Meso-level eco-efficiency indicators to assess technologies and their uptake in water use sectors

Collaborative project, Grant Agreement No: 282882

Deliverable 3.1

Value Chain Description of the Analysed Urban Water Systems

December 2012

DOCUMENT INFORMATION

Project	
Project acronym:	EcoWater
Project full title:	Meso-level eco-efficiency indicators to assess technologies and their uptake in water use sectors
Grant agreement no.:	282882
Funding scheme:	Collaborative Project
Project start date:	01/11/2011
Project duration:	36 months
Call topic:	ENV.2011.3.1.9-2: Development of eco-efficiency meso-level indicators for technology assessment
Project web-site:	http://environ.chemeng.ntua.gr/ecowater
Document	
Deliverable number:	Deliverable 3.1
Deliverable title:	Value chain description of the analysed urban water systems
Due date of deliverable:	31 October 2012
Actual submission date:	07 December 2012
Editor(s):	Vassilis Kourentzis
Author(s):	Galina Dimova, Christoph Hugi, Claudia Niewersch, Irina Ribarova, Peyo Stanchev, Olga Steiger
Reviewer(s):	Ino Katsiardi, Thanos Angelis-Dimakis
Work Package no.:	WP 3
Work Package title:	Eco-efficiency assessments in urban water systems
Work Package Leader:	FHNW
Dissemination level:	PU
Version:	8
Draft/Final:	Final
No of pages (including cover):	120
Keywords:	Value chain description, Urban water systems, Zurich, Sofia

Abstract

The “Value Chain Description of the Analysed Urban Water Systems” summarizes the first results of the Case Studies of the FP7 EcoWater Project in the Canton of Zurich, Switzerland and in Sofia, Bulgaria. These results form the basis for the elaboration of a set of meso-level indicators to quantify the eco-efficiency of the whole investigated system and to assess the effects of new technologies.

In the Canton of Zurich the Case Study has been carried out in the municipality of Waedenswil, where data has been collected from the relevant actors of the value chain, namely water supplier, four SMEs as water users and the wastewater treatment plant. The other relevant water users, i.e. households, are characterised according to the available statistical information. Processes in SMEs have been analysed with a QuickScan-Analysis, a method developed for the Cleaner Production concept, where a company`s processes are systematically analysed with regard to environmental impacts and financial costs. By aggregating the environmental impacts and costs over the whole value chain, potentials for improving the eco-efficiency can be identified.

The Sofia Case Study is delineated functionally by the water supply and sewerage system of the city of Sofia - starting with the water abstraction in Rila mountain and ending with the return of the treated wastewater into the Iskar river. In order to prepare this report, various approaches were applied, such as interviews, discussions with relevant stakeholders (including industry), field visits, collection of information from different sources, etc.

In this report, the two Case Study areas are presented followed by the mapping of the corresponding water systems and the description of each stage. For a closer look on the stages of the system, the processes and technologies for each stage are described. Additionally, a value chain mapping including actors at the different stages, their roles and their interactions has been performed and a selection of indicators relevant to compose eco-efficiency indicators, consisting of the description of the environmental impacts and the economic costs and benefits of each stage of the system has been provided. Finally, a preliminary list of new technologies to be assessed has been identified for both Case Studies.

Content

List of figures

List of tables

1 Introduction

The report summarizes the first results of the studies in Canton of Zurich, Switzerland and in Sofia, Bulgaria of the FP7 EcoWater Project. These first results are comprehensive value chain mappings of the urban water system in the Canton of Zurich and in the city of Sofia, which form the basis for the elaboration of a set of meso-level indicators to quantify the eco-efficiency of the whole investigated system. The methodological approach is grounded on Case Studies and the associated literature study, field work and data collection and aggregation. Considering that urban water systems are designed and operated to serve users, great emphasis was put on their characterization.

In the Canton of Zurich the Case Study has been carried out in the municipality of Waedenswil. There, field visits were made to the relevant actors of the value chain, namely water supplier, four SMEs as water users and the wastewater treatment plant. The other relevant water users, i.e. households, are characterised based on according to the available statistical information. Processes in the SMEs have been analysed with a QuickScan-Analysis, a method developed for the Cleaner Production concept, where company`s processes are systematically analysed with regard to the environmental impacts and the financial costs. Contrasting the environmental impacts to costs of the whole value chain, the potential to improve eco-efficiency can be shown.

The Sofia Case Study is delineated functionally by the water supply and sewerage system of the city of Sofia - starting with the water abstraction in Rila Mountain and ending with the return of the treated wastewater into the Iskar River. In order to prepare this report various approaches were applied, such as interviews discussions with relevant stakeholders (including industry), field visits, collection of information from different sources, etc.

The following report contains the systems of the Case Study areas in the Canton of Zurich and Sofia. First, the objectives of each Case Study are defined (Chapters 2.1 and 3.1) and an overview of the Case Study area is provided (Chapters 2.2 and 3.2). The methodology used is described (Chapter 2.3 and 3.3). In the Water Supply Chain Mapping (Chapters 2.4 and 3.4) the description of system boundaries is followed by the mapping of the water service system and the description of each stage of the system. For a closer look on the stages of the system, the processes and technologies for each stage are described. Chapters 2.5 and 3.5 depict a value chain mapping including actors at the different stages, their roles and their interactions. The selection of eco-efficiency indicators (Chapters 2.6 and 3.6) consists of the description of environmental impacts and economic costs and benefits relevant to each stage. For each Case Study, a preliminary identification of technologies to be assessed is given in Chapters 2.7 and 3.7. The report closes with some concluding remarks in Chapter 4.

2 System mapping of the urban water system of the Canton of Zurich - Waedenswil, Switzerland

2.1 Objectives of the case study

The overall objective of the Case Study in the Canton of Zurich is to support meso-level dialogue and coordination using eco-efficiency indicators to promote the uptake of promising water technologies in urban water systems.

There is a need for meso-level dialogue in the case that the total costs and benefits of promising technologies are unevenly distributed among several actors, i.e. an actor expected to employ a new technology is not compensated adequately in his/her preference structure and other actors would benefit free of charge. Meso-level dialogue and accompanying measures will facilitate optimal level of promising technology uptake. The analysis will be performed for two relevant paths/user groups:

1. Water supply system – domestic water users – wastewater treatment and discharge system
2. Water supply system – non-domestic water users (SMEs[1]) – wastewater treatment and discharge system

The specific objectives of the Case Study are to:

1. Provide measures of eco-efficiency in the above paths, through the development of indicators
2. Identify cleaner production technologies and practices and assess their performance in relation to a Baseline scenario; and
3. Elaborate different mid-term technology scenarios and assess the potential environmental and economic impacts from technology implementation and uptake.

2.1.1 Description of Task

The Task involves the mapping of two distinct value chains in urban settings as depicted in Figure 1:

1. **Value Chain 1:** Water supply system – domestic water users (households) – wastewater treatment and discharge ; and
2. **Value Chain 2:** Water supply system – non-domestic water users (SME) – wastewater treatment and discharge system

[1] Small Enterprises: 10 to 49 full-time equivalents. Medium enterprises: 50 to 250 full-time equivalents.

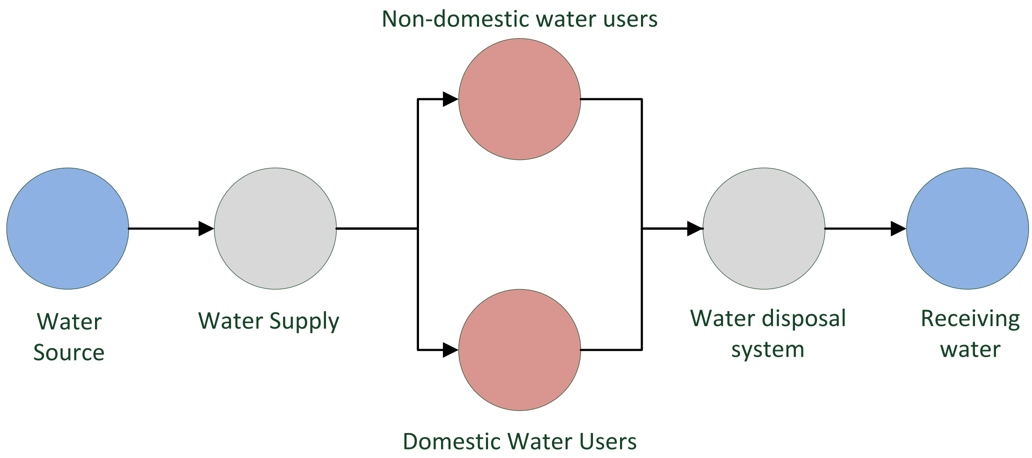


Figure 1: Analysed value chains with two distinct water user groups

Although, the two distinct chains show relevant differences, they both play a crucial role in urban water systems. Particularly with regard to the SMEs, the most relevant in the Case Study's spatial boundaries will be identified, and subsequently characterized and assessed in detail. For the characterisation of the domestic water users the available statistical data is sufficient.

Relevant structures, policies and actors, as well as their interactions will be mapped and characterized for both value chains. Emphasis will be given to the activity levels and economic value associated with the use of water along these two value chains. The policies, structures and actors regarding cleaner production/use practice, technological applications and infrastructure development will also be identified and characterized.

Furthermore, the task includes the mapping of the relevant stakeholders and a synthesis of the described components to a meso-level water system, so as to facilitate the elaboration of meso-level indicator sets.

2.1.2 Meso-Level Objectives

Indicators for economic and environmental impact will have to be derived from superior (political) goals, such as the "Sustainable Development", which is part of the Swiss federal constitution (Art. 2 und 73). Accordingly, the relevant laws and regulations will have to be consulted to formulate indicators for the impact categories. On the high-level political framework, the watershed management states the guiding principles for an integrated water resources management in Switzerland.

The watershed management is derived from the Federal Constitution, the main objectives of water management and the vision of Water Agenda 21. The aim is an efficient and sustainable realisation of the main objectives through coordination.

The basis for the Water Agenda 21 vision and the corresponding Guiding Principles is the Federal Constitution. Two articles are central:

1. Article 76: The Confederation shall ensure within the scope of its powers the economic use and the protection of water resources and provide protection against the harmful effects of water.

2. Article 73: The Confederation and the Cantons shall endeavour to achieve a balanced and sustainable relationship between the nature and its capacity to renew itself and the demands placed on it by the population.

The aim of the Confederation's environmental and resources policy and the sustainable development strategy is the conservation and the sustainable use of the natural resources which are the basis of human life. They demand a focus on long-term goals, an increase in personal responsibility and an inter-sectoral approach.

Water management covers all human interventions in relation to water bodies and water resources. The main objectives of water management are the[2]:

1. Exploitation and use of water resources;
2. Protection, conservation and restoration of the ecological, landscape and social functions of the water bodies; and
3. Protection of people and property against the adverse effects of water i.e. flooding.

2.2 Overview of case study area

This Case Study is conducted in the Canton of Zurich (Figure 2), which is located in the German speaking part of Switzerland. With about 1.4 million inhabitants, the Canton of Zurich has the highest population in Switzerland [Federal Statistical Office, 2011]. It is an economically important part of the country with SMEs playing an essential role in value creation. Water supply sources in this Canton are mainly groundwater and lakes, partly also spring water. The Lake Zurich plays an important role as provider of raw water, especially for the communities which lie by the lakeside, where it represents 70% of raw water use. The applied waste water treatment as well as the sewage sludge treatment and disposal in this area are technologically on an advanced standard.

[2] Source: http://www.bafu.admin.ch/publikationen/publikation/01576/index.html?lang=en, accessed 08.02.2012

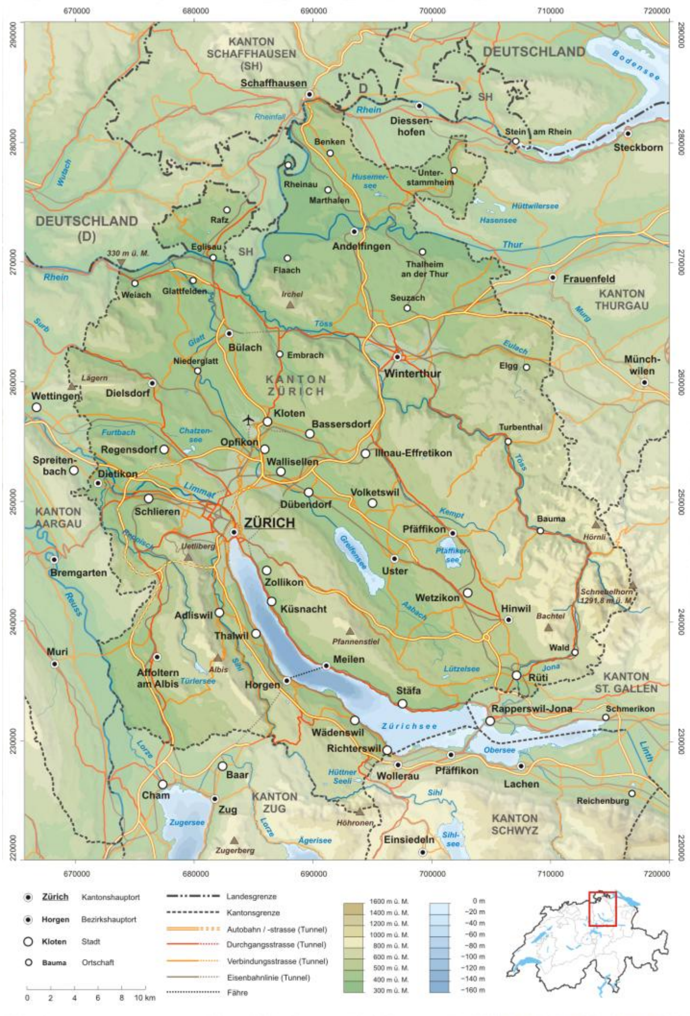


Figure 2: Map of the Canton of Zurich[3]

Figure 3 provides an overview of the main watersheds in the Canton of Zurich and Figure 4 the water supply chains on a stage-by-stage level for the Canton of Zurich. Figure 4 also indicates the complexity of the corresponding system and the high number of different processes and technologies for each stage.

[3] Source: Wikipedia: http://upload.wikimedia.org/wikipedia/commons/f/f7/Kanton_Z%C3%BCrich_Detail_DE.png accessed 17.09.2012

Figure 3: Overview of the main watersheds in the Canton of Zurich[4]

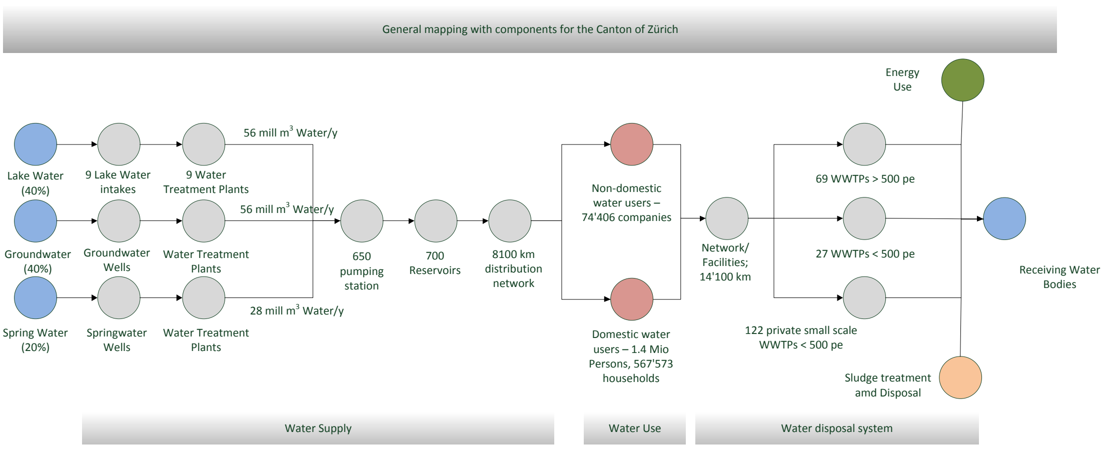


Figure 4: Overview of water supply chains for the Canton of Zurich

The analysis of the Case Study will focus on one municipality in the Canton of Zurich, i.e. the Waedenswil municipality (Figure 5), as the water use system on the Canton level is very complex, with high number of different processes and technologies for each stage. This focusing shall ensure a manageable analysis of one chain with all relevant stages and actors, and is further justified in the following chapter.

