# Deliverable 4.7

# Cost, pricing and financing of water reuse against natural water resources

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| Abstract | This deliverable provides an overview of current theory and practice of pricing strategies for reused water, as compared to pricing for conventional water supply and wastewater treatment and collection; and analyses costs, pricing and financing strategies of four demonstration sites, taking into account the whole system of water supply and wastewater collection and treatment of the reference area. |

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|---|---|
| ACA | Catalan Water Agency |
| AEQT | Asociasion Empresarial Quimica de Tarragona |
| AITASA | Tarragona Industrial Water Company |
| CASSA | Companyia D'Aigües de Sabadell, S.A. |
| CAT | Consorci d'Aigües de Tarragona |
| CTAWRP | Camp de Tarragona Advanced Water Reclamation Plant |
| MBR | Membrane Bioreactor |
| MIUR | Ministry of Education, University and Research (IT) |
| O&M | Operation and Maintenance (costs) |
| PE | Person Equivalent |
| PECOD | Person Equivalent Chemical Oxygen Demand |
| RDP | Rural Development Plan |
| UV | Ultra-Violet |
| WRU | Water Reclamation Unit |
| WWT | Wastewater treatment |
| WWTP | Wastewater treatment plant |

## Executive Summary

This deliverable builds on previous deliverables produced under WP4 of the Demoware project, and it aims at completing the puzzle composed so far on the economic and financial dimension of water reuse. More in detail, this deliverable will:

- Provide an overview of current theory and practice of pricing strategies for reused water, as compared to pricing for conventional water supply and wastewater treatment and collection;

- Analyze costs, pricing and financing strategies of four demonstration sites, taking into account the whole system of water supply and wastewater collection and treatment of the reference area.

Water reuse schemes bring new complexity in the provision of water services, as they challenge the conventional models of water supply and disposal by interconnecting different water services: water moves through the urban water supply and sewerage systems to be used and distributed again. In addition, the inclusion of recycled water in the water portfolio benefits all water users in a specific service area: in fact, recycling unlocks an additional water supply source, so that for example freshwater customers are less subject to water restrictions in periods of water scarcity. Thus, the application of unmodified pricing principles for conventional water supply –based on cost-recovery considerations only- is not always relevant or appropriate for reused water. Whereas the overall objective of pricing strategies for water reuse should always be cost-recovery, pricing strategies must adopt a system-wide approach –which considers: (i) all components of the system, i.e. water reuse as well as conventional water supply and WWT; (ii) all costs included in the system; and (iii) all benefits (also environmental benefits). As a result, the appropriate pricing strategy for water reuse should be designed and implemented as part of a wider pricing strategy including tariffs for recycled water, conventional water supply and WWT, as well as other instruments (e.g. municipal charges).

A review of available case studies around the world (collected in Deliverable 4.5 of the Demoware project) highlighted the followings:

- The most common tariff structure in use is the volumetric charge. Often, a progressive rate is applied (increasing rates for increasing water consumption levels);
- In two cases, similar price ranges for recycled water are applied to similar user groups: unitary prices for landscape irrigation range from 0.13 to 0.56 EUR/$m^3$; unitary prices for groundwater recharge range from 0.08 to 0.4 EUR m3. For industrial uses, the price range is much wider, but this might depend on the different water quality levels required for different industrial processes. In contrast, pricing ranges and structures for agricultural use are extremely diverse.
- In most cases, unitary prices only recover a part of O&M costs, so some forms of subsidization are very often in place.

Funding sources can be distinguished based on where they come from (private, public, water users), as well as on the level from which they are provided (European, national, local); in most cases, water reuse projects are funded by a combination of different funding sources. Often, investment costs are funded through European and national funding sources as well as through private investment. Operation and maintenance costs are often covered by recycled water tariffs charged on users, although public subsidies can sometimes come into play.

After this review of available evidence, this deliverable presents a detailed analysis of cost, pricing and financing in four demonstration sites, and namely:

- The **Braunschweig** site (DE) is one of very few large-scale agricultural reuse sites in Germany. It reuses the effluent of Steinhof wastewater treatment plant (WWTP) for agricultural restricted irrigation (fodder and industrial crops);

- The **Sabadell** site (ES) is associated to the Riu Sec and Ripoll wastewater treatment plants. Recycled wastewater is currently used for street cleaning, public parks and gardens irrigation, and industrial uses;

- The **Capitanata** (IT) includes the wastewater of Fiordelisi, a certified organic producer, growing and processing mainly tomato for the international market. The Fiordelisi plant has its own treatment and reuse system for wastewater from vegetables processing;

- The **Tarragona** site (ES) is a fully integrated water reclamation plant using the secondary effluent from two municipal wastewater plants, including its treatment and distribution to the end-user (petrochemical industry and cooling tower).

The four case studies provide an overview of diverse water reuse schemes, and in particular of water reuse schemes for different final users (industry, agriculture and urban users), with diverse cost and pricing profiles. The cost and pricing profiles of the four case studies are summarized in the table below.

Table 1 Costs and pricing of reused water in the four sites

| Case study | Final user | Volume – $m^3$/year | O&M costs | Investment costs | Price |
|---|---|---|---|---|---|
| **Braunschweig** | Agriculture | 11 million | 0.50 EUR/$m^3$ | | 81 EUR/ha/year (4% of costs – the rest is recovered by WWT customers) |
| **Sabadell** | Industry, non-potable urban users | 120 000 | 0.25 EUR/$m^3$ | N/A | 0.6917 EUR/$m^3$ (industry)<br>0.2767 EUR/$m^3$ (municipality) |
| **Capitanata** | Agriculture | 1000 $m^3$/year | 16.1 EUR/$m^3$ | 3.8 EUR/$m^3$ | Not sold |
| **Tarragona** | Industry | 3.4 – 4 Million $m^3$/year | 0.64 EUR/$m^3$ (all costs included) | | Not available |

The diversity of these cost and pricing profiles is often depending on the characteristics of the scheme –in Capitanata, it is a very small scheme run by Fiordelisi, a private company, whereas in Sabadell, Tarragona and Braunschweig reclaimed water is produced on a larger scale (and in Tarragona and Braunschweig in particular). Diversity can also be explained by the different types of treatment in the four sites.

In the four sites, the following considerations are made:

- Braunschweig:

  The water reuse scheme delivers important environmental benefits to the local population in terms of preservation of groundwater sources and the quality of the nearby surface water body. Currently the costs of the reuse system are covered only to a minor extent (4%) by the farmers. When determining the fee to be paid per hectare, the sewage board considered different aspects: the benefits the farmers gain from the reuse system (water and nutrient supply), the restrictions they experience[1], as well as financial feasibility (Siemers, 2016 *pers. comm.*). The major part of the costs linked to the reuse system (96%) is paid by the population connected to the public sewage system through the wastewater and rainwater fee. Although they are benefiting from the system through environmental benefits (see above), the share they pay seems very high. It corresponds to about half of the total other costs linked to the wastewater treatment. Nevertheless, considering the substantial environmental benefits they enjoy from water reuse (between 3 million EUR/year and 5.2 million EUR/year according to the results of a contingent valuation study (Mattheiß and Zayas, 2016)), the pricing and financing system for the agricultural wastewater reuse in Braunschweig seems to be equitable.

- Sabadell:

  Yearly revenues from the sales of recycled water are higher than yearly O&M costs of producing and distributing this water: thus, O&M costs are fully recovered, and also a share of investment costs. At the same time, industry and municipality pay respectively 63% and 35.5% of the price paid for conventional water and WWT, so they provide quite a good incentive to use recycled water. Nevertheless, the overall cost recovery rate of the whole system (conventional water and WWT and water reuse) is 85%, thus revenues do not fully cover the costs of the service.

  For raising current cost-recovery levels, the following can be proposed: (i) Raising prices for conventional water and WWT –however, social and economic impacts on water users should be carefully investigated; (ii) Raising prices of conventional and reused water for the municipality, but also in this case the financial impacts on municipal balance accounts should be investigated; and (iii) introduction of a municipal charge for all citizens, as they all receive some of the benefits of water reuse in the municipal area –and, as shown by the choice experiment survey, citizens are willing to pay a sum each year to secure current uses of recycled water.

  The planned expansion of the water reuse system would correspond to a decrease of unitary production costs, and this shows that unitary costs of reused water benefit from economies of scale or, in other words, the more recycled water is produced, the less it will cost per unit of production.

- Capitanata

  The costs of both primary/secondary and tertiary treatment in the site are disproportionately high as compared to the other case studies (and also as compared to the case studies reviewed in Chapter 2), but available information did not allow the study team to come up with a reasonable explanation. It is likely that costs could be reduced through economies of scale: for example, conventional and tertiary treatment could be jointly carried out by an association of firms and farmers (all using recycled water).

[1] Using treated effluent instead of groundwater for irrigation is also linked to disadvantages, like restrictions regarding the type of crops which can be cultivated, or the fact that the agreement with the sewage board includes an obligation to take the water, even in periods were rainfall is abundant (see Mattheiß and Zayas, 2016, for more information).

Unfortunately, this is not an option, as the Fiordelisi plant is isolated from other farmers and/or industries.

Furthermore, this case study also shows that, in a territorial context affected by serious water scarcity such as Puglia, finding alternative water supply sources is of paramount importance. The cost of producing reused water can be seen as the environmental and resource cost of using conventional water, and this is a cost which is not reflected in current prices for conventional water –which are likely to cover only the financial costs of water supply. The costs of reused water include the value of the externality of conventional water use, a cost that is not paid by user but is born by society and the environment as a whole.

In any case, at present these are simple hypothesis and speculations: in fact, current Italian legal standards for reused water are extremely restrictive, so that recycled water after tertiary treatment cannot be used because it sometimes exceeds N parameters –even though this water is of generally high quality.

- Tarragona

  The case study is an example of the establishment of a water partnership between municipal and industrial stakeholders for the benefit of the whole Tarragona area. It shows that municipal industrial water reuse projects can be economically and technologically feasible without jeopardising the industrial operation process (n/a, 2016).

  According to internal calculations of one of the industrial companies situated in the Camp of Tarragona area, when comparing costs of reused water and of traditional water sources, currently costs are very similar, when looked at under the angle of the long-term costs of ownership. Industries can save in wastewater treatment (less blowdown in cooling towers), less use of chemicals in cooling water circuits (as they can operate in higher concentration cycles) and less maintenance costs (less corrosion, scaling and fouling phenomena) (Arias Barrio, 2016 *pers.comm.*).

Overall, it can be seen that different tariff structures and levels can work in different contexts, so the correct 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 –for example, in Braunschweig these costs are mostly covered by urban WWT customers, whereas in Sabadell these costs are recovered by users of recycled water. In the latter case, it is also suggested to increase current cost-recovery levels with a municipal charge, accounting for the social and environmental benefits of water reuse (which are enjoyed by all Sabadell citizens).

The analysis of the four case studies yielded different outcomes: overall, it can be seen that different tariff structures and levels can work in different contexts, so 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. However, the analysis and discussion of pricing strategies in the four case studies focused on some common elements, revealing a common thread. While it is true that no generic pricing strategy for water reuse can be developed, it is definitely possible to identify a series of general steps which can be followed when developing a pricing strategy for a given water reuse scheme, expressed by a list of key questions that need to be answered to come up with a suitable, convenient pricing strategy. These questions are summarized in the figure below.

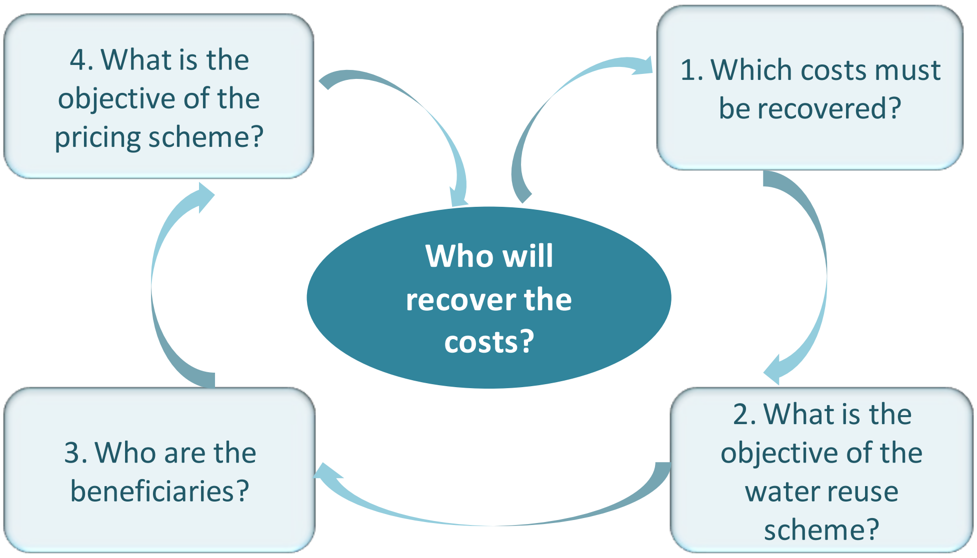



Figure 1 Key questions to be answered to guide the development of a suitable pricing strategy for a given water reuse scheme

A suitable pricing strategy revolves around a central question: **who will recover the costs?** Or, in other words: who will pay for water reuse? The answer might seem straightforward: users will pay, of course. But, as it was seen along this report, both in the case studies and in the collected examples presented in chapter 2, this is often not the case, because other considerations come into play. These elements are the ones included in the key questions, which are summarized in the table below.

Table 2 Key questions to guide the development of a suitable pricing strategy: synthesis of main elements to be taken into consideration

| 1. Which costs must be recovered? |
|---|
| This might look like a futile question; however, as it was seen in the case studies, a full understanding of the cost profiles is sometimes missing. The costs to be taken into account are not only the costs of the water reuse system, but also the water supply and conventional WWT system, if these are managed by the same operator. In fact, the ultimate objective is to recover the costs at the operator level. |
| **2. What is the objective of the water reuse scheme?** |
| The objective of the reuse scheme is the key to the identification of beneficiaries. For example, a water reuse scheme can be set up to address mismatches between water demand and water availability in water scarce areas, or it can be set up to reduce pollution in surface water bodies by injecting treated wastewater. Once the objective is clearly defined, the third question (below) can be answered. |
| **3. Who are the beneficiaries of the system?** |
| Users of recycled water are obviously the direct beneficiaries of the system. However, most water reuse schemes deliver indirect benefits to other user groups. Indirect beneficiaries are directly connected with the objective of the water reuse scheme.<br>The identification of beneficiaries is key to the identification of who should pay for the water reuse scheme, and especially in those cases where prices of recycled water cannot fully recover the unitary costs of water reuse. Unitary costs of water reuse might exceed the price charged for conventional water supply or WWT, or simply the price that potential users of recycled water can accept to pay. In these cases, part of the costs of water reuse can be borne by other (indirect) beneficiaries, be it users of conventional water supply and WWT (through cross-subsidization mechanisms) or other beneficiaries through other financing mechanisms. |
| **4. What is the objective of the pricing scheme?** |
| After all elements have been explored in the previous questions, and after some options for a pricing strategy have been put on the table, how to choose the most convenient option? This will largely depend on the water management objective of the pricing scheme, which in larger scheme of strategic importance can also be a policy objective. The final pricing structure and levels for water reuse must take into account different aspects, such as for example: (i) is there a will to provide an incentive for consumers to rely on recycled water rather than conventional water? Will consumers have a choice, or they will be obliged to use recycled water for certain uses? If the price of recycled water equals its unitary costs, which will be the social and economic impacts on local communities? Would this impact be acceptable? |

The list of key questions presented above is aimed at providing some guidance in the development of an appropriate pricing strategy for water reuse schemes, as it touches the main elements to be taken into account and proposes some possible solutions. Nevertheless, **setting-up a pricing strategy always involves some political or management decisions**, which will depend on policy/ management priorities as well as on the specific challenges to be addressed in a specific site. This is because **a “correct” pricing strategy for a given water reuse scheme does not exist**, and the objective will rather be to **develop the most convenient pricing strategy which allows for achieving full (or close-to-full) cost-recovery levels and will suit the specific characteristics and challenges associated to the specific water reuse scheme**.

# 1 Introduction

## 1.1 Background and objectives of this deliverable

The current deliverable is the last product of Work Package 4 (WP4). WP4 explored the economic aspects of water reuse, as well as business and financing opportunities. This deliverable builds on previous work conducted within WP4 and, in particular, on the following previous Demoware deliverables:

- Deliverable D4.4 - Social and environmental benefits of water reuse schemes – Economic considerations for two case studies;
- Deliverable D4.5 - Financing solutions for water reuse schemes; and
- Deliverable D4.6 - Guidelines for SMEs in the water reuse field to make use of available financing solutions.

The economic dimension of water reuse can be seen as a puzzle made out of different tiles, namely costs, benefits, revenues, financing and pricing. The first deliverable built an insight on the costs and environmental benefits of water reuse, focusing in particular on the Braunschweig and Sabadell demonstration sites. The other two deliverables explored financing opportunities for water reuse in Europe, and developed an information base on both financing opportunities and practices in Europe and worldwide. Pricing strategies for reused water, revenues, as well as their interrelations with costs and financing, are the last tiles of the puzzle that is being built, and the last bit to be explored by Work Package 4 of the Demoware project.

This deliverable aims at completing this puzzle, and it will do so by focusing on four demonstration sites. Reused water must be seen as a component of the water supply and wastewater treatment system –or, in other words, a component of the water portfolio in a designed area; it represents an alternative to conventional water supply which can be (and sometimes, must be) chosen by users. Thus, the provision of water reuse is closely linked to the provision of conventional water services; the development of a correct pricing strategy, as well as financial and economic planning, must focus on the whole system, considering water reuse, conventional water supply and wastewater collection and treatment all at once.

More in detail, this deliverable will:

- **Provide an overview of current theory and practice of pricing strategies** for reused water, as compared to pricing for conventional water supply and wastewater treatment and collection;

- **Analyse costs, pricing and financing strategies of four demonstration sites**, taking into account the whole system of water supply and wastewater collection and treatment of the reference area.

More in detail, in **the case studies** the current cost, pricing and financing frameworks were assessed, with the aim of extracting useful hints and lessons on how to develop a pricing strategy for water reuse.

In particular, cost, pricing and financing for **water reuse** will be compared to those of **conventional, alternative water supply options** in the case study area. In particular, the following questions must be answered:

- What is the cost difference between reused water and conventional water, in terms of financial, environmental and resource costs?
- What is the impact of this costs difference on tariffs for reused and conventional water? i.e. does it result in differentiated tariffs, and how large is the difference between rates?
- If tariff difference is significant, what could be a suitable financing and/or pricing scheme able to eliminate the differentiated tariff and thus promote reused water?

## 1.2 Contents of this report

This report is structured as follows:

- Chapter 2 - Cost, pricing and financing of water reuse: this chapter provides: (i) an overview of current theory and practice of pricing strategies for reused water, as compared to pricing for conventional water supply and WWT; and (ii) a quick summary of the main features of cost, financing and pricing, providing a summary of previous Demoware reports (D4.5 and D4.6);
- Chapter 3 – Methodology for the assessment of costs, pricing and financing in the four case studies;
- Chapter 4 - main findings of the Braunschweig case study;
- Chapter 5 - main findings of the Sabadell case study;
- Chapter 6 - main findings of the Capitanata case study;
- Chapter 7 – main findings of the Tarragona case study;
- Chapter 8 - Which messages can be extracted from the case studies? This chapter presents some overall considerations over case study results;
- Chapter 9 - Conclusions.

# 2 Cost, pricing and financing of water reuse against "conventional" water supply: an overview

## 2.1 Pricing strategy for water reuse: how does it differ from pricing strategies for conventional water?

Water reuse schemes bring new complexity in the provision of water services, as they challenge the conventional models of water supply and disposal by interconnecting different water services: water moves through the urban water supply and sewerage systems to be used and distributed again. In addition, the inclusion of recycled water in the water portfolio benefits all water users in a specific service area: in fact, recycling unlocks an additional water supply source, so that for example freshwater customers are less subject to water restrictions in periods of water scarcity. Thus, the application of unmodified pricing principles for conventional water supply –based on cost-recovery considerations only- is not always relevant or appropriate for reused water (Center for International Economics, 2010). Molinos-Senante et al. (2013) emphasise furthermore, that the "objectives of pricing for water demand management, pricing for encouraging the use of recycled water, and pricing for cost-recovery are not simultaneously achievable".

Whereas the overall objective of pricing strategies for water reuse should always be cost-recovery, pricing strategies must adopt a system-wide approach –which considers:

- all water services in the service area; and
- all benefits (also environmental benefits) delivered by the inclusion of reused water in the water portfolio and the related beneficiaries. In other words, pricing strategies for reused water should be based on a wide beneficiary-pays approach rather than on the user-pays principle.

This system-wide approach is presented in ¡Error! No se encuentra el origen de la referencia..

