Deliverable D4.4
Social and environmental benefits of water reuse schemes – Economic considerations for two case studies

The project "Innovation Demonstration for a Competitive and Innovative European Water Reuse Sector" (DEMOWARE) has received funding from the European Union's 7th Framework Programme for research, technological development and demonstration, theme ENV.2013.WATER INNO&DEMO-1 (Water innovation demonstration projects) under grant agreement no 619040

Deliverable Title	D4.4 Show cases demonstrating the relevance of the social and economic benefits of water reuse schemes to the local communities
Related Work Package:	WP4: Business Models and pricing strategies
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Dissemination level:	Public
Due submission date:	30/04/2016
Actual submission:	20/09/2016
Grant Agreement Number:	619040
Instrument:	FP7-ENV-2013-WATER-INNO-DEMO
Start date of the project:	01.01.2014
Duration of the project:	36 months
Website:	www.demoware.eu
Abstract	

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CBA – Cost-benefit analysis

CE – Choice Experiment

CHP plants – Combined heat and power plants

CV – Contingent Valuation

DFC – Discounted Cash Flow

FNPV(C) – Financial net present value on investment

MAP – Magnesium-ammonium phosphate

NPV – Net Present Value

WWTP – Wastewater treatment plant

Executive Summary

Whereas the direct costs of wastewater reuse schemes are often quite well known, this is less the case for the benefits side. Wastewater reuse projects are in many cases linked to significant social and environmental benefits, through alleviating drought situations, preserving natural water resources or preserving surface water quality by reducing nutrient input. Taking these benefits into account within cost-benefit considerations requires the application of specific valuation techniques (e.g. contingent valuation method, choice experiment). This has been done for the water reuse systems in Braunschweig, Germany, and Sabadell, Spain.

The city of Braunschweig lies in an area with seasonal water deficit and sandy, nutrient poor soils. Irrigation is necessary in order to sustain agricultural activities, posing a risk to local groundwater depletion. At the same time, the wastewater treatment plant Steinhof has to keep pollution discharge limits with regards to the receiving, local river Oker. Going back to a long historical development, a local water-nutrient-energy cycle has been created in Braunschweig, in order to respond to the different demands. Wastewater from the city of Braunschweig and the surrounding communities is collected and treated by the local treatment plant. About half (45 %) of the treated effluent is directed to the so-called infiltration fields, where part of the excess nitrogen and phosphate is removed through natural processes, before the water finally reaches the Oker. The other half of the effluent is mixed with sewage sludge and directed to the agricultural fields of the Sewage Board. Crops grown on these fields are either used for consumption – after further processing – or directed to the biogas plant Hillerse, which produces electricity and heat for local households.

No specific pre-treatment is required for using the effluent for irrigation. As a consequence, no specific costs occurring within the treatment plant can be attributed to the reuse activities. Costs related to the reuse are instead linked to the distribution of effluent to and on the agricultural fields (pumping, pipes, mobile irrigation machinery), restrictions to the agricultural management, spray protection hedgerows and a specific drainage system, as well as health risks for field workers. On the benefit side, the current system allows the saving of mineral fertilisers, the preservation and restoration of local groundwater resources and the preservation of the river water quality. Furthermore, benefits include also several avoided costs, in particular the avoided distribution of effluent to the infiltration fields, avoided groundwater pumping and avoided alternative disposal of sewage sludge.

Regarding environmental benefits of water reuse in Braunschweig, the preservation and restoration of local groundwater resources and the preservation of the local river water quality have been identified as the most important benefits. Taking all irrigation water needed by agriculture from groundwater would use nearly all of the sustainably usable, local and renewable groundwater reserve. Using treated wastewater not only avoids pressure on local groundwater bodies, in addition recharge of the groundwater reserve is promoted. Currently, more water is irrigated on the fields than is used by the plants, and in total more than 7 million m^3 of water are infiltrating every year in the soil towards the aquifers. The infiltration fields, which currently receive about half of the treated effluent, are at the limits of their pollutant absorption capacities. If water reuse activities for agriculture would cease, the entire wastewater volume would be discharged in the infiltration fields. This could lead to exceeding the allowed thresholds. The amount of pollutants reaching the Oker would probably double.

In order to estimate the value which these two environmental benefits represent for the local community, a contingent valuation study has been carried out, with a survey sample of 300 people. Next to valuation questions in the form of willingness to pay, questions of general awareness and acceptance have

been asked. Among the main results of the study, it turned out that only half of the population in Braunschweig are aware of the reuse system. At the same time, after having presented the system to all respondents, the consent to it is very high, with only 4% of the respondents declaring to be against it. Ensuring that sufficient water resources are available to cover the whole demand is cited as the perceived most important benefit of the reuse system. On the other hand, reduced groundwater quality and increased chemicals in water are cited as the perceived most important downsides.

When asked about their willingness to pay for preserving the current benefits in the form of a monthly contribution (on the water bill) for an environmental programme, agreement and refusal were 48 % and 52 %, respectively. Eighty-six percent of the respondents which accepted to contribute financially to preserving the benefits of the reuse system were willing to pay between 0.50 and 6 EUR per month above their current bill. Four Euros is the amount which has been chosen the most. After ruling out protest responses, it turned out that only about 10 % of the respondents truly do not attach any value to the environmental goods. Taking this into account, the mean willingness to pay for maintaining the environmental benefits stemming from the reuse system in Braunschweig is estimated at 3.38 EUR/month or 40.56 EUR/year. Aggregated for the total number of households in Braunschweig (128 885 in 2011; Landesamt für Statistik Niedersachsen 2014), the value of the environmental benefits linked to wastewater reuse in Braunschweig amounts to 5.2 million EUR/year, based on the mean willingness to pay. When using not the average but the median value, the total value of the environmental benefits is estimated at 3 million EUR/year. Both values are valid, and both values can be used to approximate the environmental benefits.

Although cost information for Braunschweig was not available in the correct format, and not as complete as needed for carrying out a proper financial analysis, elements from the case study have been entered into the web-based CBA tool in order to see in how far it can be used for the situation present in the case study. A first limitation consists in the fact that the tool is configured to carry out ex-ante CBA's for new water reuse projects. Water reuse in Braunschweig already exists since a long time, which would actually require an ex-post approach, not foreseen by the tool. Furthermore, the structure of the tool provides for specific treatment steps linked to different types of users of wastewater, which is also not applicable to Braunschweig. However, taking into account the functioning of the tool, available information can still be entered. Results seem to indicate that – from an economic point of view – benefits of the current reuse system clearly outweigh costs, mainly due to the environmental benefits. However, given the limitations of the available cost information basis, these results have to be treated with great care.

For the second case study, the city of Sabadell, historically sensitive to the problem of water (Sabadell is located in a region of Spain dealing with dry seasons and scarcity problems), has during the past decade developed a series of actions aimed at reducing pressures on regional water bodies and developing new alternative water sources to face drought situations and future scarcity risks. Such actions include the development of water reuse activities in the city.

The current reuse system in Sabadell is making indirect use of effluent coming from the Ripoll WWTP (in Sabadell north), and direct use effluent from the Riu Sec WWTP in Sabadell south. The north system is considered as an indirect reuse system because the treated water is first discharged into the Ripoll River; then by natural infiltration, part of this treated water infiltrates the river bed and recharges the alluvial aquifer which supplies the Ripoll and Ribatallada mines; water from the mines is then collected and requires only UV disinfection and chlorination in order to be "reused". For the south system, MBR technology recently installed in the Riu Sec WWTP, results in high quality treated effluent requiring only extra disinfection (tertiary treatment consisting of UV disinfection and chlorination) in order to be reused.

Thus, currently in Sabadell, around 120 000 m^3/year are covered in this way with reused water representing approximately 1% of total water demand in the city. The north network provides around 95 000

m^3/year mainly for green areas and parks irrigation and street cleaning activities, while the south network provides around 25 000m^3/year, mainly for industrial purposes, but also for green areas irrigation and street cleaning activities.

Regarding environmental benefits stemming from the reuse system in Sabadell, the system allows the preservation of potable water resources which can be either saved, or used for higher priority uses, the preservation and restoration of local aquifers and maintaining biodiversity and the ecological cycle of the Ripoll River. Nonetheless, given the context of water scarcity in the region and the fact that there have been several drought periods during the past decade, some even generating restrictions on non potable water uses in the city, the focus was to assess the value given to societal benefits stemming from securing, with reused water, different urban water uses in the city when faced with scarcity or drought situations. Indeed, faced with water scarcity, securing green areas and parks irrigation with reused water allows maintaining aesthetic values of said areas throughout the year, even faced with drought restrictions; this also allows maintaining the recreational quality of said areas. A similar reasoning can be held for securing street cleaning activities with reused water all year long.

For the moment, the current system allows covering only a small fraction of the yearly water demand for said water uses. Nonetheless, envisioned developments of the system in the near to mid future could allow completely covering the yearly water demand for said uses. In these lines, it was deemed interesting to assess the value given to completely securing the yearly water demand for green areas irrigation and street cleaning activities in the city, and thus the value of resulting societal benefits. This is also interesting since it could provide evidence to further support of the developments from a social perspective.

Thus a Choice Experiment survey was implemented, amongst a representative sample of 300 Sabadell citizens, in order to assess the value given to the previous indirect societal benefits stemming from water reuse. This survey also allowed inquiring about people's view on the reuse system in place and in general people's view and acceptance of water reuse for different urban uses in the city[1].

The results of the survey show that 79% of the respondents are aware of the fact that wastewaters can be treated and reused. This suggests that a large proportion of the population is aware of water reuse. However, only 16% of the respondents were aware of the existence of water reuse activities in Sabadell. This suggests that more information campaigns on the system in place should be encouraged.

Regarding the perception of potential benefits, "Maintaining the aesthetics of parks and fountains" is seen as a potential benefit by most respondents, followed by "Improving the preservation of rivers, lakes and ground waters" and "Avoiding water restrictions for households during droughts". Moreover, 79 % of the respondents acknowledge the potential benefits water reuse can have for the preservation of local water bodies. Overall, all the presented benefits have a proportion of "yes" answers ranging between 75 % to 80 % which implies that water reuse is seen as an activity having an overall positive outcome in terms of benefits.

While looking at answers more closely, for the subsample of respondents completely unaware of the existence of water reuse, the proportion of yes answers is lower for all benefits (53% to 64%) while being higher amongst the subsample of respondents previously aware of the existence of water reuse (80% to 87%). This highlights the importance of undertaking informational campaigns to favour the acceptance of water reuse.

Regarding the perception of potential downsides, "Human health risks related to contamination" and "Increased chemicals in water" appear to have the higher ratios of "yes" answers with 81% and 78% re-

1 The technical aspects of the Choice Experiment technique and the construction of the questionnaire are presented in Demoware deliverable 4.3 "CBA approach suited for water reuse schemes".

spectively. Also, even if there is a higher rate of acceptance of potential benefits amongst respondents previously aware of water reuse, these respondents are also more concerned about potential downsides related particularly to water quality issues than respondents previously unaware of reuse activities. Information campaigns should thus look to reassure people's views related to health risks and the use of chemicals.

With respect to the value given to selected societal benefits, results from the Choice Experiment show that on average, Sabadell households are willing to pay 15 EUR/year to ensure that all parks and green areas of the city are irrigated with reused water throughout the year; and 53 EUR/year to secure street cleaning activities in the city with reused water throughout the year. Taking into the number of households in the city, which is estimated at 82 794 households, social benefits related to securing street cleaning activities with reused water are estimated at 4.3 million EUR/year and social benefits related to securing the irrigation of parks and green areas in the city are estimated at 1.2 million EUR/year. Finally results show that respondents having a high perception of scarcity and drought risks in the city have an overall higher willingness to pay for potential uses for reused water in the city. This highlights the importance of conveying during information campaigns the fact that water scarcity and drought risks will likely increase over time in order to stress the importance of encouraging water reuse to reduce potential scarcity risks but also, to secure certain benefits affecting the quality of life in the city.

CBA methodology was applied in order to demonstrate the relevance of social or environmental benefits related to developments of the current reuse system in Sabadell. Developments of the system concern increasing current reuse volumes up to 941 000 m^3/year in order to cover total yearly water demand for green areas irrigation and street cleaning activities, and greatly increase reuse volumes for industrial activities. The developments require an expansion of both the northern and the southern systems. Taking into account the available information on the required investment costs, operational costs and revenues of the networks after expansion and, the environmental and societal externalities generated, the water reuse CBA web based tool was thus tested for the Sabadell case study.

Exclusively from a financial point of view, taking society as the relevant stakeholder of the project and considering exclusively investment needs and operational cost and revenues[2], the expansion project should not be encouraged, since the generated revenues do not cover generated costs and investments needs (negative FNPV(C) of 2.1 million EUR)[3]. Moreover, the "current reuse situation" scenario, which corresponds to the "do minimum" counterfactual situation appears as the preferable option since it generates a positive FNPV(C) of 323 000 EUR. Nonetheless when accounting for environmental and societal externalities, the project generates a positive and very significant Net Present Value (46 million EUR), largely thanks to societal benefits stemming from water reuse in the city. Thus, when accounting for economic externalities, clearly the expansion of the northern and southern networks appears to be largely beneficial to local communities (Sabadell citizens).

The Sabadell case study constitutes only a simplified version of a Cost Benefit Analysis in the essence that it applies general CBA methodology to assess the overall outcome of a given water reuse project. The objective has rather been, to demonstrate that including environmental or societal externalities stemming from water reuse[4], can significantly change the overall outcome in terms of social welfare generated by water reuse projects. These case studies provide evidence suggesting that water reuse activities can have significant positive impacts to society.

2 As required by CBA methodology to calculate Financial Net Present Value on Investment or FNPV(C)

3 This does not mean that the project is not beneficial, considering other indicators of financial performance and, investors as relevant stakeholders of the project (see section 4.4.2 on financial analysis)

4 In this case indirect social benefits related to securing urban water uses faced to water scarcity

1 Introduction

Whereas the direct costs of water reuse systems are often quite well known, this is less the case for the benefits side of such systems. Wastewater reuse schemes can help to alleviate water scarcity situations, providing for a new, alternative source of water. This has – in very general terms – implications for the environment, from which potentially less water is abstracted, and on the local population, which might face less restrictions linked to the use of water. Wastewater reuse can furthermore have implications on the water quality of the local water bodies, for example by reducing the amount of nutrients reaching the local environment after agricultural reuse. However, these benefits, which are particularly relevant for the local communities, cannot be valued straight ahead, but require specific evaluation techniques (e.g. choice experiment, contingent valuation study). These techniques have been introduced and described in the Demoware Deliverable 4.3 “CBA approach suited for water reuse schemes”, which contains the theoretical aspects on evaluation techniques for environmental benefits as well as methodological reflections on costs and benefits of water reuse schemes, including the web-based CBA tool, which has been further developed within the project.

In the present report, the specific wastewater reuse schemes in Braunschweig (Germany) and Sabadell (Spain) will be looked at in detail, shedding light on the importance of the existing and/or potential local benefits linked to them. After a short description of the methodology used to collect information, both case studies will be described, respecting the following structure:

- Overall case study description
- Description of the case study specific benefits and costs of the reuse scheme
- Evaluation of the case study specific environmental or societal benefits – including a description of the results from the valuation surveys
- Feedback from testing the water reuse CBA tool

The report is completed by overall conclusions for both case studies.

2 Methodology

The present deliverable has to be seen in connection with the Demoware deliverable 4.3 (Zayas et al., 2016), which explains main methodological issues on cost-benefit analysis for water reuse projects. It also provides details on the Contingent Valuation and the Choice Experiment techniques, which are the two methods used for evaluating environmental or societal benefits in the two case studies. Whereas the results of the evaluation studies are described in the present report, the full questionnaires can be found in Deliverable 4.3.

This methodological section focuses on the case study related work, and in particular on the information collection process. The work undertaken for the water reuse case studies (both Braunschweig and Sabadell) involved a certain number of steps, which are listed in Table 1.

Table 1 Steps of the case study work

What?	How?
In-depth understanding of the case studies and elaboration of detailed case study descriptions	- Site visits, including elaboration of written records - Literature review - Validation of case study descriptions by the plant managers and a representative of the Sewage Board (for Braunschweig)
Identification and monetary assessment of selected environmental and/or social benefits of the reuse systems	- Literature review and analysis to determine the importance of the environmental and/or social benefits - Development of the Choice Experiment questionnaire for Sabadell and of the Contingent Valuation questionnaire for Braunschweig - Implementation of representative online surveys through professional survey companies - Econometrical and Statistical analysis of the survey results
Identification and quantification of specific costs and benefit data from the systems operation	- Identification of operational cost and benefit categories through the analysis of available information - Elaboration of CBA scenarios - Elaboration of questionnaires and exchanges (written and oral) with plant managers (as well as a representative of the Sewage Board for Braunschweig) for collection of cost data - Test of the web-based CBA tool with elements from the case studies

For the purpose of data collection, detailed cost questionnaires were developed and sent to the case study experts (plant managers and – in the case of Braunschweig – representatives of the Sewage Board). The information which has been asked for each (cost or benefit) element is shown in the table below (Table 2). Data was, however, not available in such detail. For Braunschweig, all relevant cost (and benefit) information which could be collected is shown in the Table 8 and Table 9. For Sabadell, all the relevant cost (and benefit) information which could be collected is detailed in section 4.2 (Description of case study specific benefits and costs).

Table 2 Elements of the cost questionnaire used for data collection

Cost or benefit element	Dimension	Amount of the initial investment	Year of the initial investment	Lifetime	Replacement costs	Frequency of replacement (or year of replacement)	Maintenance costs	Labour costs	Energy requirements
Element 1									
Element 2									
Element 3									

3 Braunschweig case study

3.1 Case study description

The wastewater treatment plant (WWTP) Steinhof in Braunschweig is the property of the Abwasserverband Braunschweig (Braunschweig Wastewater Association / Sewage Board), and managed by the Stadtentwässerung Braunschweig (SE/BS)[5]. After treatment, the effluent is discharged into the river *Oker*, a small adjacent water body in which certain discharge limits need to be met (see Table 3).

Table 3 Discharge limits of the effluent to the river Oker
Source: Values reported in De Paoli, 2014

Parameter	Discharge limit
COD	50 mg/l
BOD	15 mg/l
NH_4-N	7 mg/l
N_{anorg}	12 mg/l
P_{ges}	1 mg/l
pH	6.0 – 8.5

At the same time, agricultural soils located in the north of the treatment plant are very sandy, and not able to store much water. The area is furthermore characterized by a seasonal water deficit: in summer, evapotranspiration exceeds precipitations (see Figure 1) by about 200 mm on average (maximum 350 mm) (Klein et al. 2013). As a consequence, agricultural activities require irrigation – posing a risk to local groundwater depletion. Soils are furthermore lacking sufficient nutrients for plant growth (De Paoli 2014).

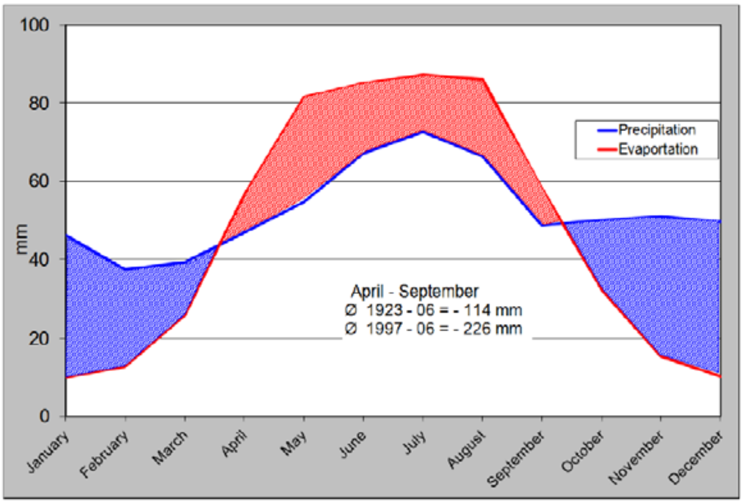


Figure 1 Average water balance in Braunschweig 1923-2014
Source: DWD, Station Braunschweig, in Abwasserverband Braunschweig (2016)

[5] The Sewage Board Braunschweig is formed by the City of Braunschweig, the Waterboard Gifhorn (including neighbouring communities) and farmers. SE/BS is the service provider for wastewater for the city of Braunschweig. It is entirely part of BS Energy. 74.9% of BS Energy belongs to Veolia 25.1% of BS Energy belongs to the city of Braunschweig. A contract between the city of Braunschweig and the Sewage Board defines the responsibilities of each entity (Casado Cañeque et al., 2015).

Given this background, a logical solution had been to address both constraints – nutrient pressures on the local surface water body and a seasonal water imbalance – with a combined approach by using treated wastewater for irrigation in agriculture. A part of the crops produced on the fields (43,000 tons of maize and rye per year; Abwasserverband Braunschweig, 2016) supply the nearby biogas plant Hillerse and are used for the production of electricity and heat. The overall system is called the **Braunschweig model**. It links 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 further detailed in the following.

Box 1 Historical development of the wastewater (reuse) system in Braunschweig

Back in 1894, the first sewage fields (*alte Rieselfelser*) were initiated. They covered an area of 460 ha, where a daily amount of 10 000 m^3 of sewage water has been treated from the city of Braunschweig - which back then counted 100 000 inhabitants. 60 years later the number of inhabitants had increased to such an extent that the capacity of the infiltration fields was not sufficient anymore. A reorganization of the wastewater disposal was necessary (Lindner, 2015).

For this purpose, the Braunschweig Wastewater Association has been founded by the city of Braunschweig and the owners of today's irrigation fields in the sectors I and II. In 1955 the area of the wastewater association has been increased by the irrigation sectors III and IV to the current size of 4 300 ha. In the same year, the construction period of 11 years (1955-1966) for the four irrigation pumping stations started for the respective sectors (Lindner, 2015).

Once the sprinkler irrigation system of (only) mechanically pre-treated wastewater was developed, the agricultural reuse started. The actual treatment plant was then built, in four stages, between 1979 and 1991 (De Paoli, 2014). Approximately in the same period (1985-1990) a part of the infiltration fields has been converted to a system of meanders. This system of flowing water extends over a length of several kilometres and took over in 1991 the task of biological post-treatment (Ahlers and Eggers 2004, in Lindner, 2015). The sludge digester was finally built in the year 2000 (De Paoli, 2014).

In 2006, the scheme has been extended through the construction of a biogas plant. Currently (2015 – 2016), process water treatment and sludge desintegration components are in the planning phase (Teiser, 2015).

Figure 2 below illustrates the location of the different elements of the Braunschweig model, highlighting in particular (De Paoli, 2014): The drainage area: the Braunschweig WWTP collects and treats wastewater coming from the city of Braunschweig and its surroundings;

- The location of the WWTP;
- The infiltration area (wetland), where post-treatment takes place;
- The sprinkling area, where treated wastewater and digested sludge mixed together are used to irrigate agricultural crops.

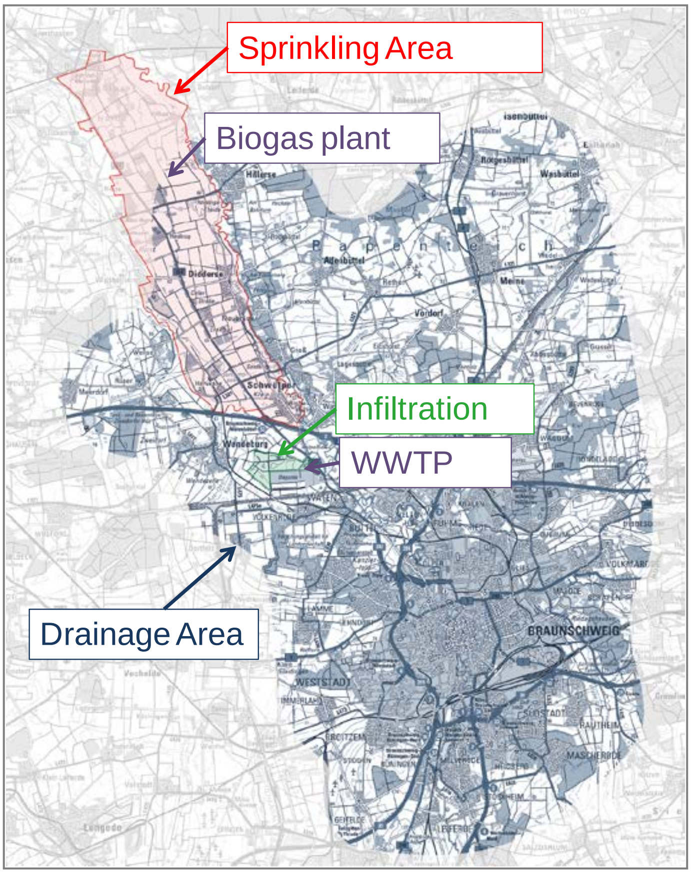


Figure 2 The area of operation of the Braunschweig wastewater treatment plant
Source: courtesy of Bernhard Teiser, Director of Abwasserverband Braunschweig) (De Paoli, 2014)

3.1.1 The water-nutrient-energy cycle

The main steps of the Braunschweig water-nutrient-energy cycle are illustrated in (Figure 3), and will be described in the following.

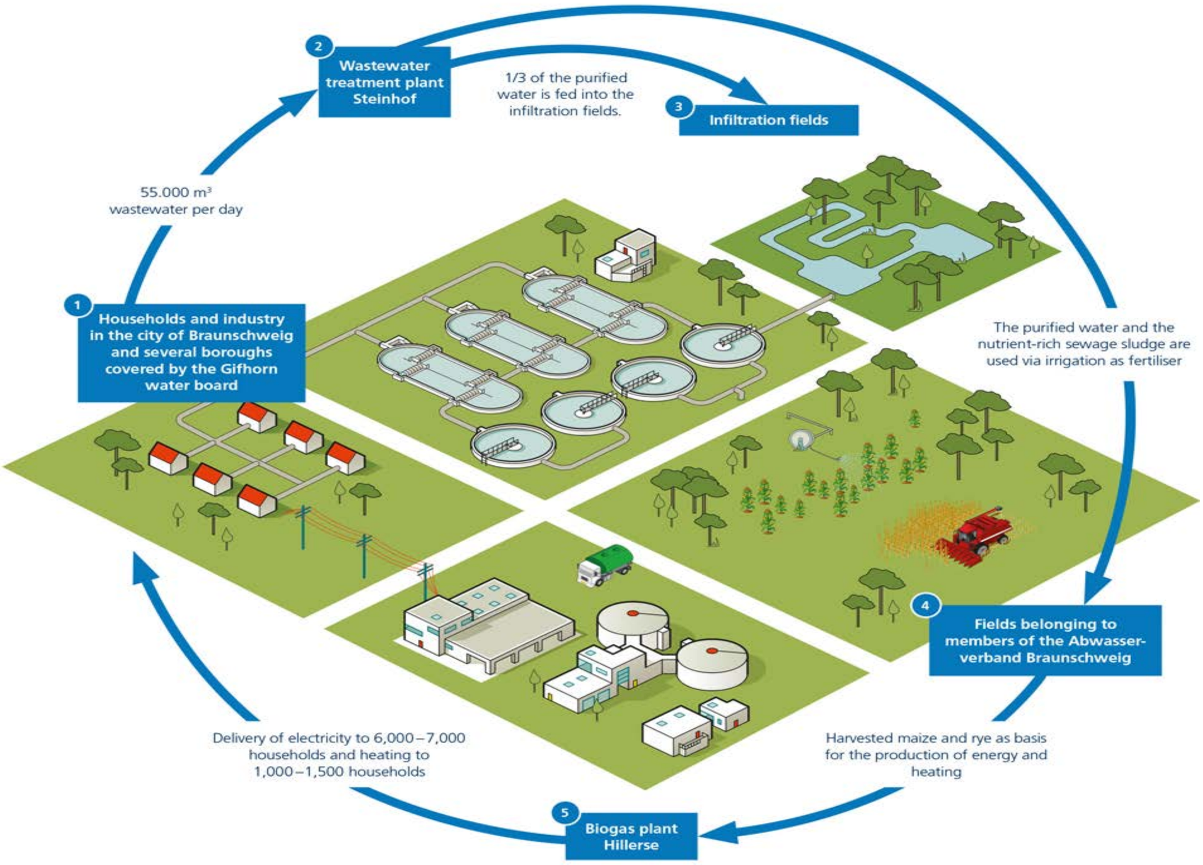


Figure 3 The water-nutrient-energy cycle developed in the Braunschweig site
Source: Abwasserverband Braunschweig, 2014

3.1.1.1 Households and industry producing wastewater (1)

Households and industry 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 wastewater treatment scheme of the city of Braunschweig treats and disposes the municipal and industrial wastewater. The WWTP BS-Steinhof receives a wastewater load of 350 000 PECOD per year, of which 280 000 PE are from inhabitants of Braunschweig and 70 000 PE are from industries (SE/BS 2012) (Remy, 2012)

3.1.1.2 Wastewater treatment plant Steinhof (2)

As a first treatment step after mechanical treatment, wastewater and sludge are separated through primary sedimentation. Wastewater is treated for the removal of suspended solids, organic matter, and the nutrients nitrogen (N) and phosphorous (P) in a conventional activated sludge process with nutrient removal (Remy, 2012). No specific additional advanced treatment is applied before reuse. Figure 4 illustrates the scheme of the Braunschweig wastewater treatment system as it has been used for a Life Cycle Analysis done for 2010 (Remy, 2012).

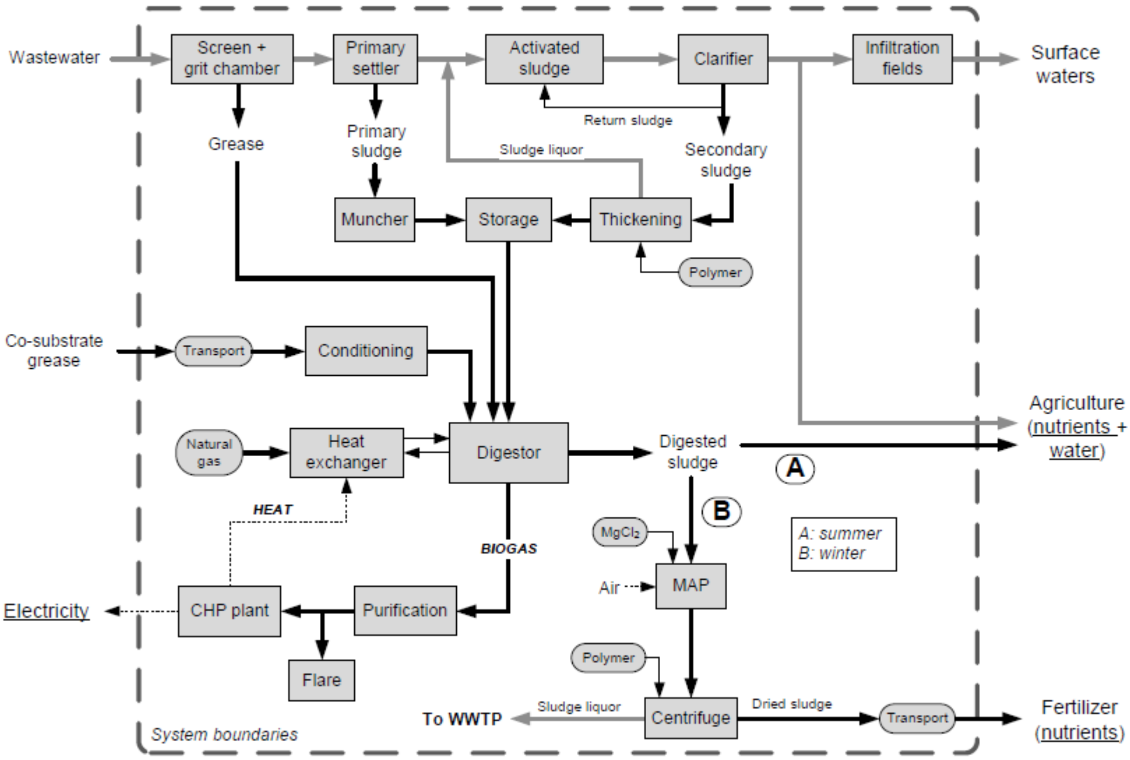


Figure 4 The wastewater treatment scheme in Braunschweig in the year 2010
(as developed by Remy 2012; secondary products are underlined)

Sewage sludge is stabilized via anaerobic digestion and, since 2001, digested sludge is added to the treated effluent during the growing season. It acts as a fertilizer in agriculture (Lindner, 2015). During the winter and a short summer period (four weeks), 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). As a result, currently 100% of the sludge produced per year is spread and reused on agricultural fields (De Paoli, 2014).

Table 4 Amounts of sewage sludge in the wastewater treatment process in Braunschweig
Source: Abwasserverband Braunschweig, 2016

Type of sludge	Amount of total solid content per year
Primary and activated sludge	6 800 t
Reduction of the amount through digestion by 30 %	2 050 t
Digested sludge	4 750 t
Of the digested sludge:	
Approximately 60 % irrigated within the area of the association	2 750 t
Approximately 40 % used in agriculture outside of the area of the association	2 000 t

3.1.1.3 Infiltration fields (in German: Rieselfelder)

About 45 % of the treated water is pumped into the historic infiltration fields[6] adjacent to the WWTP for post-treatment (Teiser, 2015). The 275 ha of infiltration fields (Abwasserverband Braunschweig, 2016) have been in operation for more than 100 years, which polishes the effluent naturally by soil passage. This occurs through physico-chemical (filtration + adsorption) or biological (nitrification / denitrification) processes (Remy, 2012). The wetland system is isolated from groundwater by a natural clay layer which avoids contamination (Teiser, 2015).

In terms of the management of the infiltration fields, a clear difference is made between the summer and the winter period. During the winter months, all treated effluent from the treatment plant is directed to this area[7]. This concerns in particular the months of December and January, and partly also February (if there is a lot of frost during this month) (Siemers, 2015).

Box 2 The functioning of the infiltration fields in detail

The treated effluent is led through a network of pressure pipes with a length of about 9 km to the about 25 discharge points on the infiltration field area. Through open distribution structures, channels and blanking discs it is possible to direct the effluent within the infiltration fields. Here it infiltrates through the upper soil layers, which allows a post treatment through plants and the micro-organisms in the soil.

Within the meandering system, the effluent is sent through a river-resembling course in a horizontal passage, so that an optimal post treatment takes place over several kilometers. A retention time of more than 10 days is ensured.