[4] Source: AWEL & Ernst Basler + Partner 2002b

Figure 5: Location of the municipality Waedenswil municipality in the Canton of Zurich (red circle)[5]

2.3 Methodology and data availability

A detailed analysis with primary data and concrete technology and measurements has been derived in the Case Study area for the municipality of Waedenswil with about 140 SMEs and 10,200 households. This focus and site visits to four local SMEs allowed to gain relevant insights and to derive input for the development of meso-level eco-efficiency indicators. Further analysis could be done subsequently by extrapolating the findings to the whole area of the Canton of Zurich.

General data for the Canton of Zurich is available by the Statistical Office of the Canton (www.statistik.zh.ch) and has been used to describe the Case Study area. For the development of meso-level indicators more detailed data is needed, such as performances, costs and emissions of the current state (Baseline Scenario), and potential new technologies and water quality and quantity data. Part of this data has been collected in contact with the local actors (water supply and wastewater treatment) and on-site in the SMEs. This was done in one specific part of the Case Study area: the Waedenswil area.

Specific data on the watersheds in the Canton of Zurich was available from the Department for Waste, Water, Energy and Air (Amt für Abfall, Wasser, Energie und Luft – AWEL). The Institute for Ecopreneurship has contacts to AWEL and has run a focused data collection survey in Waedenswil.

The water supply systems in the Canton of Zurich are operated by municipalities, by joint water suppliers consisting of several municipalities and by corporate and private

5 Source: http://www.statistik.zh.ch/internet/justiz_inneres/statistik/de/dienstleistungen/visualisierung/karten.html Accessed 06.03.2012

suppliers. In the focus area the municipalities of Richterswil, Horgen, Oberrieden and Waedenswil build a joint water supply authority, where relevant data has been collected.

Most wastewater treatment plants (WWTPs) in the Canton of Zurich are public and operated by the municipality. In Waedenswil, the WWTP is owned by the public construction authority. Relevant data has been collected.

2.4 Water supply chain mapping

In this section, the whole water supply chain related infrastructure is mapped. The mapping is divided into the following:

- System boundaries (section 2.4.1)
- Mapping of the water service system and description of stages (section 2.4.2)
- Process map description (section 2.4.3)
- Description of existing technologies (section 2.4.4)

2.4.1 System boundaries

The Case Study area is the Canton of Zurich. Figure 6 illustrates the spatial system boundaries of the Case Study area and the focus on a sub-system for a detailed analysis. In the Canton of Zurich there are 12 administrative districts and 13 main watersheds (see also Figure 3), of which the watershed of the Lake Zurich is selected for deeper investigation. The Canton has 28 water supply systems (see also Figure 8). Within the watershed of the Lake Zurich the municipality of Waedenswil has been chosen for a detailed analysis, which is in the water supply system Horgen-Obberrieden-Waedenswil-Richterswil (number 19 in Figure 8). Therefore, one part of the supplied water from the system is delivered to the regions of Horgen, Oberrieden and Richterswil which are not taken into consideration in the detailed analysis. The WWTP for water disposal of Waedenswil is the WWTP Waedenswil-Rietliau. In Waedenswil the water is used by about 20`000 inhabitants and about 140 SMEs.

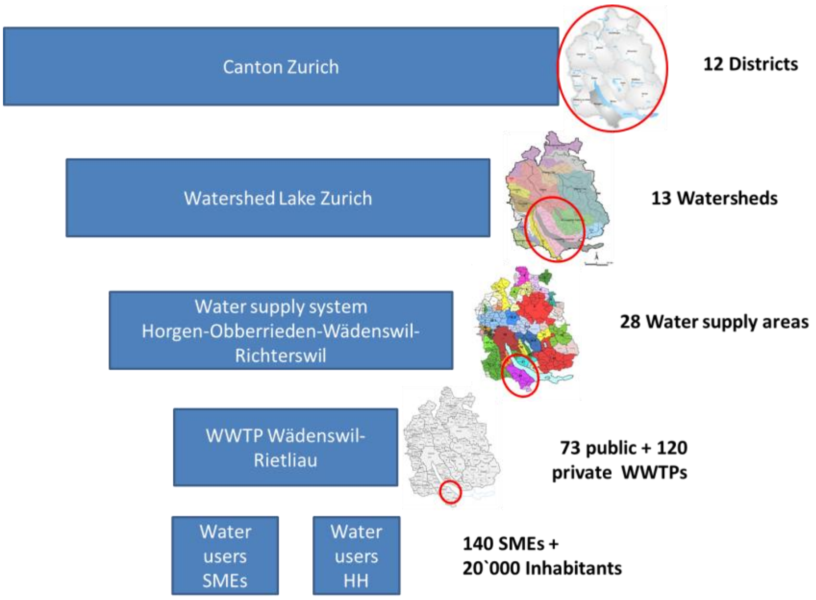


Figure 6: Spatial system boundaries of the case study

The relevant time period for indicators is one year. However, the life-span of options, technologies and changes has to be taken into account as well, in order to derive comparable numbers. The following section shows the mapping of the stages in the investigation area of Waedenswil.

2.4.2 Mapping of the water service system and description of stages

In this section the analysed water system in Waedenswil (Figure 7) is presented and the relevant stages in the system are described in the following sub-sections:

- Water Supply System (sub-section 2.4.2.1)
- Non-Domestic Water Users (sub-section 2.4.2.2)
- Domestic Water Users (sub-section 2.4.2.3)
- Wastewater Disposal System – Treatment and Discharge (sub-section 2.4.2.4)

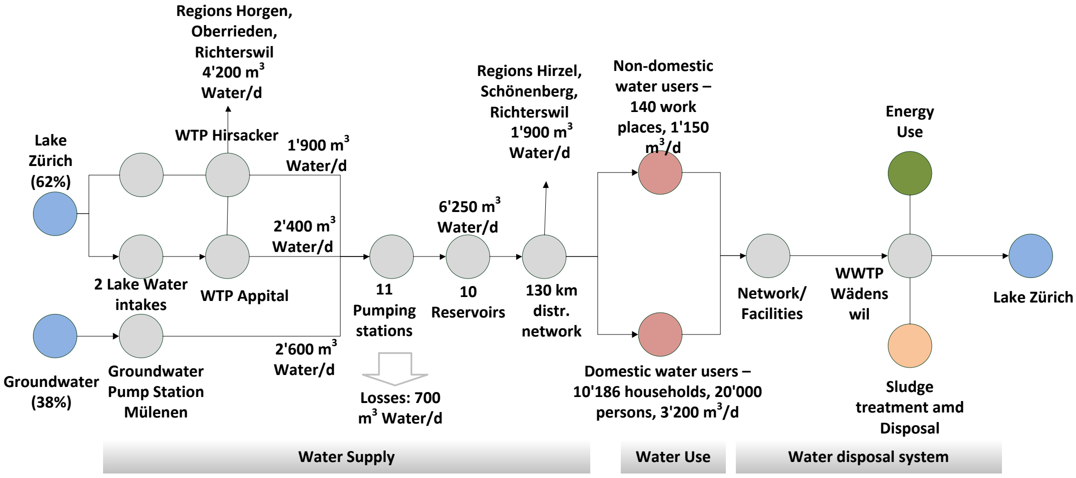


Figure 7: Mapping of the water system in Waedenswil

2.4.2.1 Water Supply System

Figure 8 presents the main water supply regions in the Canton. The water treatment plants for detailed investigation are in the network region 19 (in the south of the Canton): Horgen – Oberrieden – Waedenswil - Richterswil.

Figure 8: Drinking water network regions in the Canton of Zurich and the focus area No 19[6]

Generally, the water supply in Switzerland is highly decentralized, which results to more than 3,000 water utilities and a length of more than 50,000 km of pipes (BAFU 2012), which corresponds to about 6 meters per capita. The water in the area of Waedenswil is supplied by two water treatment plants, Hirsacker and Appital. Both plants are operated by an association of the municipalities Waedenswil, Horgen, Richterswil and Oberrieden. A quantity of about 3,800 m^3 of drinking water per day is produced by the water treatment plant of Hirsacker and 4,800 m^3 per day by that of Appital (see Figure 7). Of the total water volume produced by Appital and Hirsacker, 4,300 m^3 per day go the municipal drinking water network of Waedenswil; additional

[6] Source: AWEL 2011

2,600 m^3 per day come to the Waedenswil network from the groundwater pumping station Muelenen. The water treatment plant has been recently rebuilt and is now working in test mode. The plant will be taken in operation and replace the old one in 2013. The drinking water from both water treatment plants is supplied by the association to the main network, while the further distribution, including 11 pumping stations, 10 water reservoirs and 130 km of distribution network is managed by the municipality of Waedenswil itself.

About two thirds of drinking water in Waedenswil comes from Lake Zurich and one third from groundwater. Figure 9 shows the main users of the supplied water in Switzerland (approx. 1 Billion m^3/a); 59.6% of the water supplied concerns households and small industries. They are followed by the larger industry with about 19.1%. A significant amount, about 13.3% of the water supplied, is being lost in the system. In Waedenswil we assume a similar water use distribution, with slightly lower water losses of about 10% in 2010 (Stadt Waedenswil, 2012).

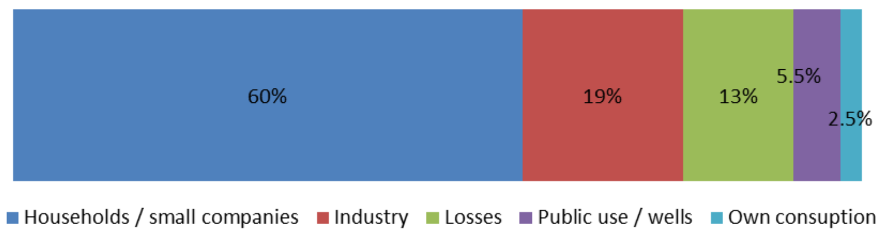


Figure 9: Water supply amount and main users in Switzerland 2010 (1 Billion m^3/a in total = 100%)[7]

The investigated water supply systems are larger spatially than the wastewater disposal systems, as indicated in the following sections. This means that the covered spatial areas of the water supply and the waste water treatment do often not match. As the analysis will emphasize on the user level (domestic / non-domestic) the focus can be placed on the intersection (analyse only users from the same intersection) of one supply and one disposal system to keep things simple.

2.4.2.2 Non-Domestic Water Users

Table 1 and Table 2 depict the economic structure of the municipality of Waedenswil in relation to the whole Canton.

Table 1: Workplaces, persons employed and full-time equivalents in the Canton of Zurich and in Waedenswil in year 2008, in secondary and tertiary sectors[8]

Area	Work places	Persons employed	Full-time equivalents
Canton of Zurich	70,179	799,079	670,186
Waedenswil	922	7,603	6,264

[7] Source: Adapted from http://www.trinkwasser.ch/dt/frameset.htm?html/trinkwasser/nav_tw.html~leftFrame; accessed 08.02.2012

[8] Secondary sector: production, tertiary sector: services.

Table 2: Work places, persons employed and full-time equivalents in SMEs in Waedenswil 2008

Sector	Enterprise size	Work places	Persons employed	Full-time equivalents
Secondary sector	Small enterprises	38	952	897
	Medium enterprises	5	500	469
Tertiary sector	Small enterprises	88	2,229	1,820
	Medium enterprises	8	871	696

Three SMEs from the secondary sector and one (1) SME from the tertiary sector (sports facility) have been chosen to be analysed in the Case Study (Table 3) and an input/output-analysis in quantity and quality for the different companies has been conducted.

Table 3: Companies for data collection

Company	Sector
Data collection completed	
SME1	Food and beverage production
SME2	Surface processing and heat treatment
SME3	Cosmetics production
SME4	Sports facilities
Participation in 2013	
SME5	Food and beverage production

2.4.2.3 Domestic Water Users

An average household in Switzerland uses 162 litres of water per person per day (see Figure 10). About 30% of the total volume, (almost 50 litres) is used for toilet flushing, around 20% for bathing and showering and about as many for the washing machine. In addition, 15% is used for cooking, drinking and manual dishwashing and about 12% for personal hygiene and manual washing.

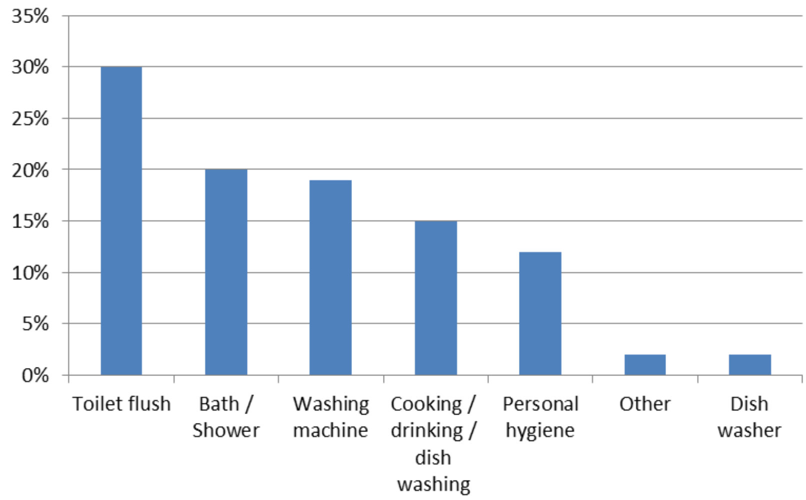


Figure 10: Main use of water in domestic setting[9]

[9] Source: Adapted from http://www.trinkwasser.ch/dt/html/download/pdf/twi5.pdf; accessed 08. February 2012

The region of Waedenswil, on which the meso-level indicator analysis will focus, has 19,528 inhabitants and around 10,200 households with an average drinking water consumption of 164 litres per person per day. It is not expected that the processes or data obtained for Waedenswil will be significantly different from the average population in the Canton of Zurich.

2.4.2.4 Wastewater Disposal System – Treatment and Discharge

Figure 11 depicts the location of the waste water treatment plants in the Canton of Zurich (red points), the catchment areas of these treatment plants, and the responsible regulatory persons in the AWEL.