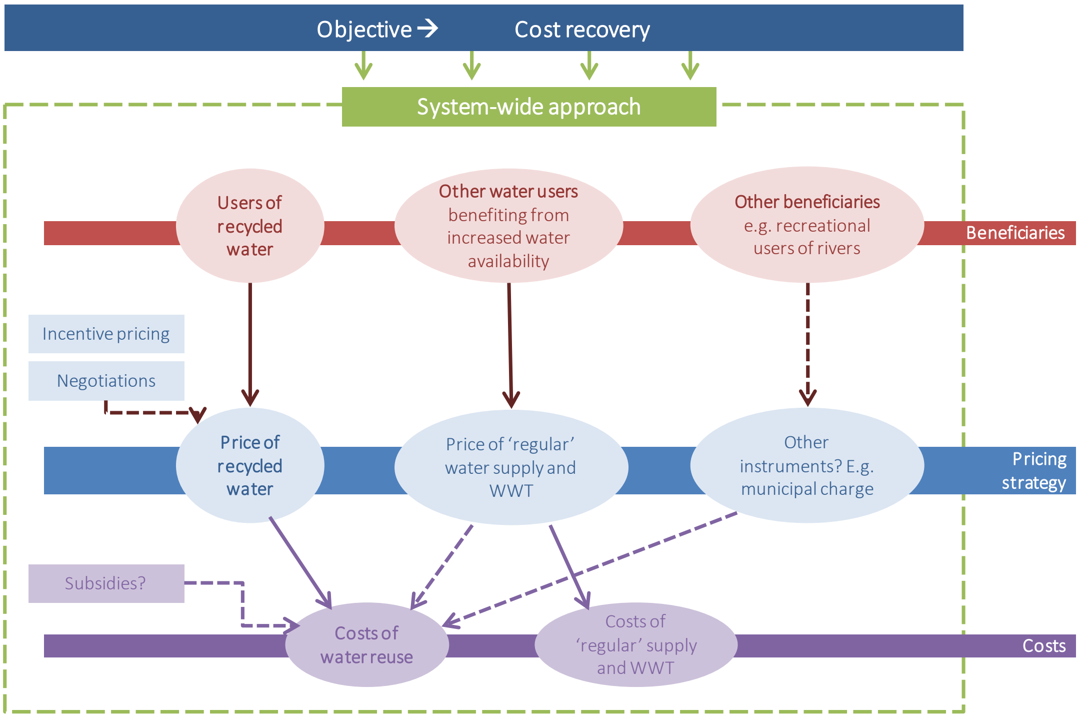



Figure 2 System-wide approach for the development of an equitable pricing strategy for water reuse (source: authors'elaboration)

On the **beneficiaries**' side, three groups can be distinguished:

- **Users of recycled water**;
- **Other water users** (e.g. drinking water users) benefiting from increased water availability;
- **Other beneficiaries**: this group can include different beneficiaries, depending on the wider benefits provided by the inclusion of reused water in the water portfolio. For example, wastewater can be treated, disinfected and re-injected in a river or channel, to be used downstream by agricultural users. This will improve the quality of the receiving water body, which can then become attractive for recreational uses (e.g. walks on river banks, recreational fishing, etc.). In this case, recreational users must also be considered as beneficiaries of the water reuse projects.

On the cost side, the **costs of recycling water** can be divided in two components:

- **Costs of 'regular' water supply and wastewater treatment**: these costs are not modified by the development of a water reuse system. In particular, the costs of 'regular' wastewater collection and treatment will be incurred anyway –even in the absence of the water reuse system-, so they should not be accounted for as part of the costs of the reuse system;
- **Costs of recycled water**: these costs include two components: (i) the costs of the additional water treatment required to reach the quality standards for water reuse; and (ii) the costs of distributing reused water (as it is normally distributed through a separate network).

As a result, the appropriate pricing strategy for water reuse should be designed and implemented as part of a wider pricing strategy including all components:

- **Tariffs for recycled water**: price charged on consumers for the use of recycled water;
- **Tariffs for wastewater collection and treatment**: price charged on all consumers for wastewater collection and treatment, which cover part of the treatment costs for reusing effluents;
- **Tariffs for freshwater supply (cross-subsidy)**: in general, the price charged for water should correspond to the costs of producing and distributing that water. However, producing and distributing recycled water is very often more expensive than abstracting freshwater, treating it and distributing it to consumers. This would result in recycled water being more expensive than freshwater, so that consumers would not have any incentive to consume recycled water. For this reason, water managers may want to encourage the use of recycled water by keeping its price lower than the price of water from conventional sources. This could mean that the price of recycled water does not fully recover the costs of production and distribution: to cover these costs, the price of freshwater can be kept higher than its cost of production and distribution, so as to fully recover the costs of water reuse. This also reflects the benefits received by conventional water users, such as for example increased water availability. This strategy is pretty common and it is known as cross-subsidization (see e.g. Zayas et al, 2016);
- **Other instruments**: other instruments can be put in place to account for the additional benefits of water reuse. For example, a municipal charge can be put in place to account for the recreational

benefits brought by the reinjection of reused water in a river or channel, as these benefits are enjoyed by residents in the area. The type of instruments which can be put in place to account for these benefits are very site- and case-specific, as they depend on the particular benefits delivered by a water reuse projects and the related beneficiaries.

It must also be noted that, although cost-recovery should be the overall objective of a pricing strategies, other political considerations can come into play. For example, let us suppose that a municipality or water agency might want to promote the uptake of recycled water, but the costs of recycled water are higher than conventional water, and for various reasons it is not possible to introduce cross-subsidization mechanisms in the overall pricing strategy: in such cases, public subsidies might also play a role in the recovery of the costs of producing recycled water.

It remains furthermore to specify that the reflections above are based on the European context. In the EU, recovering costs for water services is an obligation fixed by the EU Water Framework Directive (Directive 2000/60/EC). Furthermore, also urban wastewater treatment is obligatory following the EU Urban Waste Water Treatment Directive (Directive 91/271/EEC), and legal discharge limits exist for protecting the water quality of surface water bodies. In this context, both the establishment of wastewater treatment and the cover of its costs by the ones producing the wastewater form part of the existing system to which wastewater reuse – and corresponding pricing strategies – can be added. In regions outside of Europe where this basic system does not exist, the situation might be very different. In these cases, where establishing a water reuse system involves also establishing basic wastewater treatment, all costs linked to it might a priori be attributed to the users of the wastewater, and the pricing system might look very different.

## 2.2 Costs and pricing of water reuse: review of current practices

Deliverable D4.5 of the Demoware project (De Paoli, 2016) is a database collecting information on costs, pricing and financing for water reuse. In particular, the database provides a review of the followings: available funding sources (discussed later on in this chapter) and existing water reuse systems around the world (case studies).

Overall, evidence on costs, financing and pricing for water reuse is scattered and incomplete in several cases. Nevertheless, the case studies collected in the database can provide an overview of existing experiences of costs and pricing of water reuse. Case studies included in the database were mainly drawn from Lazarova et al (2013): these cases are the ones with the best economic information available. Case studies from other sources were also included in the database, although information on costs, financing and pricing was scarce.

The table below provides a review of some of the case studies included in the database –all cases are drawn from Lazarova et al. Case studies with incomplete or missing economic information are not listed in the table. The table provides a very synthetic (and also schematic) overview of pricing schemes applied in different water reuse schemes around the world, and compares pricing schemes with unitary O&M costs (by cubic metre - when this information is available). Investment costs are not considered in the table, because in most cases it was not possible to come up with unitary investment costs (investment costs by cubic metre), and the juxtaposition of total investment costs and unitary prices (by cubic metre) would have not been very informative. On the contrary, the comparison between unitary O&M costs and unitary prices already allows for making some considerations. The case studies are grouped by user group: in principle, providing recycled water to a specific user group requires a certain quality level[2], so it makes sense to group and compare price levels based on the user group which recycled water is produced for. Some water reuse schemes included in the table (Honolulu, Tianjin, Cyprus, El Segundo in California) provide recycled water for different user groups, often applying different rates depending on the final use: these cases are highlighted in different colours in the table.

[2] Of course, quality levels of recycled water provided to different user groups can vary from one country to the other, based on quality standards established by the national law in each country. So, comparing pricing levels in different countries for the same final uses can be seen as an over-simplification, and to a certain extent it is an oversimplification. However, the aim of this section is to provide an overview of costs and pricing of water reuse in a structured way, and this is a challenging task considering the complexity and site-specificity of costs and pricing. Thus, this is seen as an acceptable way of presenting available evidence in a structured way.

Table 3 Synthesis of cost and pricing information in selected water reuse schemes around the world, grouped by final user

Source: Lazarova et al, 2013; case studies collected in Deliverable 4.5 of the Demoware project (De Paoli, 2016)

| Final user - Sector | Location | O&M costs | Price |
|---|---|---|---|
| Landscape irrigation | Madrid - ES | N/A | 0.154 ÷ 0.338 EUR/m$^3$ |
| | Honolulu - USA | N/A | 0.13 ÷ 0.47 |
| | Bora Bora – French Polinesia | 0.68 EUR/m$^3$ | 187 EUR/year + 0.67 ÷ 2.18 EUR/m$^3$ |
| | Tianjin - PRC | N/A | 0.32 ÷ 0.33 EUR/m$^3$ |
| | Cyprus - CY | 0.46 EUR/m$^3$ | 0.15 ÷ 0.21 EUR/m$^3$ |
| | El Segundo, California - USA | N/A | 0.50 ÷ 0.56 EUR/m$^3$ |
| Industry | Honolulu - USA | N/A | 1.15 EUR/m$^3$ |
| | Tianjin - PRC | N/A | 0.32 ÷ 0.33 EUR/m$^3$ |
| | El Segundo, California - USA | N/A | 0.56 EUR/m$^3$ |
| Agriculture | Cyprus - CY | 0.46 EUR/m$^3$ | 0.05 ÷ 0.07 EUR/m$^3$ |
| | Milan - IT | 0.115 ÷ 0.39 EUR/m$^3$ | 1 827 EUR/year + 27 000 EUR/year for energy consumption[3] |
| | Noirmoutier - FR | 0.54 EUR/m$^3$ | 190 EUR/year + 0.3 EUR/m$^3$ |
| Groundwater recharge[4] | Cyprus - CY | 0.46 EUR/m$^3$ | 0.08 EUR/m$^3$ |
| | El Segundo, California - USA | N/A | 0.4 EUR/m$^3$ |
| | California - USA | 0.31 EUR/m$^3$ | 0.18 EUR/m$^3$ |

The most common **tariff structure** in use is the **volumetric charge**: recycled water is charged by cubic metre. In five cases, a one-rate tariff is applied –that is, a single unitary rate is charged on customers, regardless of consumption levels. In seven cases, a progressive rate is applied (in the table, it is indicated as a price range): the unitary rate charged on customers' increase with increasing consumption of recycled water,

[3] In Milan, the WWT and water reuse operator charges the irrigation consortium for the supply of recycled water. In this case study, recycled water is provided for indirect reuse: the treated effluent is released into the irrigation channel, managed by the consortium, where it mixes with water in the irrigation channel, which is abstracted from other sources and it is the conventional irrigation water supply. The consortium pays a fixed amount each year to the WWT and water reuse operator for the provision of treated wastewater into their channel. Water from the channel (conventional + recycled water) is then sold to farmers by the consortium.

[4] In the two case studies in California, the WWT and water reuse operator charges retail water operators abstracting from the groundwater body for the recycled water that is injected in the groundwater body.

and more precisely different rates are applied to different consumption ranges. In two cases, a **mixed tariff** is applied, featuring a fixed component (a fixed amount paid by each customer every year) and a volumetric component (thus charged on actual volumes of recycled water used by the customer); the volumetric component can be both a one-rate tariff (in Bora Bora) or a progressive tariff (in Noirmoutier). Only in Milan a **flat rate** is applied: the irrigation consortium (the only direct customer of the water reuse scheme) pays a fixed amount each year for recycled water, plus a fixed amount which is meant to cover energy expenditures for producing recycled water[5].

In terms of price levels, similar price ranges can be observed, with some exceptions. In particular:

- Unitary rates for **landscape irrigation** range from 0.13 to 0.56 EUR/m$^3$. Only in Bora Bora recycled water is much more expensive, with volumetric rates ranging between 0.67 and 2.18 EUR/m3 and an additional fixed component paid by customers each year. This might suggest that in Bora Bora costs are recovered to a large extent by water reuse customers: for sure, O&M costs (0.68 EUR/m$^3$) are fully recovered by users, but tariff levels also suggest that at least a part of investment costs are recovered by users. However, it is difficult to compare cost-recovery levels across the different sites, as O&M cost figures are only available for Cyprus (and not for the other case studies). Nevertheless, in Cyprus O&M costs are 0.46 EUR/m3, against unitary rates comprised in the range 0.15-0.21 EUR/m3 for landscape irrigation (and for much lower rates for the other user groups involved in the scheme, as illustrated below): at least in this case, it can be said that water prices are far from recovering even O&M costs, which are thus partly subsidized, and that investment costs were likely to be fully subsidized.

- Unitary rates for **industrial use** range from 0.32-0.33 in China, 0.56 in El Segundo and 1.15 EUR/m$^3$ in Honolulu. This is quite a wide range: the difference between prices in Honolulu and the other two cases could be mainly due to the high quality of water provided by this scheme. Unfortunately, information on O&M costs for these three schemes are not available.

- Unitary rates for **agricultural use** are extremely diverse, in contrast to what can be observed in the other user groups.

- Unitary rates for **groundwater recharge** are in a close range, 0.08 to 0.4 EUR/m$^3$. These rates are lower than rates for landscape irrigation and industrial use, and one reason for it can be that water is not directly provided to consumers –and thus the costs associated to this are not born by the water reuse provider- but it is injected in a groundwater body. Nevertheless, in the two cases for which O&M cost figures are available (Cyprus and California) the price charged on water retailers is lower than O&M costs, indicating that some degree of subsidization or cross-subsidization is in place.

Overall, it can be seen from these case studies that, in most cases, unitary prices only recover a part of O&M costs –and, it follows, prices do not cover at all investment costs. Thus, some form of subsidization is very often in place. Unfortunately, available information does not allow for getting a deeper understanding of cost-recovery and subsidization in these case studies.

[5] Information on the yearly volumes supplied by the water reuse scheme in Milan is not available, so it was not possible to estimate the price paid by the Irrigation Consortium per cubic metre of water.

## 2.3 Financing water reuse: overview of current practices, opportunities and constraints

Funding sources can be distinguished based on where they come from (private, public, water users), as well as on the level from which they are provided (European, national, local). The figure below illustrates and classifies funding sources based on these two characteristics (source: own elaboration from funding sources and case studies collected under WP4, taken from De Paoli, 2016, Demoware D4.5).

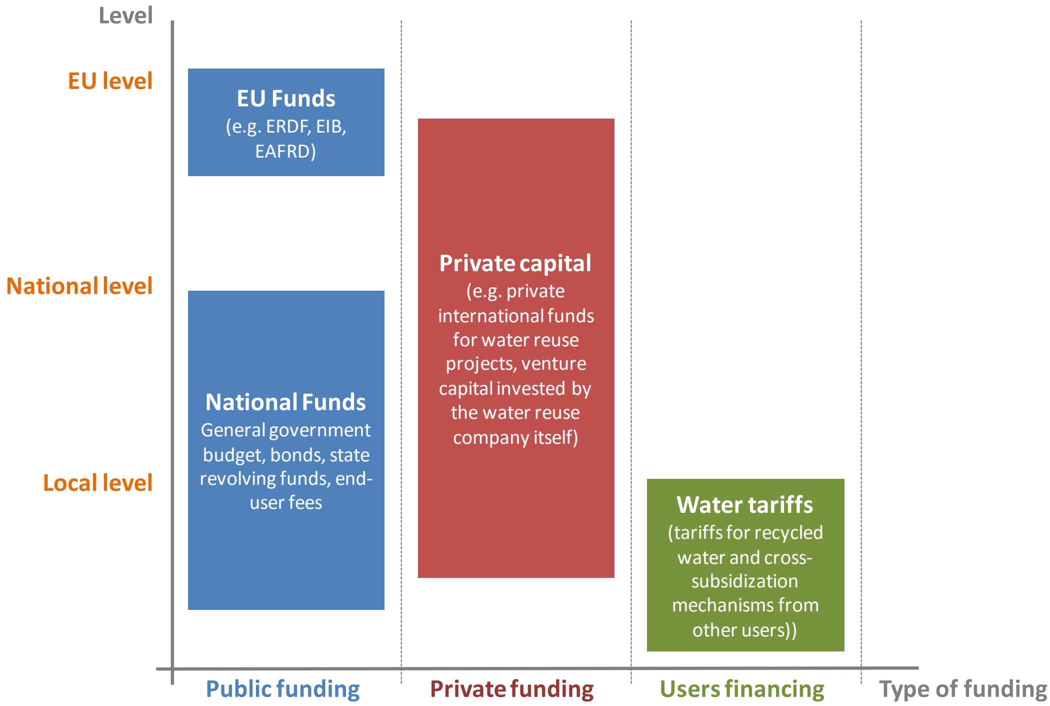



Figure 3 Funding sources classified according to type of funding and geographical level
(Source: Demoware D4.5)

In most cases, **water reuse projects are funded by a combination of different funding sources**.

Often, **investment costs** are funded through European and national funding sources as well as through private investment –and through different combinations of these three sources. In some cases, investment costs are first covered by public budget and then recovered through user tariffs (see the case study below in Spain).

**Operation and maintenance costs** are often covered by recycled water tariffs charged on users, although public subsidies can sometimes come into play. In a few cases, water tariffs also contribute to recover (part of) the investment costs.

Private investment can also be employed in the construction phase and be refunded by public funding later on.

The overall financial flows in a water reuse system are illustrated in the figure below (Source: source: own elaboration from funding sources and case studies collected under WP4, taken from De Paoli, 2016, Demoware D4.5).

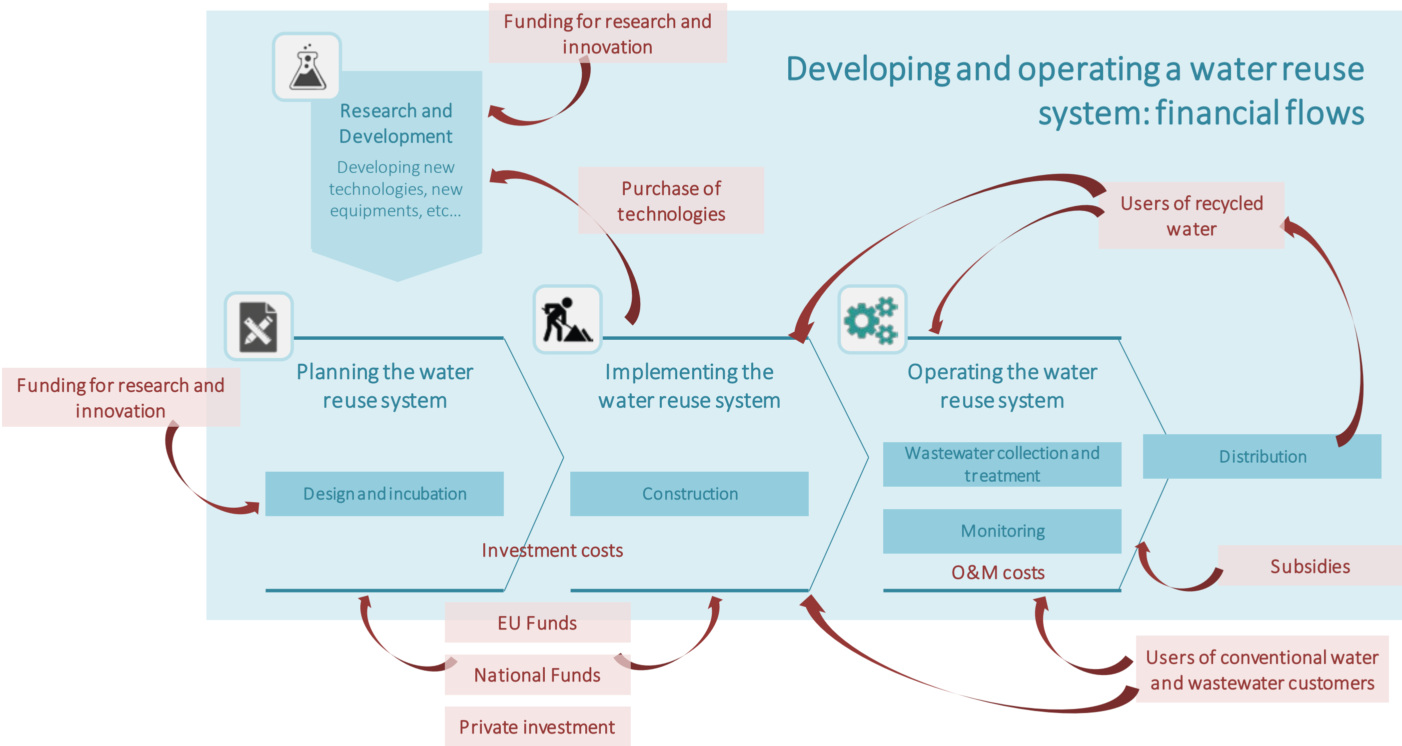



Figure 4 Development and operation of a water reuse system: financial flows
(Source: Demoware D4.5)

Pricing strategies are the main instruments to recover O&M costs of a water reuse scheme, and often to recover investment costs too. Different actors come into play when it comes to pricing strategies for water reuse systems: not only users of recycled water are involved, but also wastewater customers and users of conventional water (De Paoli and Zayas, 2016).

