssTP, EIP Water Action Groups, ERRIN and NETWERCH2O. The existing network of contacts outside Europe with representatives of important water reuse institutions such as Watereuse (USA), CSIRO (Australia) or PUB (Singapore) has also been a very important way to disseminate DEMOWARE’s main result outside Europe.

Finally, dissemination to the scientific audience has also been a very important part of DEMOWARE dissemination strategy. At the time of writing this report 2 papers were already published in peer-reviewed scientific journals and a total of 5 more were under either preparation or review process. Regarding presence in conference proceedings, a total of 16 publications were identified in regional and international conferences of the reuse sector. At least, six Ph.D. students were also involved in DEMOWARE and it is expected that in, the coming years, DEMOWARE results included in their Ph.D. thesis and the publications related.

However, regarding exploitation of foreground, 34 different items were identified. Most of them were general advancements of knowledge acquired by research institutions that will be transferred to the industrial sector through their activities to be performed in the upcoming years.

However, some commercially exploitable developments have also arisen from DEMOWARE’s technology providers including technologies for water reclamation but also monitoring and analysis techniques specifically developed for water reuse and tools and consultancy related on-line tools for private companies willing to expand their business activities in the water reuse sector.

Some of the end-users involved in the project will exploit the results through innovation on their industrial activities, mainly through the implementation of water reuse schemes that will make them more efficient in the use of resources and increase their competitiveness in their sector of application.

Finally, as stated previously, one of the main outcomes of the project has been the establishment of an association for the European reuse sector: Water Reuse Europe. WRE has already developed an event based marketing strategy, which allowed presenting WRE to large audiences at various international events. It is expected that WRE will become, in the upcoming years, the reference point for all European stakeholders (private companies, research institutions, authorities, policy-makers, general public, etc.) on the water reuse sector.

# 6 Public Website

The public website of DEMOWARE can be found at www.demoware.eu

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