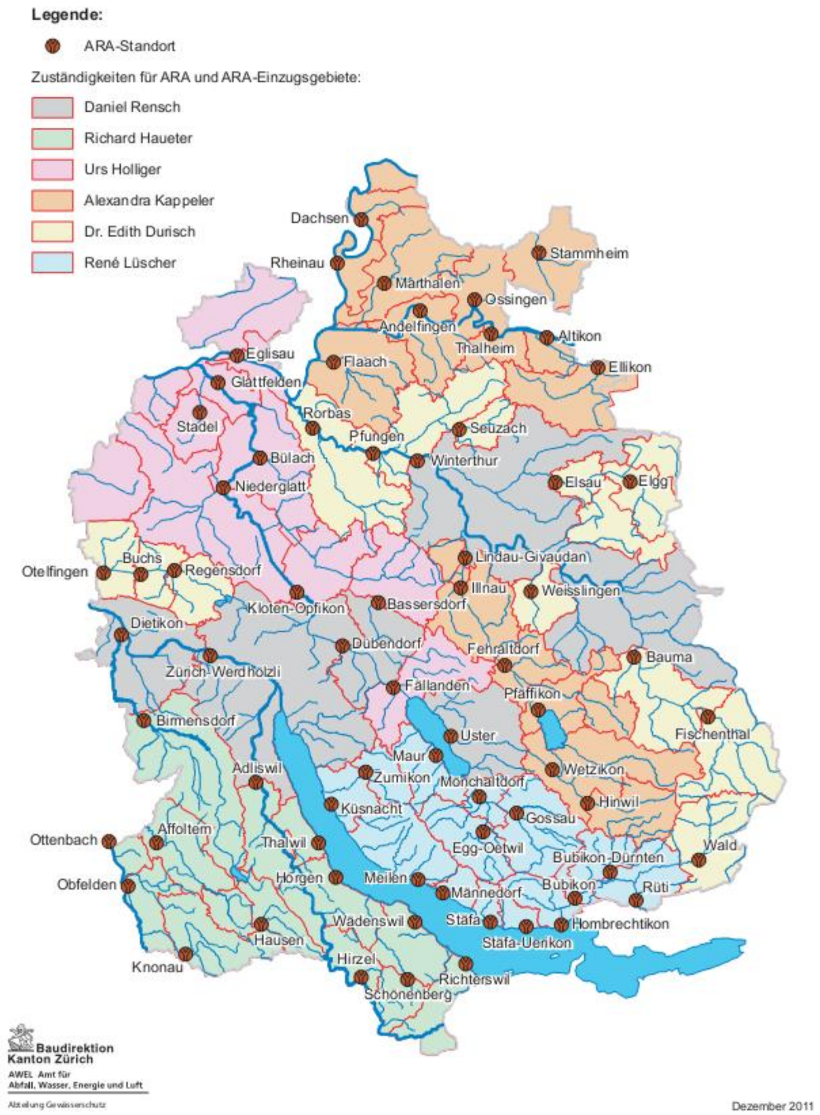


Figure 11: Wastewater treatment plants in the Canton of Zurich[10]

---

10 Source: http://www.awel.zh.ch/internet/baudirektion/awel/de/betriebe_anlagen_baustellen/abwasserreinigungsanlagen/_jcr_content/contentPar/downloadlist/downloaditems/392_1287581797683.spooler.download.1323958424539.pdf/Gebietseinteilung_ARA.pdf, accessed 8. February 2012

The wastewater treatment plant relevant to the Case Study is the Waedenswil-Rietliau WWTP, which is located in Waedenswil. Figure 11 depicts the key parameters of this WWTP.

Catchment area: Waedenswil
19,528 Inhabitants (2005)
Owner: Public construction authority

Design capacity: 44,000 person equivalent (pe)
Receiving water body: Lake Zurich
Operating since: 1967
Last upgrade: 2005

Figure 12: Wastewater treatment plant Waedenswil-Rietliau and key parameters[11]

2.4.3 Process map description

In this section the processes of each stage will be mapped and described.

- Water supply (section 2.4.3.1)
- Non-domestic water use (section 2.4.2.2)
- Domestic water use (section 2.4.2.3)
- Wastewater disposal system (section 2.4.3.4)

2.4.3.1 Water supply

The aim of the public water supply system in the Canton of Zurich is the allocation and delivery of drinking water in sound quality, under sufficient pressure and in adequate amount for drinking, usage and fire extinguishing. The system consists of 8,100 km pipes (about 6 meters per capita[12] excluding the building connections), approx. 700 reservoirs, 650 pumping stations, 9 lake water treatment plants and 65,000 hydrants.

The public water supply in the Canton of Zurich is provided by 157 communities and cities, 30 grouped water suppliers, 48 associations, respectively corporations and 7 joint stock companies. Alongside there is a number of small private suppliers[13].

In the area of Waedenswil there is one groundwater pumping and treatment station (Mülenen), 11 pumping stations, 10 reservoirs and 130 km of distribution network and two water treatment plants (maximum capacities: Hirsacker 29,000 m^3 Water/d and Appital 35,000 m^3 Water/d) (see also Figure 7). The drinking water treatment is organised by a cooperation of four municipalities, i.e. Waedenswil, Horgen, Richterswil and Oberrieden. The drinking water distribution including the network and

[11] Source: www.hw.zh.ch/ara/Waedenswil.pdf, accessed 14. February 2012

[12] Own estimation based on 1.4 mio population in the Canton of Zurich in 2010. Source: Federal Statistical Office, 2011.

[13] Sources: http://www.awel.zh.ch/internet/baudirektion/awel/de/wasserwirtschaft/wasserversorgung.html; http://www.awel.zh.ch/internet/baudirektion/awel/de/wasserwirtschaft/wasserversorgung/wasserstatistik.html

pumping of treated water is organized, financed and maintained by each municipality separately. Water allocation in Waedenswil for 2010 is shown in Table 4. 73% of the total water supply is used by domestic users (households) and 27% by non-domestic users (business and industry). The percentage of water used by households is slightly above the Swiss average of 60% (Figure 9).

Table 4: Water supply operating figures Waedenswil 2010

	Water supply 2010 in m^3/d
Domestic users (19,528 inhabitants)	3,200
Non-domestic users (business and industry)	1,150
Contract communities	1,900
Total	**6,250**

As shown in Table 4 the drinking water supply per inhabitant in Waedenswil is around 164 litres per person per day for households and grows to around 210 litres per person per day if non-domestic users' consumption is included.

The following two figures (Figure 13 and Figure 14) complement the preliminary mapping of the focus area by showing the water treatment on process level. There are two lake water treatment plants i.e. Appital (Figure 13) and Hirsacker (Figure 14), whereas the groundwater does not have to be treated.

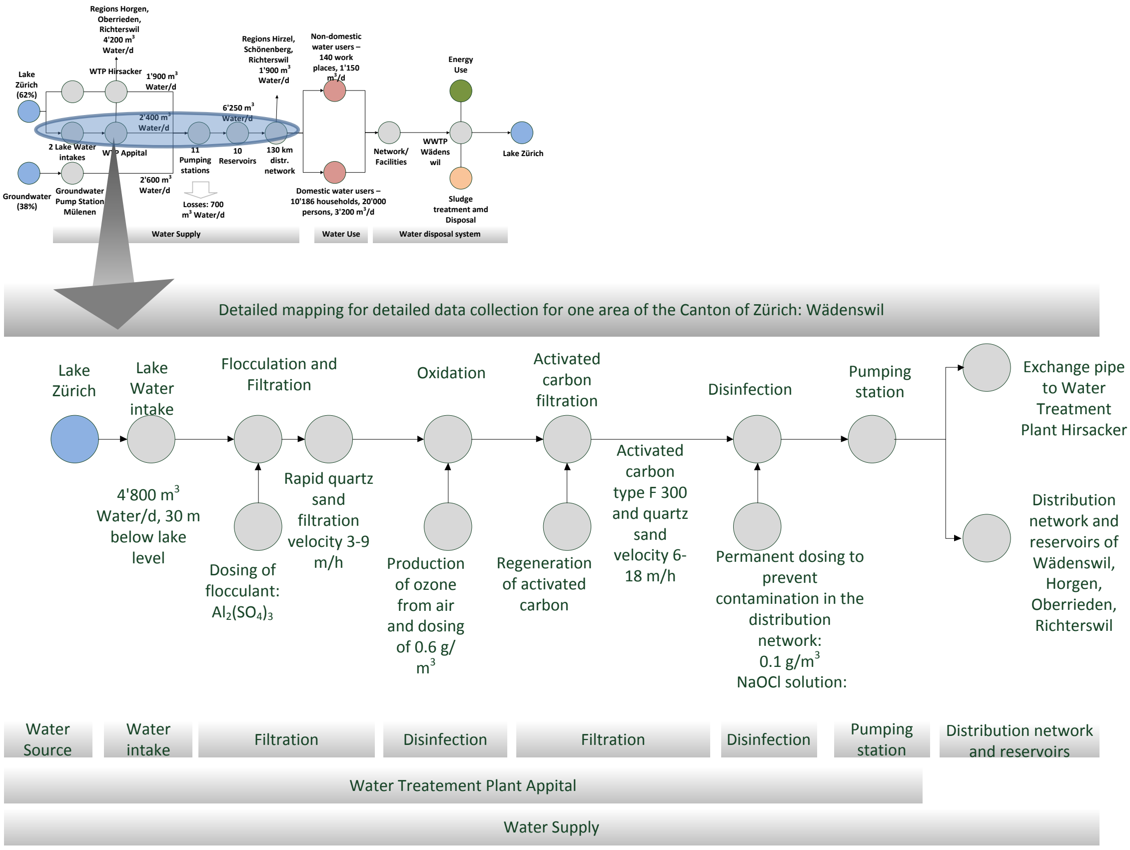


Figure 13: The Appital WTP: Process map

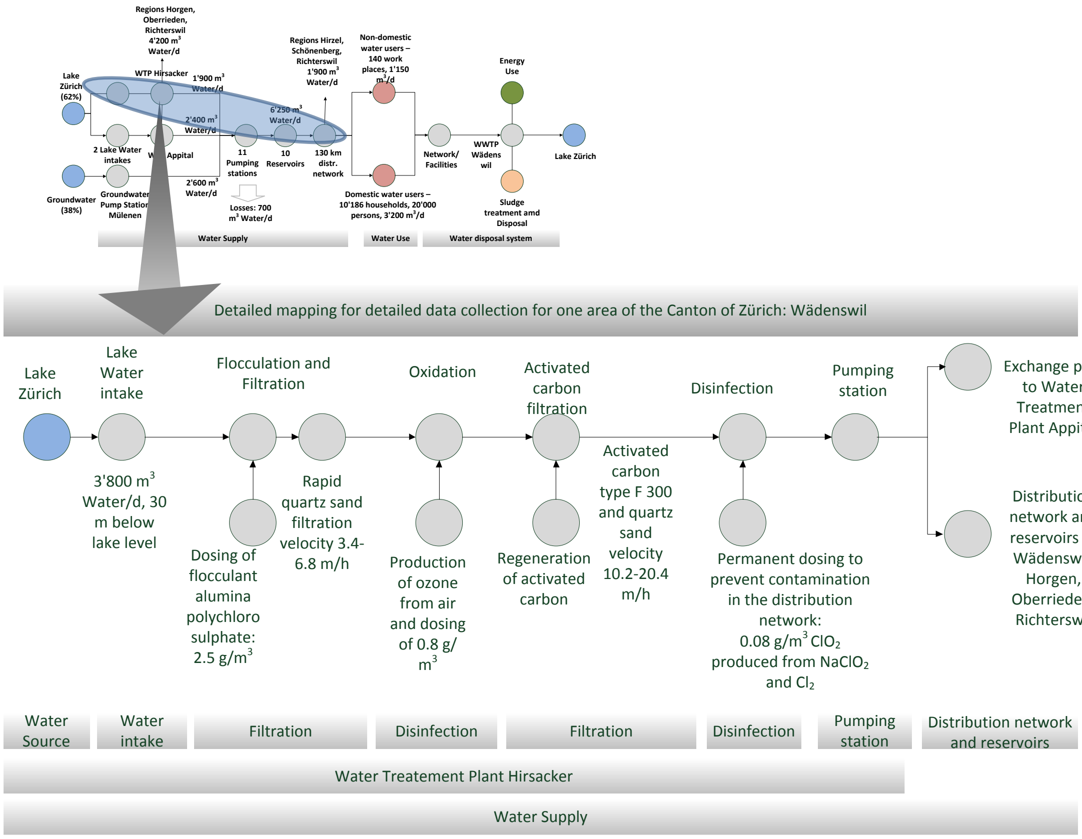


Figure 14: The Hirsacker WTP: Process map

2.4.3.2 Non-domestic water users

Non-domestic water uses cover many processes and many different purposes, such as[14]:

- Water as product, reactant (e.g. production of beverages, hydrolysis);
- Water as solvent, absorption (e.g. gas scrubber, pickling);
- Water for washing, absorption, rinsing (e.g. textile finishing, cleaning of equipment, installation and piping);
- Water for transport and energy exchange (e.g. cooling, stream circuits)

A general water balance of water use by non-domestic water users is presented in Figure 15, which illustrates where and for which purpose water is used in the industry.

[14] Source: van de Worp 2002

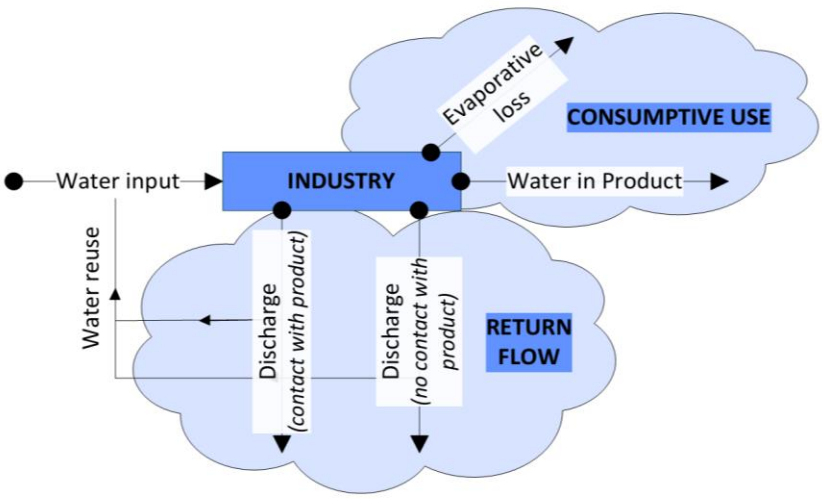


Figure 15: General water balance in an industrial process[15]

Figure 16 shows the water demand of non-domestic water users in terms of generic processes.