## 2.4 Available funding sources for water reuse in the EU

Available funding sources for water reuse schemes in the EU are collected and described in Deliverable D4.5 of the Demoware project (De Paoli, 2016). Deliverable D4.6 (De Paoli and Zayas, 2016), in turn, provide guidance on how to access available EU funding sources as well as the main private funding sources. For more detailed information on available sources it is therefore suggested to consult these two deliverables; the table below provides a quick description of available sources.

Table 4 Available EU funding sources for water reuse
(De Paoli and Zayas, 2016)

| EU funding sources | |
|---|---|
| Horizon 2020 | Horizon 2020 is the biggest EU Research and Innovation programme ever with nearly €80 billion of funding available over 7 years (2014 to 2020). The programme includes a specific section on climate action, environment, resource efficiency and raw material –which can be relevant for research in the water reuse field. |
| Horizon 2020 SMEs Instrument | It offers funding and coaching support to innovative SMEs, and boosts actions in the areas of climate action , environment, resource efficiency and raw materials. The instrument is directed to high growth, highly innovative SMEs with global ambitions, actively investing in innovation, and looking to grow. To access the fund, SMEs should be already established further than the start-up stage. |
| InnovFin | InnovFin financing tools cover a wide range of loans and guarantees which can be tailored to innovators' needs. InnovFin can support the development of water reuse projects from the definition of concept and the assessment of their feasibility, to the demonstration of innovative projects and their commercialization. |
| COSME | COSME is the EU programme for the Competitiveness of Enterprises and SMEs, and it supports SMEs in the following areas: (i) Facilitating access to finance; (ii) Supporting internationalization and access to markets; (iii) Creating an environment favourable to competitiveness; and (iv) Encouraging an entrepreneurial culture. |
| LIFE+ | The LIFE programme is the EU's funding instrument for the environment and climate action. Water reuse projects can be funded under the sub-programme Environment and resource efficiency. Water reuse projects can be best-practice (application of state-of-the-art techniques), demonstration (application of new techniques and technologies that are new to the project context) or pilot projects (applications of techniques that have never been tested before) projects. |
| European Regional Development Fund (ERDF) | The European Regional Development Fund (ERDF) supports programmes addressing regional development, economic change, enhanced competitiveness and territorial cooperation throughout the EU, and it aims at helping to reduce regional disparities across the Union. Funding priorities include research, innovation, environmental protection and risk prevention, while infrastructure investment retains an important role. Water reuse, together with efficient water supply and wastewater treatment, is an investment priority for the ERDF. |
| European Agricultural Fund for Rural Development (EAFRD) | The EU's rural development policy helps the rural areas of the EU to meet the wide range of economic, environmental and social challenges of the 21st century. Frequently called "the second pillar" of the Common Agricultural Policy (CAP), it complements the system of direct payments to farmers and measures to manage agricultural markets (the so-called "first pillar"). The Fund focuses on agriculture, forestry, environment and countryside, as well as quality of life in rural areas. EAFRD resources can be used to finance **water reuse infrastructures in agriculture**. |
| European Fund for Strategic Investment (EFSI) | EFSI is an initiative launched jointly by the EIB Group - European Investment Bank (EIB) and European Investment Fund (EIF) - and the European Commission. With EFSI support, the EIB Group provides loans for economically viable projects where it adds value, including projects with a higher risk profile than ordinary EIB activities, focusing for example on strategic infrastructures and the expansion of renewable energy and resource efficiency. |

| | |
|---|---|
| Financial instruments for SMEs offered by the European Investment Fund (EIF) | EIF is a specialist provider of risk finance to benefit small and medium-sized enterprises (SME) across Europe. It is part of the EIB Group. By developing and offering targeted financial products to intermediaries, such as banks, guarantee and leasing companies, micro-credit providers and private equity funds, EIF enhances SMEs access to finance. |
| European Investment Bank (EIB) – Lending instruments | The EIB provides long-term loan financing to both public and private clients in the water sector, using a range of instruments. In the field of water and wastewater management, the EIB support investment to ensure reliable provision of sustainable and affordable water and wastewater-related services. In the field of agriculture and rural development, funding is provided to support investment in rural infrastructures and innovative resource management. Water reuse projects can fall under both categories. |

Table 5 Main private funding sources for water reuse available in the EU

| Private funding sources | |
|---|---|
| ACQUEAU | ACQUEAU supports near water-market projects, in order to facilitate the development of innovative products, processes and systems in the water sector. ACQUEAU is an industry-driven EUREKA initiative dedicated to water related technologies and innovation. It aims at promoting innovation and market driven solutions to develop new technologies in the European water sector. |
| Veolia VIA | Veolia's Open Innovation initiative VIA acts as a matchmaker between innovative solution providers and the Veolia ecosystem: researchers, Business Unit managers, experts in France and internationally. VIA aims at: (i) supporting startups and the Veolia ecosystem, so that the proposed innovation is rapidly integrated; and (ii) developing an active sourcing approach, reaching out to those with innovative solutions |
| ISLE Utilities | ISLE connects start-up companies with end users and investors focusing on pre-commercial technologies that may be 1–2 years from market. Isle tracks many potential deals from the incubator stage through pilots and demonstration to commercial market uptake. |
| Eurostars | Eurostars supports international innovative projects led by research and development-performing small- and medium-sized enterprises (R&D-performing SMEs). Water innovation is included. |
| Business angels or angel investors | An angel investor or angel is an affluent individual who provides capital for a business start-up, usually in exchange for convertible debt or ownership equity. Business angels associations are normally present in many EU countries, and they create a bridge between start-ups looking for funding and investors. |

# 3 Methodology

## 3.1 The four case studies

This assessment will be carried out in four sites: Braunschweig (DE), Sabadell, Tarragona (ES) and Capitanata (IT). The main characteristics of these sites are presented in the table below.

Table 6 Main features of the four case studies

| | | |
|---|---|---|
| Braunschweig (DE) | Driver | Meeting nutrient discharge limits of the nearby surface water body and nutrient and water demand of the surrounding agricultural fields at the same time |
| | Final users | Agriculture |
| | Treatment units | Primary sedimentation to separate sludge from wastewater<br>Stabilization of sewage sludge via anaerobic digestion<br>55% of treated wastewater is mixed to the treated sludge and used for irrigation and fertilization<br>Infiltration fields (remaining 45% of wastewater after primary treatment) |
| | Capacity | 11 $Mm^3$/year of treated wastewater mixed with treated sludge are used for irrigation |
| Sabadell (ES) | Driver | Water scarcity issues on the one hand, and need to reduce pollution in the river |
| | Final users | Municipality (irrigation of green areas, fountains and street cleaning) and industry |
| | Treatment units | Ripoll WWTP: release into the river after secondary treatment, infiltration in groundwater body, groundwater abstraction and disinfection (UV treatment and chlorination)<br>Riu Sec WWTP: primary treatment unit, secondary biological treatment unit (membrane bioreactor technology), tertiary treatment (UV treatment and chlorination) |
| | Capacity | 1.02 Mm3/year of reclaimed water is produced |
| Capitanata (IT) | Driver | Water scarcity |
| | Final users | Experimental agricultural fields – Fiordelisi treats its own wastewater (from food processing) and recycle part of it |
| | Treatment units | Primary and secondary treatment<br>Tertiary treatment (membrane and UV disinfection) |
| | Capacity | Production of recycled water: 1000 m3/year |
| Tarragona (ES) | Driver | Freeing up existing water rights to meet future local (municipal and tourism) demand and to decrease water tress to the Ebro River |
| | Final users | Industry |
| | Treatment units | Secondary effluent from two municipal WWTPs is reclaimed via tertiary treatment (Actiflo clarification technology, two steps filtration followed by two pass DOW FILMTEC™ reverse osmosis) |
| | Capacity | 6.8 Mm3/year of reclaimed water |

## 3.2 Data availability and trustworthiness of sources

One of the main challenges encountered when developing the case studies was data availability. In nearly all cases, available data were directly requested to plant managers (as personal communications), or were found in publications including plant managers among authors. In principle, this should have ensured the best possible data coverage. However, often plant managers did not have all the necessary information – and this holds, in particular, for cost information, which is generally available but sometimes not to the needed level of detail. In other cases, some of the requested information is confidential, so plant managers could not share it with the study team.

A second issue related with these sources of information is that the study team had to rely uniquely on information provided by plant managers, and thus it was not possible to check or compare these data with data and information from external sources.

The case study work undertaken within this report relies on data from different sources. The trustworthiness of this data will be commented in the following, taking aspects of credibility (credibility of the source, internal consistency), transparency, transferability, completeness, and confirmability into account.

### Braunschweig

In the case of Braunschweig, an important share of the key data is going back to only one source. The sources are all deemed credible, but there is – in most cases – no possibility to check the correctness of the information. An important share of the data is provided via personal communication, without being backed up with documents. The trustworthiness of all key data and data sources is commented in the table below.

Table 7 Trustworthiness of key data (sources) in Braunschweig

| Key data | Data source | Comments on trustworthiness |
|---|---|---|
| Prices for public water supply | Official websites of the administration | Publicly available information; different sources with consistent information. |
| Costs of groundwater abstraction for agriculture | Chamber of agriculture of Lower Saxony | Credible source. However, no possibility to check how these average values have been calculated. |
| Cost information about wastewater collection, treatment and reuse | Plant manager | Credible source. However, no possibility to check how these values have been calculated. |
| Environmental benefits of water reuse | DEMOWARE deliverable 4.4, written by the co-author | Origin of the data can be retraced. Results based on a contingent valuation study. |

### Sabadell

In Sabadell, data go back to only one source (CASSA). The source is deemed credible, but there is no possibility to check the correctness of the information recurring to third sources. The trustworthiness of all key data and data sources is commented in the table below.

Table 8 Trustworthiness of key data (sources) in Sabadell

| Key data | Data source | Comments on trustworthiness |
| --- | --- | --- |
| Prices for public water supply and wastewater treatment, revenues | Official websites of the administration[6] | Publicly available, consistent information. |
| Costs of existing water supply and wastewater treatment system | CASSA, yearly report to shareholders[7] | Credible source. However, no possibility to check how these overall values have been calculated. |
| Cost of planned expansion of the water reuse system | Financial feasibility study included in the 2004-2014 Master Plan (by CASSA) – Collado et al, 2003 | Credible source. However, no possibility to check how these values have been calculated. |
| Environmental benefits of water reuse | DEMOWARE deliverable 4.4, written by the co-author[8] | Origin of the data can be retraced. Results based on a choice experiment study. |

### Capitanata

In Capitanata, most information and data were provided in the form of personal communication by Fiordelisi manager –with the exception of data on public wastewater tariffs. While this source can be deemed credible, there is no possibility to check the correctness of the information recurring to third sources; in addition, only general figures were provided (e.g. on costs). This is also illustrated in the table below.

Table 9 Trustworthiness of key data (sources) in Capitanata

| Key data | Data source | Comments on trustworthiness |
| --- | --- | --- |
| Costs of the water reuse system, costs of self-abstraction, irrigation water tariffs from the consortium, financing sources | Fiordelisi manager | Credible source. However, no possibility to check how these values have been calculated. |
| Wastewater tariffs applied by the public water supply and WWT system | Official website of the water provider | Publicly available, consistent information. |

### Tarragona

In the case of Tarragona, very little relevant cost and pricing data about the Tarragona reuse system could be found in publicly available documents. Important information was not accessible either for confidentiality reasons (e.g. detailed cost calculations, fees paid for reclaimed water), or due to missing reactivity of the relevant stakeholders (e.g. costs of conventional water supply and wastewater treatment). Information of the overall costs of the reuse system could be found in one source (without a specified author, but publicly available on the internet). The remaining information has been provided by a representative of

[6] http://www.cassa.es/phtml/blog/wp-content/uploads/2015/07/sabadell-tarifes.pdf

[7] CASSA, Resum memòria 2015 - http://www.cassa.es/phtml/blog/wp-content/uploads/2016/06/Resum-mem%C3%B2ria-2015.pdf

[8] Mattheiss and Zayas, 2016

one of the industrial companies using the reclaimed water without being backed up with documents. The trustworthiness of all key data and data sources is commented in the table below.

Table 10 Trustworthiness of key data (sources) in Tarragona

| Key data | Data source | Comments on trustworthiness |
|---|---|---|
| Overall costs of the reuse system | Document accessible on the internet | No author is indicated. Limited possibility to check the information provided. |
| Qualitative cost comparison of water reuse and use of conventional water; as well as a figure for overall cost savings | Representative of an industrial company | Credible source. However, no possibility to check how these average values have been calculated. |

## 3.3 Approach applied to the case studies

The case studies were developed following a two-steps approach, described below.

### Step 1 – Mapping the system

The design of an appropriate pricing strategy for water reuse is very site specific, and it requires that the overall water system is thoroughly analyzed and understood. In particular:

- Beneficiaries must be carefully identified, as well as all the benefits of including reused water in the water portfolio;
- Water and wastewater services in the area must be clearly identified, and the links between these operators and water reuse operators must also be identified (although the same utility can provide conventional water supply, wastewater collection and treatment and reclaimed water supply);

The environmental objectives –or, more widely, the water management objective- underlying the decision to implement a water reuse project must be clearly established: for example, there might be the political will to incentivize the use of recycled water (or also the need to substitute freshwater with reused water, e.g. in water scarce areas).

Therefore, the first step of the case study investigation will be to map the system, in terms of:

- Water flows occurring among users;
- Beneficiaries; and
- Financial flows.

### Step 2 - collect information on costs, pricing and financing of existing and projected schemes

In the second step, the financial flows occurring within the system will be identified, and monetary values will be assigned to these flows. First of all, the investment and O&M costs of the system (water supply and conventional WWT, water reuse system) must be identified. The financial flows are represented by the different ways in which these costs are recovered, and namely:

- Tariffs for conventional water supply and WWT, and for reclaimed water;
- External financing sources (for example, to cover investment costs); and
- Potential additional financing instruments, such as for example municipal charges to finance the operation and maintenance of the water reuse system.

Overall, this step allows for: (i) gaining a picture the financial sustainability of the system, and especially of the water reuse system; (ii) comparing costs and tariffs linked to each water source, and (iii) to assess whether cross-subsidization mechanisms are in place within the system.

# 4 Braunschweig case study

## 4.1 Site description

The Steinhof wastewater treatment plant (WWTP) treats wastewater from the city of Braunschweig and surrounding communities. After treatment, half of the effluent is directed towards adjacent infiltration fields. The water receives here a natural, tertiary treatment before being discharged to the nearby Aue-Oker-canal, which finally leads to the river Oker. In the river, certain water quality standards regarding the discharged water need to be met. The infiltration fields are currently at the limit of their natural purification capacity. Leading more wastewater through them would represent a risk for keeping the water quality standards. At the same time, agricultural soils around the WWTP are poor of nutrients and unable to store much water. The other half of the treated effluent is therefore reused for irrigation in the area belonging to the Sewage Board of Braunschweig.

A part of the crops produced with recycled water supplies the biogas plant Hillerse, which produces both electricity and heat for about 6000-7000 and 1000-1500 households, respectively. The Braunschweig model links therefore wastewater from the city and bio-energy from the agricultural land within a water-nutrient-energy cycle, which is unique in Germany. Its different components are illustrated in Figure 5 and further described below.

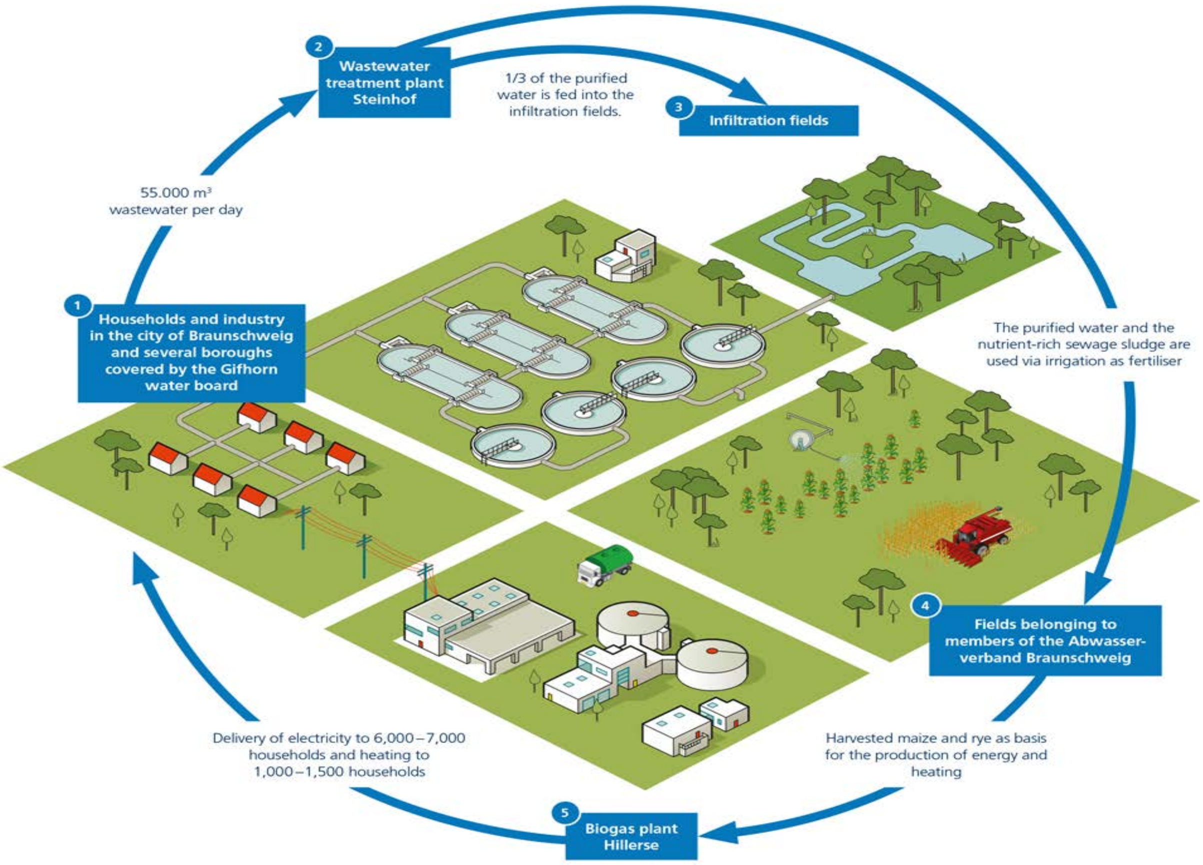



Figure 5 The water-nutrient-energy cycle developed in the Braunschweig site
Source: Abwasserverband Braunschweig, 2014; Note: Today about half of the water is distributed to the infiltration fields, and half to agriculture.

### Households and industry producing wastewater (1)

Households and industries in the city of Braunschweig and several boroughs covered by the Gifhorn water board produce about 55 000 $m^3$ of wastewater per day (Abwasserverband Braunschweig, 2014), corresponding to 22 million $m^3$ per year. In total, the Steinhof WWTP receives a wastewater load of 350 000 PECOD[9] per year, of which 280 000 PE are from inhabitants of Braunschweig and 70 000 PE are from industries (SE/BS, 2012[10]; Remy, 2012).

### Steinhof wastewater treatment plant (2)

After the mechanical treatment, wastewater and sludge are separated through primary sedimentation (Remy, 2012). In the mixing tank, biological purification starts. The mechanically pre-purified wastewater is mixed with sludge from the second clarifier. In the following steps, removal of phosphorous, decomposition of carbon compounds, and removal of nitrogen takes place[11]. Sewage sludge is stabilized via anaerobic digestion. Since 2001, digested sludge is added to the treated effluent destined to agricultural irrigation during the growing season, acting as a fertilizer (Lindner, 2015). During the winter and a short summer period, the remaining part of the sludge is dewatered and stored on-site. It is then applied to agricultural fields in the greater Braunschweig area (outside of the agricultural area of the wastewater association) (Remy, 2012).

### Infiltration fields (3)

About half of the treated water is pumped into the infiltration fields[12] adjacent to the WWTP for post-treatment (Teiser, 2015). The 275 ha (Abwasserverband Braunschweig, 2016) have been in operation for more than 100 years. They polish the effluent naturally by soil passage (Remy, 2012). The wetland system is isolated from groundwater by a natural clay layer which avoids contamination (Teiser, 2015).

### Fields belonging to the members of the wastewater association Braunschweig (4)

The remaining half[13] of the treated wastewater is mixed with the nutrient-rich sewage sludge (since 2001) and used for irrigation and fertilization (Teiser 2015). This process takes place during spring and summer (March to September) and recycles the nutrients to agriculture. All activities of agricultural reuse of effluent and sludge are operated by the Braunschweig wastewater association, which includes cooperation with local farmers (Remy, 2012).Out of the 10.5 million $m^3$/year supplied to the irrigation fields, 3.24 million $m^3$/year are used by the crops, the remaining amount (7.26 million $m^3$/year) is going back to the water cycle through infiltration (KWB, 2016 *pers.comm.*)[14].