Source : Abwasserverband Braunschweig & SE/BS, 2009; Abwasserverband Braunschweig, 2016

Within the infiltration fields, hydraulic peak loads (heavy rain events) can be leveled off in large ponds and the meandering systems (Remy, 2012). The drainage of the infiltration fields takes place via a piping system. The collected polished effluent is finally discharged to surface waters via the Aue-Oker canal - which for its part flows into the river Oker. During the passage of the infiltration fields, both quantity and quality of the effluent are altered due to evaporation and precipitation or interaction with the soil ecosystem. This is usually improving the quality of the effluent. However, some problems exist with temporary releases of phosphorous, which has accumulated in the system, especially from the historic application of untreated wastewater on the fields. In particular in low flow conditions during the summer period oxygen depletion favours the re-dissolution of soil phosphorus and hydraulic peak loads may wash out particulate phosphorous (SE/BS 2010, in Remy, 2012). This leads to the fact that legal threshold values in the Aue-Oker canal are exceeded[8]. To ensure the treatment function of the system in the long term, solutions need to be found. It is therefore planned to install additional treatment steps, in particular a combination of thermal disintegration and thermal pressure hydrolysis, followed by nutrient recovery through MAP precipitation and NH_3-stripping (Siemers, 2015).

The infiltration fields have become an important biodiversity and recreational spot (for birdwatchers), as they provide a habitat for several bird species (De Paoli, 2014). About 300 bird species are living in the area, including Red List species like the red kite, the lapwing and the corncrake. Other examples are shelduck, jack snipe and common snipe (Stoller, 2014).

7 Actually this is the case only since recently (2013). Before, part of the effluent had been applied to the agricultural areas also during the winter period, to support groundwater recharge (Siemers, 2015).

8 The sampling point for the legal discharge limits to surface waters is located after the infiltration fields, prior to discharge into the Aue-Oker canal (Remy 2012).

3.1.1.4 Fields belonging to the members of the Abwasserverband Braunschweig (4)

The remaining 55%[9] 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).

A gravity sewer delivers the mixture to the agricultural fields (over about 10 km), where four large pumping stations operate in the different irrigation sectors. From there, subsurface pressure pipes bring effluent and sludge to the different hydrants, which are regularly distributed over the area. This requires 0.37 kWh/m³ to deliver a pressure of ~ 5 bar in the system (Remy, 2012). With the help of 175 mobile spray irrigation machinery belonging to the wastewater association, effluent and sludge is spread on the agricultural fields (Ripke, 2016 *pers. comm.*). The latter is done only by using the system pressure and does not need any additional energy (Remy, 2012).

"In case of high water demand for agriculture (e.g. in hot summer periods), effluent from the infiltration fields can be diverted to agricultural reuse by an additional pumping station near the discharge point to Aue-Oker canal" (Remy, 2012). Out of the 10.5 million m^3/year supplied to the irrigation fields, 3.24 million m^3/year[10] 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.*)[11].

3.1.1.5 Biogas plant Hillerse (5)

Maize and rye which are harvested from the fields irrigated with treated effluent and sludge are used as a basis for the production of energy and heating in the biogas plant *Hillerse*, which was constructed in 2007. The plant produces 19.3 million kWh of electricity (Abwasserverband Braunschweig, 2012) and delivers electricity to 6000 – 7000 households and heating to 1000 – 1500 households (Abwasserverband Braunschweig, 2014). The produced biogas is transported to Braunschweig via earth-laid pipelines and transformed to electricity and heat by the provider BS | ENERGY (Lindner, 2015).

Overall, around one third (38 %, according to Lindner, 2015) of the sprinkling area is used to grow maize and rye for biogas production. This concerns in total about 43 000 tons per year (average productivity: 60 tons/ha of maize, 35 tons/ha of rye) (Teiser, 2015). The daily "feeding" of the biogas plant requires 101t of maize silage and 16t of rye whole-plant silage (Teiser, 2013).

3.1.2 Implications of using reused water for agricultural practices

All farmers which own land in the sprinkling area are members of the Braunschweig Wastewater Association. This includes 434 owners of agricultural land[12] and 85 farmers (De Paoli, 2014). The use of treated effluent and sludge for agricultural purposes provides for some opportunities (e.g. low priced supply of water and nutrients), but entails also certain restrictions. Against this background, farmers belonging to the wastewater association cannot base their decisions (e.g. on the type of crop they cultivate) only on individual considerations of profit and convenience. They have to consider a collective dimension, taking into account the plans of the other farmers. This organisation of the wastewater irrigation is coordinated

9 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%).

10 KWB assumes for its calculations plant needs of 3.24 million m3 (KWB, 2016 pers.comm.).

11 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).

12 http://www.abwasserverband-bs.de/de/wer-wir-sind/organisationsstruktur/ (Accessed 09/08/2016)

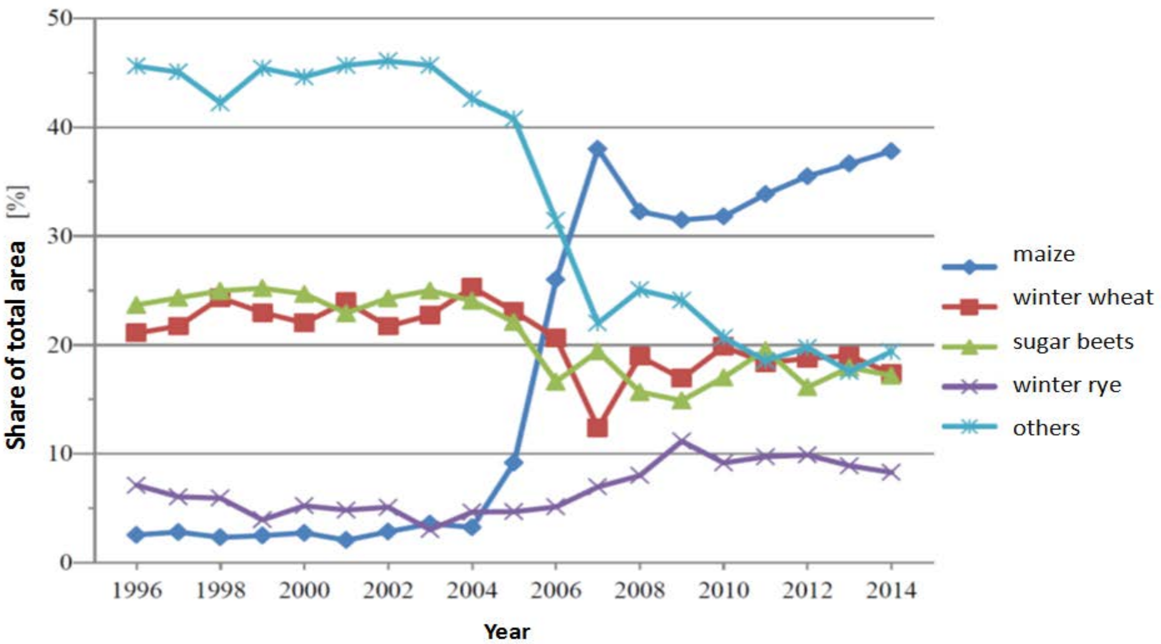
by the so-called Regenmeister, which are working for the sewage board (Ripke, 2016 *pers. comm.*). The resulting share of cultivated crops and the specificities of the water and nutrient management in the area of the Braunschweig wastewater association are further described in the following.

Overview of the crops cultivated in the area

As no water disinfection takes place, high safety standards are applied to minimize hygienic hazards to the population and food consumers (Remy, 2012): farmers cannot grow crops for direct, raw consumption, but rather crops used for energy purposes (particular varieties of maize and rye) and crops used for human consumption after processing, such as sugar beets (sugar) and rapeseed (for oil production) and grain (De Paoli, 2014). In addition, irrigation has to be stopped at least four weeks before the crops are finally harvested (Eggers 2008, in Remy, 2012).

Overall, more than 10 different crops are cultivated on the 2700 ha of cultivated land. The figure below shows the relative share of the different crops over time. Until 2005, the share of crops was relatively stable. After the start of operation of the biogas plant Hillerse, the share of maize increased to about 30-35% of the total area. After a period of transition, the relative share of crops stabilised again. The total area of crops cultivated is given in the table below (Klein et al., 2013).

Figure 5 Share of the different crops in the area of the wastewater association
Source: Lindner, 2015 (translated by the author)



Agricultural water and nutrient management

Next to constraints linked to hygiene aspects and the overall availability of effluent for irrigation, the fact that the system combines nutrient and water management implies a need to balance water needs with nutrient contents of the water conveyed to the sprinkling area. In spring, nutrients from reused water are not enough, and farmers have to complement with fertilizers, whereas in summer nutrients brought with reused water are sufficient to cover farmers' needs – but sometimes nutrients conveyed with reused water might exceed needs (Klein et al., 2013). Phosphorous, in particular, is the main constraint in nutrient management: irrigation water already includes a quantity of phosphorous very close to the crops' demand, so it is very easy to exceed this limit (De Paoli, 2014). Average nutrient loads and nutrient needs for the whole area of the Sewage Board are listed in the table below.

Table 5 Average nutrient loads and nutrient needs (kg/ha)
Source: Teiser, 2013

Nutrient	Load (kg/ha)	Needs (kg/ha)	Load (ton/year)
Nitrogen (NH_4, NO_3)	50	142	135
Phosphorus (P_2O_5)	69	70	185
Potassium (K_2O)	78	130	210
Sulphur (S)	105	25	
Magnesium (MgO)	38	45	100
Lime (CaO)	318	380	

The table below shows the nutrient loads in both the treated effluent and the sludge. It renders evident that the nutrient load in the irrigation water is mainly determined by the addition of sludge during the vegetation period (Klein et al., 2013).

Table 6 Nutrient loads in the wastewater flows for irrigation
* Assumption: Nutrient concentrations from water redirected from the infiltrations fields or the Aue-Oker Kanal (= double use of the water) corresponds to the concentrations from the plant effluent; ** extrapolated from operating data from g/kg of dry matter to mg/L
Note: only $N_{inorganic}$ is considered to be plant available; Source: Klein et al., 2013

	N_{total} average values [mg/L]	N_{inorg} average values [mg/L]	P_{total} average values [mg/L]
Treated effluent (discharge treatment plant)*	14.6	8.1	1
Total digested sludge**	3024	Not available	890
Mixed effluent/sludge in summer	45	28	15

In the current system there is a need to complement nutrients from effluent and sludge with (mainly) mineral fertilizer. Its relative importance varies, however, depending on the type of crop, and the type of nutrient. In the case of nitrogen, a study from Klein et al. (2013) showed that it is mainly (often to more than 70%) relying on additional fertilization. Overall, irrigation with treated effluent (and sludge, depending on the period of the year) provides comparatively low loads of nitrogen, but in a continuous way; whereas additional fertilization (mainly through mineral fertilizer) provides nitrogen only in specific moments in time, but in high quantity (Klein et al., 2013).

Fertilization needs regarding phosphorous, however, can be covered mainly through the irrigation with the treated effluent. Only in the case of maize the nutrient load brought through mineral fertilizer is higher in its importance compared to the loads brought by the irrigation with effluent and sludge (Klein et al., 2013). From the additional fertilization taking place for phosphorous, about one quarter is done through the application of (an organic) fermented substrate stemming from the biogas plant in Hillerse, which is - similar to the treated effluent and the sludge - a recycling product (Klein et al., 2013).

At present, about 45-55% of the total P- and N-loads which are in the treated effluent or in the sludge, respectively, are distributed for irrigation within the area of the wastewater association (Klein et al., 2013). This leaves leeway for the optimization of the process – by further replacing mineral fertilizers through nutrients stemming from the wastewater (some of which is already planned to be used in the future through the use of centrate, MAP-precipitation and NH_3-stripping). At present, the demand for additional fertilization in the area of the wastewater association is about 400 t/year for nitrogen, and 56 t/year for phosphorous (Klein et al., 2013).

Another constraining aspect of the agricultural reuse system lies in the fact that irrigation efficiency is low. As mentioned above, out of the 10.5 million m^3/year distributed via irrigation, only 3.24 million m^3 are used by the crops (KWB, 2015 *pers.comm.*). AVB (2011, in Remy, 2012) indicates, that the actual water needs for plant growth (depending on climatic variability) is 80-150 mm/(ha*a). The wastewater association, however, delivers about 400 mm/(ha*a). This fact is due to the historic development of the Braunschweig system and the only small natural receiving water body (the river Oker) (Remy, 2012), as well as the ability of the sandy soils to quickly absorb bigger volumes of water. To mitigate negative effects regarding hydraulic stress and water quality in the river Oker, a large part of the WWTP effluent has to be delivered to "soil treatment" in the agricultural area for an additional polishing. Farmers which are part of the sewage board have the privilege to receive water and nutrients at a low price, but at the same time they have the obligation to take the water under all conditions, even if weather conditions would not make it necessary (Ripke, 2016 *pers.comm.*). The reuse system is hence not optimised for the needs of the farmers in terms of nutrients and water supply, but has to be seen in a historical perspective of an additional wastewater treatment step (Remy, 2012). With regards to the amount of groundwater irrigation that is effectively substituted by reused effluent, it can be set equivalent to the actual water demand of the farmers, i.e. to about 120 mm/(ha*a) on average (KWB, 2015 *pers.comm.*).

3.1.3 The future development of the Braunschweig Model

The Braunschweig model has constantly evolved in the past, and will continue to adapt to changing situations. Planned modifications in the short- and medium-term are going back in particular to the following factors: the current temporary problems to keep P-discharge limits from the infiltration fields, the potential prohibition to use sludge in agriculture following German legislation, and reflections on how to optimise energy and nutrient flows of the system.

Based on the recent changes in the German fertilizer regulation, requirements of the Water Framework Directive as well as the content of the current coalition agreement, it can be assumed that the agricultural use of sludge and as a consequence also its irrigation will be legally restricted in the future. In this case, the plant would no longer be able to mix irrigation water and sludge, and farmers would need to rely on other types of fertilizers. One possibility in this situation would be to extract (and stabilize) nutrients from the sludge through "ammonia stripping" and struvite (MAP) precipitation. This would allow using them in a way comparable to normal "chemical fertilizers", which farmers could then distribute on the fields independent from irrigation water. These more efficient techniques for nutrient recovery – which are currently in the planning phase – would also address the issues of nutrient overloads from the infiltration fields in winter time. Although the system is not yet in place, agreements have already been made with the farmers of the wastewater association, ensuring that the secondary raw material fertilizers which would be produced would be provided for members of the association (Siemers, 2015). A selective spread of nutrient rich centrate on the fields could complement the system (Siemers, 2015).

Not spreading sludge together with the irrigation water anymore provides also some possibility to change irrigation management. More efficient irrigation techniques could be used, and accordingly, more fields could be irrigated with the available water. With regards to the possibility that German and/or European legislation could also get stricter for hygiene requirements for wastewater reuse in agriculture, another potential treatment step could be the disinfection of the water before its use in form of irrigation. In this case, farmers would not be restricted anymore concerning the type of crops they produce. This is, however, so far only under discussion (Siemers, 2015).

3.2 Description of case study specific benefits and costs

In the case of Braunschweig, the wastewater which is reused in the agricultural fields does not receive any particular additional treatment. It is of the same water quality as the water directed to the infiltration fields. Accordingly, the water reuse does not cause any costs within the treatment plant, as no specific, additional treatment is required. As a consequence, the resultant use once the treated effluent leaves the plant is of interest for cost and benefit considerations. The different areas of costs and benefits of the current reuse situation in Braunschweig are listed in the table below and will be further described afterwards.

Table 7 Cost and benefit categories of the current water reuse system in Braunschweig

Costs	Benefits
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 co-operation) 4. Spray protection hedgerows (*Sprühschutz-hecken*) 5. Drainage system 6. Health risk for field workers	1. Avoided distribution of effluent to the infiltration fields 2. Avoided groundwater pumping (pumps and energy consumption) 3. Savings of mineral fertilizer 4. Avoided alternative disposal of sewage sludge 5. Preservation and restoration of local groundwater bodies 6. Preservation of the river water quality 7. Local water-nutrient-energy cycle

Instead of all water being directed to the infiltration fields, the mixture of treated effluent and sludge is directed to the agricultural fields by a gravity sewer. Four large pumping stations are operating in the different irrigation sectors, and subsurface pressure pipes bring effluent and sludge to different hydrants, which are regularly distributed over the area.

For the actual irrigation, 175 mobile irrigation machines are deployed (status April 2016). Within the sewage board, twelve persons are working full time on irrigation, moving machines from one location to the next. In addition, the garage of the sewage board occupies two persons responsible only for the reparation of the irrigation equipment (Ripke *pers. comm.*, 2016).

Although the water reuse system supplies farmers with water and nutrients, it is also restricting their agricultural activities. For example, the cultivation of crops for direct consumption is forbidden. Furthermore, additional cooperation between farmers is required to agree on the location of the irrigation machinery. These consultations are managed by designated staff of the sewage board (so called "*Regenmeister*").

As part of the requirements imposed by the local water authority, spray protection hedgerows need to be maintained in parallel to housing areas and public roads in order to avoid undesired dispersal of the wastewater and to minimize health risks for the surrounding population. As during wastewater irrigation high volumes of water are applied to the fields, a drainage system is in place which gathers excess water. Finally, due to the fact that irrigation water is not disinfected, health risks exist for field workers.

The available quantified information on costs is summarized in Table 8. Their dimensions (e.g. number, length, size, etc.) are further detailed and monetary values are provided as far as possible.

Table 8 Cost elements of the current wastewater reuse system in Braunschweig

	Cost element	Description of individual elements and quantification	Monetary values	Source
1.	Distribution of effluent and sludge to the fields of the Sewage Board (pumping, pipes)	1) gravity sewer (10km length) 2) four large pumping stations (constructed between 1955 and 1966, energy requirements of 0.31 kWh/m^3) 3) subsurface pressure pipes 4) hydrants 5) an additional pumping station near the Aue-Oker-Kanal[13] (used in moments of high water demand, e.g. in hot summers)	1) No costs: Investment costs not relevant (dating back longtime and established before reuse). Negligible maintenance costs. [assumption] 2) For the pumping stations of the infiltration fields, the plant manager assumes a lifetime of 20 years and renewal costs which lie 15% above the initial investment costs. The same lifetime and renewal costs could be applied here [assumption]. However, no information on initial investment costs is available. Assuming investment costs in the same order of magnitude as for the pumping station near the Aue-Oker-Kanal (see point 5)) would correspond to total investment costs of 2 640 000 EUR. 3) Energy price: 0.12 EUR/kWh. With 10.5 million m^3 led to the infiltration fields the energy costs are: 390 600 EUR/year (for 3 255 000 kWh consumed per year). 4) Assumption of negligible maintenance costs. 5) Assumption of negligible maintenance costs. 6) Constructed in 2004 for 660 000 EUR; Lifetime of 30 years; 2 000 EUR maintenance costs per year	Plant manager regarding maintenance costs. KWB (2016 *pers.comm.*) for energy requirements; For the energy price: Miehe and Stüber 2016 Plant manager Author assumption Siemers (2016 *pers.comm.*) for cost information
2.	Mobile irrigation machinery (equipment, use, reparation)	1) Currently (May 2016) 175 mobile irrigation machines are in use. Machines introduced in the 1970s: 7 machines from 1974-1979 still in use today, most recent machines from 2016. 25 machines are stemming from the last 5 years. The objective is to add or exchange 5 machines each year.	1) Investment costs of machines: Current price of a mobile irrigation machine: 25 000 EUR 2) Salary of irrigation personal: 40 000 EUR per year, being 480 000 EUR in total. 3) Maintenance costs for irrigation machinery: 130 000 EUR per year. Plus salary costs of 40 000 EUR for each of the two mechanics.	For 1), 2) and 3) Ripke (2016, *pers.comm.*)

[13] German term:

	Cost element	Description of individual elements and quantification	Monetary values	Source
		2) 12 persons in the sewage board are working exclusively on irrigation. 3) For maintenance (reparation) the sewage board possesses its own garage with two full time workers.		
3.	Restrictions to the agricultural management (restrictions on crops, increased need for cooperation)	Four persons of the sewage board (so-called *Regenmeister*) are exclusively occupied with coordinating irrigation activities of the associated farmers. Restrictions regarding the types of crops which are cultivated are not valued.	Salary of the Regenmeister: 42 000 EUR, leading to total costs of 168 000 EUR per year.	Ripke (2016, *pers.comm.*)
4.	Spray protection hedgerows (*Sprühschutzhecken*)	120 km length. Hedgerows need to be regularly cut.	Investment costs unknown and assumed to be negligible (from the 1950s). Maintenance costs: 260 000 EUR per year (including labour, tools, etc.).	Ripke (2016, *pers.comm.*)
5.	Drainage system		Investment costs unknown and assumed to be negligible (no new investments since at least 24 years). Maintenance costs: 20 000 EUR per year.	Ripke (2016, *pers.comm.*)
6.	Health risk for field workers		No quantification available[14].	

[14] Specific methods exist to quantify and monetize health risks. Doing this was, however, out of the scope of the current study.

Farmers are currently paying 81 EUR per hectare and year for their membership to the sewage board and the irrigation service. The level of the fee has not change in the last 15 years (Ripke, 2016 *pers.comm.*). According to the sewage board, the fee is, however, not high enough to cover the costs of the irrigation system. This is on the one hand due to the fact that it has not been revised since several years. At the same time, the fee has been calculated in a way to take the disadvantages into account, to which the farmers are subject while receiving wastewater for irrigation. The value for the farmers of the irrigation water stemming from reuse amounts consequently to at least 81 EUR per ha, or 218 700 EUR in total. It can be interpreted as a proxy (here a minimum) value of the benefits of the reuse system for the farmers. In the following, the different benefits of the reuse system are attempted to be quantified separately.

Compared to a situation without wastewater reuse, the avoided distribution of effluent to the infiltration fields can be accounted for as benefits as well as the avoided groundwater pumping. Furthermore, stopping reuse activities would increase significantly the amount of water directed to the infiltration fields. According to the plant manager, however, assuming a good effluent water quality from the treatment plant, part of the treated effluent could be directly discharged into the Aue-Oker-canal, without requiring pumping stations. The volume is estimated to be about 5 million m^3, leaving 5.5 million m^3 to be directed in addition to the infiltration fields (Siemers, 2016 *pers.comm.*).

Furthermore, nutrients which are brought to the agricultural fields through effluent and sludge partly replace the use of mineral fertilizer. The current mixture with sludge is furthermore linked to cost savings for the treatment plant, as alternative disposal of sludge is avoided.

The environmental benefits, which will be described in more detail in the following chapter, include in particular the preservation and the restoration of local groundwater sources and the preservation of the river water quality. Whereas for example costs and benefits (the latter mainly in the form of avoided costs) for farmers could be partially approximated through existing market values, this was not the case for the environmental benefits. In order to obtain monetary estimations of their value, the implementation of a specific valuation method – the contingent valuation method – was necessary in order to determine the value the population of Braunschweig is attributing to the environmental benefits generated by the reuse scheme. Finally, also the fact that the water-nutrient-energy-cycle constitutes a local circular economy system is valuable, as it increases amongst others the local resilience of the socio-economic system.

Table 9 Benefit elements of the current wastewater reuse system in Braunschweig

	Benefit element	Description of individual elements and quantification	Monetary values	Source
1.	Avoided distribution of effluent to the infiltration fields	5.5 million m^3 would be directed to the infiltration fields in the case of no reuse. Energy needs for pumping to the infiltration fields: 0.076 kWh/m^3 Due to the higher amount of water, part of the pipeline network would need to be renewed.	Energy price: 0.12 EUR/kWh (value from 2015). Total (additional) energy costs: 50 160 EUR/year. (Or 95 760 EUR/year if all water would be led to the infiltration fields). Costs for renewal of part of the pipeline system to cope with higher water volumes: 1.8 million EUR	For energy requirements: KWB (2016, *pers.comm.*) For the energy price: Miehe and Stüber 2016 For costs of renewing the pipeline system: Siemers (2016, *pers.comm.*)
2.	Avoided groundwater pumping (pumps and energy consumption)	Without wastewater irrigation, water would be taken from the groundwater. Overall costs of agricultural groundwater pumping are available for the Land Lower Saxony.	2.30 EUR per mm (includes both variable and fixed costs). By 120 mm of irrigation (actual plant needs) the costs amount to 276 EUR/ha. The total avoided costs for the whole area of the sewage board (2700 ha) are hence 745 200 EUR.	Ripke (2016, *pers.comm.*) for costs. KWB (2015, *pers. comm.*) for actual plant needs
3.	Savings of mineral fertilizer	The reuse system in Braunschweig allows savings of mineral fertilizer, in particular phosphorous and nitrogen are distributed on the fields through both the treated wastewater (8.2 tons of P/year; 99.1 tons of N/year) and the sludge (77.7 tons of P/year; 305.4 tons of N/year).	Price of mineral fertilizer per kg: 2 EUR for phosphorous; 1 EUR for nitrogen. Savings through irrigating treated wastewater for the whole area: 16 400 EUR/year for P; 99 100 EUR/year for N (calculations are based on the amount of nutrients conveyed through the irrigation of treated wastewater and the price of mineral fertilizer). Savings through irrigating sludge for the whole area: 155 400 EUR/year for P; 305 400 EUR/year for N (calculations are based on the amount of nutrients conveyed through the irrigation of sludge and the price of mineral fertilizer). Total cost savings linked to mineral fertilizer for all the farmers: 576 300 EUR/year. This corresponds in average to cost savings of 6780 EUR/year per farmer (85 farmers).	SE/BS (2013), in Lindner, (2015) for amounts of nutrients. Klein et al. (2013) for fertiliser prices.
4.	Avoided alternative disposal of sewage	2750 tons of dry matter are currently irrigated on the sewage board fields.	1) Costs of dewatering of all sludge and disposal on agricultural fields outside the area of the sewage	1) and 2) Ripke (2016, *pers.comm.*)

	Benefit element	Description of individual elements and quantification	Monetary values	Source
	sludge	Different alternative ways of disposal of sludge are possible: 1) dewatering of all sludge and disposal on agricultural fields outside the areas of the sewage board (as it is currently done with the winter sludge). 2) Burning the sludge (in particular if agricultural disposal is not allowed anymore in the future.	board: about 140 EUR per ton of dry matter, leading to total avoided costs of 385 000 EUR per year. 2) Costs for burning sludge: 208 EUR per ton of dry matter, corresponding to total avoided costs of 572 000 EUR per year.	
5. / 6.	Environmental benefits: Preservation and restoration of local groundwater bodies and Preservation of the river water quality	The two environmental benefits have been valued via the application of a contingent valuation study (see section 3.3). The aggregated value can be calculated based on the number of households in Braunschweig: 128 885 (in 2011).	The mean willingness to pay for maintaining the environmental benefits linked to wastewater reuse is 40.56 EUR/year. The median value is 24 EUR/year. The total aggregated value (for all households) of the environmental benefits lies hence between 5 227 575 million EUR per year and 3 093 240 million EUR per year (see section 3.3 for more information).	Landesamt für Statistik Niedersachsen (2014) for number of households. Own calculations for willingness to pay.
7.	(Local water-nutrient-energy cycle)	(Some reflections and calculations can be found in Maaß and Grundmann (2016).)		

3.3 Evaluation of environmental benefits

In the following, the environmental benefits of the reuse system in the case study area will be described in more detail. This is followed by the reasoning applied for choosing the environmental benefits for evaluation as well as the evaluation method. Some key information on the survey is provided before the survey results are presented.

When looking at the environmental benefits of water reuse, reduced pressure on existing water resources is in most of the cases the obvious primary environmental benefit of the system. In Germany, which is overall a water rich country without problems of scarcity, this benefit is less obvious. However, the existing hydrological deficit around Braunschweig as well as the sandy soils make irrigation necessary for agriculture, putting pressure on local groundwater bodies.

Another important benefit of the reuse system lies in the fact that distributing treated effluent on the fields reduces the amount of wastewater which is directed (via the infiltration fields) to the river Oker. This reduces the nutrient load reaching the local surface water body, and – as a consequence – the risk of eutrophication. Reusing nutrients of the effluent (and the sludge) furthermore leads to avoiding the use of mineral fertilizer, which has also environmental benefits (e.g. savings of phosphorous, a limited resource). And finally, the whole system which has developed around the wastewater reuse in Braunschweig (including the production of biogas based on biomass produced on the fields of the sewage board) has different environmental and social benefits, linked to the establishment of a local circular economy.

However, as many different factors contribute to the circular economy system in Braunschweig (e.g. the choice of the farmers to grow biomass, the existence of the biogas plant) benefits linked to it cannot exclusively be attributed to the wastewater reuse, and will hence not be further quantified. Regarding the replacement of mineral fertilizer, it is assumed that by accounting for the market prices of phosphorous, these benefits are taken into account.

The infiltration fields (*Rieselfelder*) are part of the post-treatment of the wastewater treatment process. They constitute a valuable biotope in particular for bird species, and are used for nature observations. However, the infiltration fields would be in use also in the absence of the reuse system, so any environmental benefits linked to this area cannot be attributed to the reuse.

Following these considerations, the environmental (and social) benefits which seemed most relevant for being quantified (and monetized) via an environmental evaluation method are the preservation and recharge of the local groundwater bodies as well as the preservation of the local river water quality. The physical description of the benefits linked to the water reuse system will be provided in the following, before describing the applied evaluation method and the results.

Preservation and recharge of local groundwater resources

The areas around Braunschweig show a seasonal water deficit during the summer period, which will probably increase under the impacts of climate change, as rainfall might further shift to the winter months. Sandy soils with a low water storage capacity further contribute to the need for irrigation of agricultural land to ensure productivity (Landwirtschaftskammer Niedersachsen, 2011). In some parts of the metropolitan region Hannover-Braunschweig-Göttingen, competition with drinking water needs is possible, while drinking water is of course given the priority. Groundwater substitution efforts are mainly undertaken to secure agricultural water use, in particular in view of potential future demand in terms of foods and energy crops as well as with regards to climate change. One of the adaptation strategies at regional level is the substitution of groundwater, and at local level the regeneration of groundwater bodies (Landwirtschaftskammer Niedersachsen, 2011)[15].

Using treated effluent for irrigation provides a solution for a tight groundwater situation: it counteracts the potential drop of the groundwater level and protects hence the quantitative status of the local groundwater body. It is furthermore a preventive measure, as irrigation takes intentionally place above the level of the actual plant needs, which in addition recharges the groundwater bodies. However, quantifying the environmental benefits linked to the protection of the local groundwater resources is difficult. Some figures and information will be provided in the following in order to frame the situation.

In the context of the implementation of the Water Framework Directive, the coordination area of the River Weser has been subdivided in different examination areas (*Betrachtungsräume*). The irrigation fields of the Abwasserverband Braunschweig lie in the examination area Obere Aller, which consists of 16 different groundwater bodies.

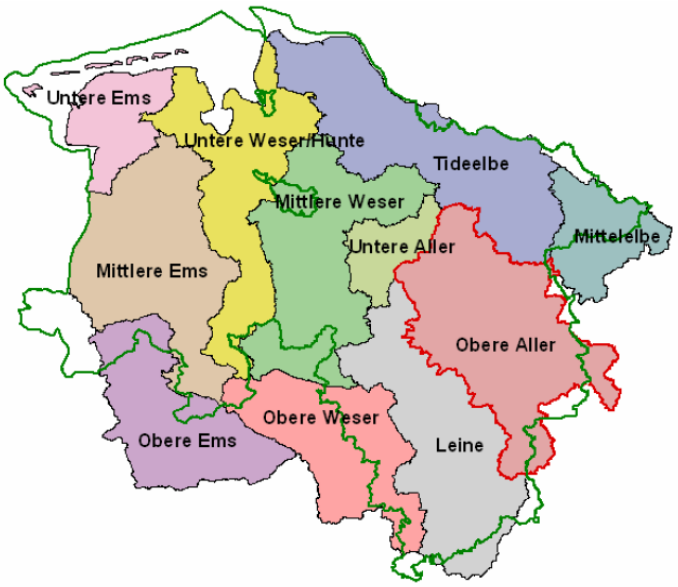


Figure 6 Groundwater examination areas in Lower Saxony
(Note: Limit of Lower Saxony in green; limit of the groundwater examination area in red; Source: NLfB & NLÖ 2005)

The area of the wastewater association is shown in the Figure 7. When comparing its location with the limits of the groundwater bodies (Figure 8), it turns out that the groundwater bodies lying below the irrigation area are mainly the two following ones: Oker Lockergestein links and Fuhse Lockergestein rechts (Figure 9). Whereas the first one is mainly entirely lying in the area of the Abwasserverband Braunschweig, only a small part of the second one is concerned.