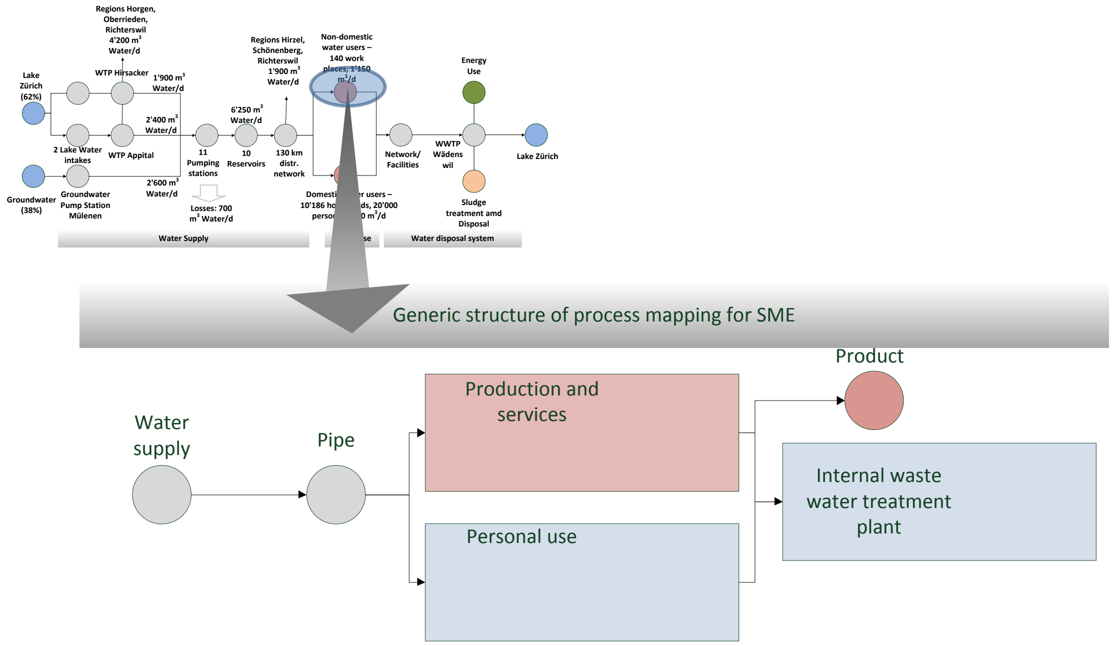


Figure 16: Generic process map for non-domestic water users

In the following paragraphs the process mapping for several non-domestic water users (SMEs) in the Case Study area is shown.

SME 1: Food production and processing sector

The SME 1 is a medium size company with 120 employees. The raw material entering the production processes is mainly plant material and chemicals. Furthermore, the solvents ethanol (1.64 t/day) and propylene glycol (0.436 t/day) are consumed. The chain of processes is relatively complex with several water and

[15] Source: Bello-Dambatta et al 2011 (according to CH2M HILL 2003)

energy consuming steps. The specific process mapping is shown in Figure 17, whereas further information for the SME 1 is presented in Table 5.

An amount of 115 m^3/day of fresh water is consumed from the water supply of Waedenswil which represents 2.6% of the total water consumption and 9.8% of the consumption of non-domestic water users in Waedenswil.

The production processes require around 29.6 MWh/day, of which 24.7 MWh/day are consumed in form of gas and 4.93 GWh/day in form of electricity.

Around 55 m^3/day of waste water is produced. The difference between water supply and waste water production is caused by the amount of water contained in the products and water which evaporates during the production process.

The wastewater is pre-treated in an internal waste water treatment plant to reduce the high organic load. Regarding the organic load, the amount of waste water load corresponds to 25,000 person equivalents (pe), which is more than the entire population of Waedenswil. The waste water treatment plant consists of an anaerobic waste water fermenter which produces biogas. The biogas produced both in the waste water fermenter and by the fermentation of biological waste from the production process is used as energy source in a combined heat and power plant. The produced energy (around 2.47 MWh/day in form of electricity) reduces the energy consumption of the company. Furthermore, a peat product is obtained from the biological waste which can be used as fertiliser and is discharged in a cost-neutral way.

Moreover, a secondary aerobic biological treatment leads to a reduction of organic load down to an average of 157 mg$_{CSB}$/L. The average CSB concentration would principally allow for a direct water disposal into the Lake Zurich. Nevertheless, the brown colour of the water is deemed unacceptable. Hence further investments, e.g. sand filter or ultrafiltration, would be required to obtain the permission for direct disposal. Therefore the pre-treated waste water is discharged into the waste water treatment plant of Waedenswil, i.e. the waste water treatment plant Rietliau.

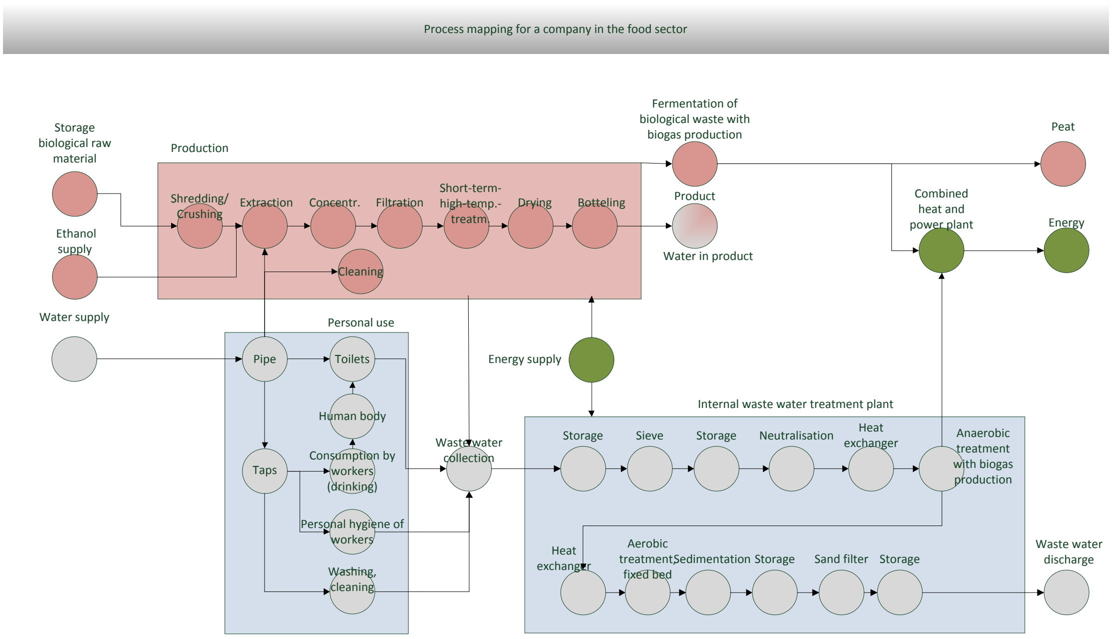


Figure 17: Process map for SME 1 - food sector

Table 5: General data for SME 1

	2011
Water consumption	115 m^3/day
Waste water production (treated in internal waste water treatment plant)	55 m^3/day
Energy consumption	29.6 MWh/day
Energy produced	2.47 MWh/day
Ethanol consumption	1.64 t/day
Propylene glycol	0.436 t/day

SME 2: Electroplating sector

The SME 2 is a medium size company with 25 employees. The company treats the surface of metal products with different electroplating processes. In order to be able to offer in a flexible way a range of different treatment modifications, four different plants operate in parallel. The process mapping for SME 2 is shown in Figure 18, whereas further information for the SME 2 is presented in Table 6. A relatively low water volume of 10.4 m^3/day is obtained from the water supply of Waedenswil which accounts for around 0.2% of the water supply of Waedenswil and for around 0.9% of the water supply for non-domestic users. An amount of 5.8 m^3/day wastewater is produced. The difference between the inflow and outflow volumes of water is attributed to the evaporation during the production processes that involve partly high temperatures.

The water is used for the electroplating baths, cleaning baths, acidic baths and cooling. Hence the waste water contains mainly inorganic pollutants like cyanide, heavy metals and acids. Internal wastewater treatment is required before the waste water is discharged into the public wastewater collection network of Waedenswil. In the waste water treatment process hydroxide sludge is produced which has to be discharged as hazardous waste (15 kg/day).

The electroplating and the waste water treatment together cause a relatively high energy consumption of around 6 MWh/day. Additionally, oil is consumed for heating purposes (50 m^3/year).

The most important cost factor is energy consumption. The costs for the electrolyte baths, the acidic baths and the chemicals required for the waste water cleaning, as well as the costs for water, waste water discharge and waste discharge, are in a comparable magnitude, but clearly lower than the costs for electricity.

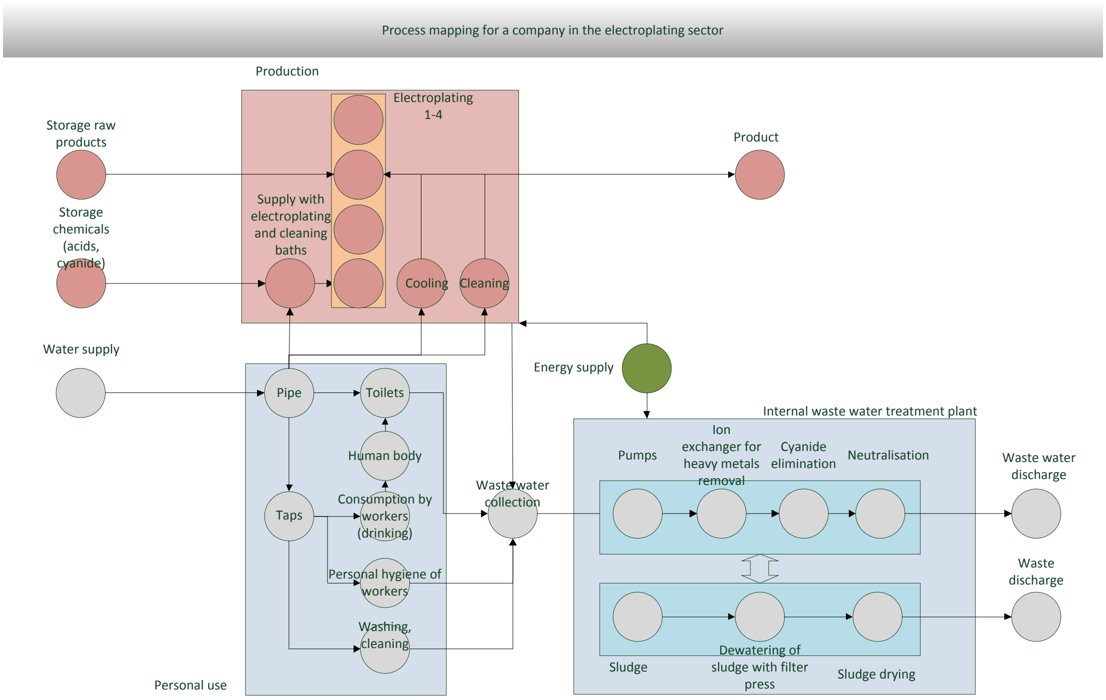


Figure 18: Process map for SME 2 - electroplating sector

Table 6: General data for SME 2

	2011
Water consumption	10.4 m^3/day
Waste water production (treated in internal waste water treatment plant)	5.8 m^3/day
Electricity consumption	6 MWh/day
Oil consumption	50 m^3/year
Hazardous waste production	15 kg/day

SME 3: Cosmetics production sector

SME 3 is a small enterprise in the cosmetics production sector. The main division of the company are the product development, production and packaging of cosmetics, including creams, balms and shampoos. Seven workers are employed and the production runs on five days per week in one shift. The yearly production is 75.6 tonnes (in 2011) (in the average 207 kg/day). The energy consumption of the company is around 77.3 kWh per day. Figure 19 illustrates the process mapping for the SME 3, and further information is provided in Table 7.

Water has to be desalinated prior to its use for the production of certain cosmetics. The company uses a desalination plant with sodium hydroxide and hydrochloric acid to produce 27 L desalinated water per day. The main production processes are heating and mixing, cooling, stirring and homogenisation. Heating with water is a circulating process, while cooling water is being directly discharged. The main water consumption concerns the cleaning of the production machines. Sub-optimal, manual cleaning practices and some products like creams on a fat-basis, result in high consumption of warm water (60°C) for cleaning (estimated to about 4.7 m^3 per day).

Additionally, sodium laureth sulphate and ethanol are used for cleaning. For wastewater treatment from the development lab, and the production and cleaning processes, there is an internal wastewater flocculation installation. About 1.6 kg of flocculation agents is used per day; about 5.5 kg per day of sludge are being incinerated.

Although there is no direct water metering for the company, as one water bill is divided to account for several tenants in the building according to the occupied surface, it can be estimated that the company is a relatively small water consumer. It consumes around 13 m^3 drinking water per day. The wastewater flow will be around the same volume, as no considerable volume of water is being included in the final product (about 0.1 m^3 per day). This company accounts for around 0.3 % of total drinking water consumption in Waedenswil.

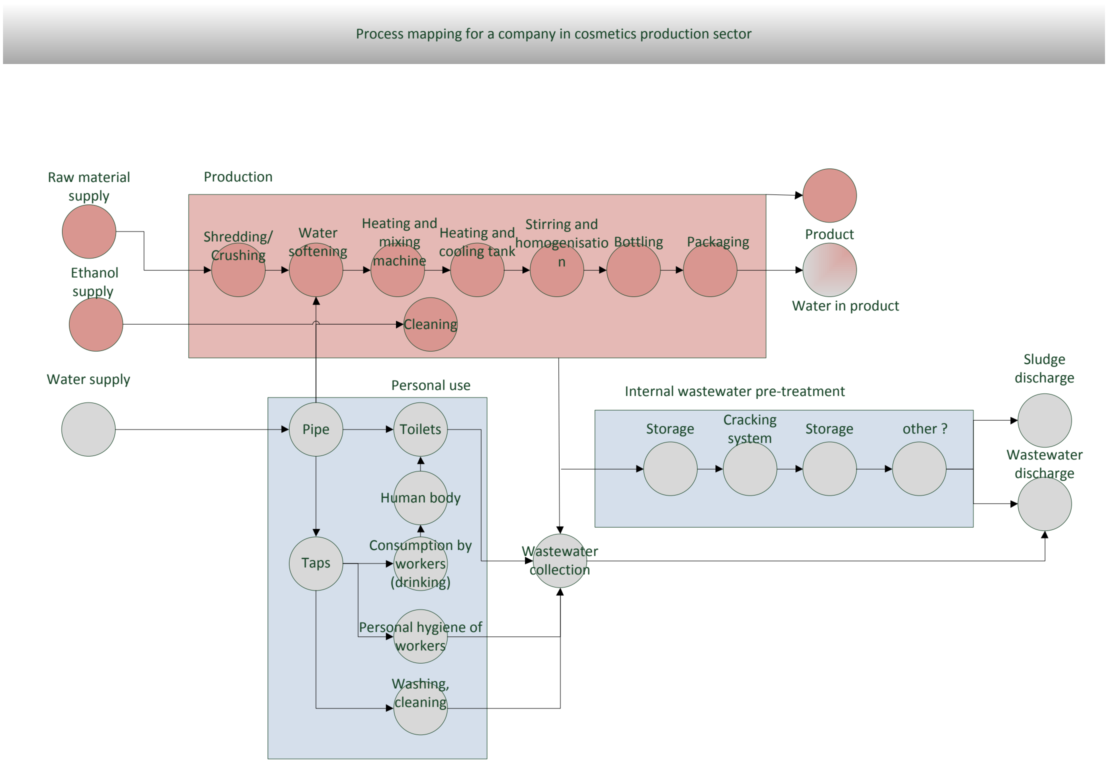


Figure 19: Process map for SME 3 - cosmetics production

Table 7: General data for SME 3

	2011
Water consumption	13 m^3/day
Water in product	0.1 m^3/day
Energy consumption	0.08 MWh/day
Production of demineralized water	27 L/day
Consumption of warm water for cleaning (app. 60°C)	4.7 kg/day
Consumption of flocculants	1.6 kg/day
Production of sludge	5.5 kg/day

SME 4: Indoor swimming pool

The indoor swimming pool in Waedenswil was built about 40 years ago and is operated by the municipality. The self-financing ratio of the organisation is 40%. It operates seven days per week, employs eight workers and around 315 guest visit the organisation on a daily basis. Three pools exist:

- Swimming pool 25x13.5 m, water temperature 29°C, water column 1.5–3.4 m;
- Educational pool 16.6x8 m, water temperature 32°C, water column 0.8–1.15 m; and
- Paddling pool, with water temperature of 32°C.