The reuse of wastewater in Braunschweig fulfils several objectives: reducing the pollution load which is led to the nearby surface water body, hence preserving its water quality and the ecosystem depending on it; supporting local agricultural activities, which depend on irrigation and which benefit from the nutrients provided with the treated wastewater; preserve and recharge local groundwater resources.

[9] PECOD stands for person equivalents of chemical oxygen demand.

[10] SE / BS (2013) Wastewater Treatment – This is how it works. http://www.abwasserverband-bs.de/wp-content/uploads/2013/03/Wastewater-Treatment-in-Braunschweig.pdf (Last access: 17/03/2015)

[11] Abwasserverband Braunschweig (n/a) Waste water purification. http://www.abwasserverband-bs.de/en/what-we-do/waste-water-treatment-plant/waste-water-purification/ (Last access: 07/12/2016)

[12] In German: Rieselfelder

13 These percentages are referred to the whole year, as water reuse follows a seasonal trend: in summer time, almost all water goes to irrigation fields, whereas in winter, everything goes to infiltration fields (De Paoli 2014). Remy states 12.7 million m3 per year (or 55%).

14 These are the recent figures (2016) used by KWB to carry out a Life Cycle Assessment for the reuse system in Braunschweig within the Demoware project. The figures indicated previously were the following: 14 million m3/year led to the irrigation fields, 3.6 million m3/year used by the crops, the remaining 10.4 million m3/year going back to the water cycle through infiltration (Teiser, 2013).

## 4.2 Water flows in the site: supply sources and discharges

The existing water flows in the Braunschweig case are illustrated in **¡Error! No se encuentra el origen de la referencia.**. Water sources which are playing a role in and around Braunschweig include both surface water and groundwater. Agriculture in the districts of Peine and Gifhorn (districts in which the fields of the Sewage Board are lying) use about 36.7 million $m^3$ per year of groundwater, and about 6.5 million $m^3$ per year of surface water (from rivers) (calculated based on Landwirtschaftskammer Niedersachsen, 2015). Households and businesses in Braunschweig which are connected to public water supply are, however, supplied to about 99% from surface water reservoirs in the nearby mountain Harz, and only about 1% is taken from local groundwater sources (BS Energy, 2016).

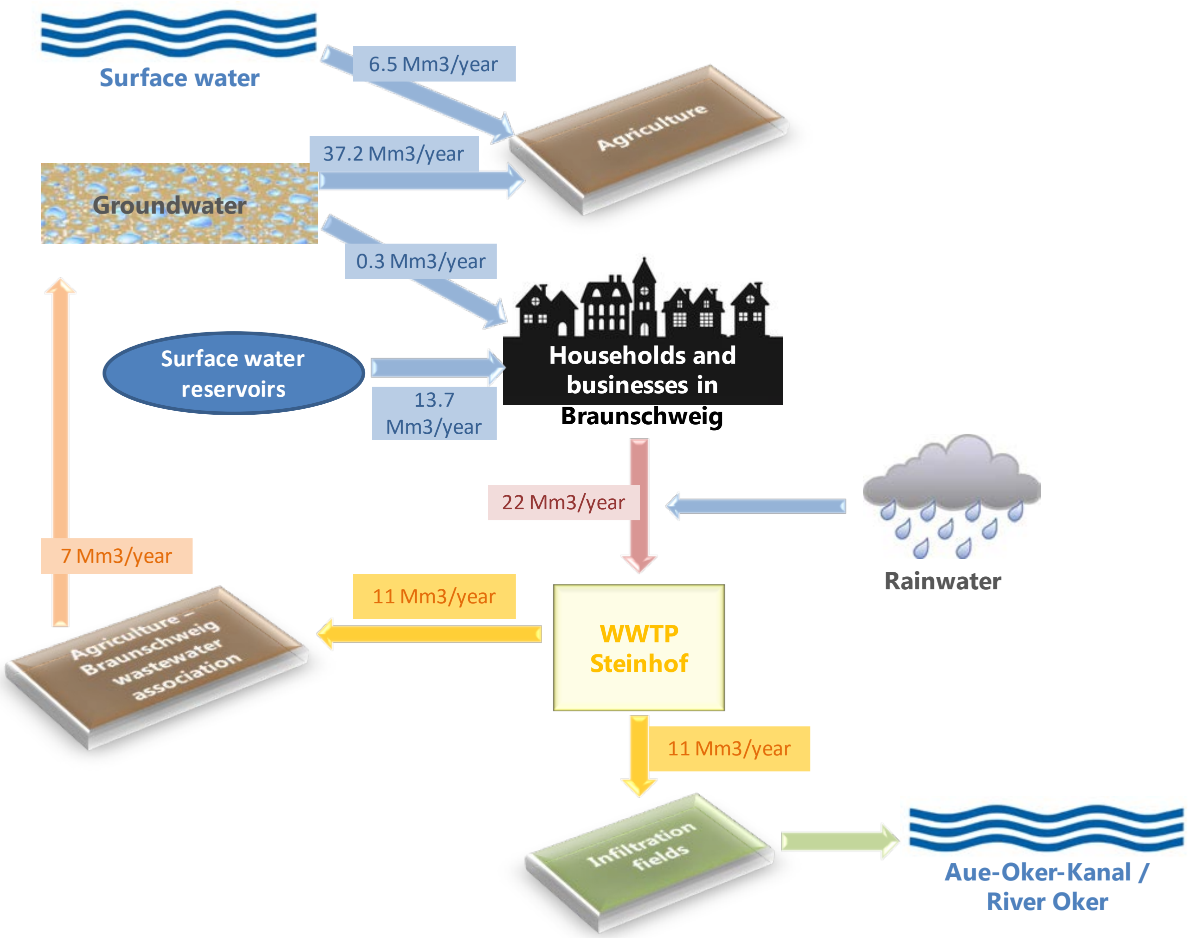



Figure 6 Water flows in the Braunschweig site

Note: Water use by agriculture: Figure calculated based on Landwirtschaftskammer Niedersachsen (2015): The reference area which has been used consists of the administrative districts of Gifhorn and Peine – as the agricultural fields of the Sewage board are lying in these districts. In these two districts, permits for groundwater abstraction for irrigation of agricultural fields are allocated for 73,447,000 $m^3$/year. Only about half of the volumes of the permits are actually used.

## 4.3 Costs, pricing strategies, and revenues: analysis of financial flows

With regards to costs and pricing strategies, it is interesting to look at the costs and pricing schemes for using conventional sources of water (for public water supply and irrigation), as well as at the costs and pricing schemes of wastewater treatment and reuse. Available data is provided in Table 11.

Table 11 Costs, pricing and revenues: financial flows for conventional water supply and wastewater treatment
Sources: BS Energy, n/a; BS Energy, 2015; Landwirtschaftskammer Niedersachsen, 2015; Siemers, 2016 pers.comm.; Mattheiß and Zayas, 2016; Stadt Braunschweig, 2014; own calculations.

| | | Public water supply | Water abstraction for irrigation | Wastewater collection | Wastewater treatment and reuse | Wastewater reuse only |
|---|---|---|---|---|---|---|
| **Operation and maintenance costs** | Annual costs – EUR/year | Not available | Not available | 21.75 million EUR | 16.5 million EUR (including operation and maintenance, interest and allowance for depreciation) | 5.2 million EUR for irrigation (included in 16.5 million EUR in the left column) |
| | Unitary costs – EUR/$m^3$ | 1.80 EUR/m3 (includes also investment costs) | 0.16 EUR/$m^3$/ha | 1.45 EUR/$m^3$ (full costs based on $m^3$ of drinking water sold) | 1.10 EUR/$m^3$ (full costs based on $m^3$ of drinking water sold) | 0.50 EUR/$m^3$ (full costs calculated per $m^3$ of wastewater irrigated[15] |
| **Investment costs** | Total costs – EUR | Not available | Not available | Not available | Not available | Not available |
| | Annualized costs – EUR/year | Not available | Not available | Included above | Included above | Included above |
| | Unitary costs – EUR/$m^3$ | See above | 0.18 EUR/$m^3$/ha | See above | See above | See above |
| **Unitary pricing** | Households - EUR/$m^3$ | 1.80 EUR/$m^3$ (varying from 1.70 EUR/$m^3$ and 1.91 EUR/$m^3$) | Not relevant | 2.52 EUR/$m^3$ for wastewater; 6.03 EUR/$m^2$ of impermeable soil for rainwater | | Not relevant |
| | Agriculture - EUR/$m^3$ | Not relevant | None. Agriculture is self-supplying. | Not relevant | Not relevant | 81 EUR/ha; corresponding to 0.02 EUR per $m^3$ irrigated; 0.07 EUR/$m^3$ |

[15] 5.2 million EUR of costs for reuse divided by the total amount of water reuse: 10.5 million $m^3$.

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | used by the plants[16] |
| **Revenues** | EUR/year | About 25 200 000 EUR/year[17] | | 38.25 million EUR/year | | 230 000 EUR (218 000 EUR from fees per ha; plus additional charge for drainage) |

### Public water supply

In the case of public water supply, tariffs applied to and paid by water users are supposed to cover all costs. Different tariffs exist for different amounts of drinking water consumed, with the average price paid per cubic meter being 1.80 EUR/m$^3$ (BS Energy, n/a). The water tariff includes a water abstraction fee of 0.075 EUR/m$^3$ which is used to cover environmental and resource costs, as revenues are used for the promotion of water-efficiency, for measures protecting water bodies and water resources and for compensatory payments linked to restrictions for agriculture or forestry (BS Energy, 2015). Following the cost-recovery-principle, households and businesses connected to the public water supply are paying for investment and operational and maintenance costs of this service.

### Water abstraction for irrigation

According to the Landwirtschaftskammer Niedersachsen (2015), the total costs for irrigation with groundwater are 3.40 EUR/mm for one hectare. Irrigating 1 mm of water per hectare corresponds to a volume of 10 m$^3$; so that the costs per cubic meter are 0.34 EUR. Of these costs, 0.16 EUR/m$^3$ are operation and maintenance costs, 0.18 EUR/m$^3$ are investment costs (based on Landwirtschaftskammer Niedersachsen, 2015). It can be assumed that farmers outside of the sewage board area, which are self-abstracting water, are financing investment costs as well as operational and maintenance costs linked to the water abstraction themselves.

The water abstraction fee is also paid for water abstracted for irrigation. For both groundwater and surface water the fee amounts to 0.007 EUR/m$^3$ (Niedersächsisches Ministerium für Umwelt, Energie und Klimaschutz, n/a).

### Wastewater treatment and reuse

In the year 2016, full costs for the wastewater treatment and reuse system amounted to 16.5 million EUR in total (including operation and maintenance costs, interest and allowance for depreciation). The different items - as specified in the budget of the city of Braunschweig – are detailed in Table 12.

[16] Of the 10.5 million m$^3$ of water irrigated on the fields of the Sewage Board, only 3.24 million m$^3$ are actually used by the plants.

[17] Calculated based on average price and water consumption in Braunschweig.

Table 12 Operational and maintenance costs of the wastewater treatment and reuse system in Braunschweig in 2016
Source: Siemers, 2016 *pers.comm.*

| Cost category | Costs |
|---|---|
| Irrigation | 5.2 million EUR |
| Infiltration fields | 1.2 million EUR |
| Sewage sludge | 0.85 million EUR |
| Treatment plant | 9.2 million EUR |
| Laboratory | 0.04 million EUR |
| Sum | **16.5 million EUR** |

The full costs (including operating costs, maintenance costs, and imputed costs) are 2.55 EUR/m$^3$ for the whole wastewater collection and treatment, based on the cubic meter of drinking water sold (15 million m$^3$/year). Revenues from fees in Braunschweig amount hence to 38.25 million EUR/year. Thereof, about 16.5 million EUR are for the treatment plant and the wastewater reuse system, which corresponds to full costs of 1.10 EUR/m$^3$ (based on the cubic meter of drinking water sold). The remaining amount covers the costs of the sewer network and the pumping stations in Braunschweig (Siemers, 2016 *pers.comm.*). Following the cost-recovery-principle, households and businesses connected to the sanitation network are paying for investment and operational and maintenance costs of conventional wastewater treatment.

No specific treatment is needed to make effluent suitable for reuse in the fields. No specific treatment costs are hence linked to the reuse system. However, different cost items linked to the irrigation of treated effluent can be identified (Mattheiß and Zayas, 2016). They are listed in Table 13.

Table 13 Cost categories linked to the current water reuse system in Braunschweig
Source: Mattheiß and Zayas, 2016

| Costs |
|---|
| 1. Distribution of effluent and sludge to the fields of the Sewage Board (pumping, pipes) |
| 2. Mobile irrigation machinery (equipment, use, reparation) |
| 3. Restrictions to the agricultural management (restrictions on crops, increased need for cooperation) |
| 4. Spray protection hedgerows |
| 5. Drainage system |
| 6. Health risk for field workers |

Wastewater treatment and the distribution of treated effluent to the fields of the sewage board are managed by the same entity (the sewage board, with the city of Braunschweig being a member). The costs (see Table 12) are financed both by the inhabitants connected to the public sewage system and the farmers belonging to the sewage board. Only very rarely some investments or projects are financed from the national government. No other subsidies from external sources exist (Siemers, 2016 *pers.comm.*).

For receiving the treated effluent on their fields, farmers pay a fee of 81 EUR/ha and year, for a total of 2700 ha. This leads to total revenues from farmers of 218 000 EUR/year (Mattheiß and Zayas, 2016). In 2015, farmers have paid 230 000 EUR, given that some areas are subject to an additional charge for drainage (Siemers, 2016 *pers.comm.*). When putting the total amount of fees paid in relation with the total amount of water irrigated (10.5 million m$^3$), the average fee paid for 1 m$^3$ is 0.02 EUR. Considering that only part of the irrigation water is actually used by the crops (3.24 million m$^3$), which corresponds to the actual demand of the farmers, they pay on average 0.07 EUR/$m^3$ of water used by the plants. These revenues are not enough to cover all costs linked to the reuse system. Compared to the cost figure for irrigation with reused water included in the budget of the city of Braunschweig (5.2 million EUR, see Table 12), fees paid by farmers cover about 4 % of the costs. The remaining costs – as well as all other costs linked to the conventional wastewater treatment (including the infiltration fields) – are covered by the tariff paid per cubic meter of wastewater (2.52 EUR/$m^3$) from the inhabitants connected to the public sewage system and by the charge for rainwater collection (6.03 EUR/$m^2$ of impermeable soil) (Stadt Braunschweig, 2014).

The wastewater and rainwater fees include also imputed costs (interest, allowance for depreciation) for past investments. No specific reserves are created for future investments. Estimations for costs of future investments are based on technical plans and integrated in the budgeting for the next years. For these investments, the sewage board uses the obtained depreciation allowances and bank loans. The costs linked to this are financed by the fees (Siemers, 2016 *pers.comm.*).

The system of financial flows linked to the water flows in the Braunschweig case is shown in Figure 7.

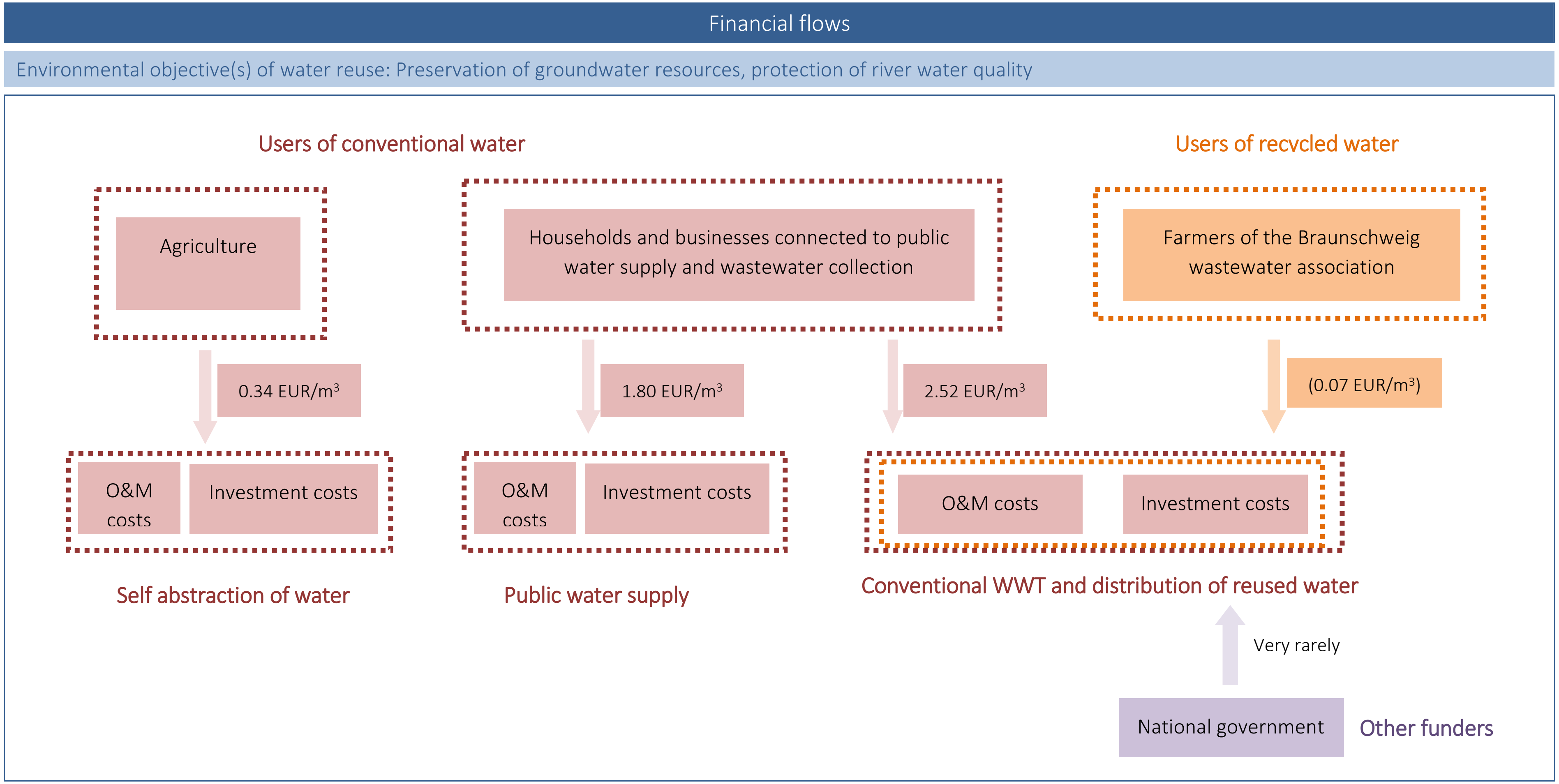



Figure 7 Financial flows in the Braunschweig site

## 4.4 Water reuse VS conventional water supply: what does the case study tell us?

In the case of the agricultural wastewater reuse system in Braunschweig, both the water itself and its nutrient content are of equal relevance. Given the seasonal water deficit and the sandy soils, agricultural activities require irrigation which – if taken only from local groundwater bodies – risks to be unsustainable. However, there is no direct competition between agricultural water use and drinking water provision to the local population, given that 99% of the drinking water supply for the city of Braunschweig is covered through surface water reservoirs in the nearby mountains. Preserving and recharging the local groundwater bodies through the reuse system increases, however, resilience with regards to potential effects of climate change. A recent study has shown that the preservation and recharge of the local groundwater bodies is valued by the local population (see Mattheiß and Zayas, 2016).

Farmers are not only benefiting from the water itself, but also from its nutrient content, as it allows saving mineral fertilizers. At the same time, transferring nutrients to agriculture is advantageous for those paying for the wastewater treatment service (the inhabitants of Braunschweig which are connected to the public sewage network), as directing water and sludge to the agricultural fields avoids alternative disposal of sludge and the need for additional treatment to meet discharge limits. At the same time, the reuse system reduces nutrient input to the river Oker and decreases the risk of eutrophication, which is linked to benefits for recreational uses on and along the river. These benefits are also valued by the local population (see Mattheiß and Zayas, 2016).

For the agricultural wastewater reuse system in Braunschweig, compared to a system without reuse which is based on conventional water supply, several beneficiaries could be identified. They are listed in Table 14.

Table 14 Beneficiaries of the wastewater reuse system in Braunschweig

| Beneficiaries | Benefits |
|---|---|
| Farmers | Supply of water and nutrients |
| Population connected to the public sewage network | Avoided costs for alternative sludge disposal and for additional treatment to meet discharge limits |
| Local population – Drinking water security | Preservation and recharge of groundwater bodies is increasing resilience with regards to future water needs in the light of climate change |
| Local population – Preservation of the river water quality / Recreational activities | Reducing the nutrient input to the river Oker contributes to preserving the river environment |

Currently only 4% of the costs of the reuse system are covered by the farmers. When determining the fee to be paid per hectare, the sewage board considered different aspects: the benefits the farmers gain from the reuse system (water and nutrient supply), the restrictions they experience[18], as well as financial feasibility (Siemers, 2016 *pers. comm.*).