15 However, at present, no restrictions of (permitted) water use in dry periods could be identified. The Wasserverband Gifhorn, for example – one of the municipalities in which the irrigation fields of the Abwasserverband Braunschweig are situated – indicates that also during the drought period in the summer 2003, a sufficient amount of water had been available all the time. Groundwater is taken from depths of up to 110 m, which are not affected by drought periods on the surface.
Source: http://www.wasserverband-gifhorn.de/index.php?option=com_content&view=article&id=126:wird-das-wasser-im-sommer-knapp&catid=44:nuetzliche-informationen&Itemid=70

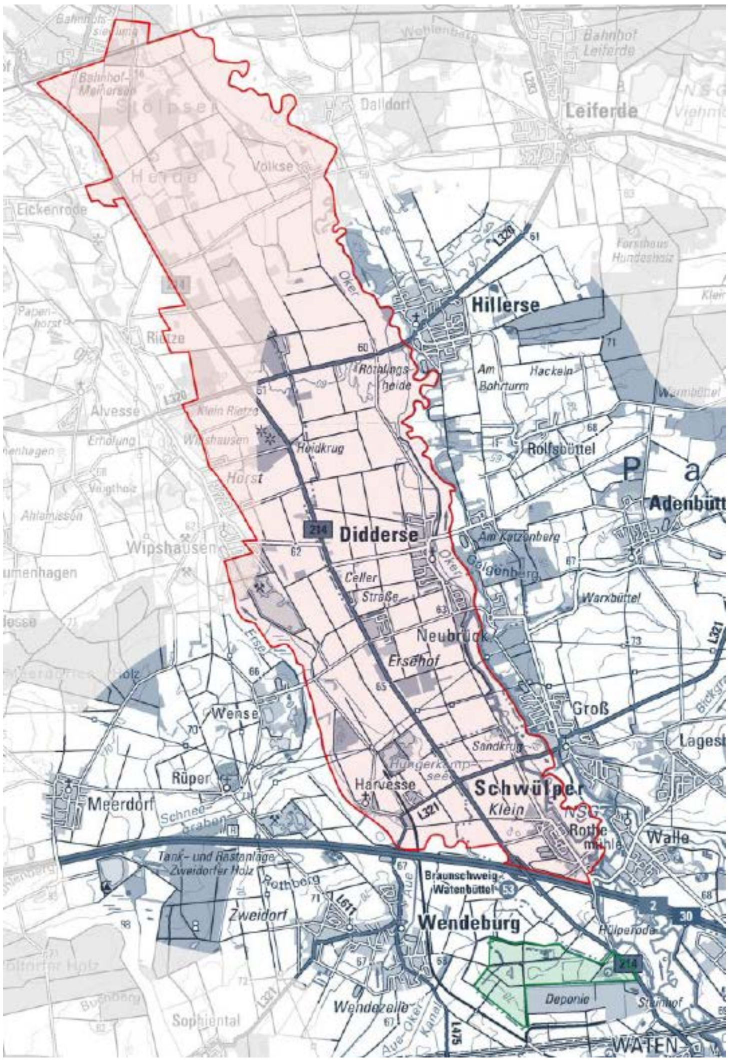


Figure 7 Area of the wastewater association Braunschweig, including the irrigation areas
(Note: red line: irrigation area; green line: infiltration fields; Source: http://www.abwasserverband-bs.de/de/wer-wir-sind/verbandsgebiet/ (Last access: 21/05/2015))

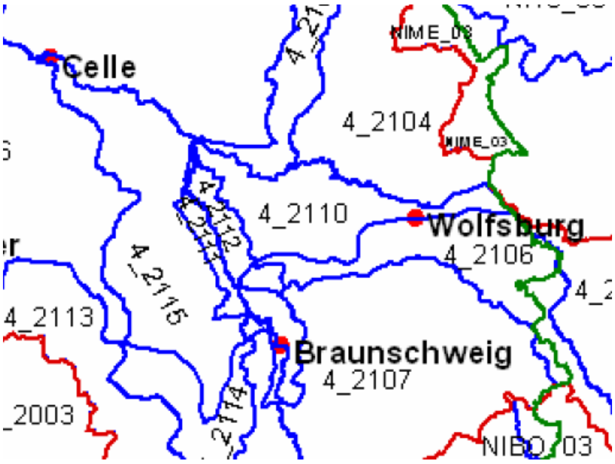


Figure 8 Limits of the groundwater bodies around the irrigation fields
(Source: NLfB & NLÖ 2005)

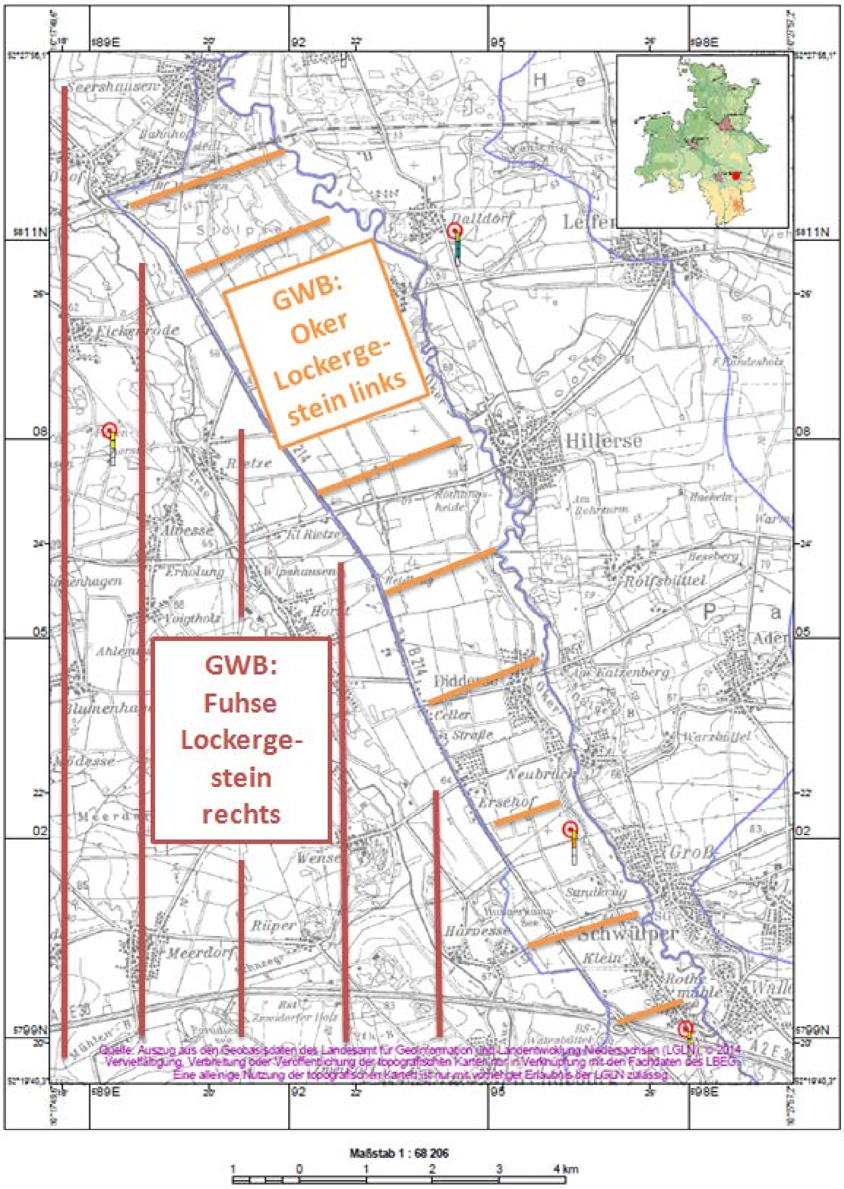


Figure 9 Location of the two groundwater bodies in the area of the Abwasserverband Braunschweig
(Note: GWB = Groundwater body; Source: Own elaboration, based on the following data source: http://nibis.lbeg.de/cardomap3/?TH=1348&lang=de#)

The Table 10 provides some key figures on the two groundwater bodies. To get a first idea on the current quantitative pressures on the groundwater bodies, existing rights for water abstraction can be compared to the groundwater recharge rate (calculated based on rainfall, evaporation, etc. independent from the infiltration of treated effluent). In the groundwater body “Oker Lockergestein links”, water rights for 35% of the groundwater recharge rate are provided. However, finally only 20% of the yearly replenishment is used. For the groundwater body “Fuhse Lockergestein rechts”, the corresponding figures are 43% of permitted abstraction and 24 % of actual water abstraction compared to the annual recharge.

Table 10 Basic characteristics of the two groundwater bodies lying in the area of the Abwasserverband Braunschweig
(Data source: NLfB & NLÖ 2005a)

Name of the groundwater body	Oker Lockergestein links	Fuhse Lockergestein rechts
Groundwater body code	4_2111	4_2115
Total surface [km²]	65	461
Groundwater replenishment [m^3/a]	6,457,970	53,352,480
Permitted water abstraction for public water supply [m^3/a]	0	2,804,000
Permitted water abstraction for irrigation or industrial water [m^3/a]	2,250,300	19,968,601
% of permitted abstraction compared to annual recharge	35%	43%
Actual water abstraction [m^3/a]	1,265,457	12,842,378
% of actual water abstraction compared to annual recharge	20%	24%

From the treated effluent spread to the fields of the Braunschweig wastewater association, 3.24 million m^3 are absorbed by the plants. To keep the same level of agricultural activities without using treated effluent, at least this amount of water would need to be abstracted from groundwater (depending on the efficiency level of the irrigation technique used). This is about half of the yearly replenishment of the groundwater body "Oker Lockergestein links". Together with the current, already existing water abstraction of 1.27 million m^3, this would amount to 4.51 million m^3 per year, or 70 % of the replenishment rate.

With regards to the importance of **additional groundwater recharge** through the wastewater distribution on the fields, this can be compared to the water consumption of the city of Braunschweig, in order to have an idea of the order of magnitude. In the area of the Abwasserverband Braunschweig, more than 7 million m^3 of water are distributed on the fields in addition to the crop needs, and are infiltrating every year in the soil towards the aquifers. With the total water consumption of the city of Braunschweig being about 13 million m^3 per year (Siemers, 2016, *pers. comm.*), the amount of additional recharge through the wastewater reuse scheme corresponds to more than half of the total drinking water consumption and can hence be considered to be a significant amount of water. In general terms, recharging groundwater bodies increases the resilience regarding potential negative consequences of climate change.

Preservation of the river water quality

Once the treated wastewater leaves the wastewater treatment plant Steinhof, the part which is not reused is directed to the infiltration fields for post-treatment step, before it reaches the nearby river Oker. While passing through the infiltration fields, part of the excess nitrogen and phosphate is removed through natural processes. Without the agricultural water reuse system, all water treated in the treatment plant would be led to the infiltration fields. The plant manager (Siemers, 2015, *pers. comm.*) estimates that this would double the amount of water which would reach the Oker. He assumes (under some uncertainty), that the concentration of nitrogen and phosphorus in the discharge would remain equal, leading to a doubling of the absolute amounts of nutrients reaching the surface water body. This could lead to exceeding allowed thresholds and increases the local risk of eutrophication.

Evaluation questionnaire

In order to evaluate the benefits of both the preservation and recharge of the local groundwater resources and the preservation of the river water quality, the contingent valuation method has been selected as the most appropriate evaluation method. The technical aspects of the contingent valuation technique and the construction of the questionnaire are presented in Demoware deliverable 4.3 "CBA approach suited for water reuse schemes" (Zayas et al., 2016). The contingent valuation survey has been carried out by a professional survey company. The questionnaire was filled in online, with a contact person being available on the phone for support in the case of questions. The survey has been carried out with 300 persons living in the city of Braunschweig, respecting quotas for income and age groups in order to ensure the representativeness of the sample. The survey has been carried out in January and February 2016.

Demographic characteristics of the sample survey

From the survey sample, 45% of respondents were males and 55% were females. Figure 10 provides information regarding the age distribution of respondents. As can be seen, a large portion of respondents (51%) were between 25 and 54 years old.

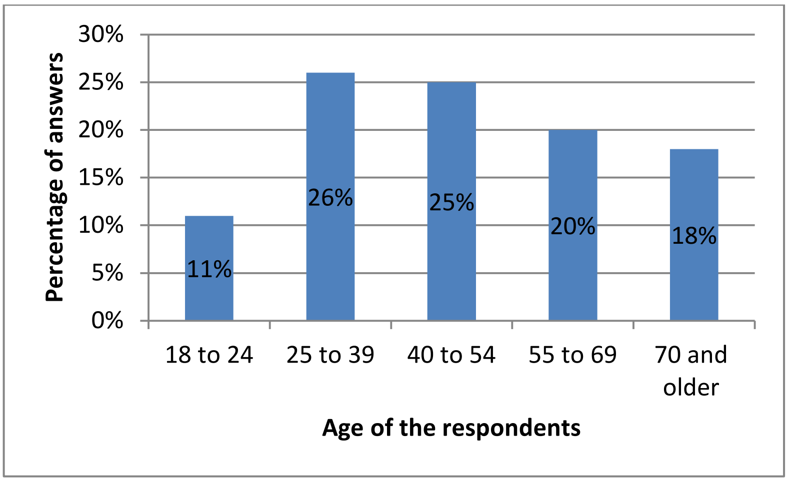


Figure 10 Age distribution of respondents in the sample

Figure 11 presents the distribution of respondents according to revenues. As can be seen, only 5% of respondents declared an overall income (for the household) lower than 1000 EUR/month. Half of the respondents reported an income ranging between 1000 and 3000 EUR/month, while 36% of respondents reported an income higher than 3000 EUR/month.

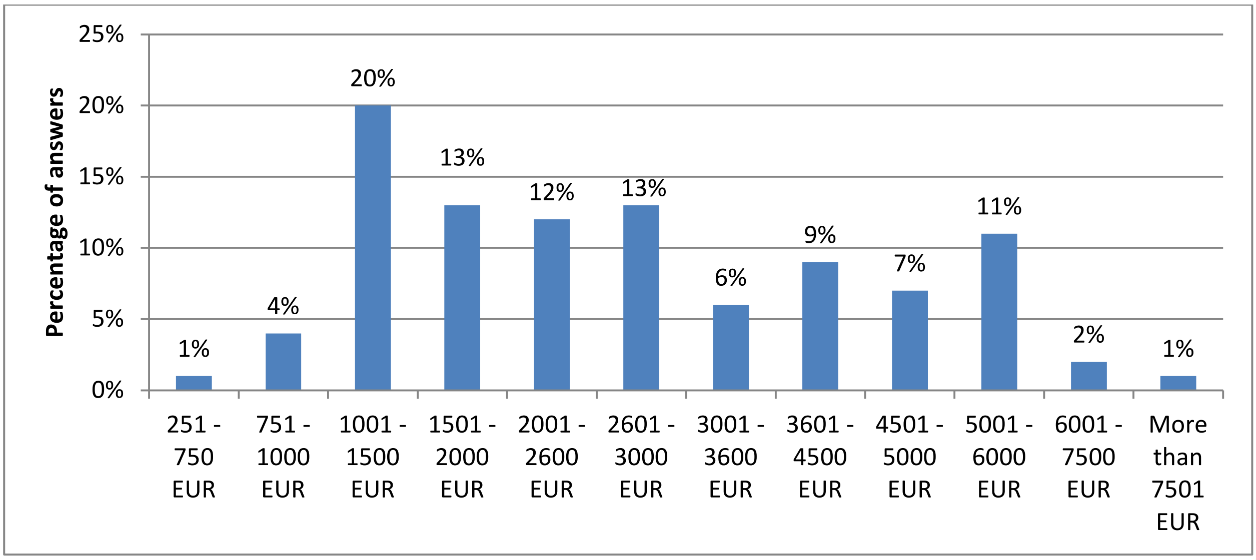


Figure 11 Monthly income distribution of respondents from the sample (per household)

Results of the evaluation of environmental benefits

The main results of the contingent valuation survey are provided in the following. From the survey sample, 82 % of all respondents were aware of the fact that treated wastewater could be reused (Figure 12). However, only 56% were aware that water reuse takes place in Braunschweig (Figure 13).

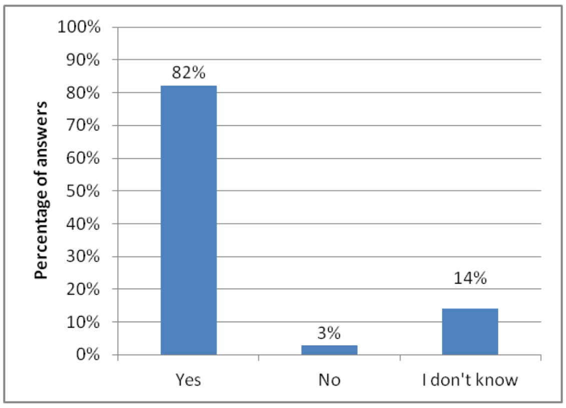


Figure 12 Belief regarding the possibility to reuse treated wastewater

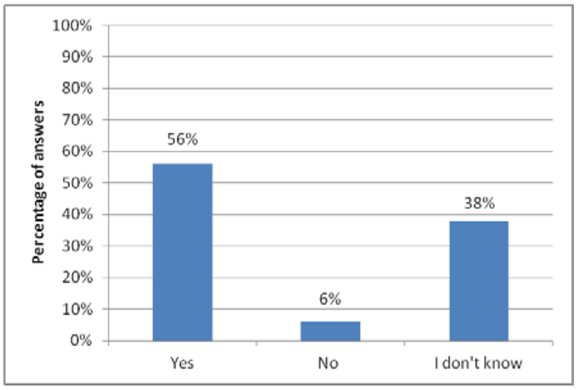


Figure 13 Belief regarding the existence of wastewater reuse in Braunschweig

More than three quarters of all interviewees are in general in favour of the idea of reusing treated wastewater. Only 2% were in general against (Figure 14). This represents a very high share of persons which are in favour of reusing wastewater, with the small restriction that 17% consider not having enough information about the subject, showing that there is leeway for communication efforts.

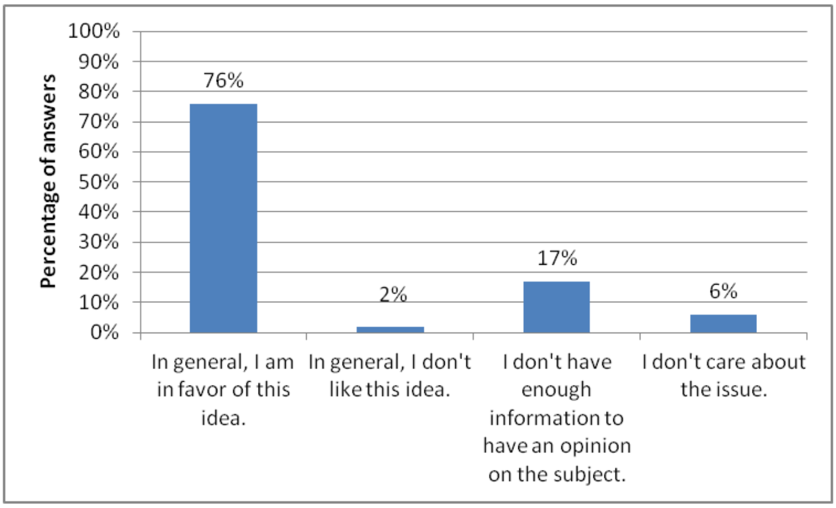


Figure 14 General preference regarding the possibility to reuse treated wastewater

When asked about the uses for which they would accept reused water in general, all proposed uses received a very high rate of acceptance (respondents answering with "agree" or "neutral") apart for the use of reused water for drinking water purposes, for which 56% disagree. 14% and 18% of the respondents disagreed with the use of reused water for artificial groundwater recharge and irrigation of crops for direct consumption, respectively. For all other proposed uses (toilet flushing, industrial uses and irrigation of crops which are either transformed before consumption or used for energy production), the rate of disagreement lied only between 2% and 6% among all respondents (Table 11).

Table 11 For what uses would you be willing to accept reused water in general?

		Irrigation of crops for direct consumption (e.g. vegetables, fruits)	Irrigation of crops which are transformed before consumption (e.g. cereals, sugar beets)	Irrigation of crops for energy production (biomass)	Industrial uses	Artificial groundwater recharge	Toilet flushing	Drinking water (tap water)
		Percentage	Percentage	Percentage	Percentage	Percentage	Percentage	Percentage
1	Disagree	18%	6%	2%	4%	14%	4%	56%
2	Neutral	26%	19%	16%	10%	37%	7%	29%
3	Agree	56%	75%	82%	86%	48%	89%	15%

The most important uses in the case of Braunschweig are irrigation of crops which are transformed before consumption, irrigation of crops for energy production and artificial groundwater recharge. The main reasons for the disagreement of the respondents for the water reuse in these cases are given in Figure 15. Irrigation of crops for direct consumption has been added, as it is the most likely other use which could potentially be considered in the future.

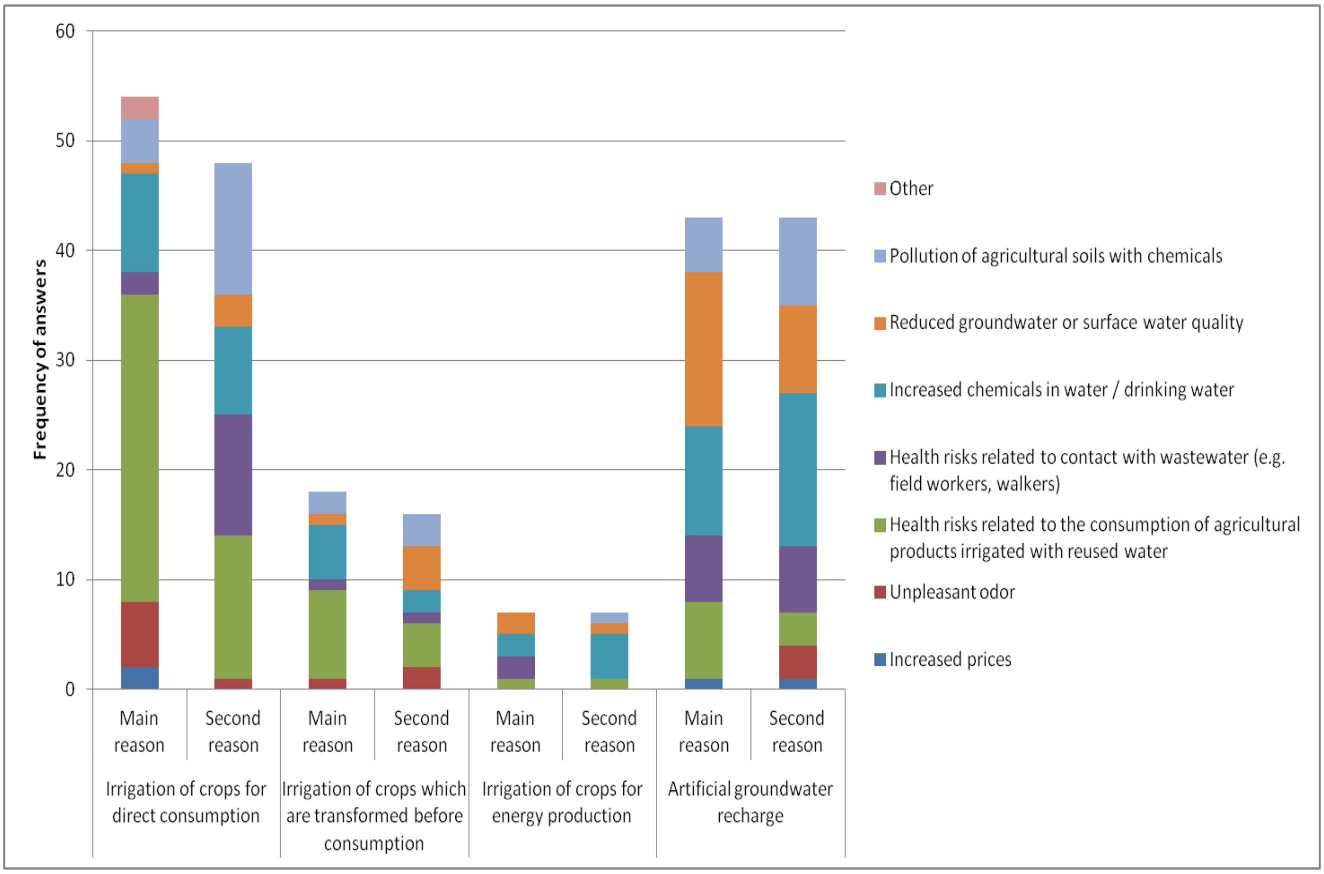


Figure 15 Reasons for disagreement per use – zoom on most relevant uses for Braunschweig – Frequency of answers

Health risks (either linked to the consumption of agricultural products irrigated with reused water related to the contact with wastewater) are the predominant reason for the disagreement with using wastewater for the irrigation of crops for direct consumption or for consumption after treatment. Health risks are also the most important reason for disagreeing with the use of wastewater for artificial groundwater recharge, including through the concern of having increased chemicals in water / drinking water (which also has often been given as a reason for disagreement in the case of irrigation with wastewater). However, in the case of artificial groundwater recharge, also the potential reduced groundwater quality has often been given as the reason for disagreement. The pollution of agricultural soils with chemicals is quite often cited as reason for disagreement with irrigation of crops for direct consumption, too. Although this risk exists of course also in the case of irrigation of other crops, the reason is not very often chosen in the other cases. Unpleasant odor or (potential) increased prices are the least chosen options.

The next set of questions relates directly to the current wastewater reuse system in Braunschweig. 63% of all respondents are either generally or completely supportive of the current system, and one third are indicating a neutral position. Only 4% of the respondents indicate to be against the current system (Table 12).

Table 12 How supportive are you of the water reuse system in Braunschweig?

	Answer	Percentage
1	Completely against	2%
2	Generally against	2%
3	Neutral	33%
4	Generally supportive	37%
5	Completely supportive	26%

With regards to the perceived benefits of water reuse in Braunschweig, 11% of the respondents did not see any benefit of the system. From the remaining 89%, the human driven, water quantity related benefits of ensuring that sufficient water resources are available to cover the whole demand and protecting water resources in view of climate change have been cited the most often. This was followed by the environmental benefit of improving the preservation of rivers, lakes and ground waters, which nearly half of the respondents cited among the three most important benefits. Increased species diversity and financial advantages for the wastewater treatment plant were the least chosen options (Figure 16).

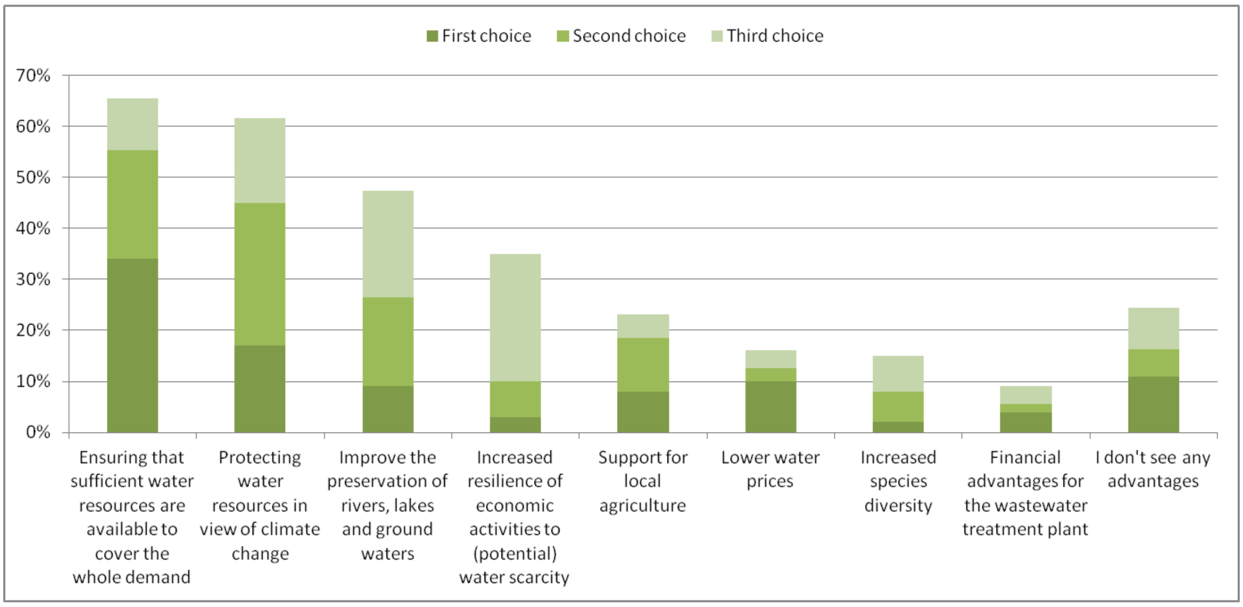


Figure 16 Perception regarding the most important benefits of water reuse in Braunschweig

Concerning the downsides of the current system, 32% of the respondents did not see any negative aspect. The remaining respondents mentioned in particular increased chemicals in water, pollution of agricultural soils with chemicals and reduced groundwater quality as perceived downsides. Health risks and unpleasant odour were cited approximately with the same frequency. Increased water prices were the least chosen option (Figure 17).

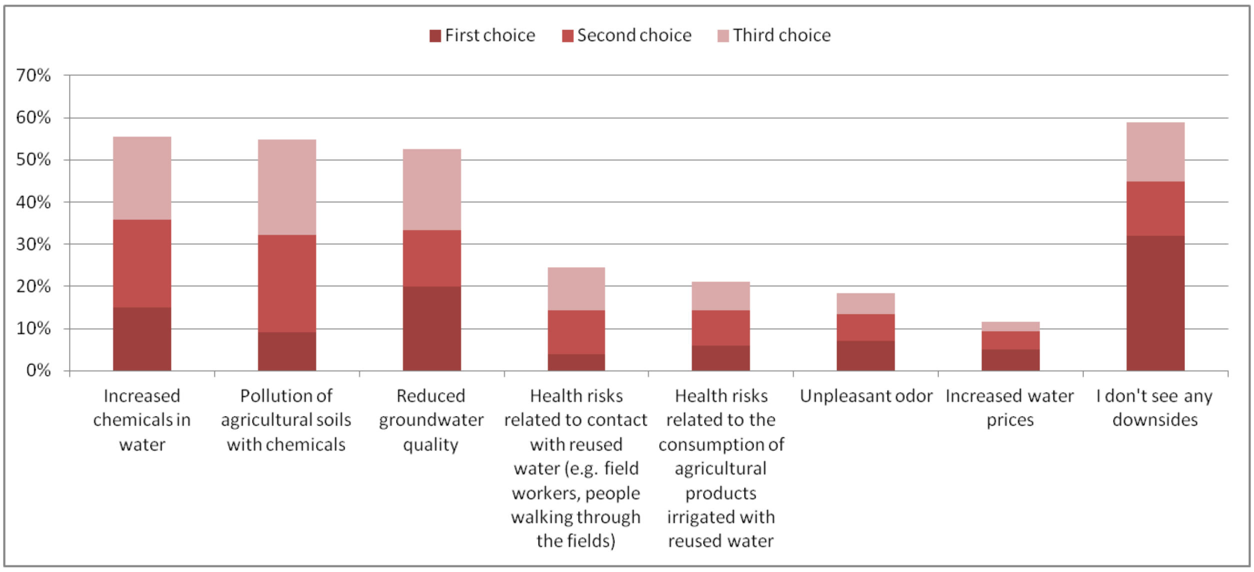


Figure 17 Perception regarding the most important downsides of water reuse in Braunschweig

When asked about their willingness to pay for preserving the current benefits in the form of a monthly contribution (on the water bill) for an environmental programme, agreement and refusal were 48% and 52%, respectively. Eighty-six percent of the respondents which accepted to contribute financially to preserving the benefits of the reuse system were ready to pay between 0.50 and 6 Euros in addition per month. The amount of 4 Euros is the one which has been chosen the most (Figure 18).

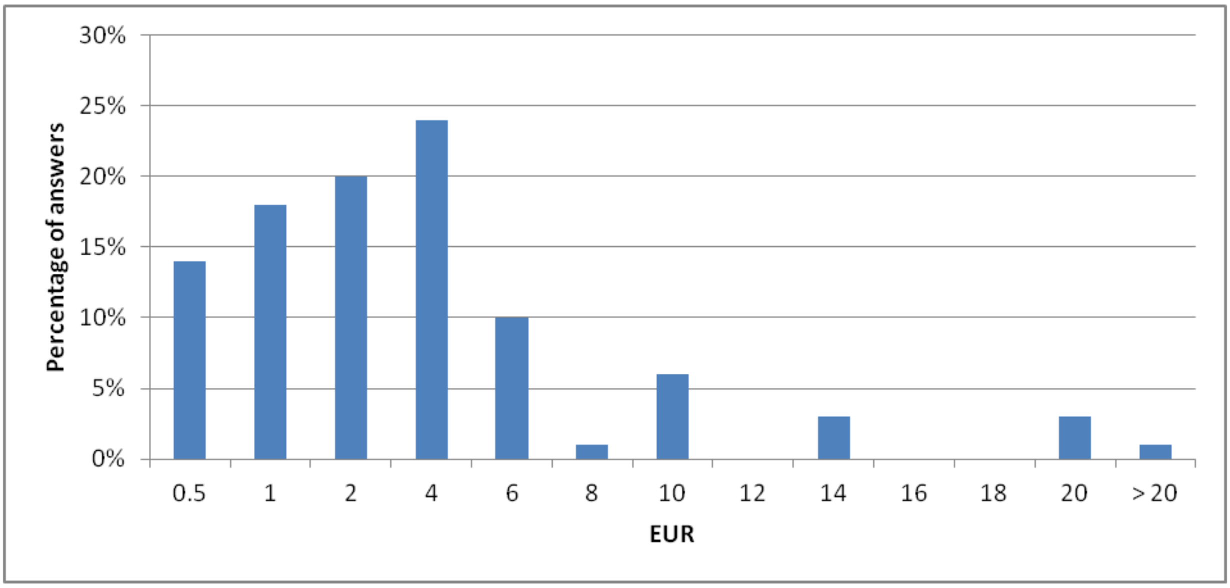


Figure 18 Accepted increase in the water bill (in euro per month and household)

From the 52% of respondents which were not willing to contribute financially to preserving the environmental benefits linked to the water reuse, the reasons which were provided the most often were "It is not me who should pay" and "I'm opposed to any form of increase in my water bill" (22% and 21%, respectively). Doubts in the proposed scenario were put forward by about 30% of the respondents which refused to pay, by choosing one of the following answers: "I don't think that the environmental protection program would work" (12%), "I'm not sure that my financial contribution will be used properly"

(10%) and "The described situation does not seem realistic to me" (10%). However, none of the respondents answered that the deterioration of the river water quality and the state of the groundwater is not a priority, indicating a high environmental awareness and an environmentally friendly attitude.

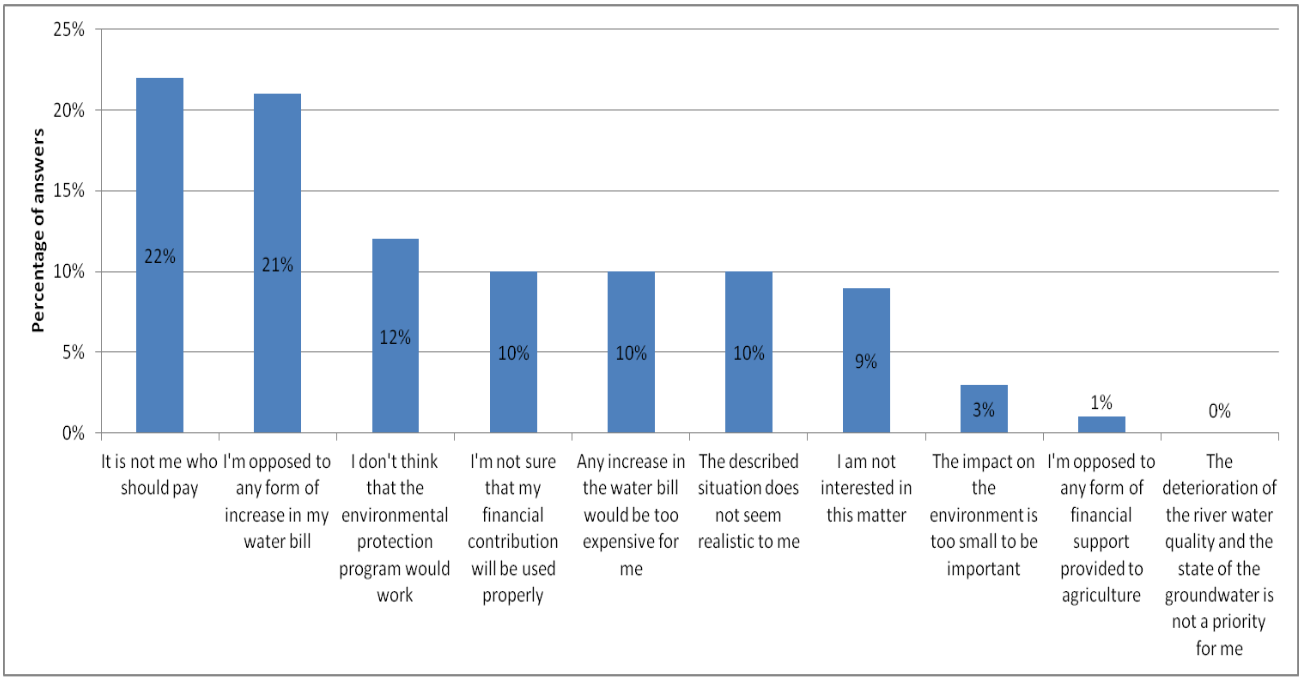


Figure 19 Reasons for refusal to pay

Reflections regarding the willingness to pay

Amongst the 300 respondents, 133 provided protest motives for unwillingness to pay. This means that – although they answered indicating that they are not willing to pay for sustaining reuse – the reasons they gave indicated that they valued the environmental benefits, but that they did not agree on the proposed scenario for other reasons. Protest responses need to be removed from the statistical analysis in order not to distort the calculation of the actual value of the environmental goods (see also Zayas et al., 2016). Amongst the protest responses, the main reasons provided for unwillingness to pay were: "It is not me who should pay" and "I'm opposed to any form of increase in my water bill" (see also Figure 19).