In addition to the high bathing water temperature, the air temperature is also fairly high to ensure the comfort of the guests, which results in very high energy demand (2.8 MWh per day in 2011). Intensive ventilation is also required, which is provided by an inefficient system, and hence it will be replaced in the next few years.

Before entering the swimming pools, water from the drinking water network (35 litres of fresh water per guest per day according to the SIA-Norm) and partly water already used from the pools has to be treated to the according regulations, resulting in four process steps. These concern the (i) filtration with kieselgur as filter material, (ii) ozonation, (iii) activated carbon filtration and (iv) disinfection with acid sulphur and potassium chloride. A certain amount of water is being used for cleaning purposes. These are done on a weekly basis and the pools are emptied and cleaned on a year basis.

The swimming pool is a moderate water consumer, although around 1,000 m^3 of treated water are constantly in the system. It consumes 50 m^3 of drinking water per day, which is around 1.1 % of total drinking water consumption in Waedenswil. The swimming pool produces around 45 m^3 of wastewater per day, which is only slightly polluted, so that no internal wastewater treatment system is installed. The process mapping for SME 4 is shown in Figure 20, whereas further information for the SME 4 is presented in Table 8.

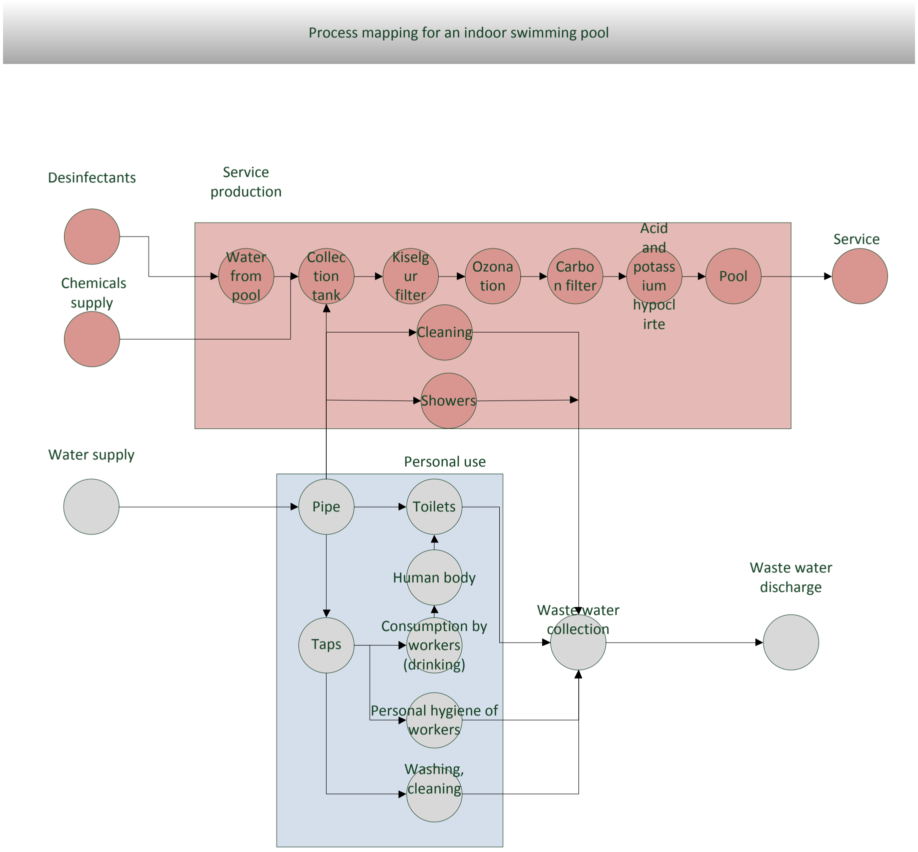


Figure 20: Process map for SME 4 - indoor swimming pool

Table 8: General data for SME 4

	2011
Water consumption	50 m^3/day
Waste water production	45 m^3/day
Energy consumption	2.8 MWh/day
Guests	315 p/day

2.4.3.3 Domestic water use

The preliminary process map for domestic water users is shown in Figure 21.

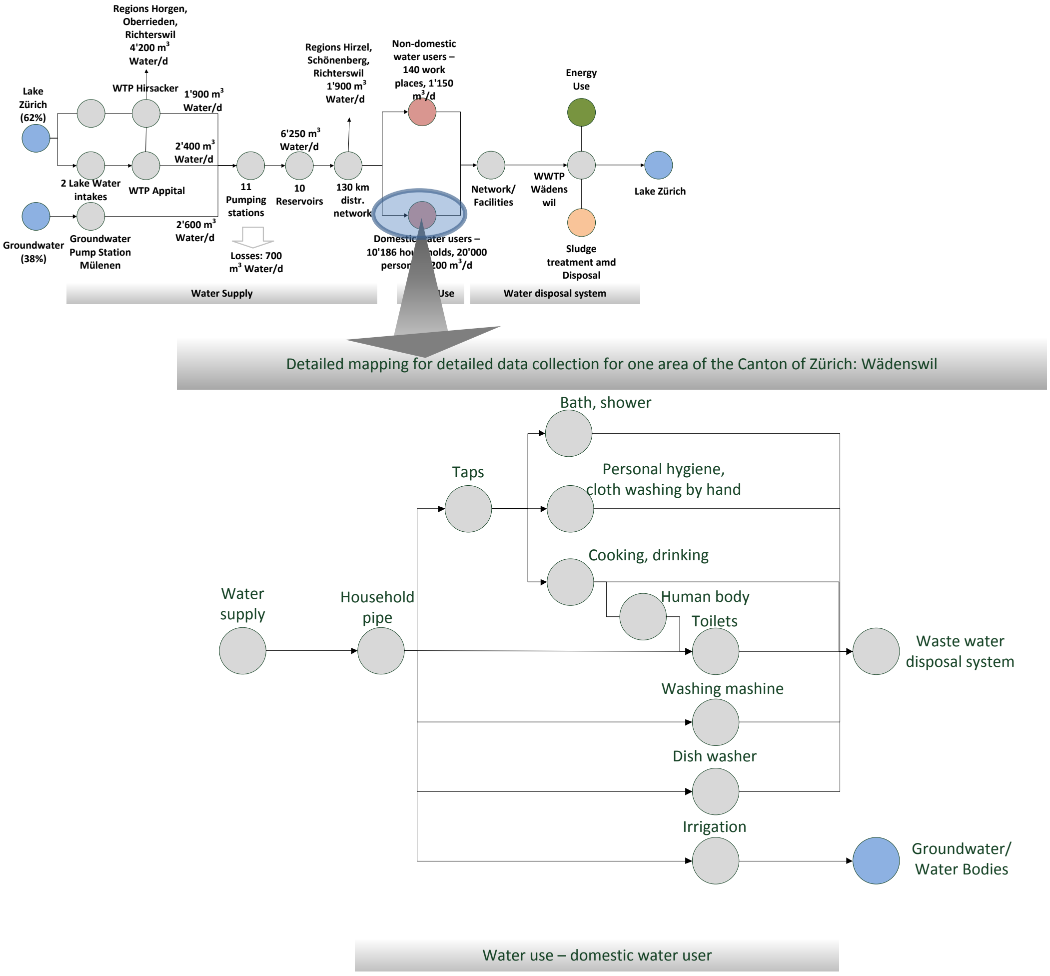


Figure 21: Preliminary process map of domestic water use

According to an image analysis of drinking water in the Canton of Zurich (AWEL by DemoSCOPE, 2011), about 80% of the population drinks tap water on a regular basis (Figure 22). The good taste was the most important reason to drink tap water. Additionally, it is cheap compared with bottled water, healthy and has a good quality. 93 % of the interviewed persons are judging the quality of water as good (dark green) to very good (light green).

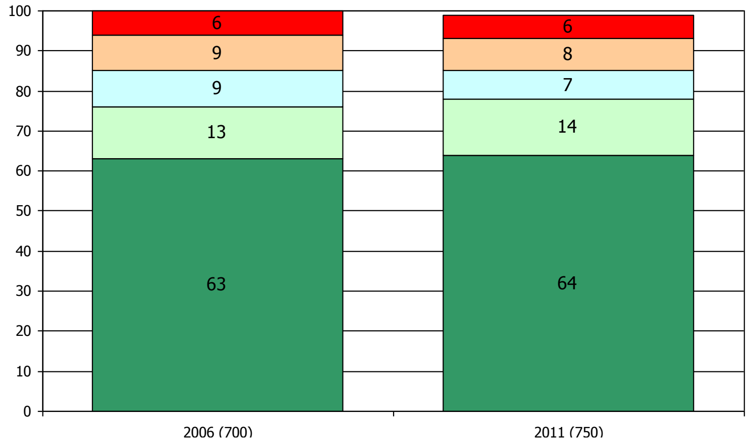


Figure 22: Answers to question: „How often do you drink tap water?“ in 2006 and 2011

2.4.3.4 Wastewater Disposal System – Treatment and Discharge

The wastewater treatment plant under investigation is the Waedenswil-Rietliau WWTP. Figure 23 shows an overview of the plant.

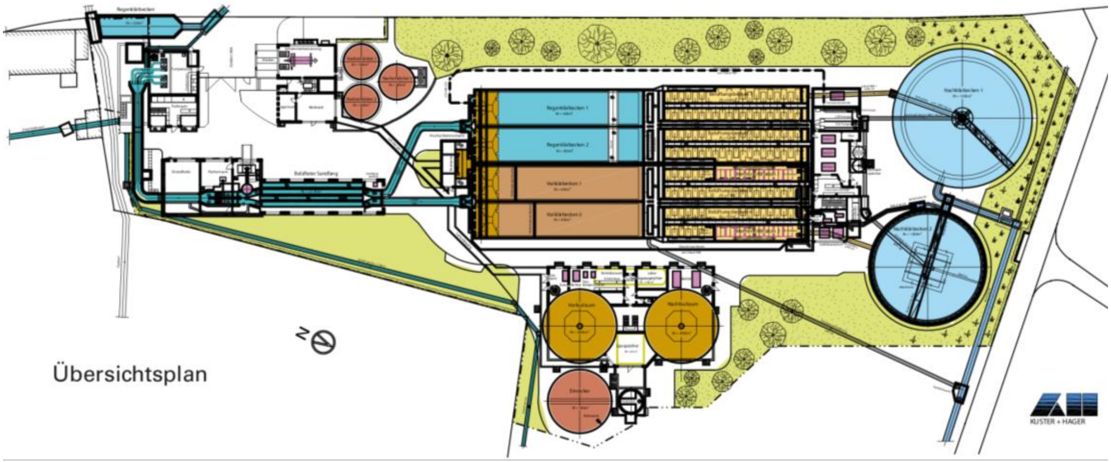


Figure 23: Overview of the WWTP Waedenswil-Rietliau

The WWTP treats around 10,000 m^3 of waste water per day (Table 9); more than 50% originates from rain flows and not from the wastewater generated by domestic and non-domestic water users. In case of extremely heavy rain, the WWTP can discharge a certain amount of untreated water in the lake.

The first two treatment steps are screens and sand trap. Two of the four primary sedimentation tanks are continuously in operation. The remaining two primary sedimentation tanks are used as buffer in case of strong rain events. The biological waste water treatment is designed in four parallel lines. Two of these lines are conventional plants followed by two secondary sedimentation tanks. Additionally, two lines of membrane bioreactors are installed. By adding iron salts, alumina salts and polymers phosphate is eliminated simultaneously and foam building is controlled.

The waste water treatment line is complemented by the sewage sludge treatment. This system consists of anaerobic sludge treatment plant, dewatering and drying of the stabilized sludge and biogas reclamation.

Additionally two concepts are integrated in the treatment plant to recover energy. Heat is recovered from the waste water after the biological treatment. Furthermore, the biogas is used in a combined heat and power plant to produce electricity which is used directly for the operation of the WWTP.

shows the process map of the Waedenswil WWTP, while Figure 25 shows the mapping of the sewage network in Waedenswil.

Table 9 General features of the Waedenswil WWTP [16]

Feature	Value in 2011	Value in 2010	Value in 2009
Total wastewater treated	3.17 mio m^3	3.77 mio m^3	3.44 mio m^3
Thereof biologically treated	2.88 mio m^3	3.27 mio m^3	3.07 mio m^3
Energy consumption	1,919,091 kWh	1,985,902 kWh	1,988,027 kWh
Thereof from own generation	516,676 kWh	566,289 kWh	577,952 kWh
Gas consumption	57,200 m^3	85,417 m^3	69,180 m^3
Precipitating agent consumption	446 t	541 t	460 t
Sludge to incineration plant	2,161 t	2,277 t	2,441 t

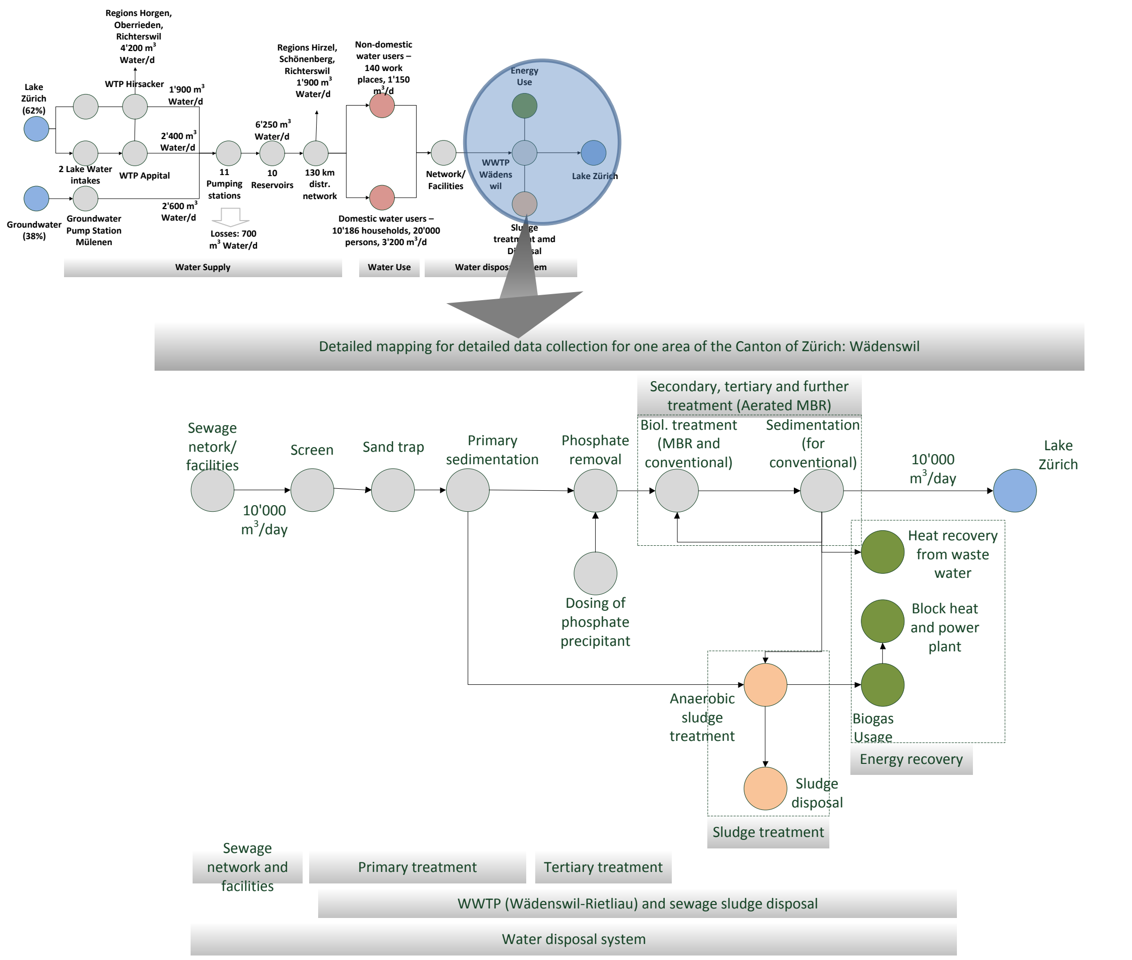


Figure 24: Waedenswil WWTP process map

[16] Source: Stadtrat Waedenswil (2012, p 88, 89)