The major part of the costs linked to the reuse system (96%) is paid by the population connected to the public sewage system through the wastewater and rainwater fee. Although they are benefiting from the

[18] Using treated effluent instead of groundwater for irrigation is also linked to disadvantages, like restrictions regarding the type of crops which can be cultivated, or the fact that the agreement with the sewage board includes an obligation to take the water, even in periods were rainfall is abundant (see Mattheiß and Zayas, 2016, for more information).

system (see above), the share they pay might at first sight seem high. It corresponds to about half of the total other costs linked to the wastewater treatment.

The benefits regarding ensuring drinking water security and the preservation of the river water quality (as well as the benefits of recreational activities depending on it) are not directly paid for. However, it can be assumed that the local population which is benefitting is largely overlapping with the population connected to the public sewage network. It can hence be argued, that their contribution to the reuse system is included in the wastewater and rainwater fees. A contingent valuation study has been carried out in Braunschweig in January 2016 in order to evaluate these environmental benefits linked to the reuse system (Mattheiß and Zayas, 2016). Results show that the total benefits linked to the preservation of local groundwater sources and of the river water quality lie between 3 million EUR/year and 5.2 million EUR/year[19]. Given these results, the relatively high contribution of the local population to the reuse system is justified through environmental benefits linked to the system.

In conclusion, the pricing and financing system for the agricultural wastewater reuse in Braunschweig seems to be equitable with regards to the different types of benefits linked to it.

[19] 3 million EUR/year is the value calculated based on the median willingness-to-pay; 5.2 million EUR/year is the value calculated based on the mean willingness-to-pay. Both values are valid and correspond to estimates of the environmental benefits (Mattheiß and Zayas, 2016).

# 5 Sabadell case study

## 5.1 Site description

The city of Sabadell, historically sensitive to the problem of water has during the past decade and recent years developed a series of actions aimed at reducing pressures on regional or local water sources (Vinyoles et al., 2005). Water reuse is thus aimed in the first place at **addressing scarcity problems** in the area. Conventional water supply is mainly fed from the Aïgues Ter-Llobregat (ALT L) network (Vinyoles et al., 2005).

Secondly, the Ripoll river was in the past the most contaminated river in this part of Spain, mainly because of the textile industry concentrated along its course. Pollution was also exacerbated by the presence of nitrogen from wastewater pipe leakages and agriculture. In addition, abstraction and discharge of large volumes of water in different points of the river could create future imbalances between extraction and contributions along the river course. To address these pollution issues, the municipality constructed in 2003 the treated water outlet from the Ripoll WWTP to the Ripoll river, with the following objectives: **dilute pollutants, guarantee the circulating flow of the river, maintain ecosystem services** (people walking, fishing, biodiversity etc.) and **recharge the aquifer** (the most upstream discharge point being only used during the summer, when the river flow is low) (Mashkina, 2014).

At present, the water reuse system in Sabadell is made of two components:

- **The Ripoll WWTP and treated water outlet**: the municipality constructed in 2003 a pressurized pipeline of treated water that can discharge reclaimed water back into the river at two points, into the Torrella Mill, half way along its course and into the Colobrers Stream, upstream of the beginning of the municipal area. Reclaimed water comes from the Ripoll WWTP, which collects and treats wastewater from the Northern part of Sabadell. After discharge into the river, by natural infiltration part of this treated water infiltrates the river bed and recharges the alluvial aquifer which supplies the Ripoll and Ribatallada mines. Finally the water from the mines is collected and disinfected (UV treatment and chlorination), and it is used mainly for the irrigation of green areas, ornamental fountains and street cleaning activities. Thus water from the WWTP is indirectly reused.

- **The Riu Sec WWTP and the Southern water reuse system**: The Riu Sec WWTP collects and treats water from the Southern part of Sabadell. It consists of a primary treatment unit and a secondary biological treatment unit, this latter based on membrane bioreactor (MBR) technology. Due to the MBR technology, the treated effluent is of very good quality, so it only needs disinfection (tertiary treatment: UV treatment and a chlorination system) and it is then reused for industrial purposes.

Both plants are the property of the Sabadell Town Municipality and are managed by the "Companyia D'Aigües de Sabadell, S.A. (CASSA). Reclaimed water is distributed through a dedicated network.

The city of Sabadell recently approved an extension of the current reuse system, which includes:

- **The Ripoll WWTP and treated water outlet:** Additional volumes of reclaimed water to use for irrigation of green areas and street cleaning;
- **The Riu Sec WWTP and the Southern water reuse system:** Additional volumes of reclaimed water to be used for industry, irrigation of green areas and street cleaning.

Part of this expansion is already under construction. The figure below illustrates both the existing network and the portion of network currently under construction or planned.

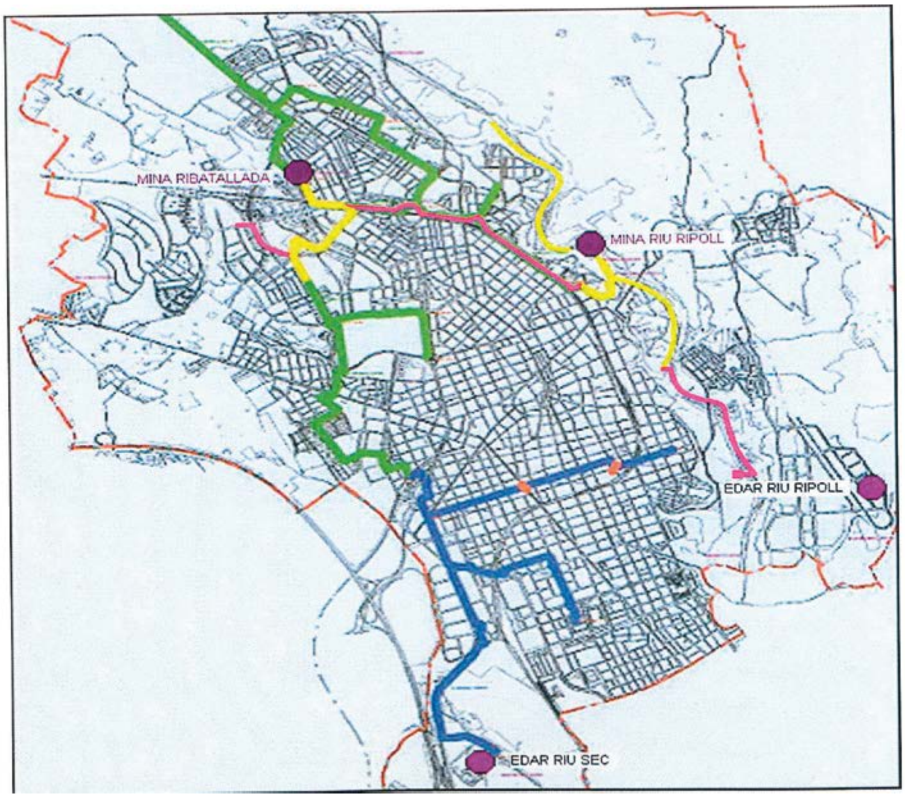



Figure 8 Infrastructure Requirements
(yellow: current network/red: under construction network/ green: irrigation network/ blue: industrial network) Source: CASSA, 2014

## 5.2 Water flows in the site: supply sources and discharges

The water flows involved in the water reuse system in Sabadell are represented in the Figure below.

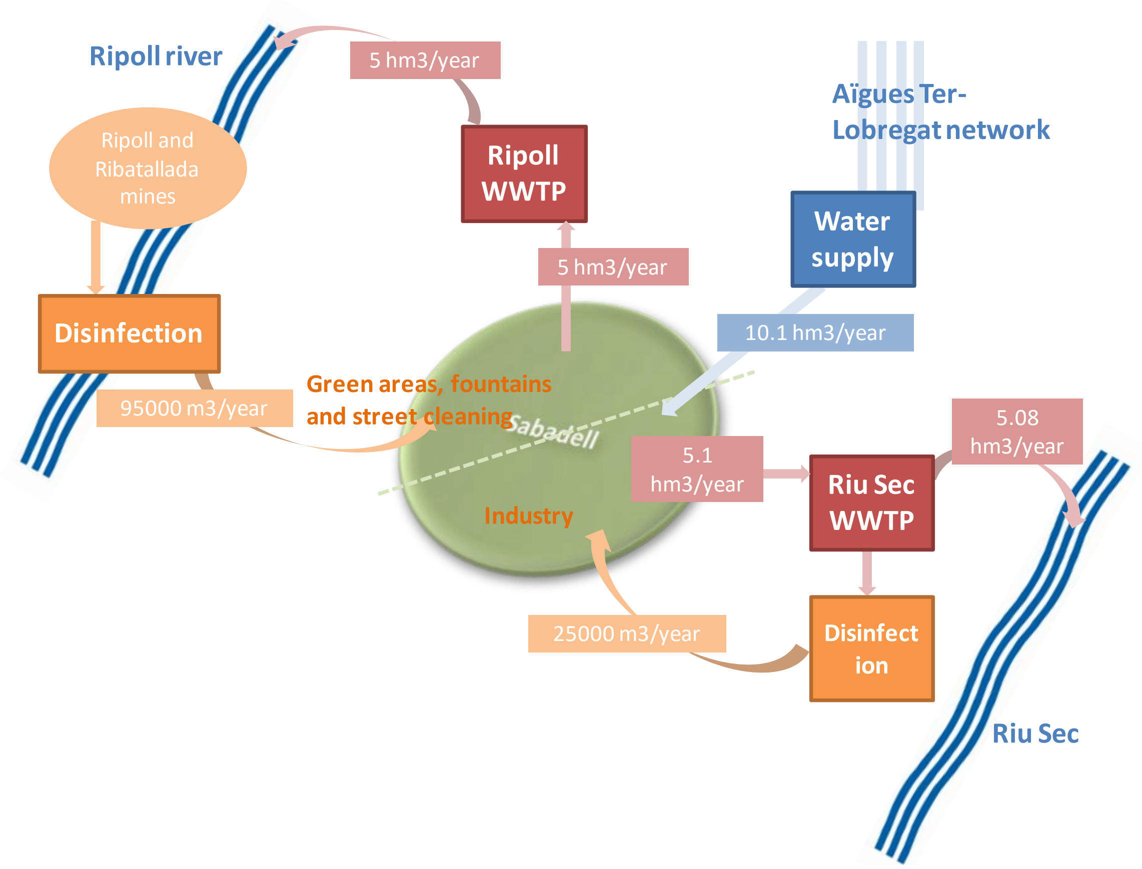



Figure 9 Water flows involved in the water reuse system in Sabadell

The city of Sabadell receives water mainly from the Aïgues Ter-Llobregat network, distributed by CASSA to the municipal area. In 2015, CASSA sold 10.22 hm$^3$ of water, of which 10.1 hm$^3$ of drinking water. Wastewater is then collected and conveyed to the city's two wastewater treatment plant:

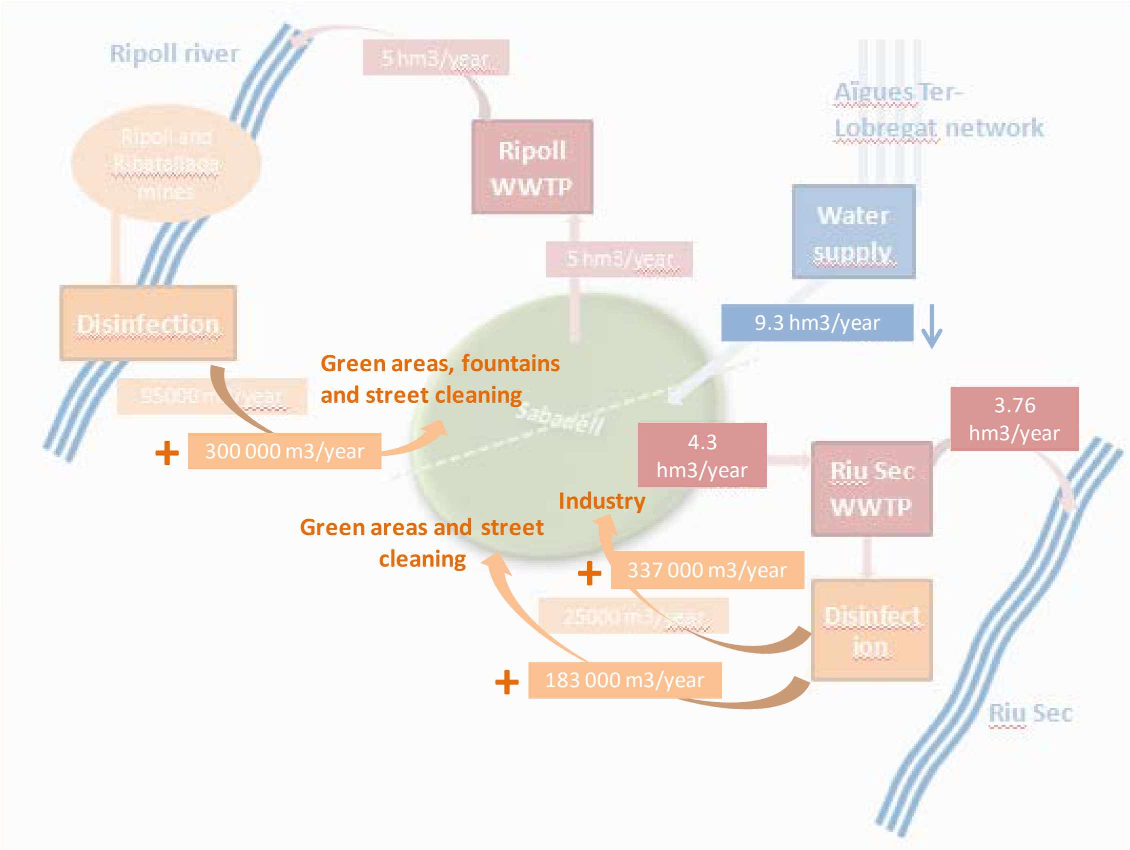
- 5 hm$^3$ per year are conveyed to and treated at the Ripoll wastewater treatment plant, part of the **Northern water reuse system**. The same amount of treated water (up to secondary treatment) is then discharged into the Ripoll river. Downstream, 95 000 m$^3$ of water are abstracted each year at the Ripoll and Ribatallada mines. This volume of water goes through tertiary treatment and is then distributed to the Northern part of Sabadell for green areas irrigation, fountains and street cleaning;

- The remaining 5.1 hm$^3$ of wastewater is conveyed to and treated at the Riu Sec wastewater treatment plant each year, part of the **Southern water reuse system**. After secondary treatment, 5.08 hm$^3$ are discharged into the Riu Sec, whereas the remaining 25 000 m3 go through tertiary treatment and are distributed to some industrial users in the Southern part of Sabadell.

An ambitious expansion of the current system was first planned in the Master Plan for the period 2004-2014 (Vinyoles et al, 2005). This expansion was eventually not implemented, so a new expansion plan of the water reuse network was included in the current Master Plan -for the 2014-2024 period. The expansion envisioned in the current Master Plan is less ambitious than what was originally planned. However, the 2014-2024 Master Plan only includes information on investment costs, whereas the Master Plan for 2004-

2014 does include a detailed financial feasibility study (Collado et al, 2003), and it was thus used as a basis for the Cost-Benefit Analysis which was carried out as part of WP4 activities under the Demoware project (Mattheiss and Zayas, 2016). In this deliverable, the Sabadell case studies builds on previous WP4 research activities in this site, and the same cost information was used –thus building on the cost information provided in Collado et al (2003) and referring to the additional volumes of reused water considered in this detailed financial feasibility study.

The figure below illustrates the planned expansion of both the Northern and Southern water reuse systems in Sabadell, and the additional water flows[20].




[20] From Mattheiss and Zayaz, 2016: „An assessment was made within the framework of the 1st edition of the Masters in Integral Water Management study (Collado et al. 2003). The study was used to design and organise the required infrastructures and developments of the existing reuse network and served for drafting the Master Plan for the use of water from outside the distribution network for drinking water in Sabadell, approved in 2004 by the Plenary Session of Sabadell Town Council (Vinyoles et al. 2005).

The application of the 2004 Master Plan for the use of water from outside the distribution network for drinking water in Sabadell should mean the liberation of 1.1 $hm^3$ per year by considering an expansion of the current north and south reuse networks in the city. Since 2004, a second master plan for the 2014-2024 period has been developed. Envisioned developments presented in the 2004 Master Plan were actually not fulfilled, even if, reuse volumes have increased from 16 000 $m^3$/year in 2004 to 120 000 $m^3$ in 2014 (Ajuntament Sabadell, 2014).

Currently, developments for the 2014-2024 periods differ from what was envisioned in the first master plan (less reuse volumes are planned (360 000 $m^3$ by 2024) and water would be used mainly for green areas irrigation). Nonetheless, for illustration purposes on CBA analysis with the Demoware reuse tool, the information on developments envisioned in 2004 will be used to test the CBA tool for the Sabadell case study. The reason being that Collado et al. 2003 provide a complete financial analysis related to the implementation of the 2004 Master Plan. Besides defining the infrastructures required and providing a detailed description of initial investments costs (and sources of financing), a financial sustainability analysis of operational costs and revenues was developed for a 20 year period for both north and south networks. Such level of detail is required if the Demoware tool is to be used properly, and especially if the objective is to carry a CBA analysis. However for developments envisioned in the 2014-2024 Master Plan, besides information on investments costs, such a financial sustainability study (and particularly information on operational costs and revenues) is not available".

Figure 10 Planned expansion of the water reuse system in Sabadell: additional water flows

The planned expansion of the water reuse system will result in the following additional volumes distributed to users in Sabadell:

- The **Northern water reuse system** will produce 300 000 additional $m^3$ per year, which will be used for irrigation of green areas, fountains and street cleaning. As a result, a total of **395 000 $m^3$** of reused water will be delivered each year for these three uses;

- The **Southern water reuse system** will produce each year, in addition to current production: (i) 337 000 $m^3$ of water for industrial users –thus, industry in Southern Sabadell will use in total 362 000 $m^3$ of reused water each year; and (ii) 183 000 $m^3$ for irrigation of green areas, fountains and street cleaning. In total, considering current and future volumes of reused water, the Southern water reuse system will produce **545 000 $m^3$** of reused water per year. As a result, a smaller volume of water will be discharged into the Riu Sec after secondary treatment (4.43 $hm^3$ per year).

Overall, the planned expansion will result in additional 800 000 $m^3$ of reused water per year; overall, the system will deliver **940 000 $m^3$ of reused water** each year to the city of Sabadell. This will result in smaller volumes of water supplied by the Aïgues Ter-Llobregat network (9.3 $hm^3$).

## 5.3 Costs, pricing strategies, and revenues: analysis of financial flows

The analysis of financial flows allows for getting an understanding of how the costs for the different services are covered –or, in other words: who benefits from which service, who pays for what and who does not pay for a service he/she is benefiting from. In order to understand these flows, the first step to be made is to get an insight of current pricing strategies and revenues collected by CASSA from the different user groups, and to compare them with cost figures.

The table below illustrates cost, pricing and revenue figures[21] for the followings: (i) conventional water supply and wastewater treatment (up to secondary treatment)[22]; (ii) the existing water reuse system (Northern and Southern system together); (iii) the costs of the planned expansion of the Northern reuse system; and (iv) the costs of the planned expansion of the Southern reuse system.

Table 15 Costs, pricing and revenues: analysis of financial flows for conventional water supply and WWT

| | | Conventional water supply and WWT | Current water reuse system | Planned expansion, Northern system | Planned expansion, Southern Network |
|---|---|---|---|---|---|
| | Annual costs – EUR/year | 21.41 Million | 35 250 | 62 910 | 109 017 |

[21] Sources: As mentioned in Seciton 3.2 of this report, the analysis of costs of the existing water supply system is based on the information made available by CASSA in its yearly report to shareholders. The analysis of costs of the planned expansion is based on Collado et al., 2003, and on Matheiss and Zayas, 2016. Figures on tariffs are provided by CASSA to customers, whereas figures on revenues were partly taken from the yearly report to shareholders and partly calculated from available figures on reused water tariffs.

[22] Available data does not make a distinction between water supply and wastewater collection and treatment, so the costs of this services are presented together.

| | | | | | |
|---|---|---|---|---|---|
| **Operation and maintenance costs** | Unitary costs – EUR/m³ | 2.1 | 0.25 | 0.1587 | 0.20 |
| **Investment costs** | Total costs – EUR | Not available | Not available | 2.66 Million | 2.62 Million |
| | Annualized costs[23] – EUR/year | Not available | Not available | 88 600 | 87 333 |
| | Unitary costs – EUR/m³ | Not available | Not available | 0.22 | 0.22 |
| **Unitary pricing[24]** | Population[25] - EUR/m³ | 1.07 | N/A | N/A | N/A |
| | Industry - EUR/m³ | 1.09 | 0.6917 | | |
| | Municipality - EUR/m³ | 0.78 | 0.2767 | | |
| **Revenues** | EUR/year | 18.32 Million EUR (Corresponding to: 1.79 EUR/m³) | 43 581 (Corresponding to: 0.363 EUR/m³) | | *To be determined* |

*Sources: CASSA website; Collado et al, 2003 ; Mattheiss and Zayas, 2016 ; CASSA yearly report to shareholders*

Looking at unitary costs, huge differences can be seen between the conventional water supply and WWT and the reuse system (both the current one and the planned expansions): in fact, the costs of the reuse system only include the cost of tertiary treatment and distribution of reused water, whereas the costs of the conventional water supply and WWT include several processes (drinking water distribution, wastewater collection and transport to the WWTP, primary and secondary treatment, discharge).