Amongst the 177 respondents providing valid responses, 33 provided true zero values for the proposed environmental improvements, meaning that 33 respondents (about 10%) were truly unwilling to pay for the proposed environmental benefits and did not attach any value to the environmental good. Amongst the valid zero values, the main reasons for unwillingness to pay were: "Any increase in the water bill would be too expensive for me" and "I am not interested in this matter" (see also Figure 19).

Based on the outcomes of the contingent valuation study, the mean willingness to pay for maintaining the proposed environmental benefits stemming from the reuse system in Braunschweig is estimated at 3.38 EUR/month or 40.56 EUR/year. This mean willingness to pay has been calculated based on all 177 valid responses and account for both the answers shown in Figure 18 and the 33 respondents which did not attach any value to the environmental benefits. The latter have been considered with a "zero willingness to pay". Thus, on average, households are willing to pay 40.56 EUR/year to maintain the positive impacts stemming from the reuse system in Braunschweig, in terms of preservation of the local groundwater bodies and the preservation of the water quality of the river Oker. Aggregated for the total number of households in Braunschweig (128 885 in 2011; Landesamt für Statistik Niedersachsen 2014), the estimated value of the environmental benefits linked to wastewater reuse in Braunschweig amounts to 5.2 million EUR/year, based on the mean willingness to pay[16].

The median willingness to pay provides another good estimation, being less sensitive to extreme values in the sample. The median willingness to pay is estimated at 2 EUR/month or 24 EUR/year, thus providing a more conservative estimation than the mean willingness to pay. Similar to the mean willingness to pay, the median willingness to pay has been calculated based on all 177 valid responses and account for both the answers shown in Figure 18 and the 33 respondents which did not attach any value to the environmental benefits. The latter have been considered with a "zero willingness to pay". Aggregated for the total number of households in Braunschweig, the estimated value of the environmental benefits linked to wastewater reuse in Braunschweig amounts to 3 million EUR/year, based on the median willingness to pay[17]. Both values are valid, and both values can be used to approximate the environmental benefits stemming from the reuse system in Braunschweig for the preservation of the regional water bodies.

A simple standard OLS regression[18] was used to assess the impact of selected socio economic characteristics on willingness to pay. Only the results relative to the best fitted regression and only statistically significant effects are presented:

In general, income level has a positive impact on willingness to pay, households having a monthly income greater or equal than 1500 EUR/month are, on average, willing to pay 1.87 EUR/month or 22.40 EUR/year more than households having a monthly income of less than 1500 EUR/month. Though this variable is not particularly relevant in terms of information provided about respondent's choices, it allows verifying the coherence of results.

Based on responses to one of the questions, a variable capturing the degree of trust in the current reuse system in Braunschweig was created[19]. The estimated coefficient for this variable is positive and significant, meaning that respondents stating to have a significant degree of trust in the water service provider to manage the reuse system in a way that protects the environment and particularly public health are willing to pay 1.40 EUR/month or 16.80 EUR/year more than individuals stating to have little or no trust.

On the other hand, the fact of having children seems to have a negative impact on the willingness to pay, as respondents with children are on average willing to pay 1.70 EUR/month or 20.40 EUR/year less than respondents without children. This can potentially be explained by the fact that these respondents might be particularly concerned by health risks linked to the use of wastewater for irrigation. Also the fact that households with children have additional expenses and therefore a smaller effective budget might play a role for explaining the lower willingness to pay.

Other effects on willingness to pay were also tested, namely, the effects of having previous knowledge on the existence of water reuse, the belief of the existence of quality problems in the Oker river and the effects of education level, sex and age. Nonetheless, these effects are not discussed here since they were found to be statistically not significant. This does not mean these variables do not strictly affect willingness to pay, but in this case the sample of observations was somewhat too small to assess all these impacts, since of the 300 observations, 133 had to be removed to rule out protest responses. Nonetheless,

[16] The mean willingness to pay considers all valid responses, including the respondents which did not attach any value to the environmental benefits and which were accounted for in the calculations with a zero willingness to pay.

[17] The median willingness to pay considers all valid responses, including the respondents which did not attach any value to the environmental benefits and which were accounted for in the calculations with a zero willingness to pay.

18 Ordinary Least Squares regression

19 The question has been: "To what extent do you trust the water service provider to manage this recycled water system in a way that protects the environment and particularly public health?"

the statistically significant results presented above can be interpreted as true causal relations affecting willingness to pay.

3.4 Feedback from testing the Water reuse CBA tool

In order to use the web-based CBA tool for water reuse projects which has been developed within the Demoware project (see Zayas et al., 2016) correctly and with meaningful results, cost and income values need to be available net of all economic distortions, like taxes. In the case of Braunschweig, cost information is only partially available and no preliminary financial analysis has taken place. In order to still provide feedback on the CBA tool, some elements available from the case study of Braunschweig have been entered. Given the limitations, results will need to be treated with great care. More information about the tool, its calculations, conditions and limitations will be provided in the feedback section from the Sabadell case study further below. In the following, a feedback from this testing for the Braunschweig case study is provided. For the analysis, the Sewage Board in Braunschweig is considered as the relevant stakeholder from a financial point of view. For the economic analysis, both avoided costs and benefits for the environment will be added to the analysis.

In the first place, the CBA tool allows providing some background information on the economic and social context as well as on the water context and the water market relevant for the case study. Within the section on the water market, different water consumers can be specified under “Demand”, and different water suppliers under the category “Supply”. Within the concept of the tool, the demand side for reused water in the case of Braunschweig does not only include the farmers of the Sewage Board, but needs to include as well the environment (the Oker, as the local surface water body) and the infiltration fields – as directing water to them is linked to specific costs. For each of these water consumers (called “demand sector” in the tool), information on the context, the number of agents[20] as well as their average consumption can be entered into the tool.

The Farmers of the sewage board have been entered as one demand sector, with two agents: the farmers (with their actual water demand) and the groundwater recharge, taking into account that currently more water than needed is applied on the fields. The infiltration fields have been added as a second demand sector, with the amount of treated effluent currently directed to them. On the supply site, both the wastewater treatment plant and “groundwater” have been included.

20 As the farmers belonging to the sewage board are handled as an entity, for which the total amount of water consumed is fixed, the number of agents to be included in the tool is “1”, with the average consumption being 3 240 000 m3 per year.

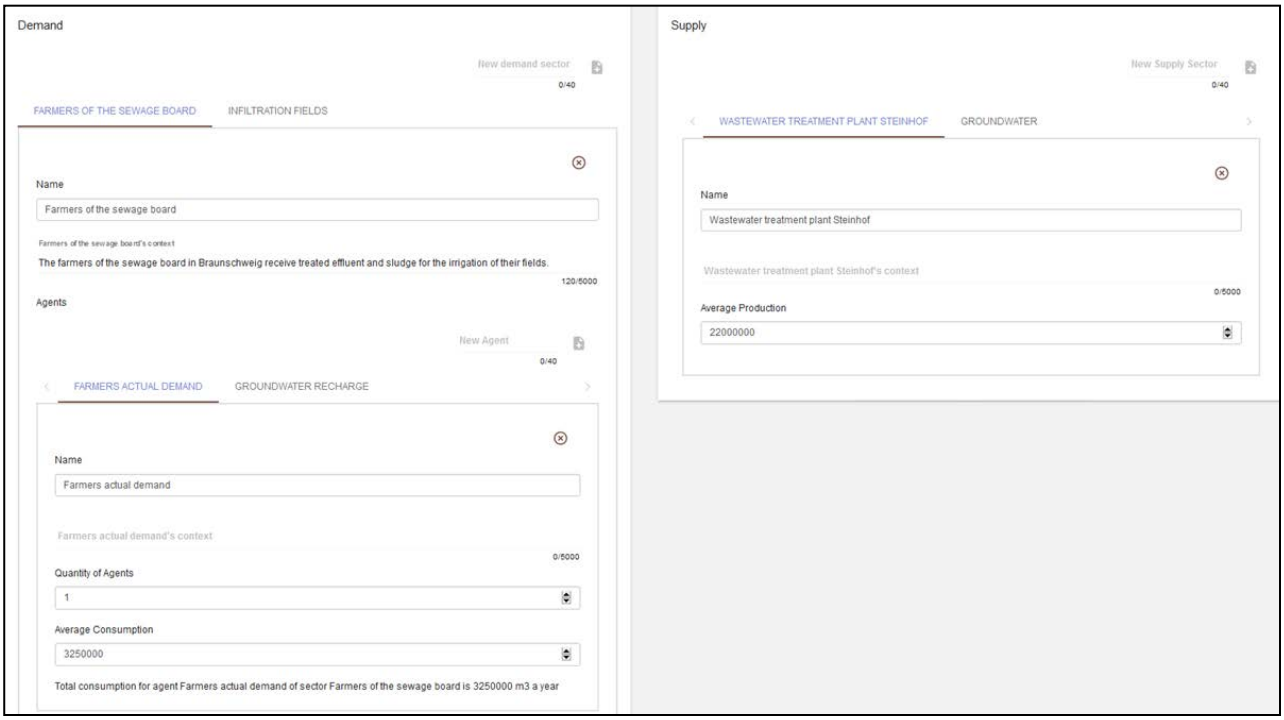


Figure 20 Informed water demand and supply side

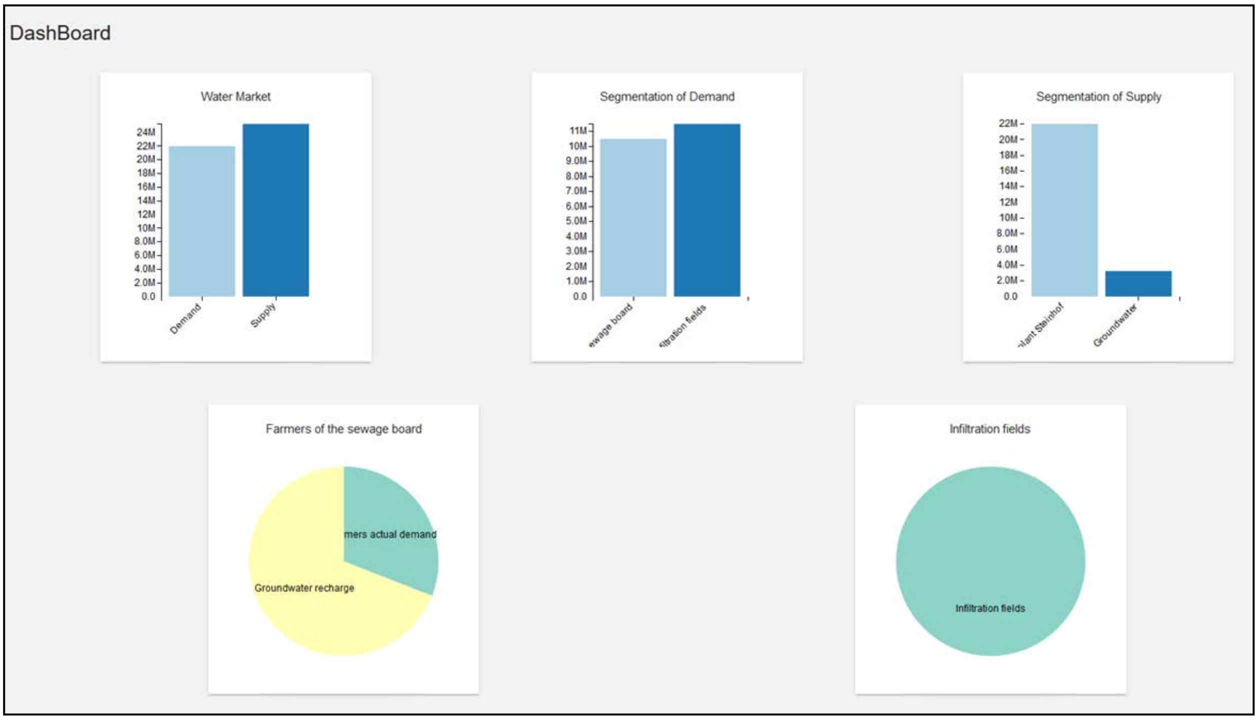


Figure 21 Graphical representation of the water demand and supply side

The next step of the tool looks at the general assumptions for the financial analysis. The standard values which are already provided by the tool (regarding labour costs, energy price, lifetime of the project, time of construction and discount rate) have been adapted for the actual energy price (0.12 EUR/kWh). The time of construction has also been reduced to zero, accounting for the fact that the reuse system under review started based on an existing irrigation infrastructure.

On the same tool screen, different scenarios can be included. In the case of Braunschweig, only a baseline scenario (for the current reuse situation) will be informed. In order to compare the current situation to a situation without agricultural reuse, two possibilities exist. Either a second, no-reuse scenario is created, or the avoided costs of this second scenario are included as benefits in the current baseline scenario. The second option has been chosen. Each scenario asks in a first step for the introduction of a “new factory”. This goes back to the fact that the tool has been built in the first instance for new water reuse projects – including either the construction of a new treatment plant – or at least the introduction of additional treatment steps necessary to improve the quality of the water for reuse. In the case of Braunschweig, no additional treatment step is applied before reuse. However, infrastructure is needed in particular to direct the water to the agricultural fields and to organize irrigation. For each “new factory” in the tool, information on the “shared treatment” can be included, which includes the general treatment to which all wastewater is subject. This is followed by information on “specific treatment” which corresponds to the specific treatment applied for the part of the wastewater which is reused. For both treatment parts, prior created “treatment units” can be added.

As mentioned above, no specific treatment is applied for reuse in Braunschweig. For the part on shared treatment, a treatment unit has been included with zero costs, as none of the current treatment costs can be attributed to the reuse (- they would also occur in the absence of reuse activities). Regarding investment costs, the tool provides a differentiation between construction, machinery and electric parts. For each of them, investment costs as well as lifetime can be indicated separately. Also pollutants emitted during the building time can be indicated, including at least CO_2 emission. Other pollutants can be added. For operational and maintenance costs, the tool allows specifying full time equivalents of workers, construction maintenance, machinery maintenance, electric parts maintenance, chemicals, other costs and energy consumption. No such detailed information was available for the case study, and some aggregated figures have been used instead. None of the graphic icons which are proposed actually fits to the situation in Braunschweig, but does not hinder the functionalities of the tool.

In a next step of the tool, specific treatment can be further defined. As mentioned before, no specific treatment for reuse is applied in Braunschweig. However, costs linked to pumping towards the agricultural fields can be included here, as well as other costs linked to irrigation with treated wastewater. For the testing, cost information for the following elements has been included: Distribution to the agricultural fields, the pump near the Aue-Oker canal, costs linked to the irrigation machines, spray protection hedges, the drainage system and the costs of the Regenmeister. The tool provides for indicating the associated customer for each treatment line. This goes back to the basic idea reflected in the tool that different treatment lines (different levels of treatment and hence different water qualities) can be necessary for different types of users of wastewater. Specifying the customer includes providing information on the quantity of customers, their average consumption, the annual fees they pay as well as the price they pay per cubic meter. This allows later on seeing the effects of changing the number of customers, their consumption or the price they pay. However, in the case of Braunschweig, farmers are not paying a price per cubic meter of wastewater, but per hectare. This situation is not foreseen by the tool. The case study information can still be included, by adapting it to the categories foreseen by the tool: all farmers of the sewage board are entered in the tool as a whole (one customer), and hence an average consumption corresponding to the total amount of water distributed to the agricultural fields (10.5 million m^3) is used. The price per cubic meter is kept zero, but for the “annual fee” the product of the fee per hectare (81 EUR) and the total area (2700 ha) is applied (218 700 EUR). When entering the different cost elements in the tool, it turns out that different investments over time – as well as different lifetimes of the same cost element are not foreseen by the standard approach of the tool, but are necessary for example for including the costs of the irrigation machinery in Braunschweig, which has been steadily increased and irregularly replaced in the last 40 years. The tool allows, however, including such elements one by one manually. The different cost elements can hence be included for different scenarios under the part of the financial analysis, and other cost and benefit elements in the subsequent economic part.

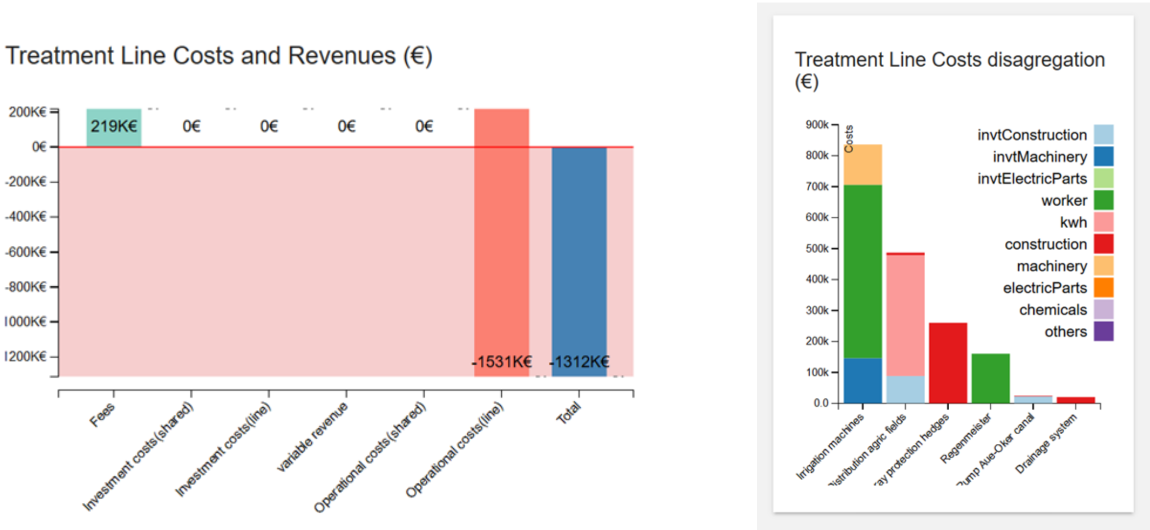


Figure 22 Examples of graphical representation of the financial costs and revenues by the CBA tool

A purely financial analysis of these parts shows very high costs compared to very low income provided by the fees paid by the farmers. However, avoided costs and economic benefits linked to the system are not yet considered. This will be done under the economic analysis part. Among the benefits of the current system, the avoided distribution of the wastewater to the infiltration fields needs to be considered. The avoided costs are consisting of avoided energy costs[21], which can be included in the tool, given that the tool provides for annual economic benefits and costs. Though, if all wastewater would be directed to the infiltration fields, a renewal of the pipeline system would be required. However, the tool does currently not allow entering one-time costs or benefits. They either need to be entered in an annualized way, or manually at the final step in the tool. Regarding the avoided alternative disposal of sewage sludge, it has been assumed that it would be burned instead (total avoided costs of 572 000 EUR/year). For the environmental benefits which have been evaluated by the contingent valuation study, the more conservative values have been used, based on the median willingness to pay (3 093 240 EUR/year in total). When including in particular economic benefits in the system, the resulting net benefit from the reuse in Braunschweig becomes largely positive. The main economic benefits are stemming from the appreciation of the environmental benefits (in particular preservation and restoration of local groundwater resources as well as the protection of the river water quality) which emerged from the contingent valuation study. This emphasizes the benefits of the reuse system for the local community.

21 Taking into account the current energy mix in Germany, CO_2 emissions of 600 g/kWh have been considered. 43.42 Euro per ton of CO_2 are used, see feedback section on the Sabadell case study for further explanations.

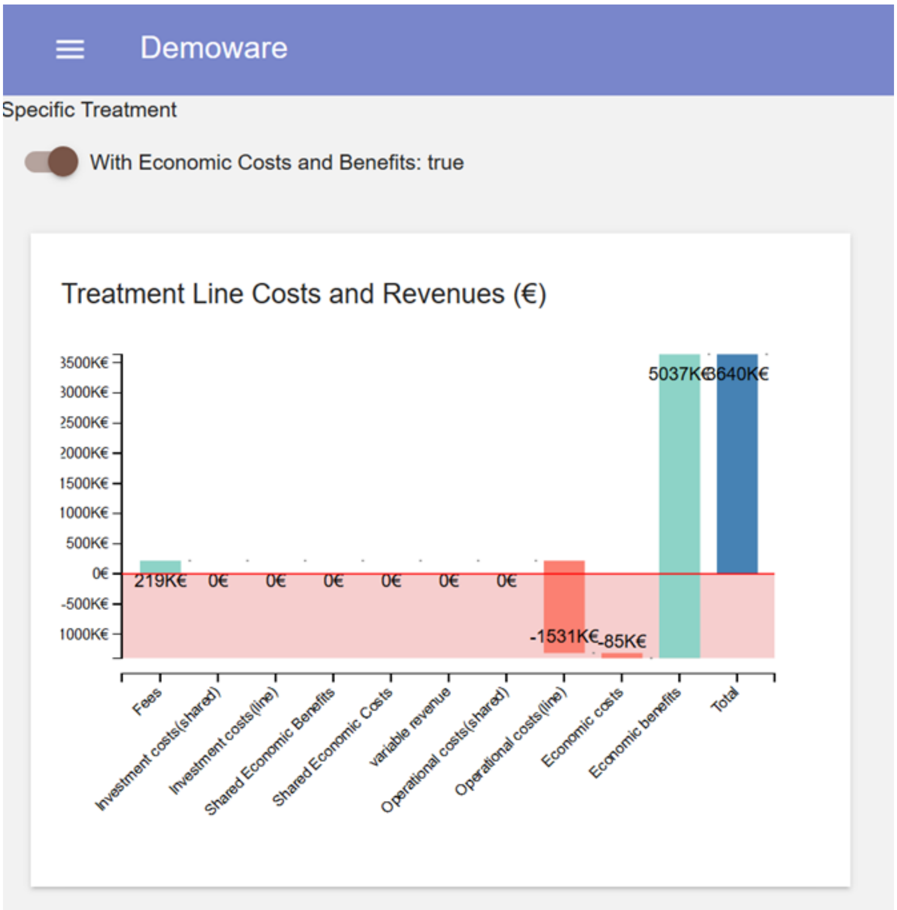


Figure 23 Graphical representation of financial and economic benefits and costs

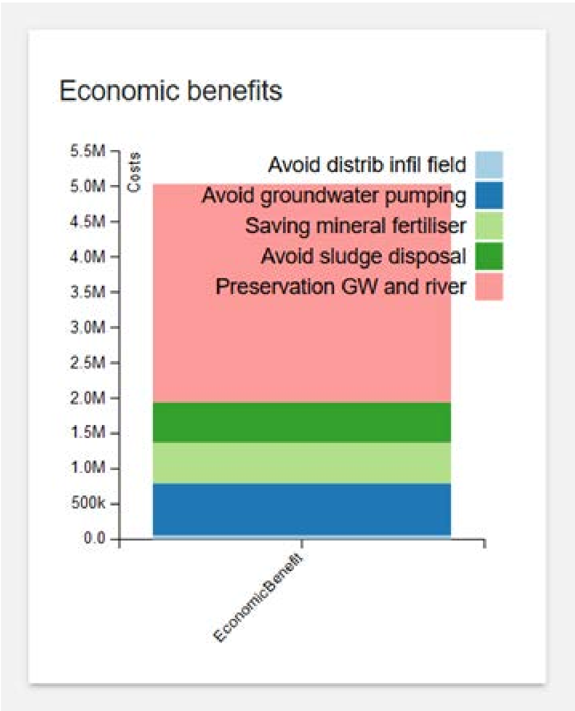


Figure 24 Graphical representation of the split of the different economic benefits

It has to be emphasized that the results shown in the figures above need to be treated very carefully. They are based on partial cost and benefit information from Braunschweig, and actual results might differ significantly. Nevertheless, first conclusions indicate that – from an economic point of view – benefits of the current reuse system clearly outweigh costs.

As mentioned before, available cost information did not allow carrying out a proper ex-post cost-benefit analysis on the Braunschweig case study. With these limitations in mind, still some conclusions can be drawn regarding the applicability of the CBA tool on the specific case: The web-based CBA waterreuse tool is not directly adapted for reuse situations like in Braunschweig, amongst others because: 1) The plant and the reuse system already exist, which requires an ex-post approach to CBA. The tool, however, has been elaborated for ex-ante situations. Nevertheless, it is possible to enter information on current costs and to compare the actual situation with a situation without reuse – seen from today's point of view. 2) The need for specific treatment steps to allow for wastewater reuse is one of the basic assumptions of the tool. In the case of Braunschweig, however, this is not the case. Nevertheless, by taking into account how the tool works and how different elements are used for calculating final values, the different provisions of the tool can still be used for different, specific situations (e.g. costs linked to pumping to the agricultural fields can be included under "specific treatment"). So even if the specific case study does not correspond to the situation for which the tool has initially been created (introduction of new wastewater reuse, with different users requiring different specific treatment steps), the provisions of the tool can still be used to provide quick and simplified CBA estimations. However, complete and correct financial information is an indispensible pre-condition for correct results.

4 Sabadell case study

4.1 Case study description

The city of Sabadell has a surface area of 37.89 km² and a population of 193,954 inhabitants (2004 census). It is situated 20.6 km north west of the city of Barcelona. The natural ecosystems in this area are influenced by the proximity of the Sant Llorenç del Munt massif with the course of the Ripoll River and its tributaries (Tort River, Colobrer Stream and Ribatallada Stream). The Sec River, that flows through the southern part of the municipality at its border with Sant Quirze del Vallès, is a water body with a lesser water flow. The climate in this area is typically Mediterranean, with dry summers and most plentiful rainfall during spring, and particularly in autumn. The volume supplied by the distribution network of the city is of approximately 15.2 hm^3 per year, mainly from the Aïgues Ter-Llobregat (ALT L) network. (Vinyoles et al., 2005).

Waste water treatment activities started in 1992, with the construction of the wastewater treatment plant in the Sec River and in 2001 the construction of the WWTP in the Ripoll River. The city of Sabadell, historically sensitive to the problem of water (Sabadell is located in a region of Spain dealing with dry seasons and scarcity problems), has during the past decade and recent years developed a series of actions aimed at reducing pressures on regional or local water sources. Such actions include the environmental improvement of the Ripoll River with the construction of a treated water outlet or lessening pressures on regional water bodies by the use of alternative water sources such as the Ribatallada and Ripoll Mines (Vinyoles et al., 2005). Both plants are the property of the Sabadell Town Municipality and are managed by the "Companyia D'Aigües de Sabadell, S.A. (CASSA). For the collection and treatment of wastewaters; Sabadell is divided into two different areas; half of the city sends its wastewaters to the Riu Sec WWTP and the other half to the Ripoll WWTP (Ayuso-Gabella and Salgot, 2012).

4.1.1 The Ripoll WWTP and treated water outlet

The availability of resources provided by the Ripoll River brought about a concentration of industrial activities along its course. The Ripoll was in the past the most contaminated river in this part of Spain, mainly because of the presence of the textile industry. Water from the alluvial aquifer was used for industrial activities and discharged back into the river afterwards. Although factories started to have their own treatment systems to comply with regulations, the discharge of large volumes of treated waters at single points, located mainly downstream from abstraction points, could create future imbalances between extractions and contributions along the river course (Vinyoles et al., 2005). Moreover, even though water was being treated by industrial users previous to discharge, problems associated to the presence of nitrogen from waste water pipe leakages and agriculture still needed to be solved (Mashkina, 2014). Thus the construction of the wastewater treatment plant in 2001 was intended to further reduce pollution in the river and to prevent future imbalance problems between extractions and contributions along the river course.

The municipality constructed in 2003 a pressurized pipeline of treated water that can discharge reclaimed water back into the river at two points, the Torrella Mill, half way along its course and Colobrers Stream, upstream at the beginning of the municipal area. The reasons for having treated water pumped upstream are mainly environmental ones: guaranteeing the circulating flow of the river, maintaining ecosystem services (people walking, fishing, biodiversity etc.) and recharging the aquifer (the most upstream discharge point being only used during the summer, when the river flow is low) (Mashkina, 2014). A pipe collects the reclaimed water from the Ripoll WWTP and takes it, by gravity, to Torrella Mill, where part of it is discharged. From here to the area of the Colobrers Stream, the water is driven by pumping equipment. The length of the outlet is 6.3 km and it has the ability to return the following volumes to the river (Vinyoles et al. 2005):

- Sant Oleguer: 12 000 m^3/day
- Torella Mill: 10 000 m^3/day
- Colobrers Stream: 8000 m^3/day

Based on sampling campaigns during the Reclaim Water Project (Ayuso-Gabella and Salgot, 2012) only around 15 000 m^3 to 16 000 m^3 are discharged daily into the river. Approximately, 5 hm^3 are sent to the river yearly.

4.1.1.1 Sabadell north indirect reuse system

Currently, an indirect reuse system in Sabadell north provides water for urban uses that require lesser quality standards than water for potable consumption. The system is considered as an indirect reuse system because the treated water is first discharged into the Ripoll River; then 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 used mainly for the irrigation of green areas, ornamental fountains and street cleaning activities. Thus water is not being directly reused from the WWTP.

The Ripoll and Ribatallada mines are installations that were previously used for supplying drinking water for the city (until the middle of the 20^{th} century) but that were closed down due to the presence of microbiological contamination. Given to the fact that conditioning this water required only disinfection so that it could be used for watering green areas and street cleaning activities, it was decided to renew the existing equipment on both mines and install the necessary elements to guarantee its quality. Both mines are in use since 2004 (Mashkina, 2014).

The Ripoll installation consists of a well that is 1 metre wide and 1.5 metres high that goes through the riverbed to a depth of 7 metres and takes the water to a collecting well; from there the water is pumped to the system of disinfection with ultraviolet radiation and is stored in a tank with a capacity of 100 m^3. The water is chlorinated with sodium hypochlorite in this tank, using automatic dosing equipment with a chlorine analyser. In addition to the continuous control of the chlorine, transmission and conductivity probes were installed to guarantee the quality of the water supplied. Part of the water is driven from this tank to the Taulí tank, from where it supplies the watering system of the Tauli park and a service system to load tankers for street cleaning activities. The rest of the water is taken directly from the Ripoll tank for watering the River Parc Lineal (Vinyoles et al., 2005). The figure below presents the main elements of this system.

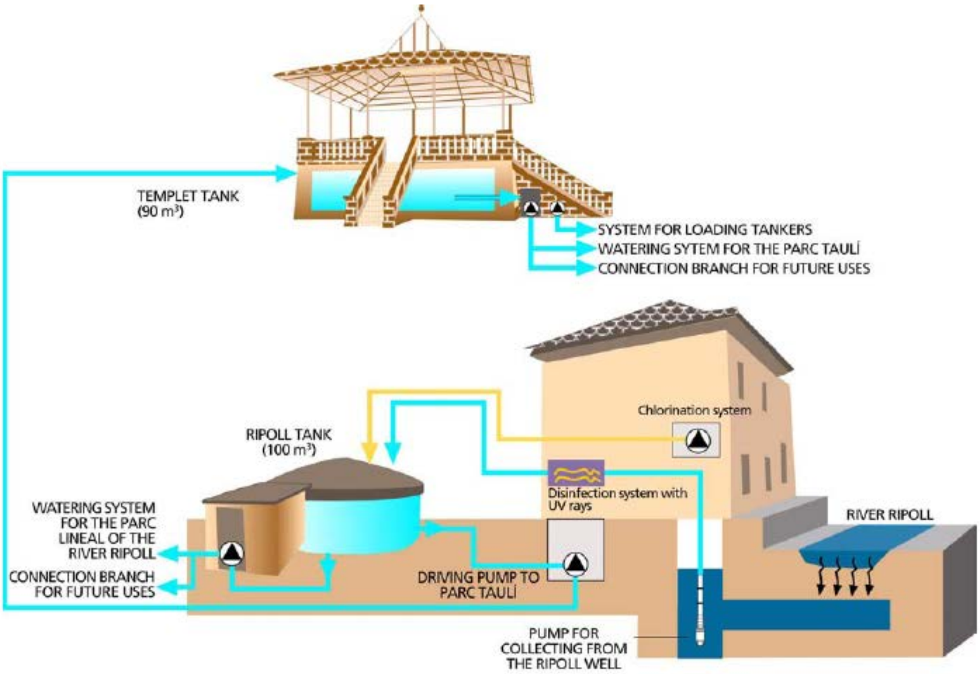


Figure 25 Main elements of the Ripoll mine system
Source: Vinyoles et al. 2005

The Ribatallada Mine installation consists of a storage tank of 150 m^3 in Carrer de Nàpols, which collects water from the mine. The tank has chlorinating equipment and a turbidimeter to control the quality of the water. From there, the water is pumped to the areas where it is used providing water for street cleaning activities (loading tankers) and supplying water to the Via Alexandra sector, which consists of an ornamental fountain, and a watering system in the park Can Llong (Vinyoles et al., 2005).

The action of collecting and using water in these installations is directly related to the existence of the treated water outlet in the Ripoll, as it enables the extraction of volumes from the aquifer that have been previously discharged further upstream. It manages to create a closed circuit in these sections of the river that enables the use of a determined volume of water to be guaranteed without decreasing the circulating flow of the river-aquifer system (Vinyoles et al., 2005).

4.1.2 The Riu Sec WWTP and the south reuse system

The Riu Sec WWTP (in Sabadell South), consists of a primary treatment capacity of 50 000 m^3/ day and a secondary biological treatment capacity of 35 000 m^3/day, based on membrane bioreactor (MBR) technology. Currently, around 28 600 m^3/day is treated in the Riu Sec WWTP (Ajuntament de Sabadell, 2014). Due to the MBR technology, the treated effluent is of a very good quality requiring only disinfection (tertiary treatment) in order to be used for green areas irrigation, street cleaning activities and industrial or commercial uses. Thus a tertiary treatment step has been recently incorporated (based on UV treatment and a chlorination system) allowing to supply reused water for urban uses in Sabadell south; current uses are mainly for industrial purposes (Vinyoles 2016, *pers.comm.*).