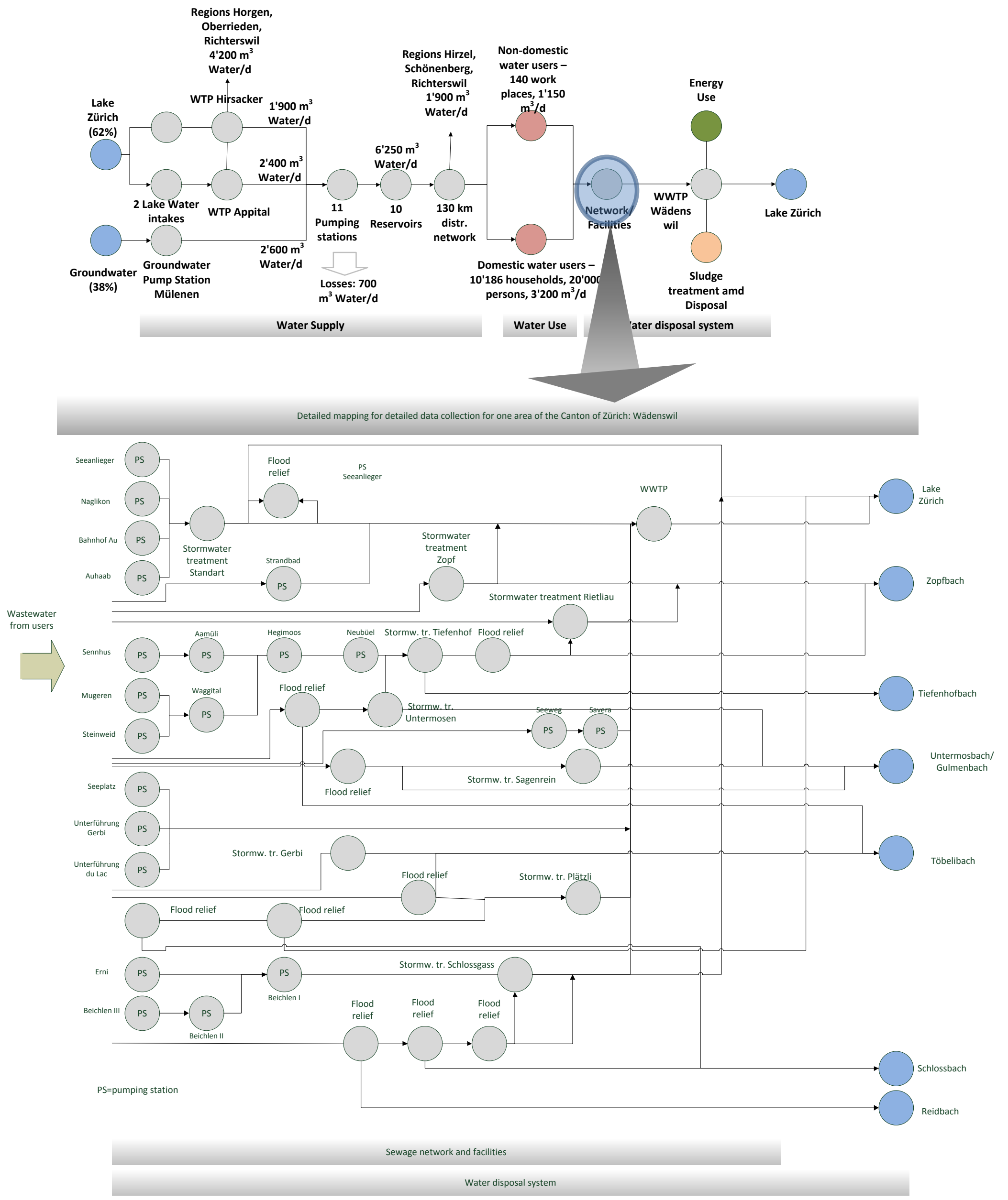


Figure 25: Process map of wastewater network system

2.4.4 Description of existing technologies

The following sub-sections focus on the existing technologies of each of the main stages, according to the following grouping:

- Water supply (sub-section 2.4.4.1)
- Non-domestic water users (sub-section 2.4.4.2)
- Domestic water users (sub-section 2.4.4.3)
- Wastewater disposal (sub-section 2.4.4.4)

Table 10 includes an overview of the existing technologies in the water supply chain of Waedenswil. A brief description of the relevant technologies is provided further below.

Table 10: Structure of the case study in nodes and overview of existing technologies

	No	Generic Node	Specification on process level for case study	Variety of processes
Water supply	1	Water intake	Intake from groundwater well	One well
			Lake water intakes	Two very similar intakes from Zürich lake
	2	Pre-treatment	Screens at lake intakes	Very similar for lake water supply
	3	Filtration	Sand filtration	Two different flocculant types
			Activated carbon filtration	Two very similar
	4	Disinfection	UV-Disinfection	One for groundwater
			Ozonation	Two very similar
			Chlorination	Two different disinfectant types
	5	Pumping stations		11 similar
	6	Distribution network and reservoirs		10 reservoirs, 130 km network, similar technologies
Water use	7	Production, Service	Extraction, cleaning, transfer in product, usage for sportive activity, preparation of baths for electroplating, internal waste water treatment technologies	Large variety between the different SMEs, especially between different sectors
	8	Washing/ Cleaning		Similar in households and SMEs
	9	Cooling		Similar systems, relevant for SMEs
	10	Irrigation		Similar in households and SMEs
	11	Toilet		Similar in households and SMEs
	12	Consumption		Similar in households and SMEs
	13	Personal hygiene		Similar in households and SMEs
Water disposal system	14	Sewage network and network facilities		One plant
	15	Primary treatment	Screening, sand trap, primary sedimentation, rain water buffer	One plant with these four components
	16	Secondary treatment	Conventional biological treatment with secondary sedimentation, membrane bio reactor	One plant with these two technologies in parallel
	17	Tertiary treatment	Simultaneous phosphorus elimination with chemical precipitation	One plant
	18	Further treatment (e.g. for micro pollutants)	Filtration step included in membrane bioreactor, additional treatment is planned (probably activated carbon filtration)	One plant
	19	Treated water discharge		One plant
	20	Sludge treatment	Thickening, anaerobic stabilization, dewatering	One plant
	21	Energy recovery	Biogas usage with block heat and power plant	Waste water treatment plant and one SME using similar technologies
	22	Sludge disposal	Incineration	One plant disposing sludge in one incineration plant

2.4.4.1 Water supply

The main applied technologies in the water supply side are:

- Flocculation;
- Rapid sand filtration;
- Activated carbon filtration;
- Ozonation;
- Disinfection by chlorination; and
- Disinfection by UV-radiation.

These are described in the following paragraphs:

Flocculation

Several compounds like very small dispersed particles, humic substances and dissolved compounds cannot be separated from the raw water by filtration or sedimentation directly. Furthermore, bacteria and microorganisms can be attached to small particles which reduce the effectiveness of disinfection technologies. By adding flocculation agents, it is aimed to aggregate those types of substances and hence to make an elimination by sedimentation or filtration technologies. The flocculation can be divided in four sub-processes: (i) dosing of the flocculation agents, (ii) de-stabilisation of colloidal dispersion, (iii) aggregation of micro flocs and (iv) aggregation of macro flocs. In the water treatment plants in Waedenswil aluminium salts are used as flocculation agents [DVGW W217].

Rapid sand filtration

The raw water permeates the granular filter material from top to bottom. Rapid sand filtration can be conducted in an open way hence gravity driven or in a closed way under pressure. The filtration velocity for rapid sand filtration can be from 0.3 up to 30 m/h whereas a velocity above 15 m/h is only possible for close filters under pressure. The filtration effectiveness is increased significantly in combination with a flocculation.

In both water treatment plants (WTPs) in Waedenswil, the filters are operated in an open, gravity driven configuration and in combination with a flocculation. In the Hirsacker WTP, the filtration velocity is between 3.4 and 6.8 m/h whereas in the Appital WTP between 3 and 9 m/h.

Cleaning of the filtration material can be done by backwash with clean water and air [DVGW W213-3].

Activated carbon filtration

In this type of filtration dissolved substances are removed by adsorption to the filtration material. Important properties of activated carbon influencing the adsorption are the specific surface, surface characteristics like hydrophilicity, catalytic properties or acidity. Activated carbons are granulate with a high carbon content which was activated e.g. with high temperature, chemicals or steam. The filter break-through occurs when the adsorption capacity of an activated carbon filter is exceeded. After the filter break-through the elimination effectiveness decreases sharply. After a filtration period, the activated carbon material can be regenerated.

The activated carbon filters contain a combination of the material F300 and quartz sand in both the Waedenswil water treatment plants. The filtration velocity reaches 6-18 m/h in the activated carbon filtration of the plant Appital and 10.2-20.4 m/h in the activated carbon filtration of the plant Hirsacker [DVGW W239; W240].

Ozonation

Ozone is a very strong oxidant and can decompose bacteria and micro pollutants as well as organic molecules. Ozone is not stable, and hence it is decomposed after a short time.

Ozonation of raw water is an effective disinfection technology if a contact time in the magnitude of 10 min and a concentration in the magnitude of 0.4 mg/L are achieved. For a high elimination and disinfection rate it is also important to maintain raw water with low turbulence.

In both water treatment plants in Waedenswil the ozone is produced from air. In the newly constructed plant Hirsacker which will operate from the end of 2012 onwards, the ozone is produced from liquid oxygen which was found to be more cost and energy efficient. In addition, the remaining ozone in gas and water phase is decomposed in order to ensure security. In both water treatment plants a concentration of 0.8 mg/L ozone is maintained for disinfection [DVGW W225].

Disinfection by chlorination

Chlorine compounds or chloride dioxide are strong oxidants, which allow for a decomposition of microorganisms and bacteria. Dosing of a sufficient concentration depending on the water properties is an effective disinfection technology. Similarly with other disinfection technologies a low turbulence is important for an effective disinfection.

Both water treatment plants in Waedenswil apply disinfection by chlorination as a complementary to ozonation disinfection technology, in order to ensure disinfection during the residence time of the water in the distribution network and to increase the drinking water quality security. The treatment plant Appital applies 0.1 mg/L NaOCl and the treatment plant Hirsacker 0.08 ClO_2 which is produced onsite from $NaClO_2$ and Cl_2.

Disinfection by UV-radiation

Light with wave length between 240 and 290 nm is referred to as UV-light. Radiation with this light has a biocide effect and is used as disinfection technology in drinking water treatment. An important pre-condition for an effective disinfection is to prevent the existence of particles in the water to be treated. Microorganisms and bacteria which are attached to particles or in pores of particles are exposed to a lower extent to the radiation.

Groundwater produced in the Canton of Zurich is treated in many cases with UV-radiation as disinfection step [DVGW W294].

2.4.4.2 Non-domestic water users

The investigated SMEs apply the following water relevant technologies:

- Extraction;

- Washing/Cleaning;
- Baths for electroplating;
- Internal waste water treatment technologies; and
- Water treatment technologies for swimming pools.

Extraction

The extraction technology allows for the transfer of compounds from solids into a solvent. For instance, active substances from plants can be transferred from parts of the plants into a liquid solvent in order to make them available for production processes. The extraction process often uses water or mixtures of water and organic solvents like ethanol. According to the operational conditions like pressure, temperature and process design, there are different extraction technologies such as distillation, percolation and maceration.

The solvents used for the extraction can normally be recovered, often in a subsequent thermal concentration process.

Washing/Cleaning

Cleaning plays an important role in most of the water using processes. Hygienic safety plays an important role as well, especially in production processes in the food and beverage sector. Quality standards also require a cleaning of media-contacting parts of the process equipment, especially in the cases that production flexibility is achieved by using the same equipment for different products in an alternating way.

Cleaning technologies are partly simple and manual. Pressure washers can contribute significantly to water saving. Optimised cleaning equipment like zip-cleaning with jet cleaning can save around 20% of water consumption.

Baths for electroplating

The technology of electroplating uses electrochemical reactions to produce metal layers on products. The products are immersed in electrolysis baths as well as baths for pre-treatment. Between different treatment steps, cleaning baths are required. The technology is energy intensive, as electricity is used and partly high temperatures is required. The immersion processes are partly realized in a manual way; partly automated plants are applied.

Internal waste water treatment technologies

Although the technologies applied by non-domestic users for decentralized wastewater treatment are principally similar to those of the municipal wastewater treatment plants, they are adapted to the requirements of the specific wastewater and the conditions in the corresponding company. For instance, a SME in Waedenswil designed a waste water treatment process for pre-cleaning the generated wastewater. Since the plant had to be integrated in the production and the space for building the biological treatment was limited, it was necessary to construct an unusual deep biological treatment tank of 12 m depth. Accordingly, the aeration technology had to be optimized, in order to reduce the energy demand.

Water treatment technologies for swimming pools

In swimming pool facilities, water from pools is usually reused, and hence has to be treated according to the regulations for bathing water before entering the swimming pools again. The first step in the process is the filtration with kieselgur as filter medium, which has a high porosity, because of microscopically small, hollow particles. This filter is used to sterilise water to eliminate suspends particles and to detain bacteria. This first step is followed by ozonation and activated carbon filtration, which are similar to the technologies described in chapter 2.4.4.1. Finally, water is being disinfected with acid sulphur and potassium chloride.

2.4.4.3 Domestic water users

The use of water in households is often dependent not only on the technologies applied, but even more on the behavior of the users themselves. The investigated households apply the following water relevant technologies:

- Toilet flush;
- Tabs in bath and shower; and
- Washing machines.

Table 11 summarizes the most important water-relevant technologies in households and the potential for reduction of water consumption, in the case that the Best Available Technology (BAT) is used.

Table 11: Technologies and potential for reduction of water consumption

	Usual water consumption	Potential for reduction of water consumption with BAT
Toilet flush	9 litres per flush	30%
Tabs in bath and shower	16 litres per minute	25% - 70%
Washing machine	250 litres per washing	60%

Toilet flush

The main water consumer in households, which accounts for 30% of the total water consumption, is the toilet flush. There are no reports of usage of water-free toilets in households in Waedenswil. However, toilet flushes which use different amounts of water exist. The average toilet flush in Switzerland uses 9 liters of water per flush, while some appliances are equipped with a “stop” button, which can reduce the water consumption by 30%[17] when used consequently for urine flushing. There are also appliances which use grey water instead of drinking water, which, applied without the reduction of the volume, will reduce the drinking water consumption but not the volume of wastewater discharge from the toilet.