For **conventional water supply and WWT**, total yearly O&M costs are larger than total yearly revenues –and thus only 86% of O&M costs are recovered by water tariffs. The average unitary price paid by industry and municipality customers is respectively 52% and 37% the unitary O&M costs of conventional drinking water supply and conventional wastewater collection and treatment. In addition, while the average unitary price paid by customers –calculated across all customer groups- and the average domestic tariff –paid by the population of Sabadell- are respectively 85% and 51% of the unitary O&M costs of conventional water

[23] By annualized costs it is meant the total investment costs spread over a 30 year period

[24] For conventional water supply a wastewater treatment, tariffs are differentiated across consumption blocks, and they are structured as follows: Fixed component, paid per month, differentiated per consumption block + volumetric component (two tariffs, the same tariffs for each consumption block). In the case of reused water, the unitary price provided in the table is the actual price paid by industrial and municipal customers for reused water

[25] Population refers to drinking water customers other than industry and municipality. Residential consumers are charged according to a progressive block tariff, which is structured in a fixed monthly component and a volumetric component. The average tariff refers to domestic consumers belonging to the 2nd consumption block. Domestic average tariff is provided to provide a more complete indication of water tariffs in Sabadell, although it cannot be compared to tariffs for reclaimed water as reclaimed water is only supplied to industry and municipality for non-municipal uses.

supply and conventional WWT, the revenue remain higher than the costs incurred. We were not able to obtain information on current investment allowing us to understand this high revenue.

In the case of **reclaimed water supply**, unitary price is higher than unitary costs, an consequently yearly revenues outweigh O&M costs, which are thus fully recovered by users. As revenues are higher, it can be inferred that reused water prices also contribute to the recovery of investment costs; however, at present, information on investment costs of the water reuse system is not available, so further research is being made to have a better insight on this. In line with pricing principles for water reuse, the price of reused water is aimed at recovering only the costs of tertiary treatment, whereas the costs of primary and secondary treatment (the "conventional" treatment) are, at least in principle, charged on users of conventional water and WWT.

The figure below illustrates the financial flows occurring in the current system, based on the information currently available (thus, investment costs are not included). Information on financing sources other than user tariffs was requested but could not be obtained, so it is not included in the figure.

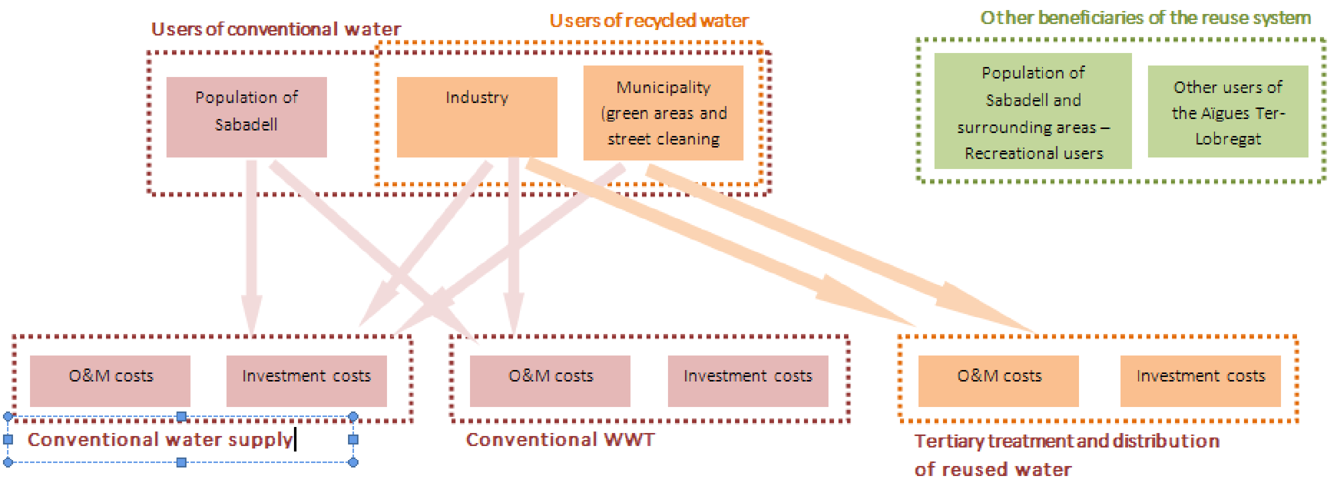



Figure 11 Financial flows occurring within the current water, WWT and water reuse system in Sabadell: recovery of operational and maintenance costs

Financial flows can thus be described as follows:

- Population of Sabadell (drinking water and WWT users): these customers pay for a large share (86%) of the services they use, i.e. water supply and wastewater treatment;
- Industrial users: this group includes both users of conventional water and WWT services and users of recycled water. These user group pays for the services they use –actually, the unitary price they pay is way larger than unitary O&M costs of producing recycled water, and thus tariffs paid by these users are likely to recover also investment costs;
- Municipality (for irrigation of green areas, fountains and street cleaning): this group includes both users of conventional water and WWT services and users of recycled water. Also in this case, these user group pays for the services they use as the unitary price is slightly larger than the unitary O&M costs of providing reused water;

- Population of Sabadell: this group indirectly benefits for water reuse activities in the Sabadell municipal area: in fact, discharge of water after secondary treatment in the Ripoll River has significantly contributed to raising water quality, thus making possible the recreational uses of the river. Currently, these beneficiaries are not providing any financial contribution to the water reuse system (e.g. through municipal fees), it will be seen later on whether they could contribute based on cost-recovery considerations;

- Other users of the Aïgues Ter-Llobregat supply system out of the Sabadell municipal area: water reuse activities reduce the city's demand for potable water from the aqueduct, so more water is available for other cities connected to the same system. Currently, these beneficiaries are not providing any financial contribution to the water reuse system (e.g. through municipal/regional fees), it will be seen later on whether they could contribute based on cost-recovery considerations.

Concerning the planned expansion of the current water reuse system, a suitable pricing strategy will need to be designed: some preliminary considerations are provided in section 5.6 of this report.

## 5.4 Water reuse VS conventional water supply: what does the case study tell us?

Based on the data presented above, some overall considerations can be made:

- In Sabadell, water supply and wastewater collection and treatment are charged together, under the assumption that the volume of water supplied is the same volume that users will then discharge into the wastewater collection system. In contrast, the price of reused water does not include wastewater collection and treatment. However, at least part of this recycled water is discharged into the sewers after use: this raises some questions on the overall financial sustainability of the system (who pays for treatment and collection of recycled water discharged into sewers after use?) which cannot be answered based on available information –in fact, information financing sources other than user tariffs is missing;

- For both conventional and recycled water, CASSA adopts a tariff policy in favour of municipal uses, i.e. a discounted unitary rate to water used by the municipality. The reason behind this, probably, is the recognition of the public interest behind municipal uses (irrigation of green areas, street cleaning etc.);

- Yearly revenues from the sales of recycled water are higher than yearly O&M costs of producing and distributing this water: thus, O&M costs are fully recovered, and also a share of investment costs –with the information currently available, it is not possible to estimate the share of investment costs recovered through user tariffs. As mentioned above, the price paid by industrial customers is almost three times the unitary cost of production, whereas municipality pays 10% more than the unitary costs of supply: this suggests that, if production and distribution of reused water are considered as a separate system (separate from supply of conventional water and WWT), there could be a cross-subsidization mechanism, where industrial users pay part of the production costs attributable to the water used by the municipality. This is in line with the overall tariff policy adopted by CASSA, which applies a discounted rate to municipal uses;

- Nevertheless, recycled water is an integral part of the whole water supply system (conventional water and WWT AND water reuse), as it is managed by the same authority: thus, the overall cost-recovery rate to be considered is 85%;

- Reused water is extremely convenient for users: industry pays 63% of the average price paid for conventional water and WWT, whereas the municipality pays only 35.5% of the price paid for conventional water and WWT. Therefore, current prices in Sabadell provide quite a good incentive to use reused water in substitution of conventional water;

- The costs of the planned expansion of the water reuse system would allow for maintaining the current tariffs for reclaimed water: based on the planned yearly production, revenues generated by user tariffs would largely outweigh the yearly costs of the system.

So far, only the costs of the system have been considered in relation to the pricing strategy, as the current pricing strategy does not account for the public benefits deriving from the use of recycled water. These social and environmental benefits, described in the table below, are received by the whole population of Sabadell, and at present these users are not charged any financial contribution.

Table 16 The benefits of the current water reuse system in Sabadell

| Benefits |
|---|
| • Avoided costs associated to water supply from the public distribution system (substituted by reclaimed water)<br>• Preservation of potable water resources<br>• Maintaining the Ripoll river ecological cycle and environmental amenities<br>• Preservation and restoration of local aquifers<br>• Resilience of industrial activities to water scarcity and droughts<br>• Social benefits related to securing the aesthetic values of Sabadell green areas and parks faced to scarcity and drought restrictions<br>• Social benefits related to securing street cleaning activities faced to water scarcity and drought restrictions<br>• Revenues generated from the exploitation of the current reuse system |

As revealed by the choice experiment survey carried out in Sabadell as part of WP4 activities (Mattheiss and Zayas, 2016), 81% of Sabadell citizens are not even aware of the existence of water reuse in Sabadell, thus they cannot be aware of the benefits that this practice deliver to the city –for example, when they walk along the Ripoll river, they do not know that the river is no longer that polluted thanks to the discharge of treated wastewater upstream. However, when asked to consider the possibility of water reuse, 4/5 of respondents to the survey seem to acknowledge the potential benefits water reuse can have for the preservation of local water bodies. Overall, water reuse is seen as having an overall positive outcome in terms of benefits, although citizens have a clear perception of the potential downsides of water reuse (e.g. health risk, colour problems, etc.). Nevertheless, current uses of reclaimed water in Sabadell are thus supported by the large majority, if not the full sample, of respondents. Also, envisioned future uses (toilet flushing and industrial uses) are well accepted by a large majority. In addition, more than half of respondents think that the benefits of water reuse outweigh its potential risk, and more than 70% of them trust the water provider.

This general positive perception and acceptance of water reuse results in citizens willing to pay for ensuring that this service is maintained in the city. More in detail, the choice experiment survey revealed that:

- On average, households are willing to pay **15 EUR/year** to ensure that **all parks and green areas** of the city are irrigated with reused water all year long;
- On average, households are willing to pay **53 EUR/year** to secure **street cleaning** activities in the city with reused water;
- On average, households are willing to pay **27 EUR/year** to secure that **domestic outdoor uses and water needs for toilets flushing** are covered with reused water during the occurrence of severe droughts generating restrictions on domestic uses or mandatory water cuts.

As seen in the previous section, the overall cost recovery rate of the whole system (conventional water and WWT and water reuse) is 85%, thus revenues do not fully cover the costs of the service. At the same time, current prices of recycled water are able to recover the costs of its provision, and provide an incentive to use recycled water at the same time. Thus it seems nor recommendable, nor sensible, to raise current prices for reused water. Raising prices for conventional water and WWT could be an option towards full cost-recovery, but social and economic impacts on water users should be carefully investigated. Another option could be to raise the prices of conventional and reused water for the municipality, but also in this case the financial impacts on municipal balance accounts should be investigated –and, besides, current lower prices of water for municipal uses are justified by the public interest behind these water uses. It should also be noted, however, that an increase of prices paid by the municipality could be compensated by the municipal charge on water reuse, as suggested in the following chapter.

The introduction of a municipal charge for all citizens could in fact be a promising option, as the whole population receives some of the benefits of water reuse in the municipal area. As shown by the choice experiment results, citizens are willing to pay each year 68 EUR to secure current uses of recycled water, plus an additional 27 EUR for domestic outdoor uses and toilet flushing. Making a gross calculation, 15 EUR per inhabitant per year would be enough to raise the current difference between the costs of water services and the revenues from water sales (3.13 Million EUR)[26]. This charge could be increased (e.g. up to 30 EUR per inhabitant per year) to account for part of the investment costs of expanding the system. At present, however, most of the citizens are not aware of water reuse practices in Sabadell, so the municipal charge would need to be accompanied by a suitable awareness and information campaign about the current and planned water reuse system, its benefits but also its risks.

A second question to be answered relates to the planned expansion of the current water reuse system: would the current pricing strategy be suitable for the expanded system too? The first thing that jumps to the eyes in table 4 is that unitary O&M costs would be lower than current ones: 0.16 EUR/$m^3$ in the Northern system and 0.2 EUR/$m^3$ in the Southern system (against 0.25 EUR/$m^3$ on average in the current system). This reveals what could intuitively be anticipated: the unitary costs of reused water benefit from economies of scale; the more recycled water is produced, the less it will cost per unit of production. Thus, an expansion of the system will be beneficial from the point of view of costs. Unfortunately, at the moment it is not

[26] This calculation considers the full population of Sabadell, around 207,444 inhabitants, this also including children and retired people. Alternatively, the municipal charge could be calculated on a household basis.

possible to make a similar comparison on the investment costs, as information on investment costs of the current system is not yet available –more research is being done on this.

The expanded system would cost, each year, 381 000 EUR (O&M costs plus annualized investment costs). If the current tariffs for reused water are maintained, yearly revenues would amount to 410 000 EUR: this pricing strategy would then allow for a full recovery of the costs of reused water, and it would even leave a small extra amount (29 000 EUR) which could contribute to the cost-recovery of the full system. As in the current system, the current prices are also effective in providing an incentive for a more efficient water use, and this would also hold after the expansion of the water reuse production. Thus, current prices could be maintained. At the same time, if the prices of conventional water supply and WWT remain the same, cost recovery levels of the whole system are not expected to improve: also in this case, the option of a municipal charge to account for the social and economic benefits of water reuse could be considered.

# 6 Capitanata case study

## 6.1 Site description

The Capitanata site is situated in the Puglia Region in south eastern Italy. Fiordelisi is a certified organic producer, growing and processing tomato and other vegetables –mainly for the international market. Processed vegetables are mainly grown on site, although a small share of vegetables is bought from external producers.

Water is supplied to the food processing plant and agricultural fields from two sources: groundwater self-abstraction and the irrigation consortium (the public entity in charge of managing and supplying irrigation water in the Capitanata area)[27]. Water used in the food processing plant (production and cleaning) goes through primary and secondary treatment on-site; a large share of this treated water is discharged into the consortium channel, whereas a small share goes through tertiary treatment and it is then used to irrigate some experimental crops.

At present, recycled water is thus used at the experimental level only, and vegetables grown on the experimental field are not used in the food processing plant (and for human consumption in general). The objective of this experimental water reuse system is to assess the feasibility of water recycling in the site, and in particular to: (i) monitor water quality resulting from tertiary treatment; and (ii) monitor quality parameters of crops irrigated with reused water. So far, although water quality resulting from tertiary treatment is excellent, it has not been possible to use this water for irrigation purposes other than in the experimental fields. Italian legislation sets in fact very restrictive quality parameters for reused water, which are extremely difficult to attain: restrictive thresholds are fixed for 55 parameters, regardless of the final use of recycled water. Overall, the recycled water produced with tertiary treatment in the Fiordelisi site complies with all thresholds, with the exception of N thresholds which are sometimes overcome –and thus, it cannot be used to irrigate crops other than the ones in the experimental field (Fiordelisi, G., personal communication).

For the particular characteristics of the water reuse system in Capitanata, this case study differs from the other three case studies, for the following reasons:

- The water reuse system is internal to Fiordelisi, and it was built to respond to Fiordelisi water needs –thus, water is not sold to third parties;
- At present, the water reuse system is operated at the experimental level, as reused water does not fully comply with Italian legal requirements for reused water.

Thus, no pricing strategy exists in Fiordelisi, and it does not even make sense to talk about a correct pricing strategy for this site. Rather, this case study will focus on the analysis of costs, and on the potential for a wider use of recycled water in the area.

The use of recycled water in Fiordelisi's production cycle would bring significant benefits in terms of water resource management. The Puglia region is normally affected by water scarcity, which is further worsened by over abstraction and by the consequent reduction of groundwater levels. According to the company owner and management, groundwater levels have sensibly decreased since the 1970s: back then, the capacity of the borehole was 10-12 liters per second, today it is 2-3 liters per second (average discharge over the whole year). This means that a much smaller area can now be irrigated with self-abstracted water, and much more water needs to be purchased from the irrigation consortium. This has an impact on the costs of water self-provision: to increase water security, internal reservoirs had to be built to collect water from

[27] Consorzio per la Bonifica della Capitanata: http://consorzio.fg.it/

the borehole, so that it is available when needed (e.g. water shortages from the irrigation consortium). In addition, a greater reliance on water provided by the irrigation consortium has a negative impact on water security for the company: in fact, water supply from the consortium is sometimes uncertain, as it shows seasonal variations and sometimes subject to restrictions –in scarcity periods, water is supplied according to pre-established shifts among farmers (Source: Fiordelisi, G., personal communication).

The water reuse system in the Fiordelisi plant, if regularly used for food crops (thus beyond the experimental level), would benefits indirectly other farmers in the area; Fiordelisi would use less water from the irrigation system, thus making more water available for other farmers, especially in water scarcity periods.

## 6.2 Water flows in the site: supply sources and discharges

Water flows in the site are described in the figure below, and they can be synthesized as follows (Fiordelisi, G., personal communication):

- 29 000 $m^3$ of water are abstracted and treated (potabilisation) every year from Fiordelisi's private borehole. Of these, 14 000 $m^3$ are used in the food processing plant, whereas 15 000 $m^3$ are used to irrigate Fiordelisi's crops;
- 10 000 $m^3$ are bought each year from the irrigation consortium, and used to irrigate Fiordelisi's own crops;
- The 14 000 $m^3$ used every year in the food processing plant go through primary and secondary treatment, in Fiordelisi's own treatment plant. Of these, 13 000 $m^3$ are discharged into the consortium channel;
- 1 000 $m^3$ go through tertiary treatment (Membrane and UV disinfection), in Fiordelisi's own treatment plant, and are used to irrigate Fiordelisi's experimental crops.

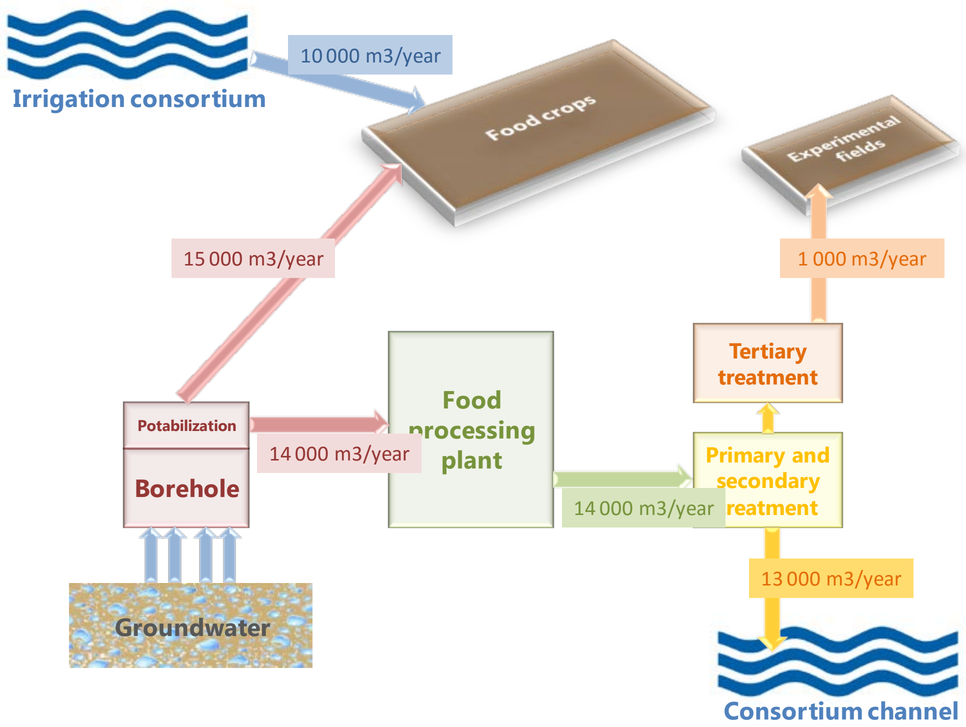



Figure 12 Water flows in the Capitanata site

## 6.3 Analysis of financial flows

The costs of water supply, wastewater treatment and water reuse in the Capitanata site are provided in the table below.