4.1.3 Available water resources

Currently, around 120 000 m^3 is covered with reused water representing approximately 1 % of the volumes supplied by the water distribution network. Of these volumes, around 95 000 m^3/year comes from the Ripoll and Ribatallada mines, and thus indirectly comes from the Ripoll WWTP and around 25 000 m^3/year from the Riu Sec WWTP (Ajuntanment de Sabadell, 2014).

The reclaimed network is 25 km and there are 26 reclaimed water supply points for non human use in Sabadell municipality (CASSA, 2014). The figure below provides an overview of the main elements of the reused network and its current state.

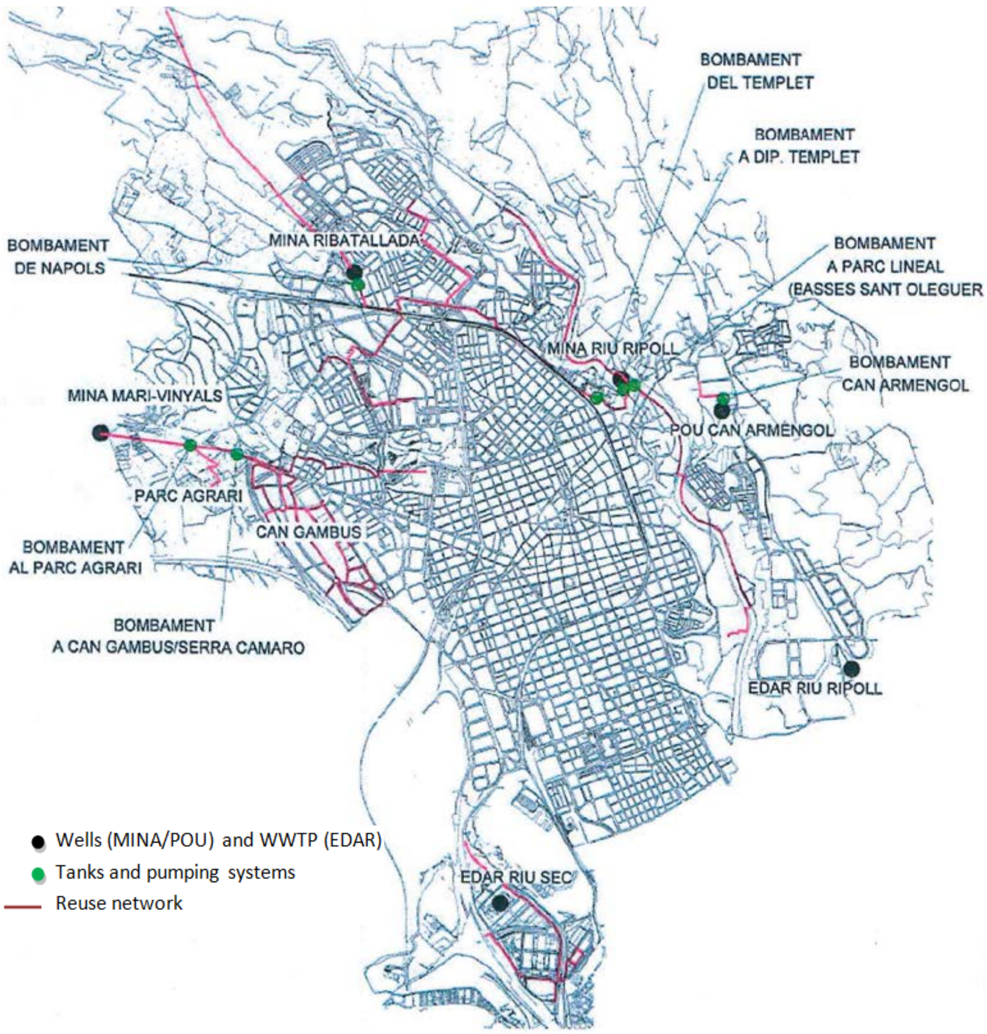


Figure 26 Current state of the water reuse network (25 km)
Source: CASSA, 2014

Available water resources are presented below.

Table 13 Resources available, limitations of existing quality and proposed treatments
Source: Vinyoles et al. 2005

Resource	Volume of flow (hm^3/year)	Limitations of quality	Treatment Required
Riu Sec WWTP	12	Solids in suspension and ammonium Bacteriological pollution	Elimination of nutrients Tertiary treatment Disinfection
Ripoll WWTP	6.5	Solids in suspension Bacteriological pollution	Tertiary treatment Disinfection
Ribatallada Mine	0.15	Bacteriological pollution	Disinfection
Ripoll Mine	0.35	Bacteriological pollution	Disinfection
TOTAL	19		

4.1.4 Future developments

4.1.4.1 Potential Users

An assessment of potential users for reclaimed water in the city is necessary in order to determine what the most viable potential developments could be. Such 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).

Based on this assessment, potential users in the city of Sabadell were grouped into three main types: public (urban use for green areas irrigation and streets cleaning), industrial and agricultural. With respect to agriculture, most of the agricultural surface area of Sabadell corresponds to dry-ground land cultivation (vineyards, cereals, sunflowers, etc.). Irrigated crops are only found in orchards near the Ripoll River and in some areas of the agricultural park “Parc Agrari”. The Ripoll river orchard comprises a surface of 36 ha (28 ha irrigated with surface waters from the river and 8 ha irrigated with ground water from rural wells). “Parc Agrari” covers an area of 500 ha of which only 30 ha are irrigated mainly with ground water from rural wells (23 ha of ornamental plants and cypresses; 7 ha of vegetables) (Collado et al, 2003).Total consumption is estimated at 330 000 m^3 per year from the collection of surface waters from the Ripoll (140 000 m^3/year) and rural wells (190 000 m^3/year). The possibility of covering this use in (Vinyoles et al. 2005) was ruled out for various reasons: (i) part of the water taken from the Ripoll can be considered already as indirect reuse since treated effluent is discharged further upstream thus users taking water directly from the river are also making use of treated effluent to some degree; (ii) users from “Parc Agrari” are currently making use of water from rural wells without apparent problems of sustainable provision; (iii) it was considered not reasonable to try to meet this demand through reclaimed water for the low costs that water resources currently represent for agricultural users, as well as their geographical dispersion which makes proposing an economically competitive alternative difficult. Besides agriculture, potential demand for reclaimed water was estimated at 1.34 hm^3/year (Vinyoles et al. 2005). The distribution of uses is shown below.

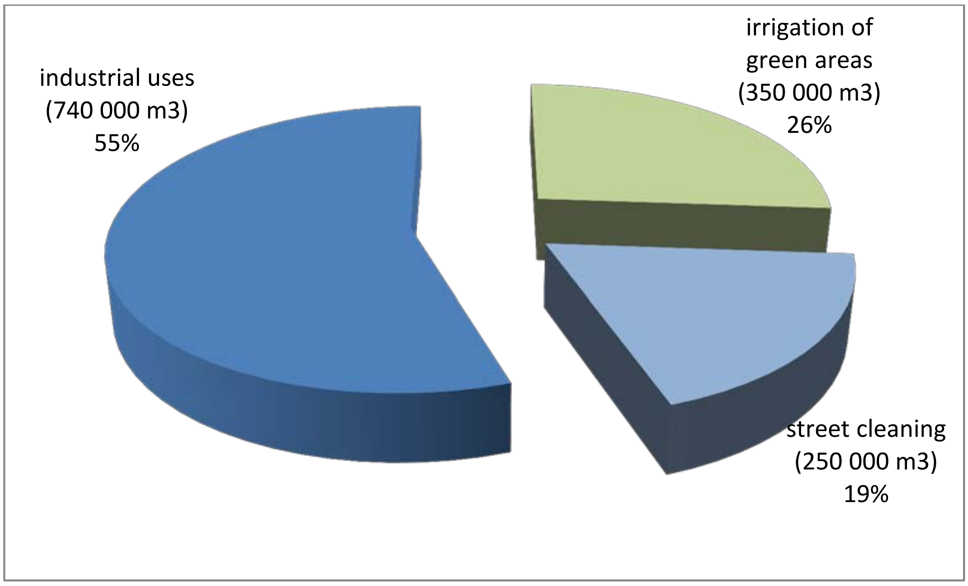


Figure 27 Summary of potential demand for reclaimed water in Sabadell
Source: Vinyoles et al.2005

The North Area of the city stands out because of a greater share of treated effluent destined for watering green areas. The Southern Area stands out for its demand that is mainly coming from industrial users. With regards to street cleaning, it is considered that the consumption is distributed in equal parts between the two areas. Of the initially considered 1.34 hm^3/year potential demand, only 1.107 hm^3/year were considered to be covered because of the differences of uses between the north and south areas and the required distribution networks. Considering an 85% performance of the distribution network, only 941 000 m^3 reach final users while 1.107 hm^3 are actually distributed (Vinyoles et al. 2005). This means that in terms of water volumes from the public distribution network, 1.1 hm^3/year would be available for other uses, representing approximately 25 days of water supply in Sabadell and accounting for 7.2 % of yearly demand (Vinyoles et al. 2005). The reused water demand according to uses for the North and South areas of the city is shown below.

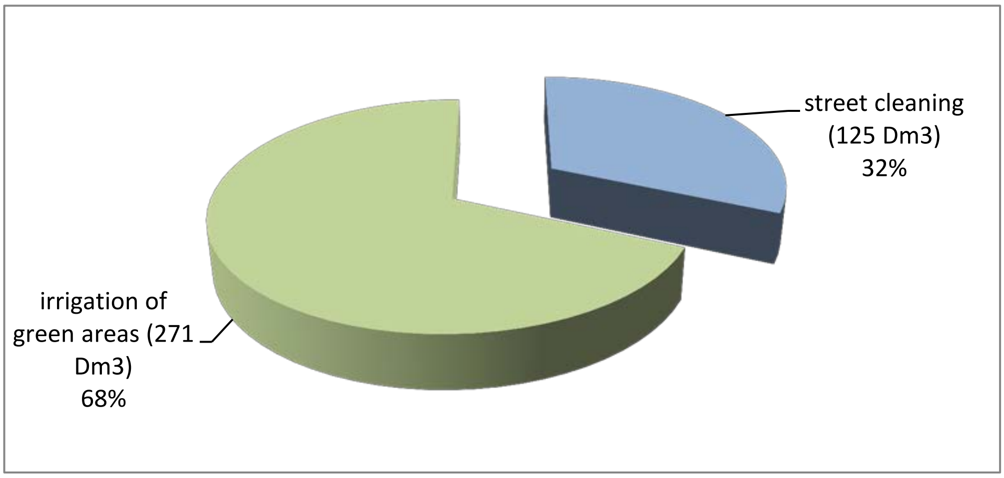


Figure 28 Potential reused water demand for the north area (annual volume registered 396 Dm3)
Source: Vinyoles et al. 2005

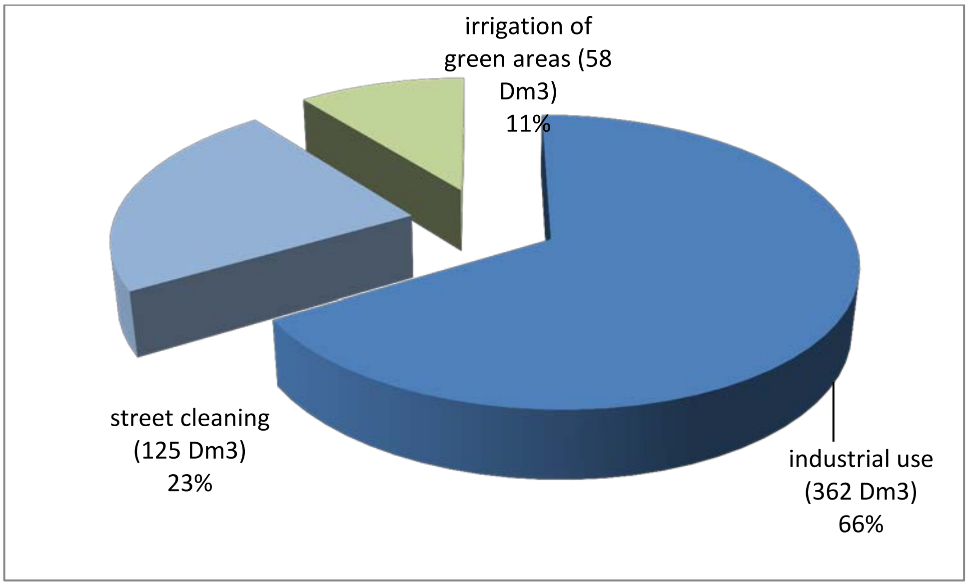


Figure 29 Potential reused water demand for the south area (annual volume registered 545 Dm3)
Source: Vinyoles et al. 2005

For the North area, a network exclusively for watering green areas would be required (with supply points for street cleaning tankers). The northern network would make use of water resources coming from current existing installations in both Ripoll and Ribatallada Mines. For the south area, the distribution network required would mainly be for industrial purposes, but it would also contemplate the watering of green areas close to its path (also with supply points for street cleaning tankers). The southern network would make use of reused water coming directly from the Riu Sec WWTP (Vinyoles et al. 2005). Details on infrastructures required and investment costs to develop each network, as well as general operational costs are presented in section 4.2.2.

4.1.4.2 Activities in progress

The figures below provide an overview of the works in progress to update the water reuse network in Sabadell.

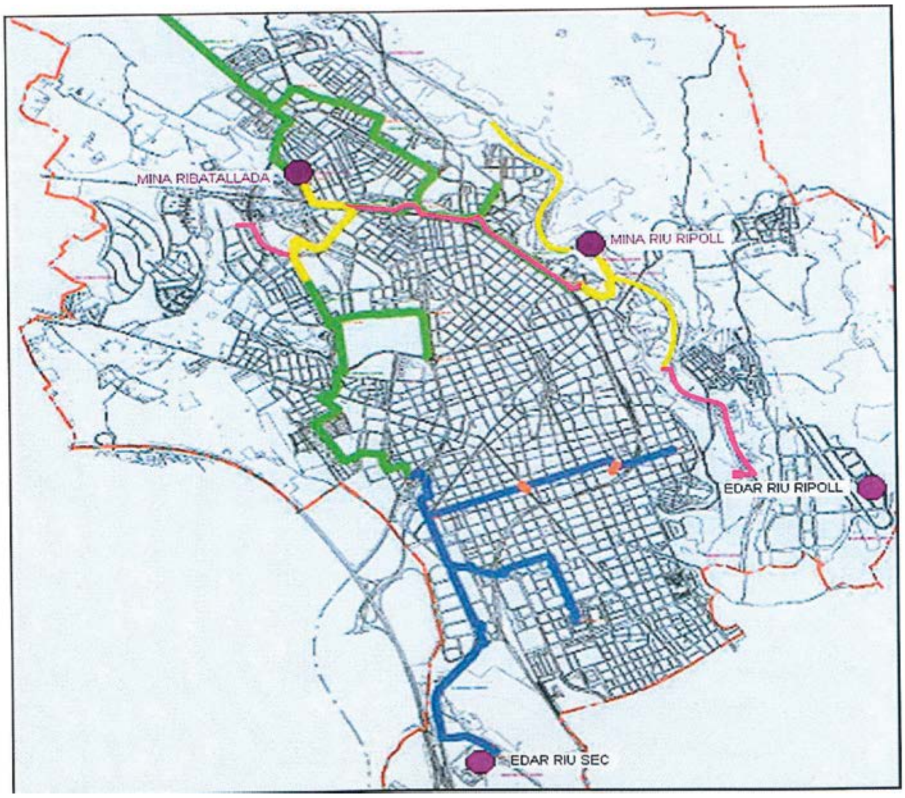


Figure 30 Infrastructure Requirements (yellow: current network/red: under construction network/ green: irrigation network/ blue: industrial network)
Source: CASSA, 2014

Below are presented other activities in progress and plans for potential developments of the reused system in Sabadell.

- Double piped areas: Incorporation of an industrial and commercial park (Riu sec Sant Pau Industrial Park) to the water reuse network (already functional for some industrial users and for an IKEA complex (covering toilet flushing needs)) ; one residential area (promoter paid for the double net), (Mashkina, 2014)
- Connections to the Sant Cugat Municipality for the use of reclaimed water supplied from Riu-Sec's WWTP to irrigate golf camps and other urban uses; an estimated 600 000 m^3/year foreseen (internal document provided by CASSA). Nonetheless, financing issues associated to high costs 3-4 million euros have lead to long delays (the golf courses: need to pay for the pipes) (Mashkina, 2014)
- The recently approved "Managing Plan for the use of reclaimed water 2014-2024" established the objective of enlarging the network to 67 km and to distribute 359 884 m^3 (3% of the overall urban water consumption). Another envisaged action is to reuse gases escaping from the wastewater treatment plant digestion process to create biogas for a cogeneration station (Aigües Sabadell, 2014).
- In the next 10 years possible development of private uses (non potable outside uses such as gardening, car washing etc.)for reused water but developing the legislation will take time (Mashkina, 2014)
- Survey to industrial and commercial users: Possibility to replace up to 75 % of water volumes consumed for cooling purposes (no limiting quality requirements), even though users are unwill-

ing to implement the dual internal networks. Currently there is no use of reclaimed water for cooling purposes (Mashkina, 2014).

4.2 Description of case study specific benefits and costs

4.2.1 Description of costs and benefits related to the current reuse system in Sabadell

The current reuse system in Sabadell is making indirect use of effluent coming from the Ripoll WWTP, in Sabadell north, and direct use of effluent coming from the Riu Sec WWTP in Sabadell south.

The north system does not generate additional treatment costs at the Ripoll WWTP level, as no additional treatment is required in the plant. As a consequence, only the effluent use once it leaves the plant is of interest for cost and benefits considerations. The effluent is discharged into the Ripoll River, and water is then recovered from the Ripoll and Ribatallada wells Pumping, UV disinfection and chlorination costs appear at this level. From the mines, the water is then pumped through a distribution network to the areas where it is used and stored in regulation tanks.

The south system does generate additional costs at the Riu Sec WWTP, as the treated effluent goes through additional tertiary treatment (UV treatment + chlorination) in the plant, before being distributed through a pressurized pipes network. The different areas of costs and benefits of the current reuse situation in Sabadell are listed in the table below and will be further described in the following.

Table 14 Costs and benefits of the current water reuse system in Sabadell

<table>
<tr><th>Costs</th><th>Benefits</th></tr>
<tr><td>Northern network</td><td rowspan="6">• Avoided costs in terms of water volumes stemming from the public distribution system
• Preservation of potable water resources
• Maintaining the Ripoll river ecological cycle and environmental amenities
• Preservation and restoration of local aquifers
• Resilience of industrial activities to water scarcity and droughts
• Social benefits related to securing the aesthetic values of Sabadell green areas and parks faced to scarcity and drought restrictions
• Social benefits related to securing street cleaning activities faced to water scarcity and drought restrictions
• Revenues generated from the exploitation of the current reuse system</td></tr>
<tr><td>• Discharge points in the Ripoll River (pumping, pipes)
• Pumping costs of the water from the mines
• Treatment costs (UV + chlorination)
• Distribution of the reused water to the areas where it is used (pumping, pipes, regulation tanks)</td></tr>
<tr><td>Southern network</td></tr>
<tr><td>• Treatment costs (UV + chlorination)
• Distribution of the reused water to the areas where it is used (pumping, pipes, regulation tank)</td></tr>
<tr><td>• Health risks related to contact with the reused water
• CO2 emissions from energy consumed</td></tr>
</table>

The available quantified information on costs is further detailed below and monetary values are provided as far as possible.

Table 15 Cost elements of the current wastewater reuse system in Sabadell

Cost element	Description of individual elements and quantification	Monetary values	Source
Total costs from the exploitation of the current reuse system (considering joint costs from north and south networks)	Pumping systems, UV disinfection and chlorination systems, storage tanks, distribution network (pressurized pipelines), energy demand etc. Cost per m^3 of water supplied: 0.25 EUR/m^3;	A total of 141 000 m^3/year are supplied in order to provide 120 000 m^3/year to final costumers (considering an 85% network efficiency). Thus costs are estimated at 35 250 EUR/year.	(1) Vinyoles 2016, *pers.comm.*
Health risks related to contact with the reused water	Potential contamination risks related to human contact with the reused water, could be the source of costs in terms of illness and subsequent treatment and other costs related, as well as increased morbidity rates. Nonetheless such estimations require the calculation of contamination risks which are uncertain, as well as the estimation for the cost of illnesses. Monetizing health risks and capturing uncertainty is a very complex task; an estimation of said risks was not available.	No quantification for this cost.	
CO_2 emissions from energy consumed	Information on energy demand of the current reuse system was not available. An estimation was provided based on the average value of kWh per m^3 produced for both north and south networks after expansion, as specified in Collado et al 2003. An average value of 0.64 kWh/m^3 [22] was estimated (1). For the CO_2 emissions per kWh of energy consumed, the value of 0.302 kg of CO_2 per kWh[23] is considered, taking into account the energy mix in the region of Catalonia. A value of 43.42 EUR/ton of CO_2 was selected for the price per ton of CO_2 emitted by applying the growth trend[24] proposed by Quinet, to account for the true value of CO_2 emissions (including environmental	An estimation of 90 240 kWh/year is obtained as energy consumption from the operation of the current reuse system (considering 141 000 m^3/year supplied). Considering the previous values, estimated CO_2 emissions are of 27 tons of CO_2/year[25]. Considering the price per ton of CO_2, total costs related to CO_2 emissions are estimated at 1172 EUR/year.	(1) Own calculations based on Collado et al. 2003 (2) (CAS, 2009)

22½ (316 467 KWh/ 545 000 m3) (for the southern network) + ½ (279 200 KWh/ 396 000 m3) (for the northern network) = 0.64KWh/m3 for both north and south networks. It is acknowledged the data on energy consumption from the current system should have been updated, but the information was not available at the time of writing the report. Nonetheless, this information was only used for estimating current CO2 emissions from the system's operation. For energy costs considerations, the current cost of energy is already accounted for in the cost/m3 supplied

23http://canviclimatic.gencat.cat/es/redueix_emissions/factors_demissio_associats_a_lenergia/

24 From an initial value of 32 €/ton of CO2 in 2010, Quinet proposes a growth trend of 1.0522 per year for the 2010-2020 period. Thus $32€ \, x \, (1.0522)^6 \simeq 43.42€$

25 90 240 X 0.302 = 27 252 kg of CO2/year

Cost element	Description of individual elements and quantification	Monetary values	Source
	negative externalities) (2)		

Table 16 Benefit elements of the current water reuse system in Sabadell

Benefit element	Description of individual elements and quantification	Monetary values	Source
Total revenues from the exploitation of the current reuse system (considering joint benefits from north and south networks)	Currently around 120 000 m^3/year are consumed by the final users (1). There are two volumetric water tariffs applied of 0.2767 EUR/m^3 and 0.6917 EUR/m^3 (2). Since information on the proportion of costumers paying each tariff as compared to total volumes supplied was not available, an average between the two tariffs is used. The average value is of 0.4842 EUR/m^3.	A total of 58 000 EUR/year is estimated as operational revenue stemming exclusively from volumetric tariffs.	(1)Ajuntament de Sabadell, 2014 (2) Vinyoles 2016, *pers.comm.*
Avoided costs per m^3 of water volumes from the public distribution system	Replacing potable water volumes with reused water also implies saving the costs of providing this volumes. Currently the system provides 141 000 m^3/year for an average registered volume of 120 000 m^3 (considering an 85% network efficiency) (2). The information on the average cost of production per m^3 from the public distribution system was not available, thus total savings could not be quantified.	No quantification for this benefit.	(2) Ajuntament de Sabadell, 2014
Preservation of potable water resources	The fact of reducing the yearly volumes of potable resources used, allows the preservation or use of the volumes for other priority uses. This benefit is surely not negligible in a region that suffers from water scarcity problems. In order to emphasize the true value of water in a water scarce coastal region, a "rough" estimation would be to compare it to the cost of providing the same volumes with RO[26] technologies.	The system currently allows the preservation of approximately 141 000 m^3/year. This represents 0.9 % of the yearly water demand in Sabadell, or approximately 3 days of water supply in the city (1). The costs of producing potable water from desalination technologies is estimated at 0.6 EUR/m3 for the largest and most recent desalination plant in the region ("Desalinizadora el Prat del Llobregat")[27]. Thus the benefit of preserving potable resources is estimated at 85 000 EUR/year.	(1) Own calculations based on Vinyoles et al. 2005

[26] Reverse Osmosis

Benefit element	Description of individual elements and quantification	Monetary values	Source
Maintaining the Ripoll River ecological cycle and environmental amenities	By discharging the effluent upstream at two different points, the system allows maintaining the ecological functions of the Ripoll River, especially during summer , dry seasons or drought periods, when the river's flow becomes low (1). By doing so, not only the river's flow is maintained but also other environmental amenities provided by the river, such as maintaining habitat conditions for biodiversity (fish, ducks etc.), improved aesthetics and maintaining recreational potential of the river for the local population (walking along the river park, fishing, watching local biodiversity etc.)(2).	Around 15 to 16 000 m^3 are daily discharged in the Ripoll river. Around 5 hm^3 are sent to the river yearly (2). No quantification for this benefit.	(1) Vinyoles et al. 2005 (2) Ayuso-Gabella and Salgot . 2012
Preservation and restoration of local aquifers	Since the Ripoll River Basin is highly permeable (formed mainly of sand and gravel), the system also serves indirectly for groundwater aquifer recharge, by infiltration through the river bed. Natural infiltration of the Ripoll River water through the river bed occurs along the entire course of the river but the recharge is enhanced close to the mine locations because the groundwater level is 7 m below the river (45-51 m^3/day for the Ripoll mine). Thus, the discharged effluent contributes to recharge the alluvial aquifer of the Ripoll and Ribatallada Mines which provide the water used for green areas irrigation and street cleaning activities	No quantification for this benefit.	Ayuso-Gabella and Salgo 2012
Resilience of industrial activities to water scarcity and droughts	The current system allows providing reused water to industrial users in Sabadell south (1). A total of 20 000 m^3/year are supplied in Sabadell south (2), but the proportion supplied for industrial activities in unknown. Moreover, the degree to which each user is dependent	No quantification for this benefit.	(1) Vinyoles 2016, *pers.comm.* (2) Ajuntament de Sabadell, 2014

[27] https://www.ayesa.com/es/proyectos/desaladora_de_el_prat_de_llobregat
http://www.lavanguardia.com/vida/20090720/53749138847/hoy-entra-en-funcionamiento-la-desalinizadora-de-el-prat.html
Also depending on the specific technologies used, the costs of producing desalinated water are estimated between 0.3EUR/m3 and 0.8EUR/m3 (http://www.acuamed.es/media/publicaciones/desalinizacion-en-espana.pdf); this seems reasonable with the proposed value

Benefit element	Description of individual elements and quantification	Monetary values	Source
	on a regular water provision is unknown.		
Social benefits related to securing the aesthetic values of Sabadell's green areas and parks faced to scarcity and drought restrictions	The current system allows securing a fraction of the yearly demand for irrigation of green areas and parks in the city, thus ensuring aesthetic values of the irrigated areas faced to water scarcity and drought restrictions	The Choice Experimentprovided an estimation of the willingness to pay for securing the entire yearly demand for the irrigation of green areas and parks in the city. The current reuse system allows covering only 25% of the yearly demand for parks and green areas irrigation (1). Preferences are most likely not linear thus, the current benefits from the reuse system cannot be monetarized.	(1) Own calculations based on Vinyoles et al. 2005
Social benefits related to securing street cleaning activities faced to water scarcity and drought restrictions	The current system allows securing a fraction of the yearly demand of water for street cleaning activities in the city, thus securing part of these activities in case of water scarcity and drought restrictions.	The CE provided an estimation of the willingness to pay for securing the entire yearly demand of water for street cleaning activities in the city. The current system allows covering only 22 % of the yearly water demand for street cleaning purposes (1). Preferences are most likely not linear thus, the current benefits from the reuse system cannot be monetarized.	(1) Own calculations based on Vinyoles et al. 2005

4.2.2 Description of costs and benefits related to developments of the current reuse system

As was previously presented, 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.

Thus, this section presents the costs and benefits related to the application of the 2004 Master Plan as developed in Collado et al. 2003. More precisely, this section presents the costs and benefits related to the expansion of the reuse network in Sabadell north and south (as presented in section 3.1.4.1.).

For the northern area, the required network would be an extra 10.8 km. In order to store the treated water and make it available for use, the construction of three tanks with a 500m^3 capacity each would be required; the network would also make use of an already existing tank of 150 m^3 capacity (Collado et al. 2003). For the southern area, the required network would be an extra 7 km long. To store and supply the treated water, a single tank with a 2000 m^3 capacity would be required. There would also be the need of expanding current tertiary treatment capacities in the Riu Sec WWTP (55 m^3-100 m^3/day[28]) up to 3000 m^3 per day (Collado et al., 2003).

28 Data stemming from an internal document provided by CTM.

Table 17 Costs and benefits related to the northern and southern network expansion

Costs	Benefits
Northern Network	• Increased "avoided costs" in terms of water volumes stemming from the public distribution system • Increasing the preservation of potable water resources • Increased social benefits related to securing the aesthetic values of Sabadell green areas and parks faced to scarcity and drought restrictions • Increased resilience of industrial activities to water scarcity and droughts • Increased social benefits related to securing street cleaning activities faced to water scarcity and drought restrictions • Increased resilience of industrial activities to water scarcity and droughts • Increased revenues generated for the supplied volumes for each network
• Investment in infrastructures required (storage regulations tanks and pumping systems, pressurized pipes, other general expenses related to initial investment) • General yearly operational costs (labour costs, maintenance costs, transports, water analyzes, administrative expenses, treatment costs (chlorination), electric consumption) •	
Southern Network	
• Investment in infrastructures required (pressurized pipes; tertiary treatment: sedimentation, sand filtration, UV disinfection and chlorination; regulation tank and pumping system; other general expenses related to initial investment) • General yearly operational costs (labour costs, maintenance costs, transports, water analyzes, administrative expenses, treatment costs (tertiary treatment), electric consumption)	
• Increased health risks related to contact with the reused water • Increased CO2 emissions related to extra energy used	

Table 18 Costs related to developments of the water reuse system in Sabadell

Cost element	Description of individual elements and quantification	Monetary values	Source
Total investments required for the northern network expansion	1) Storage, regulation tanks and pumping systems (3 500 m^3 tanks, 2 chlorination systems, pumps, valves, informatics systems, electric supply, cables, fuses etc.) 2) Pressurized pipes (10.8 km long network with standard pipe diameter of 180 mm) 3) Other general expenses (project management, general expenses, industrial profit, health risks and safety study)	1) 384 000 € 2) 1 576 000€ 3) 524 000 € Total: 2 484 000€ Other expenses: 174 000 € (fees, bank charges etc.) Total initial investment required: 2 658 000 €	Collado et al. 2003
Yearly operational costs for the northern network	1) Personnel costs (technical staff and management team, operator, administrative and commercial staff) 2) Maintenance costs (maintenance of network, meters and connections, electromechanical equipment and tanks) 3) Transports costs (Rental costs, gas, insurance etc.) 4) Water analyzes (8 control analyzes and 3 full analyzes) 5) Administrative expenses (billing costs, subscribers management , offices, overhead expenses) 6) Treatment costs (9 327 kg of sodium hypochlorite, at 0.222€/kg) 7) Electric consumption (279 209 KW/year)	1) 19 600€/year 2) 3770 €/year 3) 2530 €/year 4) 4320 €/year 5) 7 100€/year 6) 2070 €/year 7) 23 690 €/year Total: 62 910€/year Registered volumes: 396 000 m3/year Exploitation costs per m3: 0.1587€/m3	Collado et al. 2003
Total investments required for the southern network expansion	1) Regulation tank and pumping system (2000 m^3 tank, 4 30 Kw pumps, informatics etc.) 2) Tertiary treatment for a daily capacity of 3000 m3/day (sedimentation, sand filtration, UV disinfection and chlorination) 3) Pressurized pipes (7 km long network with 110 – 315 mm pipe diameters) 4) Other general expenses (project management, general	1) 212 000€ 2) 485 000€ 3) 1 234 000€ 4) 516 000 Total: 2 446 000€ Other expenses: 171 000 € (fees, bank charges etc.)	Collado et al. 2003

Cost element	Description of individual elements and quantification	Monetary values	Source
	expenses, industrial profit, health risks and safety study)	Total initial investment required: 2 617 000 €	
Yearly operational costs for the southern network	1) Personnel costs (technical staff and management team, operator, administrative and commercial staff) 2) Maintenance costs (maintenance of network, meters and connections, electromechanical equipment and tanks) 3) Transports costs (Rental costs, gas, insurance etc.) 4) Water analyzes (4 control analyzes and 1 full analysis) 5) Administrative expenses (billing costs, subscribers management , offices, overhead expenses) 6) Treatment costs (sedimentation, sand filtration and UV disinfection: 0.07 €/m^3 ; 12 827Kg of sodium hypochlorite: 0.222 €/kg) 7) Electric consumption (316 467 KW/year)	1) 19 600€/year 2) 2450€/year 3) 2350€/year 4) 1570€/year 5) 4860 €/year 6) 47 740€/year 7) 30 432€/year Total: 109 017 €/year Registered volumes: 545 00 m3/year Exploitation cost per m3: 0.20€/m3	Collado et al. 2003
Increased health risks related to contact with the reused water	Increasing water reuse volumes increases the risks related to human contact with the reused water, and thus the subsequent costs (see Table 15)	No quantification for this cost	
Increased CO2 emissions related to extra energy used	84 tons of CO_2/year for the northern network[29] 95 tons of CO_2/year for the southern network[30] A value of 43.42 EUR/ton CO_2 is used (see Table 15)	Considering the price per ton of CO_2, total costs related to CO_2 emissions from both networks are estimated at 7772 EUR/year. Thus an extra 6600 EUR/year as compared to the current situation (see Table 15).	Own calculations based on Collado et al.2003

29((279 000KWh X 0.302 kg))/1000 = 84,258 tons of CO2
30 ((316 467 KWh X 0.302 kg))/1000 =95,5 tons of CO2

Table 19 Benefits related to developments of the water reuse system in Sabadell

Benefit element	Description of individual elements and quantification	Monetary values	Source
Increased avoided costs in terms of water volumes stemming from the public distribution system	Replacing potable water volumes with reused water also implies saving the costs of providing these volumes. Information on the average cost of production per m^3 from the public distribution system was not available, thus total savings could not be quantified.	No quantification for this benefit	
Increased preservation of potable water resources	The fact of reducing the yearly volumes of potable resources used, allows the preservation or use of these volumes for other priority uses. This benefit is surely not negligible in a region that suffers from water scarcity problems. In order to emphasize the true value of water in a water scarce coastal region, a "rough" estimation would be to compare it to the cost of providing the same volumes with reverse osmosis technologies.	The system would allow the preservation of 1.1 hm^3/year. This represents 7.2% of the yearly water demand in Sabadell, or approximately 25 days of water supply in the city (1). The costs of producing potable water from desalination technologies is estimated at 0.6 EUR/m3 for the largest and most recent desalination plant in the region ("Desalinizadora el Prat del Llobregat")[31].Thus the benefit of preserving potable resources is estimated at 660 000 EUR/year.	(1) Vinyoles et al. 2005
Social benefits related to securing aesthetic values of Sabadell's green areas and parks faced to scarcity and drought restrictions	The system would allow to secure almost entirely the yearly water demand for irrigation of green areas and parks in the city, thus ensuring aesthetic values of the irrigated areas faced to water scarcity and drought restrictions	The CE provided an estimation of the willingness to pay for securing the entire yearly water demand for the irrigation of green areas and parks in the city. Average willingness to pay is estimated at 15 EUR/year per household. With an estimated number of households of 82 794[32], total bene-	Zayas et al. 2016

[31] https://www.ayesa.com/es/proyectos/desaladora_de_el_prat_de_llobregat
http://www.lavanguardia.com/vida/20090720/53749138847/hoy-entra-en-funcionamiento-la-desalinizadora-de-el-prat.html
Also depending on the specific technologies used, the costs of producing desalinated water are estimated between 0.3EUR/m3 and 0.8EUR/m3 (http://www.acuamed.es/media/publicaciones/desalinizacion-en-espana.pdf); this seems reasonable with the proposed value

[32] Considering a mean number of 2.51 individuals per household in Spain, and considering a population of 207 814 habitants living in Sabadell; an average number of 82 794 households is estimated for Sabadell. Data taken from: http://www.ine.es/inebaseDYN/ech30274/ech_inicio.htm, http://www.ine.es/welcome.shtml

Benefit element	Description of individual elements and quantification	Monetary values	Source
		fits are estimated at 1.2 million EUR/year.	
Social benefits related to securing street cleaning activities faced to water scarcity and drought restrictions	The system would allow securing the entire yearly demand of water for street cleaning activities in the city, thus securing these activities in case of water scarcity and drought restrictions.	The CE provided an estimation of the willingness to pay for securing the entire yearly water demand for street cleaning activities in the city. Average willingness to pay is estimated at 53 EUR/year per household. With an estimated number of households of 82 794, total benefits are estimated at 4.3 million EUR/year.	Zayas et al. 2016
Increased resilience of industrial activities to water scarcity and droughts	The system would allow increasing reuse volumes provided for industrial activities, thus increasing resilience of said activities faced to water scarcity. Approximately 362 000 m^3 would be made available each year (1). The degree to which each user is dependent on a regular water provision is unknown.	No quantification for this benefit.	(1) Collado et al. 2003
Revenues generated for the northern network	The northern network would provision: 214 users for irrigation of green areas and parks in Sabadell north, for a total volume of 270 000 m^3/year. 8 trucks for street cleaning activities, for a total of 125 000 m^3/year.	A total registered volume of 396 000 m^3/year for the northern network. The price per m^3 for the northern network is set at 0.31 €/m^3	Collado et al.2003
Revenues generated for the southern network	The southern network would provision: 25 industrial users for a total volume of 362 000 m^3/year 5 trucks for street cleaning activities, for a total volume of 125 000 m^3/year 100 users for irrigation of green areas and parks in Sabadell south, for a total volume of 58 000 m^3/year	A total registered volume of 545 000 m^3/year for the southern network The price per m^3 for the southern network is set at 0.57€/m^3.	Collado et al. 2003

It is acknowledged that the data used for the developments of the network dates back to 2003. It would have been optimal to update this information based on a second feasibility and profitability analysis[33] carried today (considering the same developments of the network) but such an assessment was not available. Nonetheless, when comparing the data from 2003 with current data, the information on operational costs and water tariffs applied does not appear significantly different today. First, when looking at current water tariffs (two volumetric tariffs of 0.2767 EUR/m^3 and 0.6917 EUR/m^3, seeTable 16) these tariffs are not significantly different from the tariffs considered for the expansion scenario (0.31 EUR/m^3 and 0.57 EUR/m^3, see Table 19). Also, the average cost/m^3 supplied for the current network is of 0.25 EUR/m^3 (for both north and south networks, see Table 15) while the costs for the expansion scenario were set at 0.1587 EUR/m^3 (north network) and 0.2 EUR/m^3 (south network), yielding an average cost of 0.18 EUR/m^3 supplied; it seems reasonable to consider a lower volumetric cost for the network after its expansion if one considers the scale economies realized by increasing the volumes supplied (currently 120 000 m^3 to 1 100 000 m^3 after expansion). This is usually the case with "network" type of goods (e.g., electricity, water, transport services etc.). Finally it is proposed here to consider, total investment costs as envisioned in the 2004 master plan since even if some the proposed developments are already finalized today (particularly those related to the northern network's expansion) (Ajuntament de Sabadell, 2014), the costs have nonetheless been borne and should thus be included into costs benefits considerations.