Tabs in bath and shower

The second largest water consumer in households (around 20% of the total water consumption) is bath and shower. A Swiss survey has shown that shower dominates over bath and that the potential for reductions from changing a bath to a shower is almost depleted. However, showering time can still be reduced. Economizer jets can

[17] [Source: http://www.trinkwasser.ch/dt/html/download/pdf/twi5.pdf; accessed 08. February 2012]

be used in showers and for hand and dish washing. Showers consume about 16 liters[18] of water per minute, where savings of 25% to 70% are realistic with the installation of economizer jets. Faucets for hand and dish washing consume about 12 liters of water per minute; the same saving potential exists in the case of showers.

Washing machines

The third largest water consumption in households results from washing machines, which mainly depends on their age. Old types of washing machines consume up to 250 litres, while new types only 100 litres. Apart from that users can again reduce the consumption of the washing machines or dishwashers by choosing the right programme, which uses only as much water as necessary and by filling the machines up[19].

2.4.4.4 Wastewater disposal

The WWTP applies the following water treatment technologies:

- Screening;
- Sand removal and sedimentation;
- Nutrient removal;
- Biological wastewater treatment; and
- Sludge treatment.

Screening

Screens are usually used as the first treatment step in wastewater treatment for removal of large objects. The waste retained by the screens is usually incinerated.

In the wastewater treatment plant Rietliau, two screens are connected in series to remove larger particles and subjects from the wastewater stream.

Sand removal and sedimentation

The hydraulic conditions in the sand trap are designed in such a way that the inorganic components, like sand, are separated. These particles have a relatively high density and sediment fast. If a low organic content can be achieved the material can be used for construction otherwise it has to be treated as hazardous waste.

The second sedimentation step eliminates organic suspended substances referred to as primary sludge. Together with the surplus sludge, this fraction is treated in the sewage sludge digester for stabilization and energy recovery.

Nutrient removal

Chemical phosphorus elimination is applied. The precipitation is induced by adding both alumina and iron salts immediately before the biological waste water treatment. Hence iron and aluminium phosphate precipitate out of the treated water together with the biological sludge.

Nitrogen is partly removed from wastewater. In the aerobic biological treatment nitrification takes place. Hence ammonium is decomposed into nitrate by controlling

[18] www.aquaclic.info
[19] http://www.trinkwasser.ch/dt/html/download/pdf/twi5.pdf

the oxygen concentration during the biological treatment. The nitrate load existing in the effluent can be disposed into the lake Zurich.

Biological wastewater treatment

The conventional biological treatment consists of two parallel aerobic treatment lines with sludge recirculation and 3-4 g/L TS. The aerobic zone consists of a volume of two times 490 m^3. In order to control the foam formation in the biological treatment stage, polymers and aluminium salts are added. The conventional biological lines are followed by the secondary sedimentation, so as to separate the biological activated sludge from the effluent. Part of the activated sludge is recirculated into the biological treatment process; part is removed and treated in the sludge digester.

In parallel to the conventional treatment, two lines of membrane bioreactors operate in the wastewater treatment plant Rietliau. Membrane bioreactors realize the separation of the biomass with ultrafiltration membranes. As a consequence, it is possible to reach a higher TS concentration in the biological reactor as well as a higher sludge residence time and an effluent with lower TS and of better quality.

The waste water treatment plant Rietliau contains an installation of capillary (zeeweed) ultrafiltration membranes with a pore size of 0.035 µm. The membrane is frequently cleaned with backwash and with weekly chemical cleaning, based on nitric acid and sodium hypo chloride. Aeration is applied next to the membrane modules, aiming to supply the oxygen required for the biological degradation and, at the same time, control the membrane fouling. The membrane bioreactor contains a TS concentration of 8-12 g/L.

Wastewater contains generally energy in form of increased temperature. Additionally the wastewater pumps and the biological degradation processes lead to a further energy input in form of temperature increase. This energy can be recovered using heat pumps. The waste water treatment plant in Waedenswil supplies the recovered heat to 200 households.

In the Rietliau WWTP, additional storm water basins are installed to reduce the impacts of strong storm water events. These impacts are the increased loading due to the cleaning of the network by suddenly occurring high flow rates and a high hydraulic load. As a consequence of these buffer tanks, the water directly released into the lake is less loaded and the waste water treatment plant is better protected. The direct release can partly be prevented. After storm events, water from basins can be transferred to the biological treatment.

Sludge treatment

The surplus sludge originating from the biological wastewater treatment is the main waste generated in the waste water treatment process. In Switzerland a direct usage of the sludge in agriculture is not permitted. As a result sewage sludge is disposed by incineration, in waste incineration plant, mono-incineration or in cement plants. As a preparation of this disposal routes, the sludge is usually stabilized by anaerobic treatment. Furthermore the sludge is dewatered and dried. The anaerobic treatment allows for a recovery of biogas and hence energy production.

In the wastewater treatment plant Rietliau, two combined heat and power plants are used to produce energy from biogas in the form of electricity. With these technologies, 80 and 60 kWh can be produced in the two plants. This energy recovery can substitute 46% of the total energy consumption of the wastewater treatment plant.

2.5 Value chain mapping

This chapter focuses on the specification of the directly and indirectly involved actors and stakeholders in the different stages of the system are made. It includes the identification of their current role, including their driving forces, interests and interactions (Table 12). Moreover, a description of the resource flows (financial, water, wastewater and energy) between the main actors is provided (Table 13).

Table 12: Actors and stakeholders characterization

Item	Actor	Driving force/interest/profit connected with the water value chain	Interaction/influence medias
1	Association of municipalities for water treatment Hirsacker-Appital (Zweckverband Seewasserwerk Hirsacker-Appital)	Water supply with water from Zurich lake Fulfilling contract and regulations Cost control	Influenced by items 2-5 by contract and decisions Influenced by 6 and 8 by legislation
2	Municipality Waedenswil	Functioning, sustainable and secure water supply (in means of quality and quantity) Reliable water discharge	Influenced by items 6 and 8 by legislation
3	Municipality Horgen	Functioning, sustainable and secure water supply (in means of quality and quantity) Reliable water discharge	Influenced by items 6 and 8 by legislation
4	Municipality Richterswil	Functioning, sustainable and secure water supply (in means of quality and quantity) Reliable water discharge	Influenced by items 6 and 8 by legislation
5	Municipality Oberrieden	Functioning, sustainable and secure water supply (in means of quality and quantity) Reliable water discharge	Influenced by items 6 and 8 by legislation
6	Canton of Zurich	Sustainable water resource management Indirectly cost covering (this responsibility is transferred to the municipalities) Coordination and authorisation municipal and regional planning for water supply and discharge.	Influencing items 2-5, 11 and 12 with laws: EG GSchG; VGSch; WWG; WsVV; PBG; BBV I; BVV; ABCV; AbfG In charge of legal compliance and executive organization of item 7

Item	Actor	Driving force/interest/profit connected with the water value chain	Interaction/influence medias
7	AWEL (Office of Waste, Water, Energy and Air of Canton of Zurich)	Reduction of environmental impact, sustainable Consumption of resources For the benefit of 11 and 12 in the Canton of Zurich	Supporting items 1-6 and 8-17 with information, guidance, monitoring and consultancy
8	Swiss Federation	Water protection, elaboration of legal standards, financial support of water protection and data quality evaluation of surface and ground waters and water flow conditions as far as they are of interest on the Swiss national level	Influences by EU by directives Influencing items 2-5, 6, 11 and 12 with legislation: GSchG; GSchV; ChemRRV; RPG
9	Environmental organisations / civil society	Protection or monitoring of environment against misuse or degradation, lobbying for these goals Minimization of emissions, of resources consumption	Interact with all actors as public
10	Swiss gas and water industry association svgw.ch	Non-profit professional, know-how and networking organisation of water supply, economical, scientific and administrational actors on national level	
11	Private persons/households	Functioning, sustainable and secure water supply (in means of quality and quantity) Reliable water discharge Low payments/costs/prize for supply and discharge	Influenced by item 9
12	Private companies using water and discharging waste water	Maximizing profit (reducing costs of water supply and discharge) Reliable water supply in the required amount and quality Reliable water discharge	Influenced by item 9
13	Private companies planning, maintenance, installation of WTPs	Maximizing profit (efficient processes)	
14	WWTP - Public construction authority (Bauamt), Waedenswil	Discharge and treat wastewater To cover costs	Belongs to item 2
15	District heating network (Fernwärmeverbund) ARA Rietliau	Provide energy (?) Cover costs (?)	Operated by item 2

Item	Actor	Driving force/interest/profit connected with the water value chain	Interaction/influence medias
16	Private companies planning, maintenance, installation of plants (e.g. Kuster+Hager)	Maximizing profit (efficient processes)	
17	Research Institutions (Universities,…)	Increase knowledge (?)	

Table 13: Flow of resources (financial, water, wastewater and energy)

Item	Actor	Input	Output
1	Association of municipalities for water treatment Hirsacker-Appital (Zweckverband Seewasserwerk Hirsacker-Appital)	Money from items 11 and 12 for water supply (Additional public money from municipalities?)	Water to items 2, 3, 4 and 5 and hence indirectly to 11 and 12 Money to item 13 Money to item 3 for staff (?) Wastewater to item 14
2	Municipality Waedenswil	Water from item 1 Money from items 11 and 12 for water supply (from Groundwater) and for distribution Money from Municipalities Hirzel and Schönenberg for water supply Money from item 4 for Water transit Wastewater from items 11 and 12	Water to item 11 and 12 (coming from item 1 and also from Groundwater) Water to Municipalities Hirzel and Schönenberg Water to item 4 (partly transit partly compensation for removal of a spring) Wastewater to item 14
3	Municipality Horgen	Water from item 1 Money from items 11 and 12 for water supply (from Groundwater) and for distribution Wastewater from items 11 and 12	Water to items 11 and 12 (coming from 1 and also from Groundwater) Wastewater to WWTP
4	Municipality Richterswil	Water from item 1 Money from items 11 and 12 for water supply (from Groundwater) and for distribution Wastewater from items 11 and 12	Water to items 11 and 12 (coming from 1 and also from Groundwater) Wastewater to WWTP

Item	Actor	Input	Output
5	Municipality Oberrieden	Water from item 1 Money from items 11 and 12 for water supply (from Groundwater) and for distribution Wastewater from items 11 and 12	Water to items 11 and 12 (coming from 1 and also from Groundwater) Wastewater to WWTP
6	Canton of Zurich	Exchange of money with municipalities	Exchange of money with municipalities
7	AWEL (Office of Waste, Water, Energy and Air of Canton of Zurich)	Financed by Canton of Zurich	
8	Swiss Federation	Exchange of money with municipalities and cantons	Exchange of money with municipalities and cantons
9	Environmental organisations	Funding from items 6, 8 11 and 12	
10	Swiss gas and water industry association svgw.ch	Financed by ?	
11	Private persons/households	Water from item 2 (to 5) (indirectly from 1)	Wastewater to item 2 (to 5) (indirectly to 14) Money to items 1, 14, 2 (to 5)
12	Private companies using water and discharging waste water	Water from item 2 (to 5) (indirectly from 1)	Wastewater to item 2 (to 5) (indirectly to 14) Money to items 1, 14, 2 (to 5)
13	Private companies planning, maintenance, installation of WTPs	Money from items 1-5	Plants etc. to items 1-5
14	WWTP - Public construction authority (Bauamt), Waedenswil	Money from items 11, 12 and 2 Wastewater from item 2 (indirectly from 11 and 12) Money for energy from item 11	Cleaned wastewater to lake Zurich Energy to item 15 Sludge to incineration plant
15	District heating network (Fernwärmeverbund) ARA Rietliau	Energy from item 14 Money from iteµ 11	Energy / heat to 220 households (11) and companies (12)
16	Private companies planning, maintenance, installation of plants (e.g. Kuster+Hager)	Money from items 14 and 2	Plants etc. to items 14 and 2
17	Research Institutions (Universities etc.)	Funding from e.g. items 6 and 8 (indirectly by 11 and 12)	

The interactions and resource flows described in the two Tables above are further mapped in Figure 26. The water flows are represented with blue arrows, the wastewater flows with orange, the financial flows with green and energy flows in red. Some kind of cooperation is shown in light blue bold arrows.

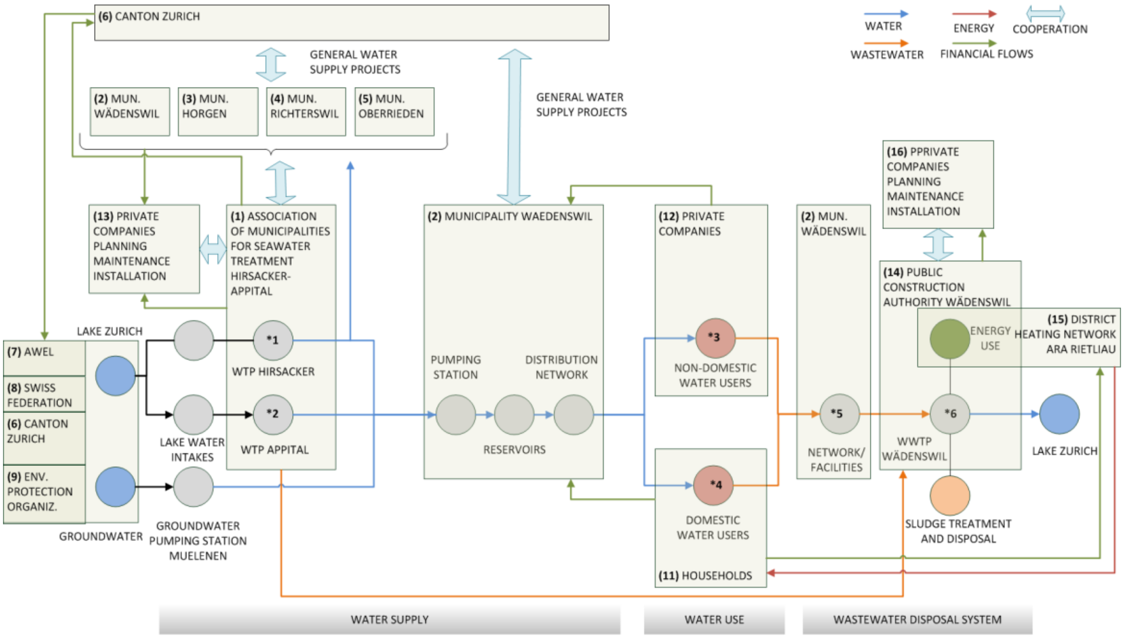


Figure 26: Mapping of actors in the Waedenswil Case Study

2.6 Selection of eco-efficiency indicators

This section introduces the underlying factors for eco-efficiency indicators are introduced. In section 2.6.1, the environmental impact indicators relevant to the Case Study area Waedenswil are introduced and in section 2.6.2, the economic costs and benefits of the corresponding analysed actors are displayed. From these two sections, the value of water to users (benefits), the costs of water supply and disposal and the corresponding environmental impacts will be used to formulate eco-efficiency indicators for the analysed Waedenswil water chain.

$$\text{Eco}-\text{efficiency indicator} = \frac{[\text{Value of water to users} - \text{Cost of supply and disposal}](\text{section 2.6.2})}{\text{Environmental Impact (section 2.6.1)}}$$

2.6.1 Environmental impacts

As an input from WP1 a comprehensive list of environmental impact indicators was identified for this Case Study. For each indicator, a number of parameters were given, which characterise the corresponding. The list of indicators and parameters is given in Table 14. For all parameters an analysis was performed to evaluate the importance for each node defined in Table 10. The importance of each parameter was assessed for each node and each parameter was characterized as “important”, “possibly important” or “not important”. Additionally, data availability was identified in the range from “not available” to “possibly available” and “available”.