Table 17 Costs of water supply, wastewater treatment and water reuse in the Capitanata site (Source: Fiordelisi, G., personal communication)

| | Irrigation water - Consortium | Groundwater – Own abstraction | Primary and secondary treatment | Tertiary treatment and distribution of re-used water |
|---|---|---|---|---|
| | Supply costs | O&M costs | O&M costs | O&M costs |
| Annual costs | 1 200 | 26 045 | 88 000 | 16 134 |
| Costs/m$^3$ | 0.12 | 0.9 | 6.3 EUR/m3 | 16.1 EUR/m3 |
| | | Investment costs | Investment costs | Investment costs |
| Total costs | N/A | 50 000 | 250 000 | 115 000 |
| Annualized costs | N/A | 1667 EUR/year<br>0.06 EUR/m3 | 8 333 EUR/year<br>0.6 EUR/m3 | 3 833 EUR/year<br>3.8 EUR/m3 |

The following observations and comments can be made:

- The unitary water price paid to the consortium is only 13% the unitary cost of self-abstraction. This might be due to the decreased water availability over the last 40-50 year (12 litres per second in the 1970s, 2-3 litres per second today), but also to the fact that irrigation water supplied by the consortium might be of lower quality –in fact, self-abstracted water also goes through potabilisation, and this has a cost;

- For the sake of comparison of cost magnitudes, let us suppose that: (i) all water used for irrigation is bought from the consortium; and (ii) all water used in the food processing plant is bought from the regional water supplier (Acquedotto di Puglia), for a unitary price of 1.6 EUR/m$^3$ [28]. On a yearly basis, this would cost to Fiordelisi 25 400 EUR; at present, the combination of water from the consortium and self-abstraction costs to the firm 27 245 EUR. The current combination of supply sources is thus more expensive, although it costs only 7% more on a yearly basis. However, even if self-abstraction is more expensive, this supply is much more reliable than supply from the irrigation consortium, which is probably why a larger share of irrigation water is taken from this source, and it provides an advantage to the firm's operations;

- The costs of primary and secondary treatment are extremely high: unitary O&M costs are 6.3 EUR/m$^3$, and investment costs are 0.6 EUR/m$^3$, for a total of 6.9 EUR/m3. For comparison, current tariffs for public wastewater collection and treatment in the area (for industrial uses) are 0.70

[28] Source: Acquedotto Pugliese,
http://www.aqp.it/portal/page/portal/MYAQP/SERVIZI/Tariffe/Il_prezzo_ATO_Puglia/Dettagli%20articolazione%20tariffaria2

EUR/m$^3$[29]. These cost figures are disproportionately high, but available information did not allow the study team to come up with a reasonable explanation;

- If the costs of primary and secondary treatment are high, the costs for tertiary treatment are simply unbearable: for the volumes currently treated, unitary O&M costs amount to 16.1 EUR/m$^3$, and investment costs to 3.8 EUR/m$^3$. However, the plant currently treats 1000 m$^3$/year, but its maximum capacity is 5000 m$^3$/year. If the plant were running to its maximum capacity[30], unitary costs would significantly fall: O&M costs would be 3.22 EUR/m$^3$ and investment costs would be 0.76 EUR/m$^3$ –but this calculation assumes that O&M costs remain unchanged if treated volumes increase, which is unlikely to be the case as, for example, energy costs would increase with a larger production. However, available information does not have the necessary level of detail to attempt an explanation for such high costs (only general cost figures are available).

Due to the characteristics of the site, financial flows in the Capitanata site are relatively easy: in fact, a large part of the water used both in irrigation and food processing is self-abstracted, and the wastewater treatment facilities were built and are operated in-house. Thus, financial flows strictly reflect cost figures presented above. More in detail (Fiordelisi, G., personal communication):

- 1 200 EUR are paid each year for the irrigation water bought from the irrigation consortium;
- The borehole (own abstraction) is fully funded by Fiordelisi: 26 045 EUR are spent each year for O&M costs, 50 000 EUR were spent at the moment of construction (investment costs);
- The construction of the primary and secondary wastewater treatment plant was co-financed by the Rural Development Fund: 125 000 were provided through the RDP, the remaining 125 000 were invested by Fiordelisi. Fiordelisi fully pays for the O&M costs of the plant (88 000 EUR per year);
- The construction of the tertiary treatment facility was co-financed by the Italian Ministry for Education, University and research (MIUR): MIUR provided 50% of total investment costs (57 500 EUR), Fiordelisi paid the rest.

These flows are represented in Figure 13.

[29] More in detail, tariffs for public wastewater collection and treatment (for industrial uses) are as follows: (i) wastewater collection 0.18 EUR/m3; (ii) wastewater treatment 0.52 EUR/m3; and (iii) fixed charge 29.14 EUR/year –based on Fiordelisi yearly treated volumes, this would correspond to 0.002 EUR/m3 (Source: Acquedotto Pugliese – See link above)

[30] And assuming that O&M costs remain unchanged if treated volumes increase.

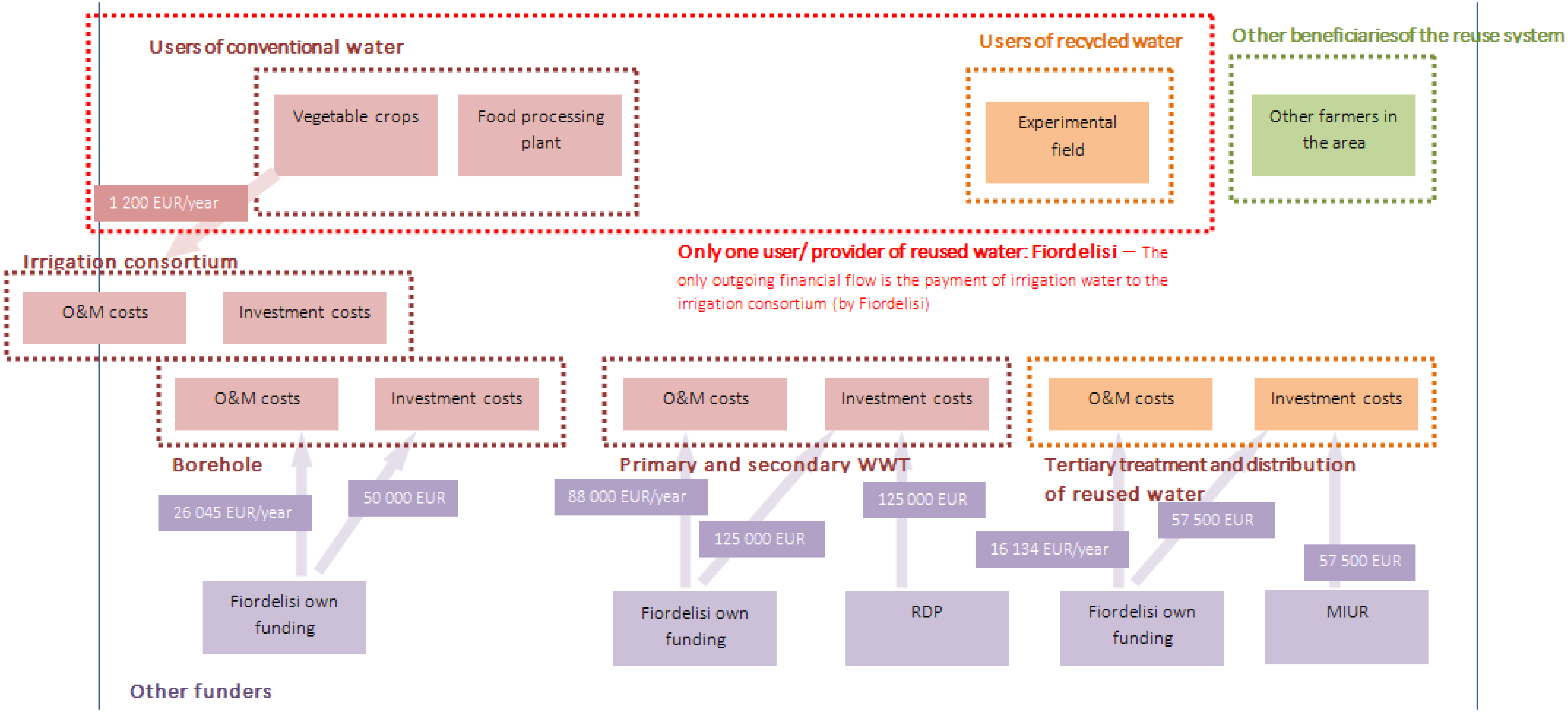



Figure 13 Financial flows in the Fiordelisi site
(Source: Fiordelisi, G., personal communication)

## 6.4 Water reuse VS conventional water supply: what does the case study tell us?

The analysis of cost figures suggests that the current size of the whole treatment system (primary, secondary and tertiary) might be one of the causes for such high costs. However, with the data and information currently available, it is not possible to provide a satisfactory explanation for these disproportionate costs. Of course, if all wastewater would be collected and treated by the collective WWT system (Acquedotto Pugliese) the costs to Fiordelisi would fall by almost ten times[31]. However, this option is not possible, as the wastewater network does not cover the area where Fiordelisi is located.

For tertiary treatment, it was shown that costs would be significantly reduced if the plant were to run at its maximum capacity. However, even in this case, the costs of reused water would still pose some issues:

- In the context of the Demoware project, ARTI conducted a survey in the Capitanata region (Puglia) on the acceptability of reused water in agriculture; both the private sector (entrepreneurs, private consultants and representatives of public enterprises) and the public sector (universities and research organizations) participated to the survey (Liddi et al, 2016). According to the majority of respondents, the fairly tariff for reused water ranges from a minimum of 0,00 €/m3 to a maximum of 0,30 €/$m^3$ with an average value of 0,23 €/$m^3$. Therefore, 3.98 EUR/m3 (the costs of reused water with the plant running at its maximum capacity) would definitely be out of scale as compared to what is perceived as a fair price;

- If the cost of reused water is high, it is also true that, in a territorial context affected by serious water scarcity such as Puglia, finding alternative water supply sources is of paramount importance. In a way, the cost of producing reused water can be seen as the environmental and resource cost of using conventional water in this context, and this is a cost which is not reflected in current prices for conventional water –which are likely to cover only the financial costs of water supply. In other words, the costs of reused water include the value of the externality of conventional water use, a cost that is not paid by user but is born by society and the environment as a whole.

This said, results suggest that the costs of both conventional (primary and secondary) and tertiary treatment could be substantially reduced through economies of scale: if these operations would be jointly carried out by an association of firms or farmers, the costs would be likely to fall. However, according to the plant manager, this solution is also not possible, because the Fiordelisi plant is isolated from other farmers and/or industries (Fiordelisi, G., 2016, personal communication).

In any case, at present these are simple hypothesis and speculations: in fact, as previously mentioned, current Italian legal standards for reused water are extremely restrictive, so that recycled water after tertiary treatment cannot be used because it sometimes exceeds N parameters –even though this water is of generally high quality (Fiordelisi, G., 2016, personal communication).

[31] Calculation based on the figures presented in the previous section.

# 7 Tarragona case study

## 7.1 Site description

The province of Tarragona is lying in Catalonia, on the Spanish Mediterranean cost. The region is struggling with water shortage for many years (Gluck et al., 2014). Since 1989 (Law 18/1981), a man-made water transfer system has been established from the Ebro River to Tarragona, managed by the water consortium of Tarragona (C.A.T. - Consorci d'Aigües de Tarragona). Urban tourist and industrial activities are concentrated in the area (Gluck et al., 2014), and despite the water transfer system, "the city has been struggling to keep up with growing water demands from residents and the growing petrochemical industry" (n/a, 2016). With the aim of freeing up existing water rights to meet future local (municipal and tourism) demand and to decrease water stress on the Ebro River, a project was started to find alternative water sources for the industrial petrochemical complex (Gilabert-Oriol, 2015).

Against this background and due to the availability of EU funds, the Catalan Water Agency (Agencia Catalana del Aigua, ACA) decided in 2011 to construct the Camp de Tarragona Advanced Water Reclamation Plant (CTAWRP) (n/a, 2016). The construction of the plant had been preceded by a nine-month demonstration project (Mengenbier, 2013), and the initiative was supported by the Chemical Business Association of Tarragona (Asociacion Empresarial Quimica de Tarragona, AEQT) and AITASA, that represented the trade and technological needs of the industrial end-users (n/a, 2016). The CTAWRP is situated in Vila-Seca (Catalonia, Spain) (Gilabert-Oriol, 2015). It started working in October 2012. The CTAWRP is operated by AITASA and the French company VEOLIA Water Solutions & Technologies as its technological partner (Mengenbier, 2013).

The Tarragona site is a fully integrated water reclamation plant, including treatment of secondary effluent and distribution to the end-user. Secondary effluent from two municipal wastewater plants is used, from Vila-Seca / Salou and Tarragona. Both WWTPs are owned by the Catalonian Water Agency ACA.

The water is reused by an industrial park (petrochemical complex), for cooling towers and boilers. Veolia installed an enhanced physico-chemical pre-treatment process – using reverse osmosis as its main process. The process allows addressing high water quality variability and meeting the water quality criteria requested from the industrial users.

Repsol and Dow Chemical were the first industrial users of reclaimed water to supply cooling towers (Mengenbier, 2013). The number of cycles that the cooling towers can operate with the same amount of water has been increased. However, this is only possible during the summer, when ambient temperatures allow high evaporation rates. With this increase of cycles during the summer, a reduction of total make up water of 110.5 $m^3$/h (22%) has been reached. Depending on the season, this frees up more than 200 $m^3$/h of water rights for the municipality (Gilabert-Oriol, 2015). This reduction of water use coincides with high municipal water demand during the summer period. More companies have started to use the reclaimed water, due to "the economic and strategic advantages in relinquishing surface water rights in exchange for more reliable and high quality reclaimed water" (Mengenbier, 2013). Today, treated effluent is used both as cooling water make-up (90%) and as deionised water for boilers (10%) (n/a, 2016).

## 7.2 Water flows in the site: supply sources and discharges

The total urban water use which is supplied from the Ebro is about 44 million $m^3$/year in the Tarragona area. Roughly about 35% are supplied for tourism, the remaining 65 % for municipal water use (Arias Barrio, 2016 *pers.comm.*). All water supplied from the Ebro water transfer is managed by CAT, and undergoes pre-treatment.

The CTAWRP is currently designed to generate about 6.8 million m$^3$ of reclaimed effluent per year (about 19 000 m$^3$/day). Today it works, however, only to 50-60% of its capacity (Arias Barrio, 2016 *pers.comm.*). Water withdrawals from the Ebro River by the petrochemical complex were reduced by 25% from the original water withdrawal of 74 000 m$^3$/d (27 million m$^3$/year) to 55 000 m$^3$/d (20 million m$^3$/year) (n/a, 2016). The secondary effluent from the two wastewater treatment plants would otherwise be discharged to the Mediterranean Sea (Mengenbier, 2013).

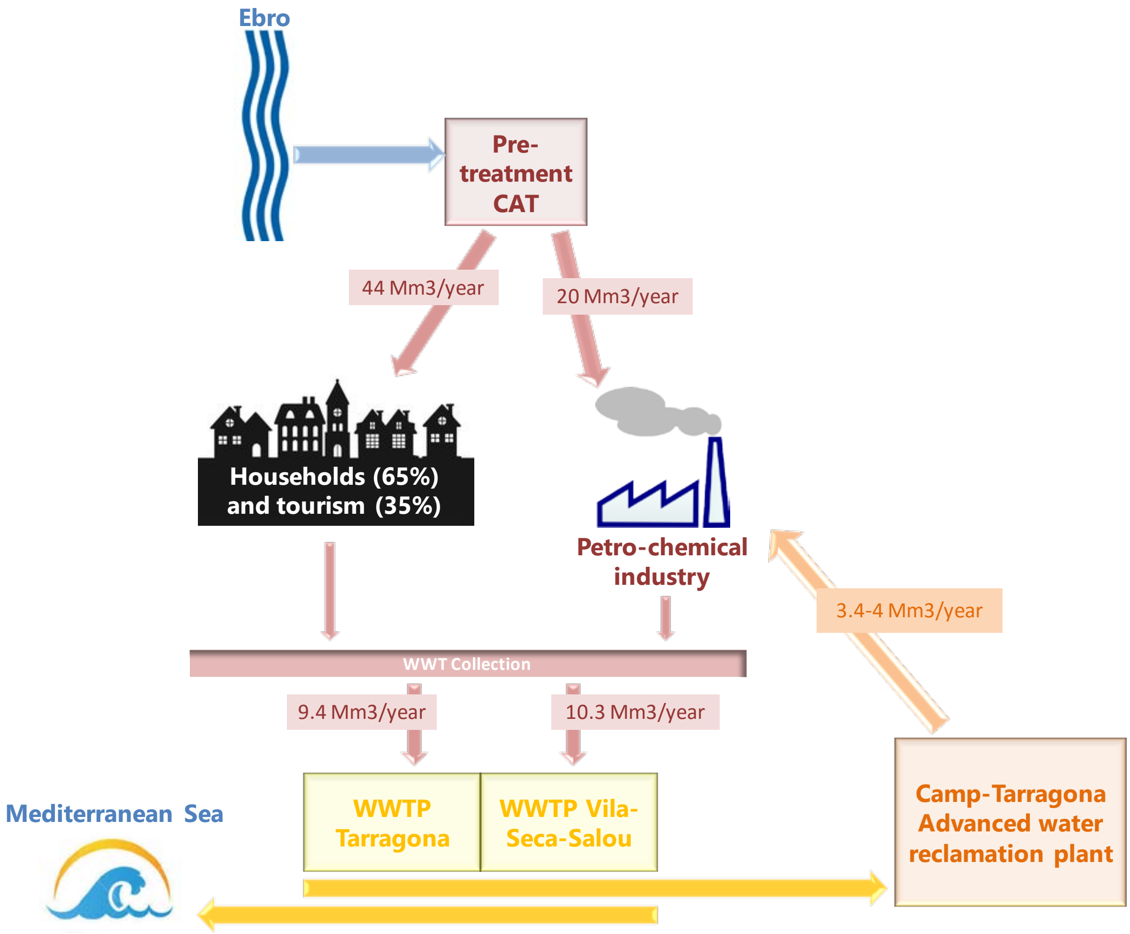



Figure 14 Water flows in the Tarragona site
Note: Amounts of wastewater treated in the WWTP have been taken from UNEP, 2011.

## 7.3 Costs, pricing strategies, and revenues: analysis of financial flows

The alternative of using reclaimed water from nearby wastewater treatment plants had been proposed to the Catalan water agency in order to reduce water use costs (Hernández-Mora et al., 2014).

The capital costs of the wastewater reuse project were about 47 million EUR, and estimated unit costs of the reused water are about 0.64 EUR/$m^3$ (n/a, 2016).

According to a representative of one of the industrial companies, when comparing costs of reused water and of traditional water sources for the industries of the Camp of Tarragona, currently costs are very similar, when looked at under the angle of the long-term costs of ownership. Industries can save in wastewater treatment (less blowdown in cooling towers), less use of chemicals in cooling water circuits (as they can operate in higher concentration cycles) and less maintenance costs (less corrosion, scaling and fouling phenomena) (Arias Barrio, 2016 *pers.comm.*). Membranes applied in the first step of the process keep costs down with less need for additional cleaning. The second step of the process produces high quality water at 33% lower pressure, reducing energy demand[32]. The different components of the water cost structure and cost calculations are listed in the table below. For each component it is indicated whether costs are higher or lower for the industries of the Camp de Tarragona when comparing the use of Ebro river freshwater (100%) with the use of reclaimed water (40%, blended with Ebro river freshwater (60%))[33].

Table 18 Qualitative cost comparison between the use of Ebro river freshwater and reclaimed water for the different cost components relevant for the Camp de Tarragona
Information source: Arias Barrio, 2016 *pers.comm.*

| Cost component | Use of Ebro river freshwater | Use of Reclaimed water |
|---|---|---|
| Fixed costs (including water reserves to be used by the company) | Higher | Lower |
| Distribution costs | Lower | Higher |
| Depreciation costs | Lower | Higher |
| Variable costs | Lower | Higher |
| Operation costs (cleaning, maintenance) | Higher | Lower |
| Chemical treatment | Less chemical consumption but higher cost through using blended water from reclaimed water and Ebro River Freshwater | |
| Wastewater treatment | Higher | Lower |

Considering all cost components, the cost of water (EUR/$m^3$) for the industries in the reclaimed use (40%) scenario is lower by 1.4%. This represents total cost savings of about 120 000 EUR/year (Arias Barrio, 2016 *pers.comm.*). These cost savings could eventually increase with the on-going optimization and capacity increase (the fixed costs will be shared by a higher volume of reclaimed water) of the CTAWRP, as well as the expected decrease of the amortization costs (Arias Barrio, 2016 *pers.comm.*).

32 http://phys.org/news/2016-07-european-reuse-opportunities.html

33 The information is based on the communication from a representative of one of the industrial companies using the reclaimed water.

Also relinquishing water rights (for freshwater from the Ebro river) leads to cost savings, as the industries need to pay less. The water rights are paid by a fixed price[34] per cubic meter which is the same for all companies (Arias Barrio, 2016 *pers.comm.*).

Regarding the historical context, the reuse system today partially replaces water from the Ebro transfer system, which had been established after an agreement in 1981. Part of this agreement has been that "industrial users in Tarragona would financially compensate farmers for the lost water rights" (Hernández-Mora et al., 2014). However, the transferred volumes were made available through agricultural modernisation plans which were publicly funded, and farmers actually suffered no real loss (Hernández-Mora et al., 2014).