4.3 Evaluation of the environmental and social benefits

In order to assess the value given to selected societal benefits stemming from the reuse system in the city, a Choice Experiment survey was conducted among a representative sample of 300 Sabadell citizens. This survey also allowed inquiring about people's view on the reuse system in place and in general people's view and acceptance of water reuse for different urban uses in the city. The technical aspects of the Choice Experiment technique and the construction of the questionnaire are presented in Demoware deliverable 4.3 "CBA approach suited for water reuse schemes" (Zayas et al., 2016).

Demographic characteristics of the survey sample

From the survey sample, 55% of respondents were males and 45% were females. Figure 31 provides information regarding the age distribution of respondents. As can be seen, the sample presents an overall good representation of all age groups, with a large portion of respondents (55%) were between 25 and 54 years old.

[33] As carried in Collado et al. 2003

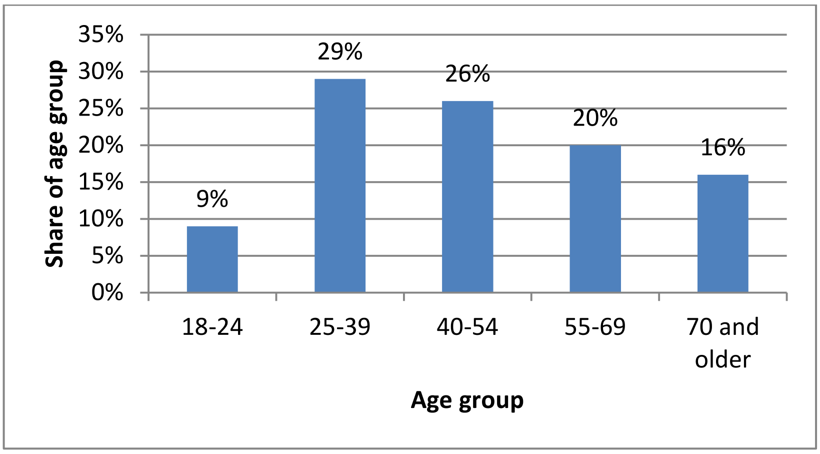


Figure 31 Age distribution of respondents in the sample

Figure 32 presents the distribution of respondents according to revenues. As can be seen, only 5% of respondents declared an overall income (for the household) lower than 1000 EUR/month. Almost half of respondents reported an income ranging between 1500 to 2500 EUR/month, while 17% of respondents reported an income higher than 3000 EUR/month. The overall "bell" looking form of the histogram shows a distribution of incomes concentrated in the "middle class" incomes.

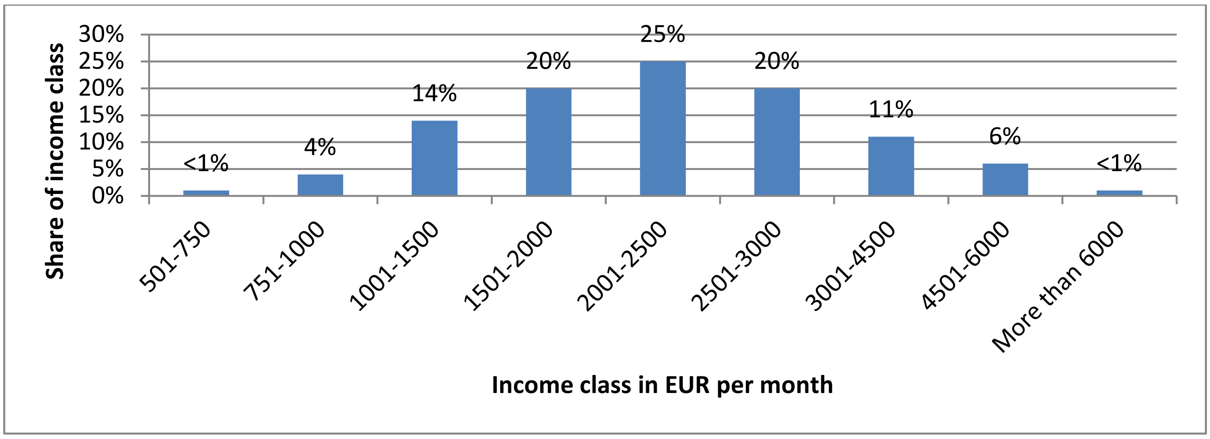


Figure 32 Monthly income distribution of respondents from the sample (per household)

Presentation of the Choice Experiment questionnaire results

From the survey sample, 79% of respondents (or 236 respondents) **were aware of the fact that wastewaters could be treated and reused, implying an overall good knowledge amongst Sabadell's citizens**. However, amongst the population aware of the existence water reuse, only 16% (37 respondents or 12% amongst the full sample) were aware of the existence of reuse activities in Sabadell.

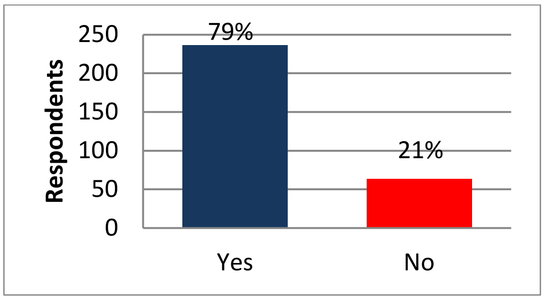


Figure 33 Belief regarding the possibility to reuse treated wastewater

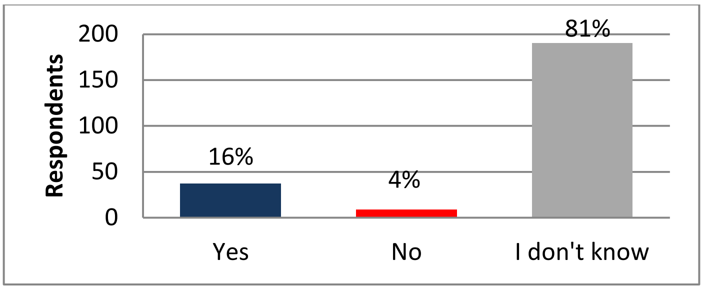


Figure 34 Belief regarding the existence of water reuse in Sabadell amongst respondents aware of the existence of water reuse

Amongst respondents aware of water reuse activities in Sabadell, which were 12% or 36 respondents: Eighty seven percent were aware of treated wastewater being used for street cleaning activities, 68% were aware of its use for park irrigation and 35% were aware of its use for municipal fountains. This suggests that **overall, more than 2/3 of individuals aware of the existence of water reuse in the city are aware of its main current uses** (only 8% of respondents with respect to the full sample). Moreover, 54% of respondents knew of its use for industrial purposes and 24% are aware of its use for toilets flushing (currently in practice only at an IKEA complex in Sabadell south). Finally, it is interesting to notice that 3 respondents aware of reuse activities in Sabadell stated that treated waste water is being used for potable consumption.

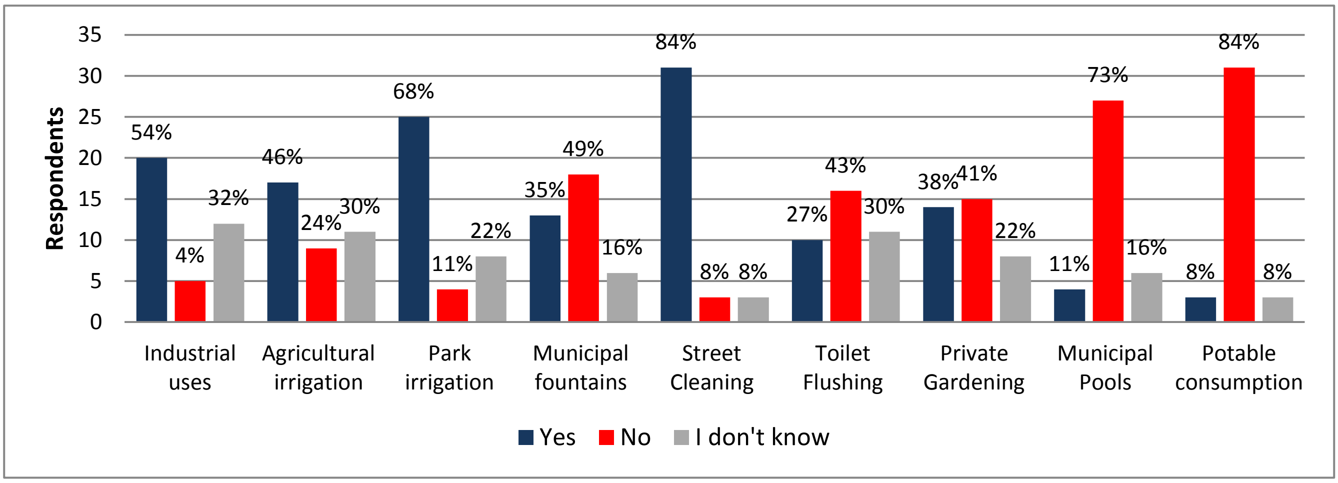


Figure 35 Belief regarding the use of treated wastewater in Sabadell (amongst respondents aware of reuse activities in Sabadell)

Regarding the potential benefits of water reuse in Sabadell, amongst the full sample of respondents, “Maintaining the aesthetics of parks and fountains” is seen as a potential benefit by the largest fraction of respondents with a ratio of 80% of “yes answers”, followed by “Improving the preservation of rivers, lakes and ground waters” and “Avoiding water restrictions for households during droughts”[34]. Thus, **4/5 of respondents seem to acknowledge the potential benefits water reuse can have for the preservation of local water bodies**. Overall, all benefits have a proportion of “yes” answers ranging between 75% to 80%, which implies that **water reuse is seen as having an overall positive outcome in terms of benefits**.

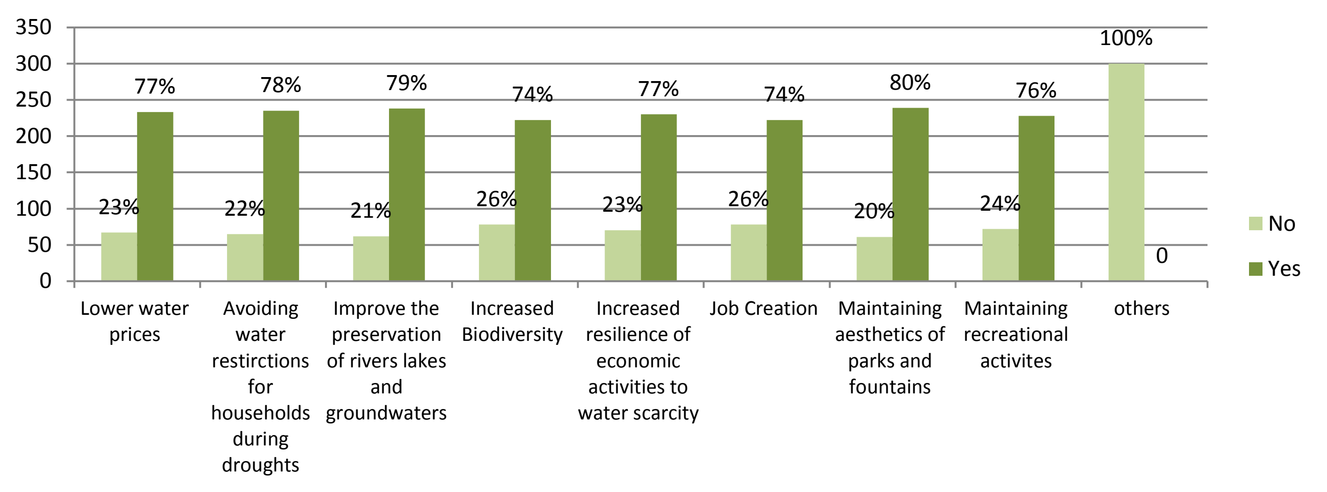


Figure 36 Belief regarding potential benefits of water reuse in Sabadell (amongst the full sample of respondents)

While looking at answers conditional on the knowledge of existence of water reuse and conditional on the knowledge of existence of water reuse activities in Sabadell, the proportion of “yes” answers differ amongst subsamples. The subsample of respondents aware of the existence of water reuse but unaware of the existence of reuse activities in Sabadell has a proportion of “yes” answers ranging between 80% to 87% for all benefits, thus having higher ratios of “yes” answers for all benefits than the overall sample. On the other hand, for **the subsample of respondents completely unaware of the existence of water reuse, the proportion of yes answers is lower ranging between 53% to 64% for all benefits**. This seems logical since respondents unaware of the existence of water reuse are likely to be more sceptical with respect to potential benefits. This **highlights the importance of undertaking informational campaigns to favour the acceptance of water reuse**.

For the subsample of respondents aware of the existence of water reuse in Sabadell, all benefits have lower proportions of yes answers ranging between 54%-65%, with the exception of “Maintaining aesthetics of parks and fountains” and “Avoiding water restrictions for households during droughts” with ratios of 84% and 70% of “yes answers” respectively. This might suggest that these respondents are indeed better informed about current reuse activities in the city and the potential benefits related to these activities but, are more sceptical with respect to other benefits.

34 With ratios of 79% and 78% of “Yes“ answers respectively

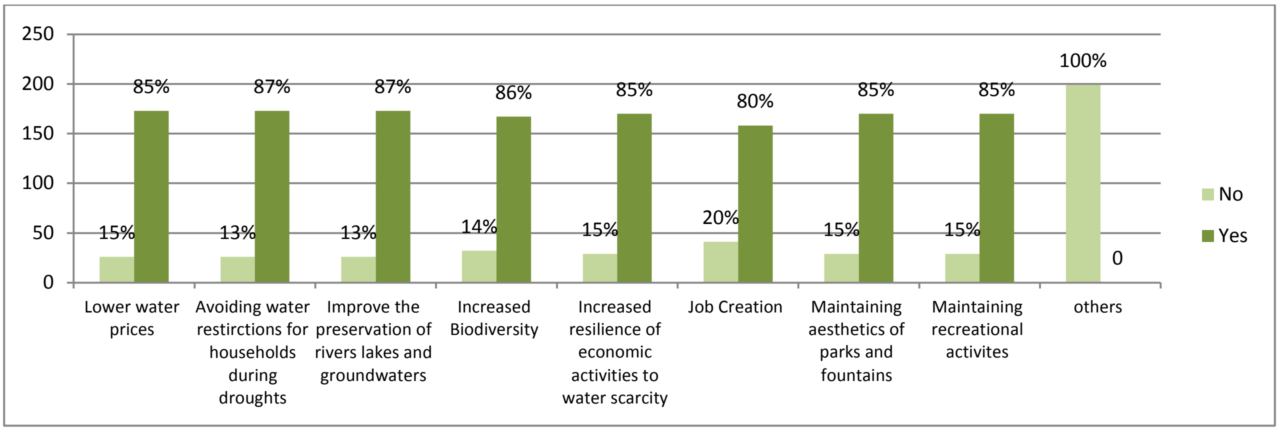


Figure 37 Belief regarding potential benefits of water reuse in Sabadell (subsample of respondents aware of the existence of water reuse but unaware of the existence of reuse in Sabadell, 190 respondents or 63% of respondents)

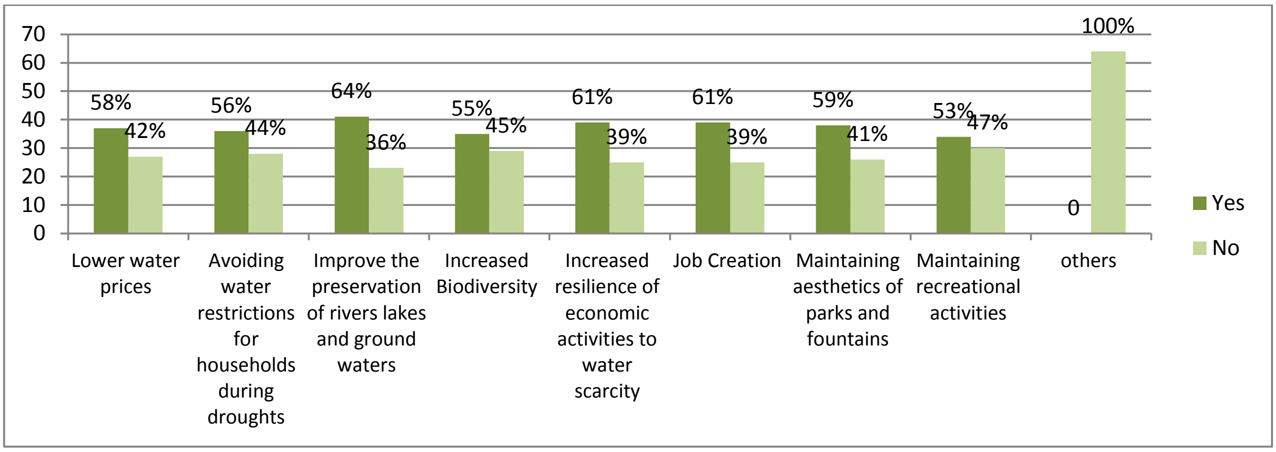


Figure 38 Belief regarding potential benefits of water reuse in Sabadell (subsample of respondents unaware of the existence of water reuse, 64 respondents or 21% of respondents)

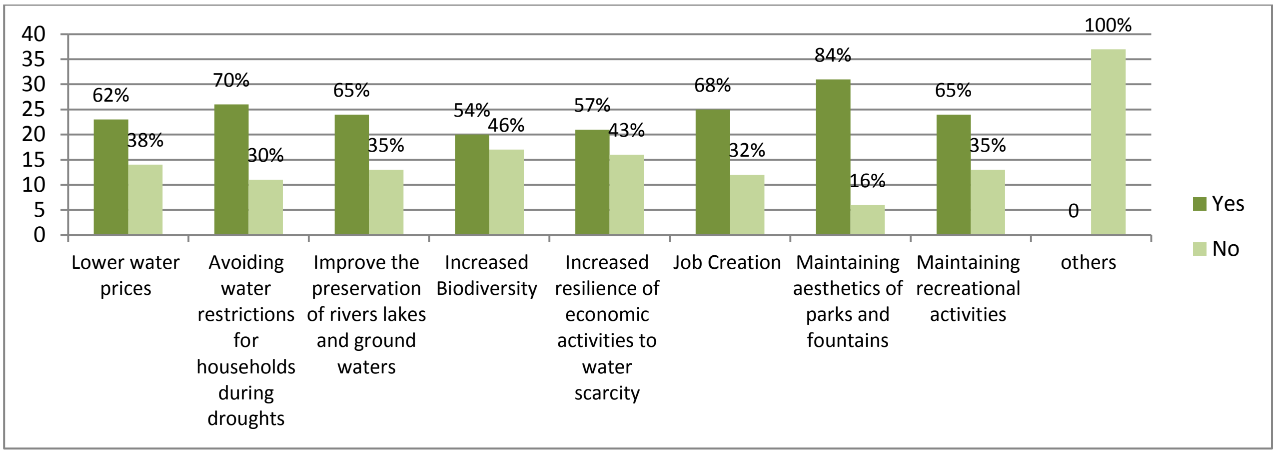


Figure 39 Belief regarding potential benefits of water reuse in Sabadell (subsample of respondents aware of the existence of water reuse in Sabadell, 37 respondents or 12% of respondents)

Regarding the potential downsides of water reuse in Sabadell, amongst the full sample of respondents, "Human health risks related to contamination" and "Increased chemicals in water" have the higher ratios of "yes" answers with 81% and 78% respectively. "Odour" and "Colour" also appear as potential downsides concerning a large fraction of respondents (76% and 73% respectively). One interesting fact is that for approximately 70% of respondents, "Increase CO_2 emissions" is perceived as a potential downside stemming from water reuse. In general, all presented downsides have a ratio of "yes" answers ranging from 64% to 80%.

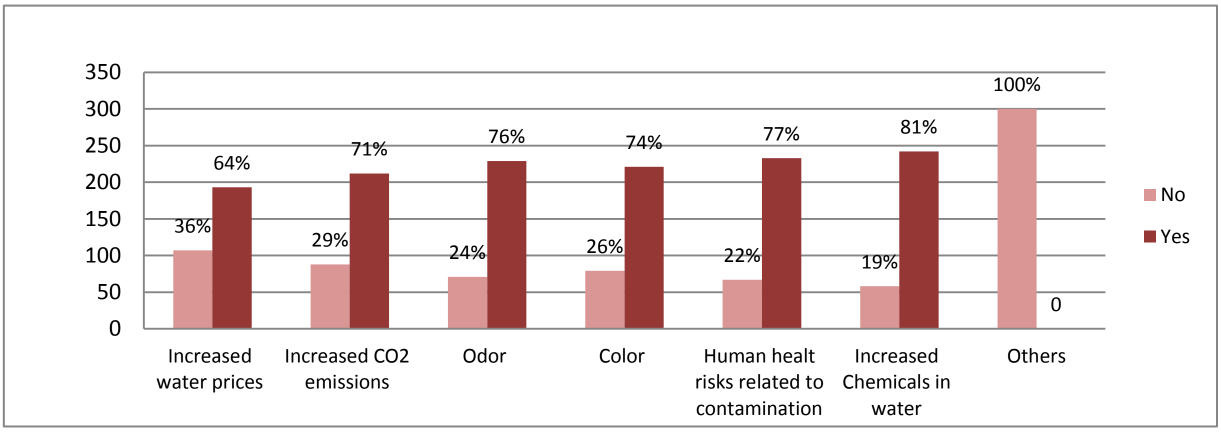


Figure 40 Belief regarding potential downsides of water reuse in Sabadell (amongst the full sample of respondents)

Amongst the subsample of respondents aware of the existence of water reuse but unaware of the existence of water reuse in Sabadell, the proportion of "yes" answers for all downsides ranges between 78%-87%, while percentages of "yes" answers range from 41% to 61% amongst the subsample off respondents unaware of the existence of water reuse at all. This suggest that, even if there is a higher rate of acceptance of potential benefits related to water reuse amongst respondents previously aware of water reuse, these respondents are also more concerned about potential downsides related particularly to water quality issues than respondents previously unaware of reuse activities. **Information campaigns should thus look to reassure people's views related health risks and the use of chemicals**.

Amongst the subsample of respondents aware of the existence of reuse activities in Sabadell, the proportion of "yes" answers ranges from 32% to 68% for all downsides.

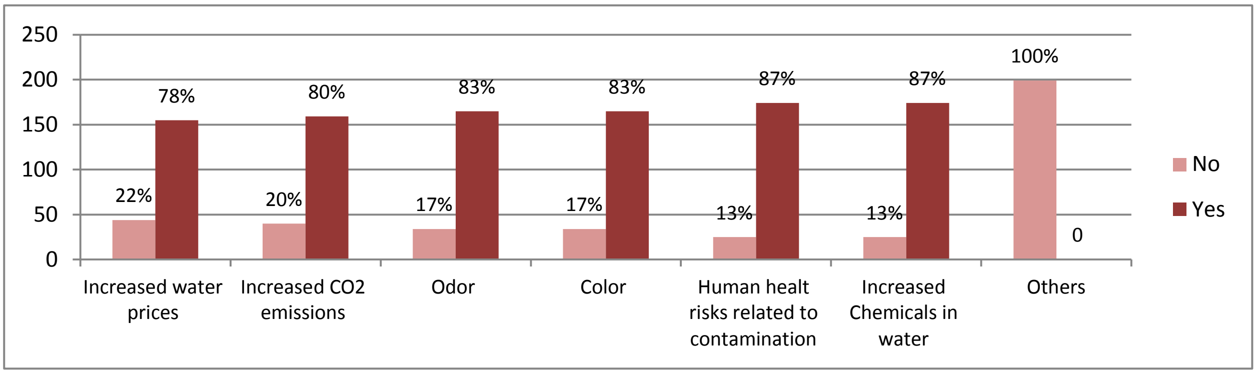


Figure 41 Belief regarding potential downsides of water reuse in Sabadell (subsample of respondents aware of the existence of water reuse but unaware of the existence of water reuse in Sabadell, 190 respondents or 63% of respondents)

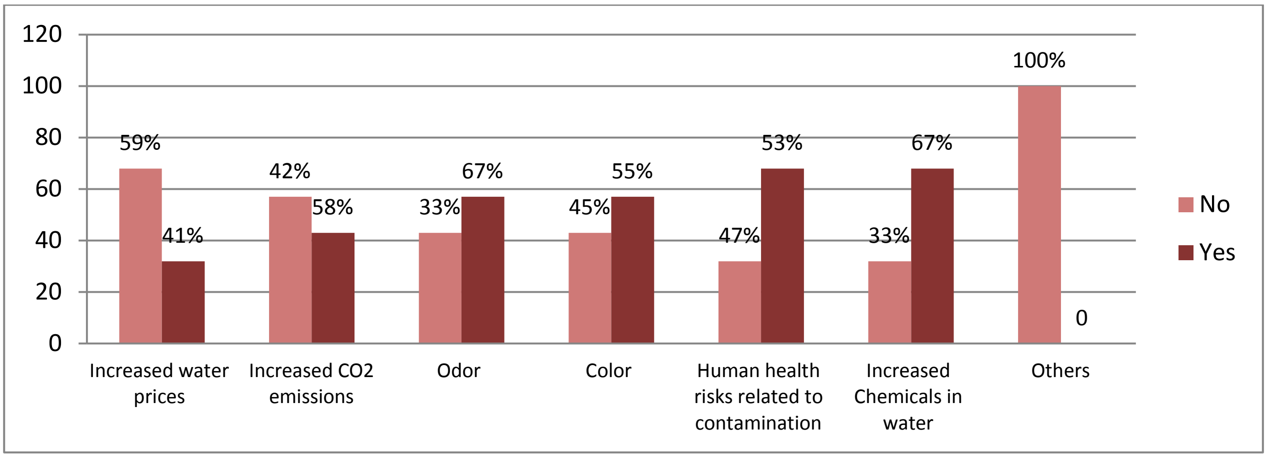


Figure 42 Belief regarding potential downsides of water reuse in Sabadell (subsample of respondents unaware of the existence of water reuse, 64 respondents or 21% of respondents)

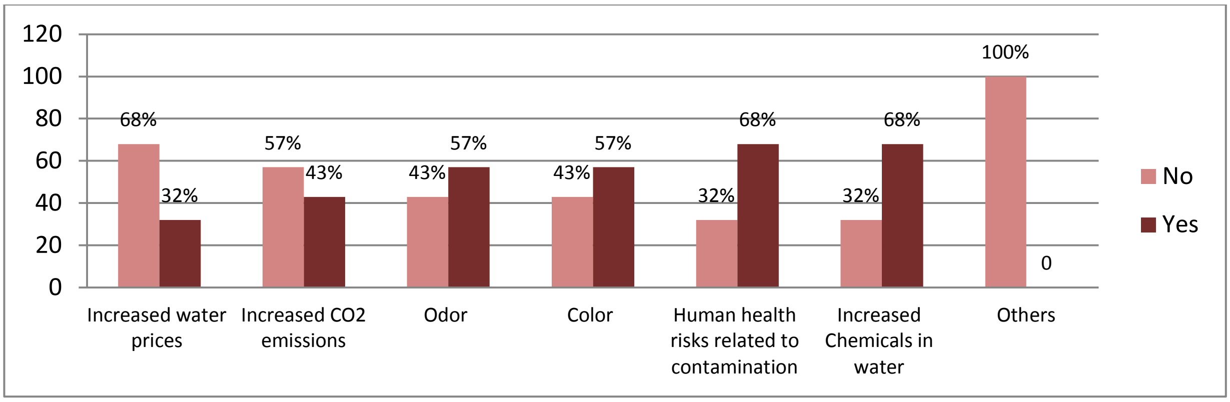


Figure 43 Belief regarding potential downsides of water reuse in Sabadell (subsample of respondents aware of the existence of water reuse in Sabadell, 37 respondents or 12% of respondents)

Regarding respondents' acceptance of different uses for reused water in the city, uses having the highest acceptances rates[35] are park irrigation, streets cleaning activities, toilet flushing, gardening activities and industrial uses with acceptance rates[36] higher than 94% for all uses. All of these uses have less than 1% "disagree" answers and 2% to 5% of "neutral" answers. **Current uses of reused water in Sabadell are thus supported by the large majority, if not the full sample, of respondents (even though only 16% of respondents are actually aware of reuse activities in the city)**. Also, envisioned future uses (toilet flushing and industrial uses) are well accepted by a large majority.

Irrigation of crops for direct and indirect consumption, also have a high acceptance rate of approximately 88% each. Both uses have only 5% of respondents stating to "disagree" and 7% of respondents declaring themselves as "neutral" with regards to these uses. Thus, **potential future use of reused water for agricultural irrigation would be supported by a majority of the population**.

Reused water for municipal fountains and municipal pools also have overall high acceptance rates[37]. It's interesting to notice such a high acceptance rate for the use of treated waste water for municipal pools

35 Sum of "agree" and "strongly agree" answers

37 With 79% and 78% acceptance rates respectively

which implies full contact with the reused water; moreover 36% of respondents stated to “strongly agree” with this use. Both uses have non acceptance rates[38] of approximately 10%, with only 3% of respondents stating to “strongly disagree” with reused water used for municipal pools.

Potable consumption has the highest non acceptance rate if compared to other uses, with a 35% non acceptance rate[39]. However, against what could have been expected, more than half of respondents (54% in total) stated to “agree” or “strongly agree” with this use. It interesting to remark that approximately 1/3 of respondents declared to strongly agree with this use.

The previous information suggests that respondents are in general in favour of water reuse, and would encourage its development in the city. Most uses are accepted by a large majority of respondents, even the ones related to potential health risks (which are accepted at least by more than half of respondents).This suggests that respondents are rather confident in the capacities of the services providers to supply good quality waters and minimize health risks. Also, this information provides evidence to support and encourage the development of water reuse in the city.