85% of the capital costs (about 40 million EUR) of the Camp Tarragona Advanced Water Reclamation Plant were covered by the EU Cohesion Funds, paid to the Catalan Water Agency. The remaining 15 % (about 7 million EUR) were financed by the Catalonian Government and Spanish Ministry of the Environment (n/a, 2016). The industrial end-users did not contribute to the capital cost of the project. Industries pay a set fee for the volume of water they use (n/a, 2016). The DEMOWARE project has financed mainly all related work to research and development to reduce fouling phenomena and to improve energy efficiency in the reverse osmosis system installed in the CTAWRP (Arias Barrio, 2016 *pers.comm.*). The prior demonstration project had been financed by the Catalan Water Agency (n/a, 2016).

The financing of future investments is still unclear. The ambition exists to apply the same scheme that was applied for CTAWRP, with subsidies from national, regional or European funding. However, it is expected that some capital from the chemical companies will be needed (Arias Barrio, 2016 *pers.comm.*).

There are common fees for all users of the treated effluent that are paid to AITASA (the operating company of the CTAWRP) and then to ACA (the owner of CTAWRP) (Arias Barrio, 2016 *pers.comm.*).

For conventional water supply, different tariffs are applied for domestic water uses and industrial water uses. The average domestic price for water in the Tarragona province is 1.972 EUR/$m^3$ for a consumption of 12 $m^3$/month (including VAT) (ACA, 2016). This price corresponds to the average value to be paid via the water bill. The different components of the water price are listed in the information box below.

**Components of the water bill in Catalonia**

The average water price which is paid via the water bill includes several components:

Low-level water supply tariff: tariffs for domestic water supply include usually the following items: (a) Fixed fee for the service and / or minimum consumption or invoicing; (b) Variable part for blocks for the conservation of meters and connections; (c) Fixed fee or for blocks for the conservation of meters and connections; (d) Other fees and surcharges linked to the service.

Water rate: The water rate has been created with an ecological aim. Its purpose is to ensure all the activities of the Catalan Water Agency, including the management of dams, groundwater and desalination plants or the sanitation of wastewater through the construction and/or operation of water treatment plants.

Drainage rate: The rate is either based on consumption, or linked to property values.

Remaining items: In some municipalities also items which are not directly related to the water cycle are included in the water bill (e.g. waste management rates). Also VAT is included in the water bills.

Source: ACA, 2016

[34] The price paid is not publicly available, but subject to confidentiality provisions. However, Arias Barrio (2016 *pers.comm.*) indicates, that the costs are substantial.

The general water rate for domestic uses in Tarragona is 0.5601 EUR/$m^3$. The rate increases with increasing water consumption (ACA, 2015). The general water rate for industrial uses in Catalonia is 0.163 EUR/$m^3$. Also specific water rates exist. In this case, the price is customized for the industrial user linked to a direct measurement of the pollutant load (ACA, 2015).

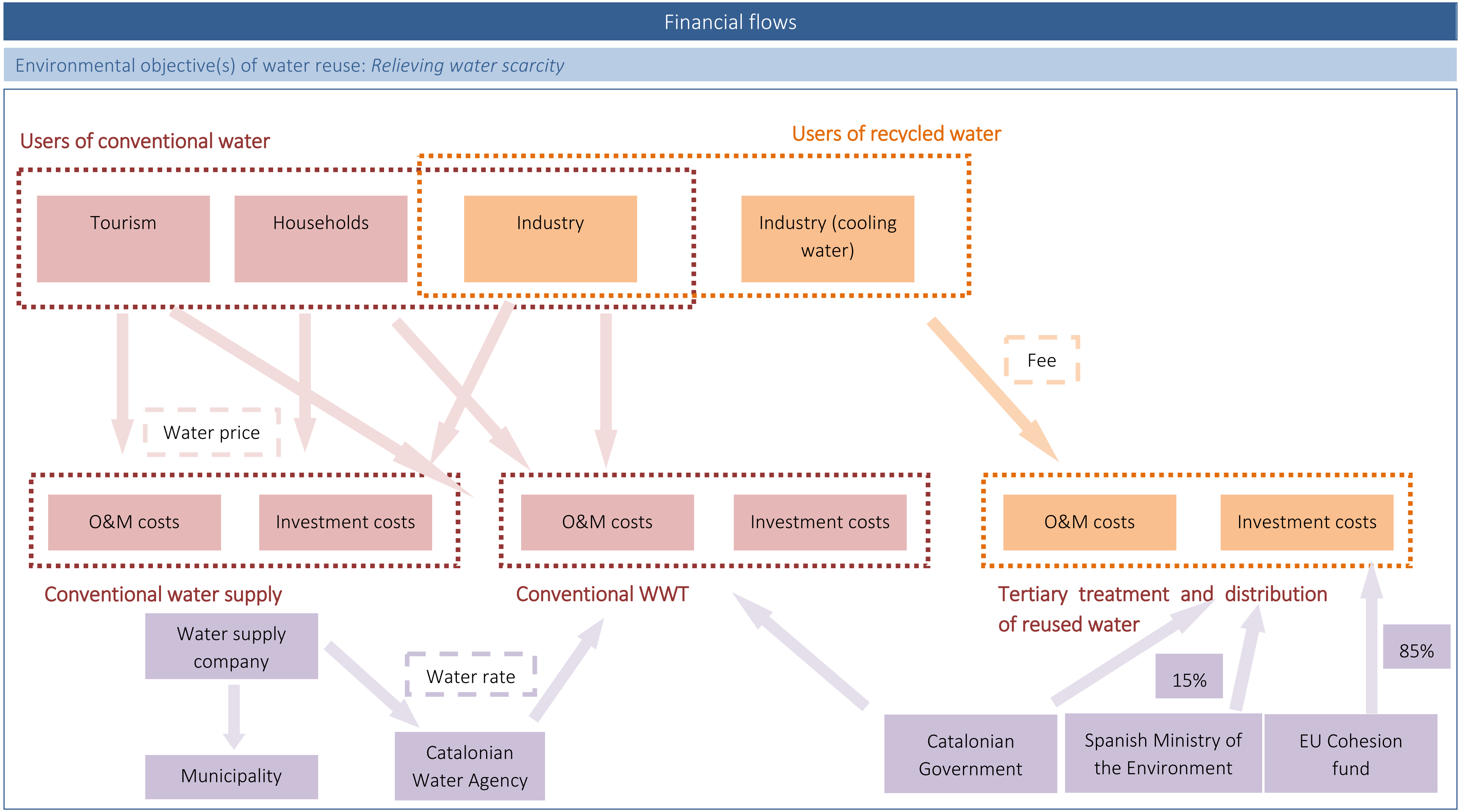



Figure 15 Financial flows in the Tarragona site

## 7.4 Water reuse VS conventional water supply: what does the case study tell us?

The case study is an example of the establishment of a water partnership between municipal and industrial stakeholders for the benefit of the whole Tarragona area (n/a, 2016). Only limited cost and financing information could be made available for this case study. Information provided from one industrial representative indicates that, when comparing costs of reused water and of traditional water sources, currently costs are very similar, when looked at under the angle of the long-term costs of ownership. Industries can save in wastewater treatment (less blowdown in cooling towers), less use of chemicals in cooling water circuits (as they can operate in higher concentration cycles) and less maintenance costs (less corrosion, scaling and fouling phenomena) (Arias Barrio, 2016 *pers.comm.*).

# 8 Cost, pricing and financing of water reuse: overall conclusions

## 8.1 Key elements from case study results

The four case studies provide an overview of diverse water reuse schemes, and in particular of water reuse schemes for different final users (industry, agriculture and urban users), with diverse cost and pricing profiles. The cost and pricing profiles of the four case studies are summarized in the table below.

Table 19 Costs and pricing of recycled water in the four demonstration sites

| Case study | Final user | Volume – $m^3$/year | O&M costs | Investment costs | Price |
|---|---|---|---|---|---|
| Braunschweig | Agriculture | 11 million | 0.50 EUR/$m^3$ | | 81 EUR/ha/year (4% of costs – the rest is recovered by WWT customers) |
| Sabadell | Industry, non-potable urban users | 120 000 | 0.25 EUR/$m^3$ | N/A | 0.6917 EUR/$m^3$ (industry)<br>0.2767 EUR/$m^3$ (municipality) |
| Capitanata | Agriculture | 1000 $m^3$/year | 16.1 EUR/$m^3$ | 3.8 EUR/$m^3$ | Not sold |
| Tarragona | Industry | 3.4 – 4 Million $m^3$/year | 0.64 EUR/$m^3$ (all costs included) | | Not available |

The diversity of these cost and pricing profiles is often depending on the characteristics of the scheme –in Capitanata, it is a very small scheme run by Fiordelisi, a private company, whereas in Sabadell, Tarragona and Braunschweig reclaimed water is produced on a larger scale (and in Tarragona and Braunschweig in particular). Diversity can also be explained by the different types of treatment in the four sites.

In the four sites, the following considerations are made:

- Braunschweig:
  The water reuse scheme delivers important environmental benefits to the local population. Currently only 4% of the costs of the reuse system are covered by the farmers. This accounts for both the benefits the farmers gain from the reuse system (water and nutrient supply), but also the restrictions they experience. It also takes financial feasibility aspects into account (Siemers, 2016 *pers. comm.*). The major part of the costs linked to the reuse system (96%) are paid by the population connected to the public sewage system through the wastewater and rainwater fee. It corresponds to about half of the total other costs linked to the wastewater treatment. Nevertheless, considering the substantial environmental benefits they enjoy from water reuse, the pricing and financing system for the agricultural wastewater reuse in Braunschweig seems to be equitable.

- Sabadell:
  Yearly revenues from the sales of recycled water are higher than yearly O&M costs of producing and distributing this water: thus, O&M costs are fully recovered, and also a share of investment costs. At the

same time, industry and municipality pay respectively 63% and 35.5% of the price paid for conventional water and WWT, so they provide quite a good incentive to use recycled water. Nevertheless, the overall cost recovery rate of the whole system (conventional water and WWT and water reuse) is 85%, thus revenues do not fully cover the costs of the service.

For raising current cost-recovery levels, the following can be proposed: (i) Raising prices for conventional water and WWT –however, social and economic impacts on water users should be carefully investigated; (ii) Raising prices of conventional and reused water for the municipality, but also in this case the financial impacts on municipal balance accounts should be investigated; and (iii) introduction of a municipal charge for all citizens, as they all receive some of the benefits of water reuse in the municipal area –and, as shown by the choice experiment survey, citizens are willing to pay a sum each year to secure current uses of recycled water.

The planned expansion of the water reuse system would correspond to a decrease of unitary production costs, and this shows that unitary costs of reused water benefit from economies of scale or, in other words, the more recycled water is produced, the less it will cost per unit of production.

- Capitanata

  The costs of both primary/secondary and tertiary treatment in the site are disproportionately high as compared to the other case studies (and also as compared to the case studies reviewed in Chapter 2), but available information did not allow the study team to come up with a reasonable explanation. It is likely that costs could be reduced through economies of scale: for example, conventional and tertiary treatment could be jointly carried out by an association of firms and farmers (all using recycled water). Unfortunately, this is not an option, as the Fiordelisi plant is isolated from other farmers and/or industries.

  Furthermore, this case study also shows that, in a territorial context affected by serious water scarcity such as Puglia, finding alternative water supply sources is of paramount importance. The cost of producing reused water can be seen as the environmental and resource cost of using conventional water, and this is a cost which is not reflected in current prices for conventional water –which are likely to cover only the financial costs of water supply. The costs of reused water include the value of the externality of conventional water use, a cost that is not paid by user but is born by society and the environment as a whole.

  In any case, at present these are simple hypothesis and speculations: in fact, current Italian legal standards for reused water are extremely restrictive, so that recycled water after tertiary treatment cannot be used because it sometimes exceeds N parameters –even though this water is of generally high quality.

- Tarragona

  The case study is an example of the establishment of a water partnership between municipal and industrial stakeholders for the benefit of the whole Tarragona area (n/a, 2016). Only limited cost and financing information could be made available for this case study. Information provided from one industrial representative indicates that, when comparing costs of recycled water and of traditional water sources, currently costs are very similar, when looked at under the angle of the long-term costs of ownership. Industries can save in wastewater treatment (less blowdown in cooling towers), less use of chemicals in cooling water circuits (as they can operate in higher concentration cycles) and less maintenance costs (less corrosion, scaling and fouling phenomena) (Arias Barrio, 2016 *pers.comm.*).

## 8.2 Developing a pricing strategy for water reuse schemes: which elements should be taken into account?

The analysis of the four case studies yielded different outcomes: overall, it can be seen that different tariff structures and levels can work in different contexts, so 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 –for example, in Braunschweig these costs are mostly covered by urban WWT customers, whereas in Sabadell these costs are recovered by users of recycled water. So, at first sight, the only strong conclusion that can be drawn from this analysis is that a correct, one-size-fits-all pricing strategy for water reuse does not exist, as it will strictly depend on the specific characteristics of each scheme and site –and this was also mentioned in Chapter 2 of this deliverable.

However, if we take a closer look at the case studies and at the elements that were analyzed, we can see that it is possible to go further than that. In all case studies, the analysis and discussion of pricing strategies focused on some common elements, such as for example: are costs recovered by users through tariffs currently in place? If not, why? Are other users recovering these costs? Why? Which other financing sources are coming into place? These common questions reveal a *fil rouge* in the way the four case studies were conducted, and this common thread can in fact be taken as a guide when a pricing strategy for water reuse needs to be developed.

In other words, while it is true that no generic pricing strategy for water reuse can be developed, it is definitely possible to identify a series of general steps which can be followed when developing a pricing strategy for a given water reuse scheme, expressed by a list of key questions that need to be answered to come up with a suitable, convenient pricing strategy. These key questions are illustrated in the figure below.

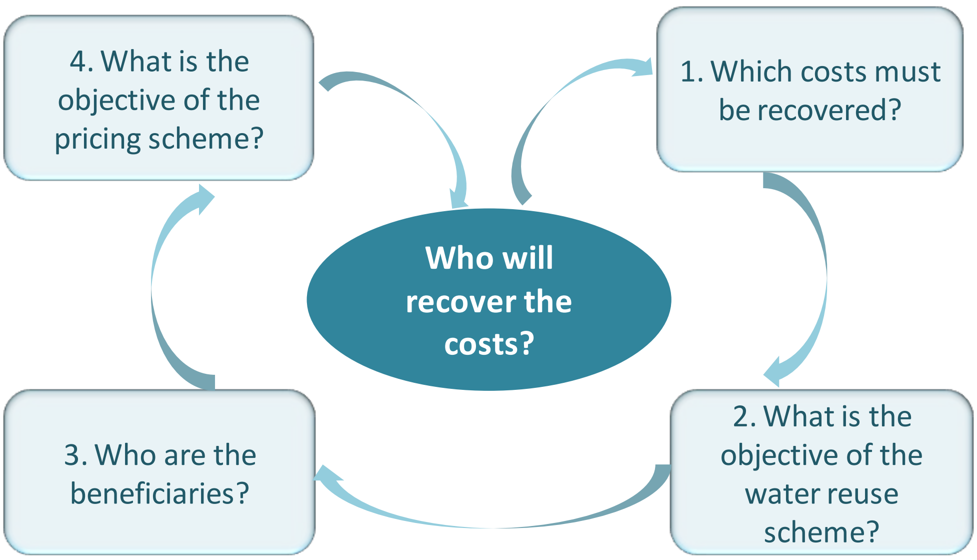



Figure 16 Key question to be answered to guide the development of a suitable pricing strategy for a given water reuse scheme

**A correct pricing strategy revolves around a central question: who will recover the costs?** Or, in other words: who will pay for water reuse? The answer might seem straightforward: users will pay, of course. But, as it was seen along this report, both in the case studies and in the collected examples presented in chapter 2, this is often not the case, because other considerations come into play. The elements to be taken into account are shown in the framework presented in the figure above, and these are: cost profiles, benefits and beneficiaries, objectives of the water reuse scheme and objectives of the pricing strategies.

These elements can be translated in four key questions to be asked when developing a pricing strategy for water reuse, which are detailed in the following paragraphs.

### 1. Which costs must be recovered?

This might look like a futile question; however, as it was seen in the case studies, a full understanding of the cost profiles is sometimes missing. The costs to be taken into account are not only the costs of the water reuse system, but also the water supply and conventional WWT system, if these are managed by the same operator. In fact, the ultimate objective is to recover the costs at the operator level. For example, in Sabadell O&M costs of the water reuse system are fully recovered, as well as part of investment costs, but the cost-recovery rate of the whole system (water reuse and conventional water supply and WWT) is 85%. In other cases, the unitary costs of recycled water are higher than the unitary costs of conventional water, or are higher than what is seen as an acceptable price by consumers: in this case, cross-subsidization mechanisms can be put in place –i.e. users of conventional water supply and WWT might pay more than the unitary costs of the service they use to cover part of the costs of water reuse (see also questions 2 and 3).

In addition, as mentioned in the previous section, it was observed that the size of the water reuse scheme has an influence on unitary costs: the larger the capacity of the plant, the smaller the unitary costs of recycled water. This can be taken into account in the planning phase of a water reuse system, when dimensioning treatment units: it will support the identification of the optimal capacity of the scheme –so that a scheme is large enough to reduce costs, but not too large to outweigh the actual demand for recycled water.

### 2. What is the objective of the water reuse scheme?

The objective of the reuse scheme is the key to the identification of beneficiaries. For example, a water reuse scheme can be set up to address mismatches between water demand and water availability in water scarce areas, or it can be set up to reduce pollution in surface water bodies by injecting treated wastewater. Once the objective is clearly defined, the third question (below) can be answered.

### 3. Who are the beneficiaries of the system?

Users of recycled water are obviously the direct beneficiaries of the system. However, most water reuse schemes deliver indirect benefits to other user groups. Indirect beneficiaries are directly connected with the objective of the water reuse scheme. For example, in water scarce areas affected by mismatches between water demand and water availability, users of conventional water supply will also benefit from the presence of the water reuse system, as more freshwater will be available for them. If recycled water is used to dilute pollutants in degraded surface water bodies, the water reuse system will benefit communities along such rivers and lakes, and in particular recreational users of such surface water bodies –this is the case, for example, in Sabadell.

The identification of beneficiaries is key to the identification of who should pay for the water reuse scheme, and especially in those cases where prices of recycled water cannot fully recover the unitary costs of water reuse. As mentioned in question No. 1, unitary costs of water reuse might exceed the price charged for conventional water supply or WWT, or simply the price that potential users of recycled water can accept to pay. In these cases, part of the costs of water reuse can be borne by other (indirect) beneficiaries, be it users of conventional water supply and WWT (through cross-subsidization mechanisms) or other beneficiaries through other financing mechanisms. In Sabadell, for example, cost-recovery levels of the whole system (conventional water supply and WWT plus water reuse scheme) could be improved by setting up a municipal charge on Sabadell citizens, as they all indirectly benefit from the water reuse scheme.

## 4. What is the objective of the pricing scheme?

When answering the previous questions, several pricing options might have emerged: for example, the costs of water reuse might be fully recovered by users of recycled water, but cross-subsidization mechanisms or municipal charges might also seem a viable option. In short, which is the most convenient option? This will largely depend on the water management objective of the pricing scheme, which in larger schemes of strategic importance can also be a policy objective. The final pricing structure and levels for water reuse must take into account different aspects, such as for example:

- Is there a will to provide an incentive for consumers to rely on recycled water rather than conventional water? If one of the objectives of the pricing strategy is to provide such incentive, then the price of recycled water must be competitive (i.e. lower) with the price of conventional water supply. Of course, a competitive price might not allow a full cost recovery, so that other users/ beneficiaries must contribute.
- Will consumers have a choice, or they will be obliged to use recycled water for certain uses (e.g. due to municipal regulations, or for lack of sufficient freshwater resources)? In principle, if consumers do not have a choice, they could be charged the full unitary cost of producing and distributing recycled water. However, water managers might decide to gradually increase water prices to the desired levels to allow consumers to adjust to the new regulations or the new supply.
- If the price of recycled water equals its unitary costs, which will be the social and economic impacts on local communities? Would this impact be acceptable? If not, which pricing structure and levels would have an acceptable impact? Social and economic impacts of water prices should always be considered when developing a pricing strategy, as negative impacts should be avoided, especially on low-income groups. If a selected pricing strategy turns out to have a negative impacts on some groups, different options can be chosen: (i) modify the pricing strategy, charging come costs on those groups who can bear an additional burden; (ii) modulate unitary rates based on consumption (progressive tariffs), so that small consumers pay less per cubic metre than large consumers –this also discourages waste; or (ii) implement accompanying measures to mitigate impacts on selected vulnerable groups (e.g. low-income groups), such as for example reduced rates for low-income groups.

## In conclusion....

The list of key questions presented above is aimed at providing some guidance in the development of an appropriate pricing strategy for water reuse schemes, as it touches the main elements to be taken into account and proposes some possible solutions. Nevertheless, as it also emerges from the previous paragraphs, **setting-up a pricing strategy always involves some political or management decisions**, which will depend on policy/ management priorities as well as on the specific challenges to be addressed in a specific site. This is because **a "correct" pricing strategy for a given water reuse scheme does not exist**, and the objective will rather be the to **develop the most convenient pricing strategy which allows for achieving full (or close-to-full) cost-recovery levels and will suit the specific characteristics and challenges associated to the specific water reuse scheme**.

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