38 Sum of “disagree“ and “strongly disagree“ answers

39 10% of respondents stating to “strongly disagree” and 25% stating to “disagree” with this use

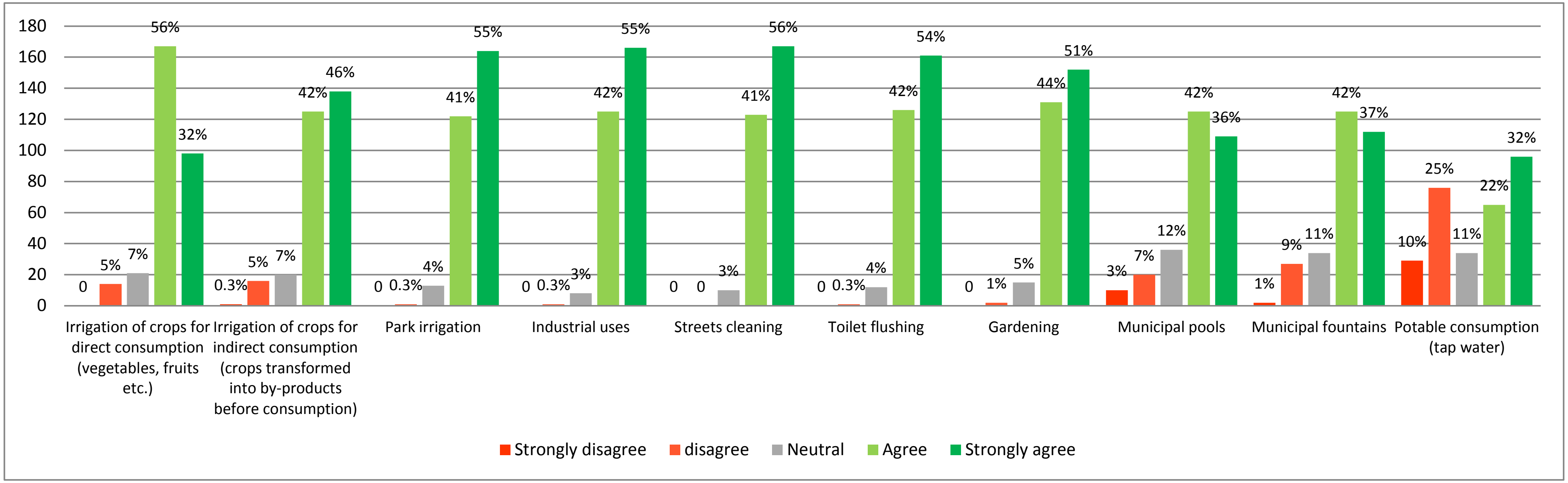


Figure 44 Acceptance of different uses for reused water in Sabadell (full sample of respondents)

Respondents stating to “disagree” or “strongly disagree” with a particular use, were asked to choose between different potential reasons for doing so. **For all uses with non acceptance answers, “Health risks related to contamination” and “Increased chemicals in waters” were both chosen as the main reasons for non acceptance by approximately 30% of respondents each**. “Odour & Colour” were chosen as the main reasons for non-acceptance by approximately 20%-22% of respondents. It is interesting to notice that approximately 20% of respondents, stating to disagree with a particular use, chose at least one reason not related to water quality at all (either “Increased water prices” or “Increased CO_2 emissions”).

Table 20 Reasons for non acceptance amongst respondents stating to "Strongly disagree" or "disagree" with a particular use for treated wastewater in the city (two reasons per respondent)

Uses	Number of "disagree" or "strongly disagree" answers	Increased water prices	Increased CO_2 emissions	Odor & Color	Human health risks related to contamination	Increased chemicals in waters	Others : ....
Irrigation of crops for direct consumption (vegetables, fruits etc.)	14	4 (14%)	2 (7%)	7 (25%)	8 (29%)	7 (25%)	0
Irrigation of crops for indirect consumption (crops transformed into by-products before consumption)	17	2 (6%)	4 (12%)	7(21%)	10 (29%)	11 (32%)	0
Park irrigation	1	0	1	0	0	1	0
Industrial uses	1	0	1	1	0	0	0
Streets cleaning	0	0	0	0	0	0	0
Toilet flushing	1	0	1	0	1	0	0
Gardening	2	1	1	0	1	1	0
Municipal pools	30	4 (7%)	8 (14%)	11 (19%)	24 (41%)	12 (20%)	0
Municipal fountains	29	7 (12%)	7 (12%)	14 (24%)	15 (26%)	15 (26%)	0
Potable consumption (tap water)	105	20 (10%)	37 (18%)	44 (21%)	65 (32%)	39 (19%)	0

The next set of questions relate directly to the current reuse system in Sabadell. Respondents were first presented with the main elements of the system and where then, asked a series of question to assess their perception and degree of support towards the system. **Approximately 79% of respondents are either "Generally supportive" or "Completely supportive" of the reuse system in place**, 15% indicated a neutral position and only 7% declared themselves against it. **Thus, overall 4/5 of individuals support the system in place.**

Table 21 How supportive are you of the current reuse system in Sabadell?

Answers	Percentage
Completely against	0 %
Generally against	7 %
Neutral	14%
Generally supportive	49%
Completely supportive	30 %

Only 4% of respondents (12 individuals) declared that the current system generates potential risks. Amongst the cited risks, the main elements were related to an increase in the presence of chemical products in the Ripoll River and human health risks related to potential contact with the reused water.

Table 22 Do you see any potential risks of this system?

Answers	Percentage
No	96 %
Yes	4 %

When asked about potential benefits compared against potential risks or costs related to the current system, 54% of respondents declared that the benefits outweigh the costs or risks of using recycled water for streets cleaning activities and irrigation of green areas and parks. 22% of respondents considered that current system entails greater costs or risks than benefits, while 23% declared that the benefits and costs are equal. **Thus more than half of the individuals consider that the current system in Sabadell generates net benefits in the city**.

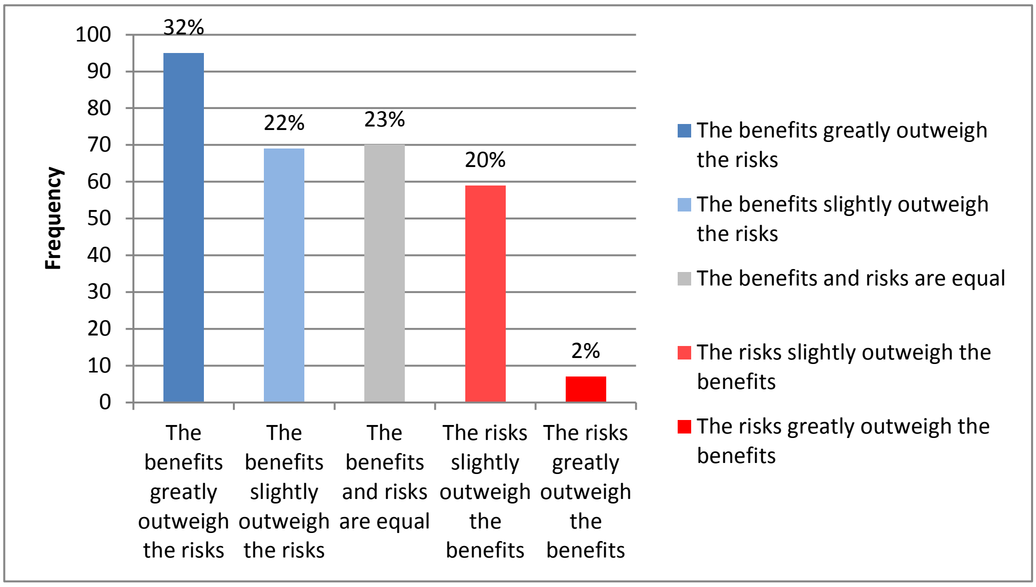


Figure 45 How would you best compare the risks versus the benefits of using recycled water in this way?

Finally, regarding the degree of trust given to the water service provider to ensure that the current reuse system protects the environment and particularly public health, in general, **71% of respondents seem to trust the water service provider** while only 12% of respondents seem doubtful with this regard.

Table 23 Do you trust the water service provider to manage this recycled water system in a way that protects the environment and particularly public health?

Answers	Percentage
Complete trust	15%
A lot of trust	56%
Some trust	18%
Little trust	8%
No trust at all	4%

Now with respect to respondents' willingness to pay for different societal benefits stemming from the Sabadell reuse system, results will be presented in the following section. Given the context of water scarcity in the region and the fact that there have been several drought periods during the past decade, the focus was to assess the value given to social benefits stemming from securing, with reused water, different urban water uses in the city when faced to scarcity or drought situations. Only statistically significant results are presented in the following (a more detailed description of the econometric analysis can be found in Annex 7.1).

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. Thus individuals do value water reuse as a means of securing the aesthetic values of Sabadell's green areas and parks, and are willing to pay for said benefits.

On average, households are willing to pay 53 EUR/year to secure street cleaning activities in the city with reused water. Thus, individuals do value the benefit of having clean streets, all year long, thanks to water reuse.

On average, households are willing to pay 27 EUR/year to secure that domestic outside 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. Willingness to pay to secure potable uses with reused water is not statistically significant and, is thus not discussed here.

While looking at the distributions of willingness to pay, a large majority of respondents seem to be willing to pay to secure street cleaning activities with reused water, with ¼ of respondents having a willingness to pay of more than 87 EUR/year. For securing domestic outside uses and toilet flushing needs, over ¼ of individuals are not willing to pay to secure said uses with reused water. On the other hand, more than 50% of individuals are willing to pay 27 EUR/year or more. This distribution suggests that, as compared to securing water needs for street cleaning activities, individuals are more divided on the idea of paying 27 EUR/year to secure domestic outside uses and toilet flushing needs with reused water but, overall more than half of respondents would be willing to make the extra effort. The distribution of the willingness to pay for green areas and park irrigation with reused water is not statistically significant and, is thus not discussed here.

In conclusion, Sabadell citizens do value water reuse as a solution to cope with water scarcity and drought situations in the city. Indeed Sabadell households are on average willing to pay 95 EUR/year or 8 EUR/month to support the development of water reuse in the city for the previously presented urban uses, and thus secure in this way certain benefits affecting the quality of life in the city when faced to water scarcity and drought situations. These values can be used to approximate the overall indirect societal benefits stemming from the development of water reuse in the city as a solution to cope with water scarcity and drought situations. Clearly securing street cleaning activities with reused water, and thus securing the maintenance of clean streets, appears as the most valued use for reused water in the city.

Finally respondents having a high perception of scarcity or drought risks in the city have an overall higher willingness to pay for potential uses for reused water in the city. This highlights the importance of conveying during information campaigns the fact that water scarcity and drought risks will likely increase over time in order to stress the importance of encouraging water reuse to reduce potential scarcity risks but also, to secure certain benefits affecting the quality of life in the city.

Considering a mean number of 2.51 individuals per household[40] in Spain, and considering a population of 207 814 habitants living in Sabadell[41]; an average number of 82 794 households is estimated for Sabadell.

40 http://www.ine.es/inebaseDYN/ech30274/ech_inicio.htm
41 http://www.ine.es/welcome.shtml

Considering the previous information and the willingness to pay for different uses of reused water in Sabadell, social benefits related to securing street cleaning activities with reused water are on average estimated at 4.3 million EUR/year and social benefits related to securing the irrigation of parks and green areas in the city are on average estimated at 1.2 million EUR/year.

4.4 Results from testing the Water reuse CBA tool for the Sabadell case study

4.4.1 General assumptions for the financial analysis

All information, on investment costs, operational costs and revenues and environmental or social benefits used to feed in data for the CBA scenarios tested with the tool was taken from section 4.2.

The tool first asks for information on labour and energy costs. Normally the tool asks for an annual mean salary in Euros that would be used for each personnel unit specified later on. Nonetheless, for the Sabadell Case study, information available only specifies total labour costs for each network (after expansion)[42] and does not specify the number of workers or personnel. Since both north and south networks have the same total labour costs specifications (19 600 EUR/year after expansion), total labour costs were inputted as mean annual salary. This causes no problems since for each network a single unit of personnel will be later specified, this single unit accounting for total labour costs. For the current reuse situation, total costs are estimated using only a cost in EUR/m3 supplied and total volumes supplied, since information on specific operational costs was not available

For energy specifications, an average value of 0.09 EUR/kWh[43] was selected, by calculating the average of total energy costs related to the yearly kWh consumed for each network.

The tool also asks for information on the projects' lifetime, time of construction and financial discount rate to be used to calculate the net present value of the future yearly cash flows. For the case study, a project life time of 20 years was selected. Even though both networks might probably run for a longer period of time, said lifetime was selected given that the financial study made in Collado et al. 2003 spans over a 20 year period. A value of 3 years was selected for the time of construction of both networks, as specified in Collado et al 2003. For the discount rate, a value of 4% was selected as recommended in the "Guide to Cost-Benefit Analysis of Investment Projects" by the European Commission (EC, 2014). Using a common value is recommended in order to ensure the uniformity of approach in calculating present values across different investment projects and also to remove incentives to adjust the discount rate to affect the outcomes of the Net Present Value (NPV) analysis (EC 2014).

The next step consists in creating the different CBA scenarios that are going to be assessed with the tool. For the Sabadell case study, two scenarios were created: one relating to the current situation of water reuse in the city ("current situation" scenario), and one in which the developments proposed in the 2004 Master Plan are considered ("north/south network expansion" scenario). The first scenario corresponds to a counterfactual situation for the CBA analysis, since it represents a "do minimum" option where only current reuse activities are maintained.

For each scenario, there is the need to define each element of the reuse system in place: that is, defining a treatment line or station by specifying the different treatment units (or treatment steps) along the entire treatment/distribution process and inputting data on investments and operational costs for each treatment unit (or step) separately if possible. If a disaggregation of costs is not possible, it is also possible to input aggregated costs of a given reuse system by attributing total costs to a single treatment unit,

42 For the current reuse system, specific information on labor costs was not available
43 (½ x (30 432 €/316 467 KWh) + ½ x (23 690€/279 209 KWh))= 0,0905€ (see Table 15)

while leaving all other units with null costs. Also, for a given treatment station, the tool asks first to specify the "shared treatment", while after, "specific treatment" units related to specific reuse objectives need to be specified[44] (see Figure 46 for a better understanding).

For each scenario, the entire reuse system was represented as best as possible. For the "current situation" scenario, reused water is coming from both Ripoll WWTP and Riu Sec WWTP. But, for simplicity purposes, since information on operational costs is only available at an aggregated level (for both stations), only one treatment station (or "factory" as named in the tool) was created (representing the current reuse system).

For initial investment costs regarding the current network, no costs were considered since the network already exists and no additional investments are required for its functioning. For operational costs, as explained previously, information is accounted at an aggregated level for both WWTPs[45]. Only costs exclusively regarding reuse activities are considered, that is costs stemming from the normal operation of both WWTPs (all costs related to water sanitation purposes) are ignored. Also, given that information on operational costs is only available for the entire system and not available for each treatment step specifically, for simplicity purposes, all cost data was attributed to one single "treatment unit". All cost information was taken from Table 15.

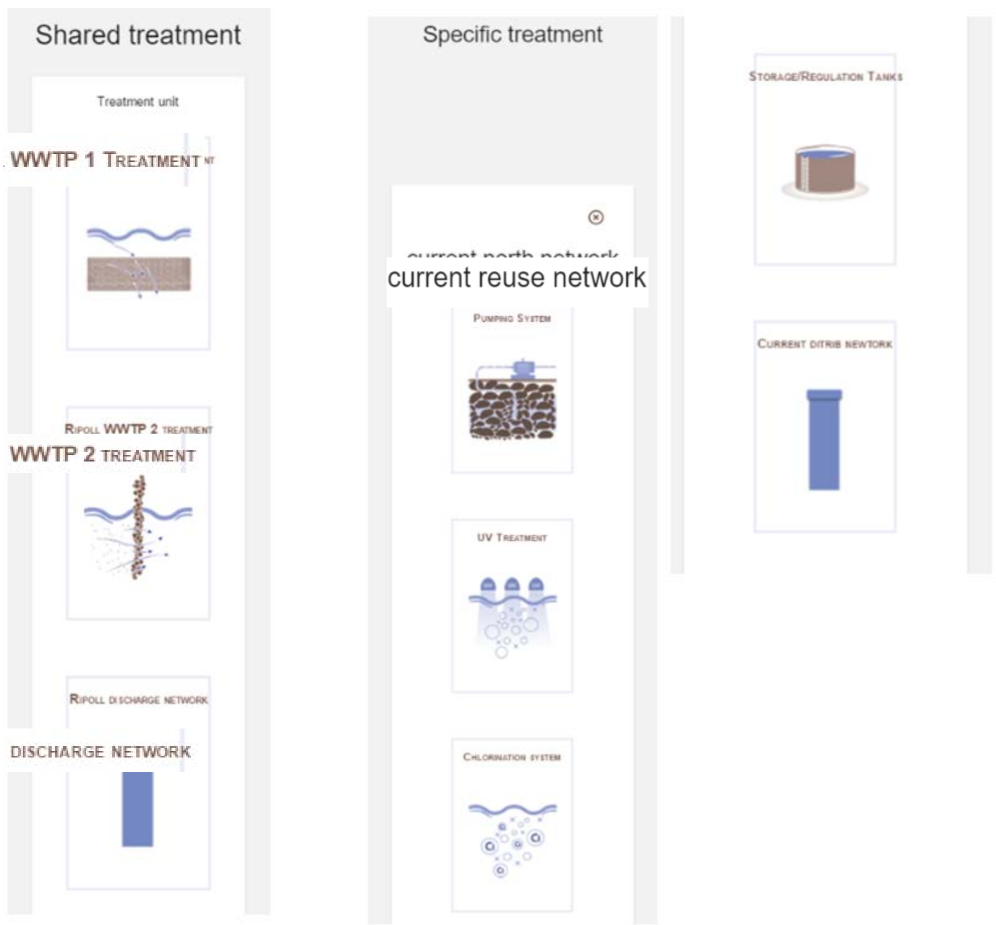


Figure 46 Treatment process for the current reuse system as represented in the tool

44 This way of structuring the treatment process, relates to the fact that wastewater can undergo a shared treatment independently of the reuse objectives and then undergo particular treatments in the same station depending on water reuse objectives
45 Only information on costs in EUR/m3 produced was considered (see Table 14).

For the “north/south network expansion” scenario, two treatment stations (or “factories” as named in the tool) were defined: the “north reuse network” and the “south reuse network”. For initial investment costs, only extra investment costs required for the expansion of both networks were considered. Regarding operational costs, for the north reuse network, the information provided concerns only total costs related directly to reuse activities after the expansion (ignoring shared treatment costs from the Ripoll WWTP). The same applies for the southern network, only extra costs generated by the new reuse activities in the Riu Sec WWTP were considered[46] (as specified in Collado et al 2003), while ignoring regular operational costs in the station[47]. Again given that for both north and south networks, available information on investment costs as well as operational and maintenance costs is only available at an aggregated level for each reuse network, all cost data was inputted to one single “treatment unit” for each network. All cost information has been taken from Table 18.

Finally, once all cost data has been entered for each scenario, the tool asks for information on final users of the reused water. For the “north/south network expansion” scenario, for the northern network, a total consumption of 396 000 m^3/year is estimated, with a number of 222 users (green areas irrigation users and cleaning trucks). The tool also asks for the price of the reused water, which was set at 0.31 EUR/m^3 for the north reuse network (Collado et al. 2003). For the south network, a total consumption of 545 000 m^3/year is estimated, with a number of 130 users (industrial users, green areas irrigation users and street cleaning trucks). The price for the southern network was set at 0.51 EUR/m^3 (Collado et al. 2003). For the “current situation” scenario, registered reuse volumes are of approximately 120 000 m^3/year and the price of the reused water was set at 0.4843 EUR/m^3 [48] (current average volumetric tariff applied).

Once all this data has been entered, the tool calculates the yearly operational costs and revenues for each scenario; within a scenario, for each treatment station or factory and; within a factory, for each treatment line (if multiple treatment lines exist within a given factory). Table 24 provides a summary of yearly annual costs and revenues for each scenario.

Table 24 Summary of yearly operational costs and revenues for each scenario (with fully operational networks)

	Current reuse situation scenario	North/south network expansion scenario	
	Current reuse network	North reuse network	South reuse network
Yearly operational revenues	58 104€	122 760 €	310 650 €
Yearly operational costs	35 250€	64 515 €	107 054 €
Yearly financial outcome per factory	+ 22 850 €	+ 58 245 €	+ 203 596 €
Yearly financial outcome per scenario	+ 22 850 €	+ 261 841 €	

4.4.2 CBA financial analysis with the tool

Having identified and quantified the set of costs and revenues of a given project, there are a number of methods/performance metrics which can be used to assess a project’s overall financial profitability. The tool’s financial (and economic) analysis criterion is based on the Discounted Cash Flow (DFC) or Net Present Value (NPV) method, as recommended for CBA analysis (EC, 2014). The NPV is the sum of the dis-

46 Extra costs related to tertiary treatment, storage/regulation and distribution of the effluent
47Primary treatment, secondary treatment based on MBR technology and discharge outlet
48 See Table 14

counted cash flows over the period of analysis. This criterion is simply based on whether the sum of discounted benefits exceeds the sum of discounted costs.

For the calculation of financial profitability, according to CBA criteria, financial profitability analysis should be based on the financial net present value on investment FNPV(C) which compares investments costs to net revenues and measures the extent to which the project's net revenues are able to repay the investment regardless of the sources or methods of financing. More precisely the FNPV(C) is defined as the sum that results when the expected investment and operating costs of the project (discounted) are deducted from the discounted value of the expected revenues (EC, 2014).

Only the project's cash inflows and outflows should be considered in the analysis, i.e. depreciation, reserves, price and technical contingencies and other accounting items which do not correspond to actual flows should be disregarded. Moreover, direct taxes (on capital income or other) should be considered only for financial sustainability verification and not for the calculation of financial profitability, which is calculated before such tax deductions[49] (EC, 2014).

The projects revenues should only account for the cash inflows directly paid by users of the goods or services provided by the operation. Transfers or subsidies (e.g. transfers from state or regional budgets), as well as other financial income (e.g. interests from bank deposits) should not be included within the operating revenues for the calculations of financial profitability because they are not directly attributable to the project's operations (EC, 2014).

Thus following all the previous guidance, the tool only takes into account the calculation of the FNPV(C) based on operational revenues paid by users, operational costs and initial investments costs[50]. The following lines present the results for the financial part of the CBA analysis as performed by the tool, for both the "current reuse situation" scenario[51] and the "north/south networks expansion" scenario, which contemplates the expansion of water reuse in Sabadell. Figure 47 illustrates the calculation of the FNPV(C) for the "north/south networks expansion" scenario, as produced by the tool.

49 The rationale is to avoid capital income tax rules complexity and variability across time and countries

50 And not accounting for sources of financing and cash transfers such as tax payments, subsidies etc.

51 Which corresponds to a "do minimum" counterfactual situation

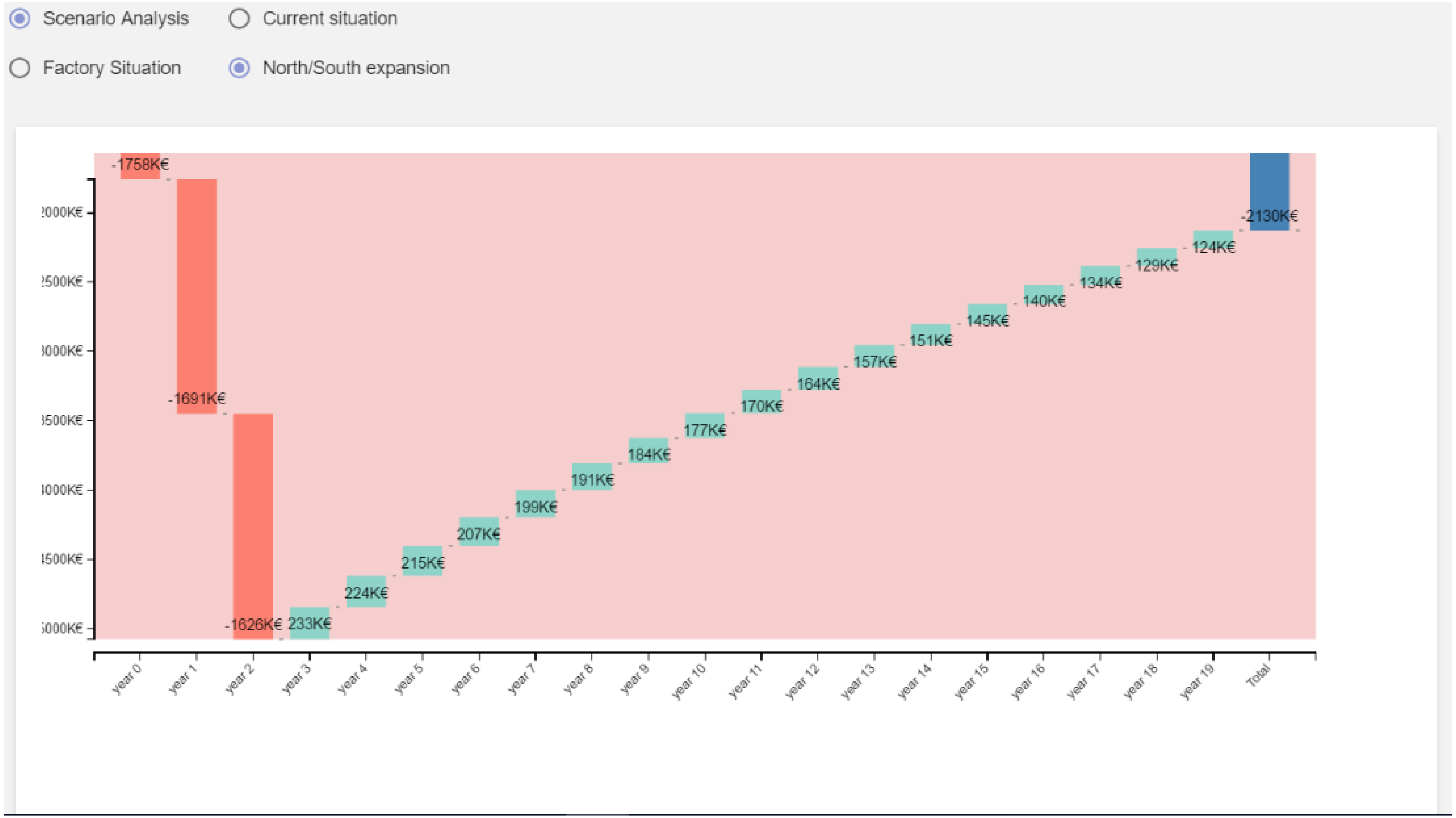


Figure 47 Yearly discounted cash flows and FNPV(C) for the “north/south networks expansion” scenario

Using a 4% discount rate, as previously explained, the graph shows the discounted cash flows for a period of 20 years, which corresponds to the selected time horizon for analysis, and the FNPV(C) which is simply the sum of these cash flows. As can be seen, the first three years of the project's cash flows corresponds only to initial investments required for the construction of both networks, while from the fourth year onwards, cash flows correspond to the yearly financial outcome from the operation of both networks (which is shown in Table 24). Values are decreasing because of the discount factor which applies from year one onwards. A negative FNPV(C) of 2 130 000 € is obtained. This implies that the sum of the project's operational revenues is not enough to cover the sum of operational costs plus initial investment needs.

Figure 48 (below) illustrates the calculation of the FNPV(C) for the "current reuse situation" scenario, as produced by the tool. One point needs to be stressed here. In its current state, the tool can only apply one value as infrastructure construction period for all scenarios and said value was set at three years[52]. Moreover, the tool assumes that while the required infrastructures are under construction period, no operations are possible. Since the current network is already fully operational and no investments are required[53], that is why the first three years for the "current situation" scenario show zero values. Nonetheless the yearly financial outcome from the current network's operation (which is shown in Table 24) should also be accounted for during these years. Thus the FNPV(C) should be corrected from 257 000 EUR, as shown in the graph, to 323 000 EUR[54].

Thus, exclusively from a financial point of view, taking society as the relevant stakeholder of the project and considering only the FNPV(C) as indicator of financial performance, the "north/south network's expansion" project should not be encouraged, since the generated revenues do not cover generated costs and investments needs. Moreover, the "current reuse situation" scenario appears as the preferable option since it generates a positive FNPV(C). Nonetheless to stop the analysis at this stage would be a mistake since economic costs and benefits generated by each scenario should also be accounted for.

One important remark needs to be pointed out at this stage. The fact that the previous conclusion leads to discouraging the project from a "financial point of view" does not mean that the project is actually not profitable if we consider CASSA as the relevant stakeholder of the investment. A financial sustainability and feasibility analysis for said developments of the networks, that is the northern/southern expansion, was carried in Collado et al. 2003, and the conclusion of this analysis is that the project would generate net benefits for the concerned stakeholders. The difference is that all monetary flows were considered in their study and especially initial sources of financing which are excluded in this CBA analysis.

Indeed the FNPV(C) is not the only indicator of financial performance, and other indicators are more appropriated and should be used if the objective is to evaluate financial performance from investors' point of view. Of course that in order for the project to be implemented, the project needs to be profitable for investors, and CBA analysis also requires a financial feasibility and sustainability analysis (CE, 2014), to check whether the project is feasible and beneficial form the stakeholder's point of view. Such an analysis, can be found in Collado et al. 2003, but will not be discussed here. The CBA tool purpose is not to carry a financial sustainability and feasibility analysis.

52 Construction period defined for the north and south networks construction

53 And thus zero investments costs were entered in the tool for the scenario

54 Accounting for the discount factor: +23000 € for year 0; + 22000 € for year 1; +21000 € for year 2

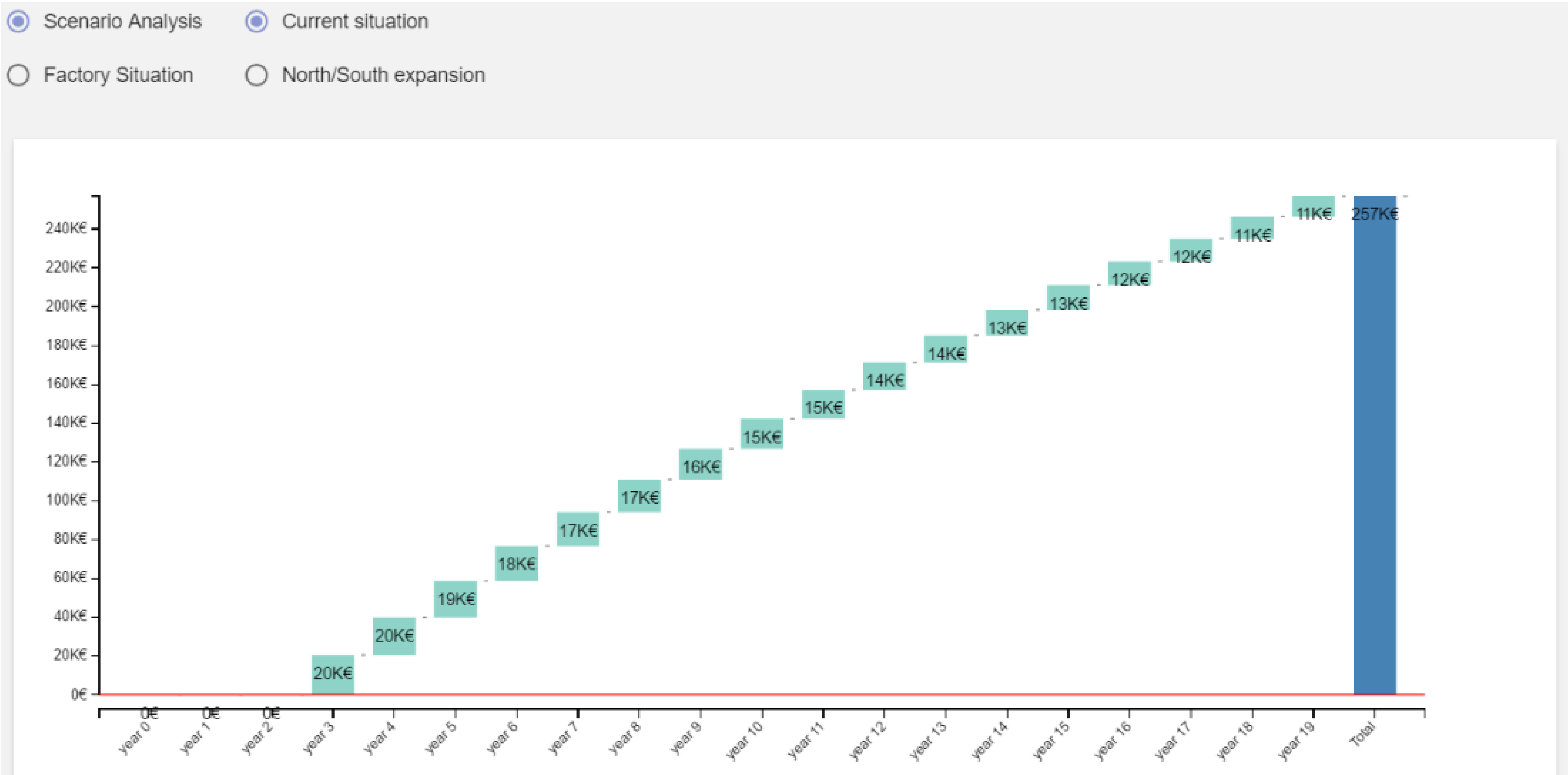


Figure 48 Yearly discounted cash flows and FNPV(C) fort the “current reuse situation” scenario

4.4.3 CBA economic analysis with the tool

Having performed the financial analysis, the next step is to include economic costs and benefits into considerations that is, to consider environmental and societal externalities. The tool's economic analysis criterion is also based on the NPV method. In this section, in order to account for negative externalities stemming from energy pollution, the tool asks for an average value for CO_2 emissions (in kg) per kWh of energy consumed and/or produced. The value of 0.302 kg of CO_2 per kWh[55] was considered, taking into account the energy mix in the region of Catalonia. Considering the previous value and energy consumption in kWh for each scenario, estimated CO_2 emissions per year are of 27 tons of CO_2/year for the "current reuse situation" scenario[56], and for the "north/south network expansion" scenario: 84 tons of CO_2/year for the north network[57] and 95 tons of CO_2/year for the south network[58].

In order to estimate a monetary value to account for CO_2 emissions, the tool also asks for a price per ton of CO_2. A value of 43.42 EUR/ton of CO_2[59] was selected.

The next step consists in defining other economic costs and benefits (if any) that are relevant for each scenario; one can manually input into the tool yearly monetary amounts either as costs or benefits for each scenario individually. The "north/south networks expansion" scenario, which contemplates the expansion of water reuse in Sabadell as proposed in the 2004 master plan, would allow securing the entire yearly demand of water for the irrigation of green areas, parks[60] and street cleaning activities[61] in the city. Faced to water scarcity, securing green areas and parks irrigation allows maintaining aesthetic values of said areas all year long, even faced to drought restrictions; this also allows maintaining the recreational quality of said areas. A similar reasoning can be held for securing street cleaning activities. Said indirect benefits stemming from water reuse in Sabadell have been valued in the Choice Experiment carried for the case study (results are presented in section 4.3) and are estimated at 4.3 million EUR/year for securing street cleaning activities and 1.2 million EUR/year for securing the irrigation of green areas and parks.

These values should be included into costs benefit considerations for the scenario. Nonetheless, the financial analysis for the scenario uses data from 2003 while the estimated societal benefits are values obtained in 2015. In order to maintain coherence when including these benefits estimations, it is proposed to adjust current benefits, using the Harmonized Consumer Price Index (HCPI)[62] for the euro area, in order to obtain the values in 2003 monetary terms (correcting for inflation). This might seem an unorthodox way of proceeding but it allows the of use values from the same reference period. Clearly, the optimal option would have been to use current values for the estimated benefits, and consider the information of an updated analysis of investments needs and operational outcomes for the expansion scenario but such information was not available; also, when comparing the data from 2003 with current data, the information on operational costs and water tariffs applied does not appear significantly different with respect to today's situation. So, using the HCPI to adjust the value of current benefits into 2003 monetary terms appears as the second best option; it is as if the CBA was actually carried in 2003 provided that the estimation of benefits would have yielded similar results (not an irrational hypothesis consid-

55http://canviclimatic.gencat.cat/es/redueix_emissions/factors_demissio_associats_a_lenergia/

56 See Table 13

57 For an annual electricity consumption of 279 200 KWh

58 For an annual electricity consumption of 316 467 KWh

59 See Table 13

60 Up to 96% of the yearly demand, see section 3.1.4.1

61 100% of demand for said use, see section 3.1.4.1

62 The HCPI (2015=100) for the euro zone was obtained from Eurostat (2015=100 means that the year 2015 is taken as relative base year for comparing monetary outcomes), http://ec.europa.eu/eurostat/web/hicp/data/database
The inflation adjusted values are obtained by multiplying current values by the 2003 HCPI and then dividing by 100.

ering the history of water scarcity and droughts in the region). Thus, adjusted benefits in 2003 monetary terms have been entered in the tool for the "north/south network expansion" scenario (3.4 million EUR[63] for securing street cleaning activities and 0.95[64] million EUR for securing the irrigation of green areas and parks). No other societal or environmental costs/benefits were accounted for this scenario. Nonetheless, It must be stressed that Table 17 presents other environmental or societal costs and benefits that should be included here. For example health risks related to contamination with the reused water should have been accounted for as an economic cost, but monetizing health risks and capturing uncertainty is a very complex task; an estimation of said risks was not available. Also, other environmental benefits could have been added, such as the preservation of potable water resources[65] and the restoration of local groundwater reserves. Nonetheless, it was not possible to provide a reliable estimation of said benefits and costs.

For the "current reuse situation" scenario, surely societal benefits stemming from current reused volumes used for the irrigation of green areas, parks and street cleaning activities are also relevant for this scenario and should be considered here. Nonetheless, the current system allows securing only a small fraction[66] of the yearly demand for said uses in the city. The CE provided an estimation of the willingness to pay for securing the entire yearly demand for the irrigation of green areas and parks, as well as the entire yearly water demand for street cleaning activities in the city. Citizen's preferences and thus utility functions are not linear and hence, it is not possible to adjust the estimations made in the CE in proportion to current volumes used for each water use. For this reason, it was not possible to include societal benefits stemming from current volumes used for the irrigation of green areas and street cleaning activities[67]. Thus, in the following section, only results regarding the "north/south network expansion" scenario will be presented.

Figure 49 illustrates the calculation of the NPV for the "north/south networks expansion" scenario as produced by the tool, including the quantified environmental costs[68] and benefits. The graph provides the same information as the financial analysis graph, only that accounting for the extra economic costs and benefits (discounted) added to the yearly discounted cash flows generated by the project. As can be seen, the project generates an estimated NPV of 46 million EUR which is largely the result of the high societal benefits estimated for the scenario.

The previous section showed that strictly from a financial point of view, considering exclusively investment needs and operational cost and revenues, and considering society as the relevant stakeholder of the project, the north/south network expansion project should not be encouraged as it generates a negative FNPV(C). Nonetheless when accounting for environmental and societal externalities, the project generates a positive and very significant NPV, largely thanks to societal benefits stemming from water reuse in the city. Thus, when accounting for economic externalities, clearly the expansion of the northern and southern networks appears to be largely beneficial to local communities (Sabadell citizens).

CBA would also require completing the analysis for the "counterfactual" situation, which in this case corresponds to the "current reuse situation" scenario, in order to determine whether the expansion project is profitable as compared to the current situation. As explained before, societal benefits stemming from water reuse could not be estimated for the current situation, and thus said analysis could not be com-

63 4300000 X (79.49/100) = 3 418 070

64 1200000 X (79.49/100) = 954 000

65 An estimation for this benefit was provided (660 000 EUR/year see Table 19). Nonetheless, this value will not be considered here, since it only constitutes a "rough" indicative value

66 Approximately 120 00 m3/year

67 These benefits exist nonetheless, even if, they are probably small given the volumes supplied relative to total demand.

68 From CO2 emissions

pleted. Nonetheless taking into account the fact that most of the environmental benefits identified for the current situation (presented in Table 14) are increasing with the volumes of reused water[69] and thus, would simply be higher for the "north/south network expansion" scenario, and considering the high NPV obtained for the scenario, it is unlikely that increased societal costs from increased health risks[70] are large enough to change the overall conclusion of encouraging the expansion project. Nonetheless, from a strict CBA point of view, no overall conclusion can be made. Moreover, CBA methodology also requires other technical steps which have not been applied here given the limited information on the case study (use of shadow wages and shadow prices (if necessary); calculating residual values for the infrastructures remaining after the selected project lifetime, carrying a risk assessment, etc. , see EC, 2014).

It is acknowledged that the data used for the expansion scenario dates back to 2003 but, since the estimated societal benefit values have been adjusted into 2003 terms; it is as if the CBA was carried in 2003 and thus, the conclusions arising from the analysis remain valid. The intended objective was not to carry a thorough analysis of a specific and well defined expansion of the system today (which requires very precise and detailed information) but rather to demonstrate that, including environmental or societal externalities stemming from water reuse into CBA assessment can significantly change the overall outcome in terms of social welfare generated by water reuse projects. Nonetheless, given the limited information available on operational costs and revenues from the current reuse system and its expansion[71] as well as missing information on other environmental costs and benefits, the conclusions from this analysis should only be considered as indicative results.

69 With the exception of "Maintaining the Ripoll river ecological cycle and environmental amenities" and "Preservation and restoration of local aquifers" which are the same for both scenarios.

70 Related to contamination with the reused water

71 For example, fixed costs from the networks operation (either for the "current situation" scenario or the "north/south network expansion" scenario) were ignored , since they were only available for the current situation (80 000 EUR/year, Vinyoles 2016, *pers.comm*); fixed monthly fees paid by users were also ignored in both scenarios, since the information was only available for the current situation (either a fixed tariff of 31 EUR/month or 38 EUR/month, Vinyoles 2016, *pers.comm.*) but the information on the total number of costumers was also unknown

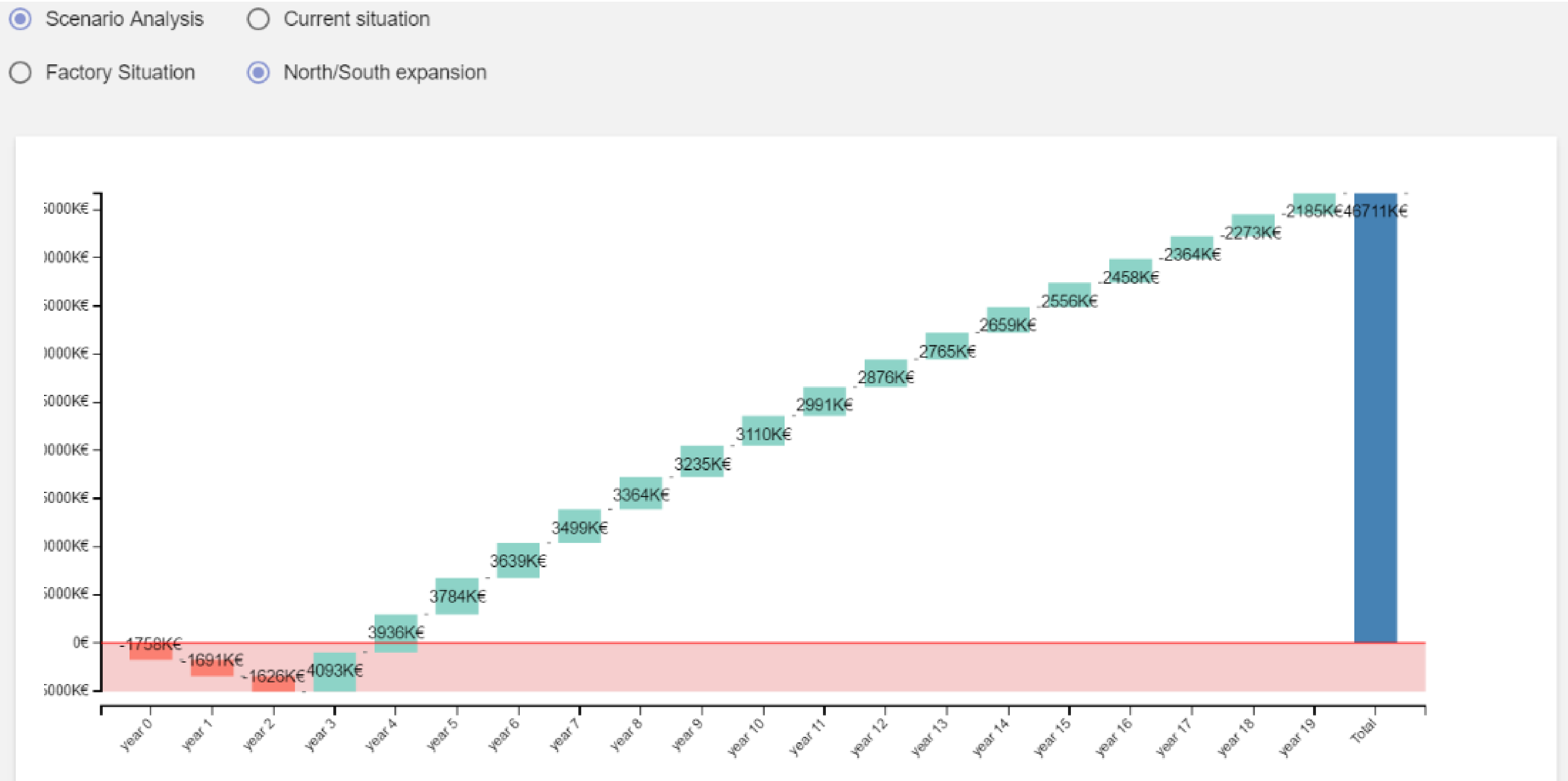


Figure 49 Yearly cost and benefits and NPV for the “north/south network expansion” scenario

5 Conclusions

In the present document, costs and benefits of two wastewater reuse systems have been investigated in detail, one in Braunschweig, Germany, and the other in Sabadell, Spain. Both case studies appear as complementary in the sense that they assess different benefits stemming from water reuse activities, the first environmental benefits and the second societal benefits. Both case studies provide evidence that supports the maintenance and/or development of the reuse systems in place from a social and environmental perspective. Moreover, benefits resulting from reuse activities are strongly dependent on the local context, thus suggesting that reuse activities can be justified for completely different reasons. Also, both studies provide evidence suggesting that reuse activities are on a general basis, well perceived by the general public.

For the first case study, the water reuse situation in Braunschweig is very site-specific, and based on a long history of irrigating wastewater in agriculture. The system is beneficial both for the farmers, which receive nutrients and water, and for the treatment plant, which can more easily comply with the discharge limits for the receiving water body. Furthermore, the system is linked to significant benefits for the local population, in particular through the preservation and restoration of local groundwater bodies and the preservation of the water quality of the river Oker. Environmental benefits linked to the wastewater reuse system are high lying between 3 and 5 million EUR per year.

The results of the contingent valuation study show, that only half of the population is aware of the existing reuse in Braunschweig. More efforts could hence be done to increase the awareness of the system. Furthermore, 17% indicated that they are missing information about the implications of wastewater reuse in order to have an opinion on the subject. Again, better communication and information could be helpful to fill this gap. At the same time, the general consent to wastewater reuse is already very high (only 4 % of the population is against the system in Braunschweig).

The high general acceptance of wastewater reuse is also coherent with the answers provided regarding the individual potential uses of wastewater. Consent was very high in general, apart regarding uses for drinking water purposes, artificial groundwater recharge and irrigation of crops for direct consumption. Health risks are the most important reason for disagreement with wastewater reuse.

With respect to the test of the CBA web-based reuse tool, available cost and benefit information for the case study did not allow carrying out a real CBA assessment with the tool. Nonetheless, the elements which were available indicate that economic benefits significantly outweigh costs.

The Sabadell case study shows the relevance of water reuse activities in order to cope with drought situations and water scarcity. Clearly the reuse system in the city is valued by Sabadell citizens: societal benefits related to securing certain urban water uses in the city with reused water, namely green areas irrigation and street cleaning activities are estimated at 1.2 million EUR/year for the irrigation of green areas and parks and at 4.3 million EUR/year for securing street cleaning activities with reused water.

Moreover results show that Sabadell households would value further developing water reuse making available reused volumes for domestic outside uses and toilet flushing needs, with an average willingness to pay of 27 EUR/year in order to secure these uses with reused water during the occurrence of severe droughts generating restrictions on domestic uses or mandatory water cuts.

With regards to public perception and acceptance, results from the CE survey highlight the importance of undertaking informational campaigns to increase awareness of reuse activities in the city (only 16 % of the population is aware of water reuse activities in the city). Moreover, results show that information campaigns should look to reassure people’s views related to health risks and the use of chemicals.

Finally with respect to the test of the CBA web-based reuse tool, the Sabadell case study constitutes only a simplified version of a Cost Benefit Analysis in the essence that it applies general CBA methodology to assess the overall outcome of a given water reuse project. The objective has rather been, to demonstrate that including environmental or societal externalities stemming from water reuse[72], can significantly change the overall outcome in terms of social welfare generated by water reuse projects or schemes. The case study provides evidence suggesting that water reuse activities can have significant positive impacts to society.

72 In this case indirect social benefits related to securing urban water uses faced to water scarcity

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Siemers, C.: Plant manager of the Braunschweig wastewater treatment plant. Phone call in June 2015 and several email exchanges 2015-2016

Teiser, B.: Director of the Abwasserverband Braunschweig. Email exchange on the 04/05/2015

Vinyoles, J.: Plant manager of Sabadell wastewater treatment plants. Several Email exchanges 2015—2016 and phone call in July 2016

7 Annex

7.1 Econometric analysis of Sabadell CE

Several mixed logistic regressions were tested. In short the mixed logit model is a general statistical model for examining discrete choices. Compared to the standard logit model, the mixed logistic model allows for random taste variation, which implies that, the Beta estimators are not the same for all respondents. Instead of getting one single Beta estimator for each variable, the mixed logit model provides a mean Beta for each variable and a distribution function for all respondents in the sample around this mean. Thus we are able to calculate a mean willingness to pay for each attribute, but also a distribution for the willingness to pay around this mean.

We begin by estimating the willingness to pay for the different attributes (urban uses for reused water in the city) and their levels for the full sample of respondents. In the regression, we include some socio economic variables to test the coherence of results as well as constructed variables which allow testing selected hypotheses about respondents' choices.

7.1.1 Estimation of the willingness to pay for each attribute and their levels

This first model allows for the estimation of the willingness to pay for each attribute and their levels for all respondents in the sample:

Attribute 1: the extent of public parks and green areas in the city that are kept irrigated, even during drought restrictions, thanks to water reuse

- Level 0: Current situation of parks and green areas irrigation with reused water (parc Tauli, parc del Rio Rippol, zona de la via Alexandra, parc del can Llong)
- Level 1 : Current situation plus irrigation of park Catalunya with reused water
- Level 2: All parks and green areas are irrigated with reused water

Attribute 2: The streets of Sabadell that are kept cleaned with water, even during drought restrictions thanks to water reuse

- Level 0: Current situation of street cleaning activities (only the most commercial streets are kept cleaned with reused water all year long)
- Level 1: All streets are kept cleaned with reused water all year long

Attribute 3: Domestic uses covered with reused water during severe droughts

- Level 0: Current situation of domestic uses covered with reused water (no domestic uses could be covered with reused water during severe drought restrictions or water cuts)
- Level 1: Reused water allows covering outside uses and toilet flushing needs during severe drought restrictions and water cuts
- Level 2: Reused water allows covering outside uses, toilets flushing needs and tap water needs during severe drought restrictions and water cuts

The results are presented in the following table (full regressions and estimated coefficients are presented in section 5):

Table 25 Willingness to pay for each attribute

Attributes levels	Willingness to pay	Degree of precision
Irrigation of parks and green areas: level 1	1,25€/month	Good, <5% error
Irrigation of parks and green areas: level 2	1,29€/month	Good, <5% error
Street cleaning activities: level 1	4.43€/month	Very good, <0.1% error
Domestic uses: level 1	2.25€/month	Very good, <1% error
Domestic uses: level 2	--	Not significant

The distributions of willingness to pay for each attribute are presented in the following graph (only distributions for "Street cleaning activities: level 1" and for "Domestic uses level 1" are statistically significant):

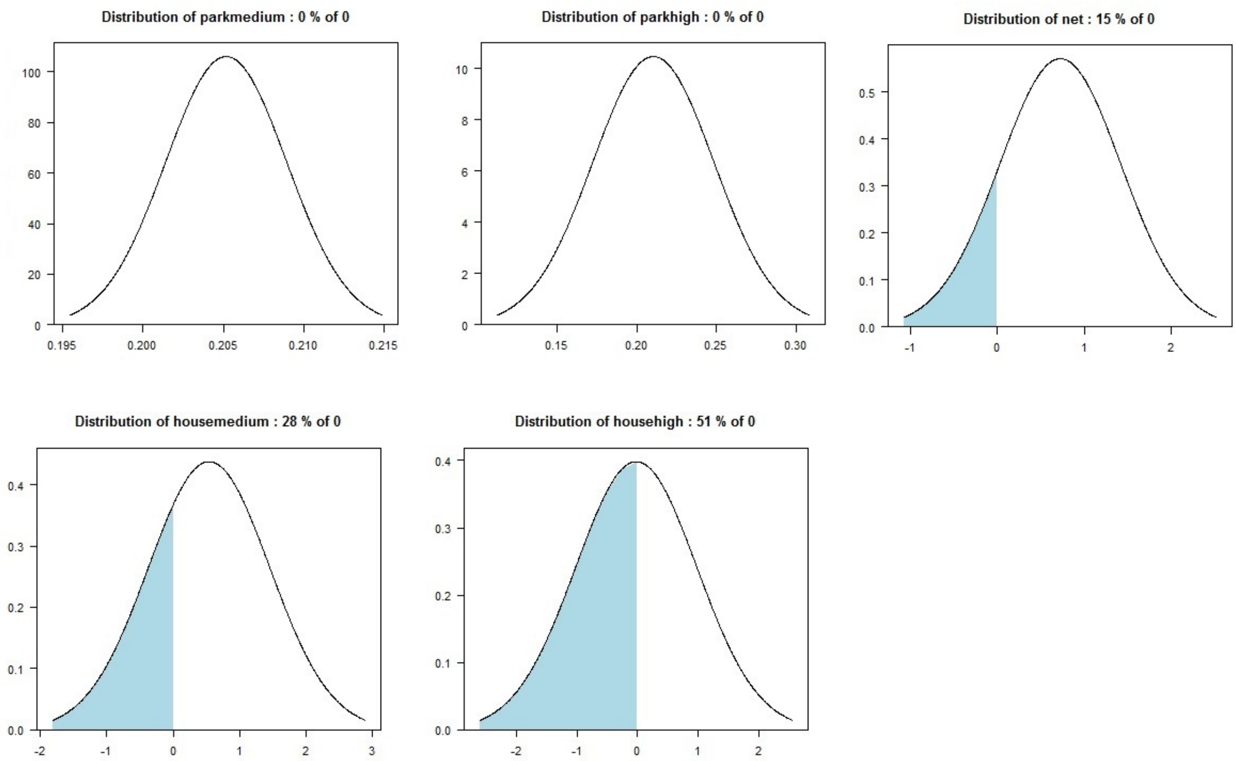

Figure 50 Distributions of willingness to pay for each attribute

Table 26 Significant distributions of willingness to pay

Attributes levels	First quartile	Median	Third quartile	Degree of precision
Street cleaning activities: level 1	1.54€/month	4.43€/month	7.3€/month	Very good, <0.1% error
Domestic uses: level 1	0€/month	2.25€/month	7€/month	Good, <5% error

As the "price attribute" estimated coefficient serves as reference value for the estimation of monetary values for each other attribute (by normalizing (i.e. dividing) each estimated coefficient with respect to this value), its interpretation in terms of willingness to pay has no sense. Nonetheless, its estimated coefficient is negative, which implies that individuals respond negatively to an increase in prices, thus coherent with economic theory.

7.1.1.1 Willingness to pay to secure the irrigation of parks and green areas in the city with reused water

On average, individuals are willing to pay 1.25 €/month or 15€/year to ensure that the main parks and green areas of the city are irrigated with reused water all year long. Nonetheless, they are not willing to pay much more to ensure that all parks and green areas in the city are irrigated with reused water, as they would be willing to pay almost the same, 1.29€/month. This implies that indeed, individuals are willing to pay to secure the aesthetic values of the most visited parks in the city, but are not willing to pay more to maintain the aesthetics of all green areas, thus revealing use motives for payment. Distributions are not significant, thus they cannot be interpreted, but on average individuals seem to value water reuse as a solution to secure the aesthetics of Sabadell's main parks.

7.1.1.2 Willingness to pay to secure street cleaning activities with reused water

On average, individuals are willing to pay 4.43€/month or 53€/year to secure street cleaning activities in the city with reused water. This suggests that individuals do value the benefit of having clean streets all year long thanks to water reuse, even during the occurrence of droughts or scarcity situations. While looking at the distribution of willingness to pay for all respondents, only 15% of respondents are not willing to pay to secure said activities with reused water, 75% of respondents have a willingness to pay of 18€/year or more and 25% of respondents are willing to pay 87,6€/year or more. Thus it can be concluded that a large majority of individuals value the fact of securing street cleaning activities with reused water and thus securing the maintenance of clean streets, even during drought or scarcity situations. Moreover, ¼ of respondents are willing to pay a substantial sum of money to secure said activities.

7.1.1.3 Willingness to pay secure domestic water uses during severe drought restrictions or water shortages

On average, individuals are willing to pay 2,25€/month or 27 €/year to secure that domestic outside 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. While looking at the distribution of willingness to pay, over ¼ of individuals are not willing to pay to secure domestic outside water uses and toilet flushing needs with reused water. On the other hand, more than 50% of individuals are willing to pay 27€/year or more, while 25% of individuals are willing to pay 84€/year or more. This distribution suggests that, as compared to securing water needs for street cleaning activities, individuals are more divided on the idea of paying 2.25€/month or 27€/year to secure domestic outside uses and toilet flushing needs with reused water but, overall more than half of respondents would be willing to make the extra effort. Also, as for street cleaning activities, 25% of respondents have a high willingness to pay with respect to the mean sample value, which suggests that these respondents have a high utility for securing their domestic water needs with reused water when faced to restrictions or scarcity situations.

7.1.2 Segmentation of willingness to pay amongst different groups of respondents

The following table presents willingness to pay results conditional on responses to questions related to environmental habits; particularly nesting amongst respondents practicing, or not, gardening activities and/or car washing activities at least once a month. It is thus possible to obtain willingness to pay per group of respondents. However, these results do not demonstrate a causal relation between group membership and willingness to pay. They only allow for the estimation of average willingness to pay for each group of individuals.

Table 27 Willingness to pay for each attribute (amongst individuals having a garden and/or practicing car washing activities)

Attributes levels	Willingness to pay	Degree of precision
parkmedium	--	Not significant
parkhigh	0€/month	Very good, <0.1% error
street	6,37€/month	Very good, <0.01% error
housemedium	3,84€/month	Good, <1% error
househigh	--	Not significant

As compared to the full sample of respondents, these individuals are on average not willing to pay to secure the irrigation of all parks and green areas in the city with reused water. This might be explained by the fact that these individuals have a substitute for green areas or parks. Also, on average, these individuals are willing to pay 6,37€/month or 76,4€/year to secure street cleaning activities with reused water, which is almost twice as the average value for the full sample of respondents.

Table 28 Willingness to pay for each attribute (amongst respondents not having a garden and not practicing car washing activities)

Attributes levels	Willingness to pay	Degree of precision
parkmedium	2,8€/month	Good<5% error
parkhigh	5,5€/month	Very good, <0.1% error
street	3,3€/month	Good, <1% error
housemedium	--	Not significant
househigh	--	Not significant

On average, these individuals are willing to pay 2,8€/month or 33,6€/year to ensure that the main parks and green areas of the city are irrigated with reused water all year long. As compared to the average willingness to pay for the full sample, these individuals are willing to pay more than twice as much to secure the irrigation of all parks and green areas in the city. This might be consistent with the fact that these individuals do not have a substitute for green areas or parks in the city. Thus on average these individuals are ready to pay a subsequent sum of money to ensure the aesthetics values of Sabadell parks and green areas all year long.

7.1.3 Analysis of marginal impacts on willingness to pay for selected socio economic characteristics

The impacts of selected socio economic variables were tested, but only statistically significant results are presented in the following. The next table presents the impacts for selected socio economic variables on willingness to pay.

Table 29 Sign of estimated coefficients for selected socio economic characteristics (general model)

Variable	Estimated coefficient sign	Degree of precision
Highincome	Positive	Good<5% error
Risk	Positive	Very good, <0.1% error

Variable	Estimated coefficient sign	Degree of precision
Info	Positive but close to zero	Good, <1% error

The variable "Highincome" corresponds to an interaction variable between the attribute price, and a variable capturing income levels for households earning more than 3000 € per month. The interaction term is positive which implies that households having high income levels have an overall higher willingness to pay for potential uses for reused water in the city. This does not provide valuable insights regarding respondents but allows checking the coherence of results.

The variable "Risk" corresponds to an interaction term between the attribute price, and a variable capturing the perception of scarcity and droughts risks in the city for each respondent based on answers to question 4) and 5) of the questionnaire. The interaction term is positive which signifies that respondents having a high perception of scarcity or drought risks in the city have an overall higher willingness to pay for potential uses for reused water in the city.

Finally the variable "Info" corresponds to an interaction term between the attribute price, and a variable capturing previous knowledge of the existence of water reuse based on answers to question 7) of the questionnaire. The interaction term is positive but close to zero which indicates that prior knowledge of the existence of water reuse does not significantly affects willingness to pay for potential uses for reused water in the city.

7.1.4 Conclusion

In conclusion, individuals do value water reuse as a solution to cope with water scarcity and drought situations in the city. Indeed Sabadell households are on average willing to pay to secure, thanks to water reuse, certain benefits affecting the quality of life in the city. Namely, households are willing to pay 15€/year to secure the irrigation of all Sabadell's parks and green areas with reused water and thus maintain their aesthetic values; 53€/year to secure the maintenance of street cleaning activities with reused water all year long; 27€/year to secure domestic outside uses and toilet flushing needs with reused water in the occurrence of severe drought restrictions or water cuts. Clearly securing street cleaning activities with reused water, and thus securing the maintenance of clean streets, is the most valued use for reused water in the city.

On average Sabadell households are willing to pay 95€/year or 8€/month to support the development of water reuse in the city for the previously presented urban uses, and secure in this way certain benefits affecting the quality of life in the city when faced to water scarcity and drought situations. These values can be used to approximate the overall societal benefits stemming from the development of water reuse in the city (or adjusting values, stemming from the current reuse system in Sabadell) as a solution to cope with water scarcity and drought situations.

Finally respondents having a high perception of scarcity or drought risks in the city have an overall higher willingness to pay for potential uses for reused water in the city. This highlights the importance of conveying during information campaigns the fact that water scarcity and drought risks will likely increase over time; this in order to stress the importance of encouraging water reuse to increase the availability of water resources and reduce potential scarcity risks but also, to secure certain benefits affecting the quality of life in the city.

7.1.5 Econometric model results

```
mlogit(formula = f1, data = dataresno1, reflevel = "0", rpar = c(parkmedium = "n",
    parkhigh = "n", net = "n", housemedium = "n", househigh = "n"),
    R = 100, halton = NA, panel = TRUE, estimate = TRUE, print.level = 0,
    print.level = 0)

Frequencies of alternatives:
        0         1         2         3         4         5         6         7         8         9        10        11
0.3458647 0.0751880 0.0100251 0.0676692 0.0125313 0.0175439 0.0325815 0.0250627 0.0175439 0.0476190 0.0075188 0.0751880
       12        13        14        15        16        17        18
0.0125313 0.0300752 0.0576441 0.0401003 0.0451128 0.0651629 0.0150376

bfgs method
9 iterations, 0h:1m:5s
g'(-H)^-1g = 0.0358
last step couldn't find higher value

Coefficients :
                  Estimate  Std. Error t-value  Pr(>|t|)
price          -0.16343495  0.02836127 -5.7626 8.282e-09 ***
parkmedium      0.20517648  0.20110496  1.0202  0.057612 .
parkhigh        0.21030226  0.21052798  0.9989  0.047830 .
net             0.72339356  0.17087219  4.2335 2.300e-05 ***
househigh       0.03109871  0.26225052  0.1186  0.905605
housemedium     0.36701194  0.18401042  1.9945  0.046096 *
risk            1.00007457  0.45899471  2.1788  0.029344 *
highinc         0.08931060  0.02826254  3.1600  0.001578 **
info            0.00074197  0.02717969  0.0273  0.058221 .
sd.parkmedium   0.00376099  8.17822840  0.0005  0.999633
sd.parkhigh    -0.03809067  5.18987355 -0.0073  0.994144
sd.net          0.69849617  0.38322387  1.8227  0.068351 .
sd.househigh    0.71653605  0.69708585  1.0279  0.303996
sd.housemedium  0.01965537  3.98745353  0.0049  0.996067
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Log-Likelihood: -397.69

random coefficients
            Min.     1st Qu.     Median       Mean   3rd Qu. Max.
parkmedium  -Inf  0.2026397 0.20517648 0.20517648 0.2077132  Inf
parkhigh    -Inf  0.1846105 0.21030226 0.21030226 0.2359940  Inf
net         -Inf  0.2522651 0.72339356 0.72339356 1.1945221  Inf
housemedium -Inf  0.3537546 0.36701194 0.36701194 0.3802693  Inf
househigh   -Inf -0.4521975 0.03109871 0.03109871 0.5143949  Inf
```

Figure 51 Results from the general model

```
summary(model.cargarden)

Call:
mlogit(formula = f1, data = dataresnoX1, reflevel = "0", method = "nr",
    print.level = 0)

Frequencies of alternatives:
      0       1       2       3       4       5       6       7       8       9      10      11      12      13      14
0.33125 0.07500 0.01250 0.06875 0.01875 0.00625 0.05625 0.02500 0.03750 0.06875 0.00625 0.06250 0.01875 0.03125 0.04375
     15      16      17      18
0.04375 0.04375 0.03750 0.01250

nr method
5 iterations, 0h:0m:0s
g'(-H)^-1g = 2.19E-12
gradient close to zero

Coefficients :
             Estimate Std. Error t-value  Pr(>|t|)
price       -0.152051   0.044939 -3.3835 0.0007156 ***
parkmedium  -0.092540   0.289350 -0.3198 0.7491040
parkhigh    -0.906011   0.346544 -2.6144 0.0089379 **
net          0.968127   0.287552  3.3668 0.0007605 ***
househigh   -0.013453   0.392783 -0.0343 0.9726769
housemedium  0.584340   0.266166  2.1954 0.0281354 *
risk         0.787996   0.695211  1.1335 0.2570195
highinc      0.073328   0.042305  1.7333 0.0830422 .
info         0.055025   0.044658  1.2321 0.2179035
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Log-Likelihood: -157.43
```

Figure 52 Results amongst group of respondents having a garden and/or practicing car washing activities

```
Call:
mlogit(formula = f1, data = dataresnoY1, reflevel = "0", rpar = c(parkmedium = "n",
    parkhigh = "n", net = "n", housemedium = "n", househigh = "n"),
    R = 100, halton = NA, panel = TRUE, estimate = TRUE, print.level = 0,
    print.level = 0)

Frequencies of alternatives:
        0         1         2         3         4         5         6         7         8         9        10        11
0.3556485 0.0753138 0.0083682 0.0669456 0.0083682 0.0251046 0.0167364 0.0251046 0.0041841 0.0334728 0.0083682 0.0836820
       12        13        14        15        16        17        18
0.0083682 0.0292887 0.0669456 0.0376569 0.0460251 0.0836820 0.0167364

bfgs method
9 iterations, 0h:0m:20s
g'(-H)^-1g = 0.169
last step couldn't find higher value

Coefficients :
                Estimate Std. Error t-value Pr(>|t|)
price          -0.1735518  0.0410223 -4.2307 2.33e-05 ***
parkmedium      0.4875939  0.2898515  1.6822 0.092526 .
parkhigh        0.9566365  0.3220487  2.9705 0.002973 **
net             0.5826636  0.2491053  2.3390 0.019334 *
househigh      -0.1316366  0.3929448 -0.3350 0.737625
housemedium     0.1717899  0.2529829  0.6791 0.497102
risk            1.0553950  0.6275611  1.6817 0.092619 .
highinc         0.0905804  0.0401956  2.2535 0.024228 *
info           -0.0306452  0.0394767 -0.7763 0.437581
sd.parkmedium   0.0148617 10.6729254  0.0014 0.998889
sd.parkhigh     0.1105101  3.5698078  0.0310 0.975304
sd.net          0.8167503  0.5026286  1.6250 0.104172
sd.househigh   -0.8578068  0.8724829 -0.9832 0.325519
sd.housemedium -0.0014128  5.0210091 -0.0003 0.999775
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Log-Likelihood: -230.08
```

Figure 53 Results amongst group of respondents not having a garden and not practicing car washing activities