Table 14: List of environmental indicators and parameters

Indicator	Parameter	Indicator	Parameter
Climate Change/ global warming	CO_2 to air emission	Ecotoxity (chemicals)	dioxin
	CH_4		furan
	CFC		polycyclic aromatic hydrocarbons
	N_2O		cadmium Cd
	Chloride		lead Pb
Water quality (this may be split into different water quality topics)	NO_3		mercury Hg
	NH_4	Biodiversity	habitat variety
	N Total	Air Quality	number of days of pollution
	PO_4		SO_2
	P Total		NO_2
	BOD (Biological oxygen demand)		NH_3
	COD (Chemical oxygen demand)		NMVOC (nonmethane volatile organic compounds)
	total pesticides	(Input) Resources 'Resource use intensities'	Energy - Electricity
	TSS		Energy - Oil/Gas
	Microbiological contaminations		Energy - Transport fuels
	Micropollutants		Surface Water
	Nanoparticles		Groundwater
Water Quantity	Total volume per year		Other water
	Abstracted water		Fertilizers
	Re-used water		Pesticides
	Ratio abstracted to returned (discharged)		Chemicals / Dye
	Used water per capita/per unit		Land use / land claim
	Leakages		Dairy
	Infiltration	Solid waste	Waste to landfill
Acidification (emissions to air)	SO_2		Waste to incineration plant
	NO_x		Waste to recycling plants
	HCl		Sludge produced per person per day
	NH_3		Used sludge - fertiliser
Tropospheric ozone formation / depletion (emissions to air)	NO_x		Used sludge - other
	NMVOC (nonmethane volatile organic compounds)		
	CO		
	CH_4		
	CFC		

Based on these estimations and an additional expert judgement with respect to the Case Sudy area the ranking of the relevance of environmental indicator parameters was performed. As a result, Table 15 shows the ten (10) most important indicator parameters that were chosen from the complete list.

Table 15: Ranking of environmental indicator parameters

Important	xxx
Possibly Important	x

Parameter	Units	1 Water intake	2 Pre-Treatment	3 Filtration	4 Disinfection	5 Pumping stations	6 Distribution network and reservoirs	7 Production	8 Washing/Cleaning	9 Cooling	10 Irrigation	11 Toilet	12 Consumption	13 Personal hygiene	14 Sewage network and facilities	15 Primary treatment	16 Secondary treatment (biological)	17 Tertiary treatment (nitrogen and phosphate removal)	18 Further treatment (e.g. for micropollutants)	19 Treated water discharge	20 Sludge Treatment	21 Energy recovery	22 Sludge disposal	Ranking:
		Water Supply (Node)						Water use							Water disposal system									
Microbiological contaminations	1/y	x	xxx	x	xxx	x	x	x	x		x	xxx					x		x	x	xxx		x	1
Total volume per year	m3/y	xxx						xxx	xxx	xxx	xxx	xxx	x	x										2
Energy - Electricity	kWh/y	x	x	x	x	x		x	x	x	x						x	x	x	x	xxx	x		3
Micropollutants	kg/y			x				x	x			xxx					x		xxx	x	x		x	4
N Total	kg/y			x				x	x		x	xxx					x	xxx	x	x	x		x	5
P Total	kg/y			x				x	x		x	xxx					x	xxx	x	x	x		x	6
Waste to incineration plant	t/y			x				x								x	x	x	x		xxx		xxx	7
total pesticides	kg/y			x				x	x		x						x		xxx	x	x		x	8
TSS	kg/y			x				x	x							xxx	x		x	x	x		x	9
COD (Chemical oxygen demand)	kg/y			x				x	x								xxx		x	x	x		x	10

The four most relevant indicators from Table 15 will be used in the analysis of the Case Study. Additionally, four other indicators for environmental impact were identified to be relevant for the urban Case Studies. Therefore the following list will form the basis for the baseline assessment.

- Total water use;
- Energy consumption;
- Micro pollutants;
- Microbiological contamination;
- Chemical consumption;
- Leakage;
- Waste production; and
- Material consumption.

2.6.2 Economic costs and benefits

This section focuses on the analysis of the economic costs and benefits of the actors involved, the willingness to pay for water, the absolute and the relative costs of water for relevant stakeholders/services/products, and the significance of the prices versus the costs.

2.6.2.1 Water supply system

Figure 27 depicts the median rebuild value of drinking water systems in the Canton of Zurich, which is about 6,000 CHF per inhabitant. The distribution network represents the major part of the total value, with nearly 80% or 4,712 CHF per inhabitant (about 3`900 Euro). The specific length of the pipe network of the drinking water system in the Canton of Zurich is 7.3 metres per capita.

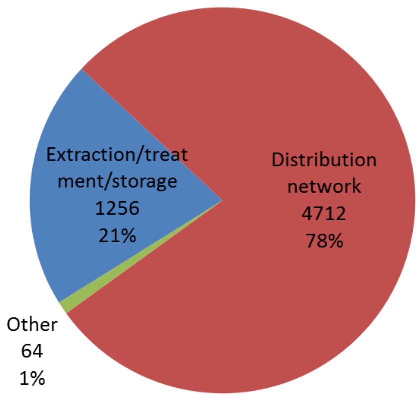


Figure 27: Median rebuild value of drinking water system in CHF per inhabitant in 2008[20]

Figure 28 depicts the median revenue of water suppliers in the Canton of Zurich in 2008. 75% of the revenue is made up by fees for the water volume used, which was 101 CHF (84 Euro) per inhabitant in 2008 and 27% is made up by fixed fees, which were 27 CHF (22 Euro) per inhabitant in 2008.

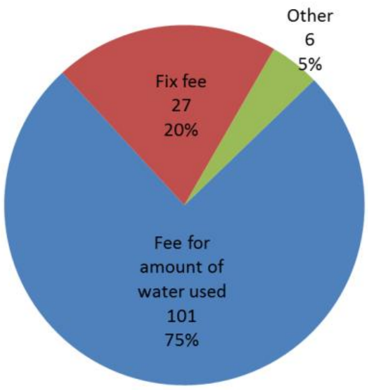


Figure 28: Median revenue in CHF per inhabitant in 2008[21]

[20] Source: AWEL/ Swissplan 2009: Finanzmanagement in der Siedlungswasserwirtschaft. Abwasser und Wasserversorgung. Kurzbericht zum Normalhaushalt 2008. Chapter 3.1

[21] Source: AWEL/ Swissplan 2009: Finanzmanagement in der Siedlungswasserwirtschaft. Abwasser und Wasserversorgung. Kurzbericht zum Normalhaushalt 2008. Table 3.2

Figure 29 depicts the median of different types of operating costs. The total operational costs of water suppliers in the Canton of Zurich are 93 CHF (78 Euro) per inhabitant. The main cost factors are water purchase (33%), staff (28%) and maintenance (25%).

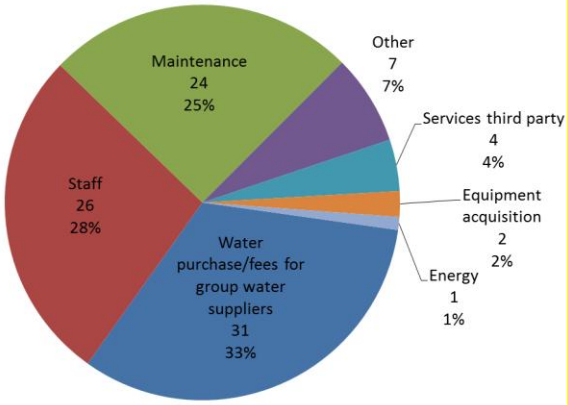


Figure 29: Total operating costs per type of cost[22] in CHF per inhabitant 2008[23]

Many networks are 80 to 100 years old and have therefore exceeded their lifetime. In future, the focus will be on the maintenance of value of the water supply system[24].

In the next step investments for maintenance of value and total costs including amortisation and capital costs, which are simultaneously the upper limit for water fees, will be analysed.

Costs and benefits of the drinking water supply system of Waedenswil

In 2011 the total revenues in the drinking water supply system of Waedenswil were 3.3 mio CHF, which exceeded the costs of 2.8 mio CHF; the total net revenues were 0.5 mio CHF[25].

Costs and benefits of the water treatment plants Hirsacker-Appital

In 2011 the total costs of 4.2 mio CHF exceed the total revenue of 2.1 mio CHF. The exceeding costs on 2.1 mio CHF are charged to the four municipalities of the association. The allocation key for the extra charges for each municipality is:

- Horgen: 33.06%
- Oberrieden: 9.21%
- Richterswil: 19.49%
- Waedenswil: 38.24%

The composition of the variable costs of the Hirsacker-Appital water treatment plants are depicted in Figure 30. The total variable costs is 319,000 CHF, 209,000 CHF of

[22] Excluding internally produced and capitalised assets.
[23] Source: AWEL/ Swissplan 2009: Finanzmanagement in der Siedlungswasserwirtschaft. Abwasser und Wasserversorgung. Kurzbericht zum Normalhaushalt 2008. p. 18
[24] Source: http://www.awel.zh.ch/internet/baudirektion/awel/de/wasserwirtschaft/wasserversorgung/finanzierung.html
[25] Stadt Waedenswil 2012, p. 51

which are spent on electricity mainly for pumping purposes. The variable cost is 8% of the total costs, accordingly, fixed costs was more than 3.8 mio CHF in 2011.

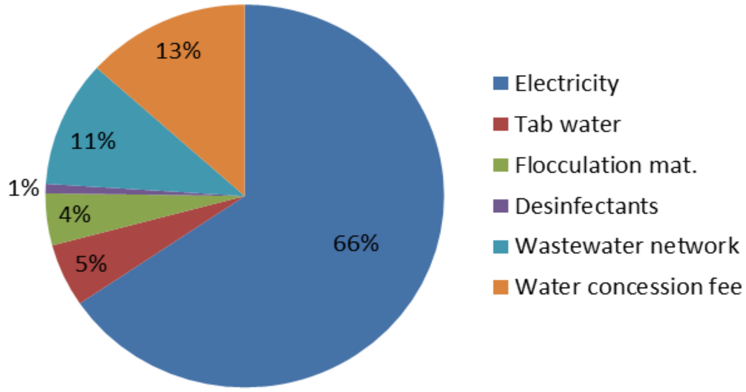


Figure 30: Variable costs Seewasserwerk Hirsacker-Appital[26]

2.6.2.2 Non-domestic water users (SMEs)

The prices for drinking water supply and wastewater discharge for SMEs in Waedenswil are composed as follows:

Drinking water price 1.50 CHF/m^3

Fix fee 120 CHF/year, additionally per entity[27] 30 CHF/year.

Additionally, there are special tariffs for certain industrial consumers. (Stadt Waedenswil 2010a)

Wastewater price[28] 1.80 CHF/m^3

Fix fee 0.10 CHF/m^2

Additionally, there are special fees for heavy polluters. (Stadt Waedenswil 2010b)

Table 16 shows an overview of the costs for water and energy and the benefits from water use for the analysed SMEs.

Table 16 Costs for water and energy and benefits from water for SMEs in the case study

	SME1	SME2	SME3	SME4
Costs for water use and discharge in CHF/year	72,500	13,000	10,000	60,000
Energy costs in CHF/year	753,500	327,000	23,000	87,000
Water added to the end product	unknown	0	40m^3	unknown

[26] [Source: Zweckverband 2012]
[27] Fix fee for 1 entity = 0 m2 - 50 m2 → 150 CHF/year; for 2 entities = 51 m2 - 100 m2 → 180 CHF/year; for 3 entities = 101 m2 - 200 m2 → 210 CHF/year; for each exceeding 200 m2, 2 entities.
[28] The wastewater prices fell in Waedenswil in the last three years from 2.- CHF/m^3 in 2009, to 1.80 CHF/m^3 in 2010 to finally 1.50 CHF/m^3 in 2011.

SME 1: Food sector

The cost for drinking water use and wastewater discharge in the SME in the food sector is 72,500 CHF per year. The company is exempt from the heavy polluter fee as it owns a wastewater treatment plant it.

The use of water of sufficient quality is essential for this company. Especially in the extraction process water plays a crucial role. Since the production would not be possible at all without the use of drinking water, the benefit of water use is the benefit of the production of this company.

SME 2: Electroplating sector

The cost for drinking water use and wastewater discharge in the SME in the electroplating sector is 13,000 CHF per year. The company is exempt from the heavy polluter fee, as it owns a wastewater treatment plant.

Water is required and is not-substitutable for the electroplating baths. The whole process would not be possible without the use of water. Therefore, the benefit of water use is the benefit of the production of this company.

SME 3: Cosmetics production

The cost for drinking water use and wastewater discharge in the SME in the cosmetics production is 10,000 CHF per year (2011), which is almost 50% of the yearly energy costs (23,000 CHF). The company is exempt from the heavy polluter fee, as it owns a wastewater treatment plant.

About 40m^3 of water is added to the end product yearly. The largest part of the water consumed by the company is, though, used for cleaning and hast to be added to the total value of the product indirectly.

SME 4: Indoor swimming pool

The cost for drinking water use and wastewater discharge for the indoor swimming pool is 60,000 CHF per year, which a significant amount compared to the energy costs (87,000 CHF).

The benefit from water use in an indoor swimming pool is difficult to be estimated because the provision of the service would not exist without water.

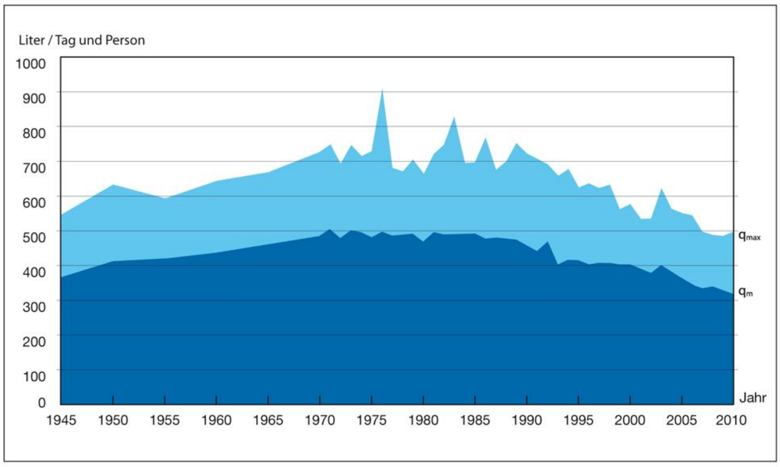
Since all SMEs could not continue their production without drinking water supply and waste water discharge, the upper limit of the added value is the total benefit of the company. A lower limit concerns the prices paid by the SMEs for the drinking water and generated waste water.

2.6.2.3 Domestic water users

During the last30 years, water consumption in Switzerland is decreasing. Structural changes in the industry, showering instead of bathing and water saving household devices lead to a decrease in water consumption per capita.

In 1981 drinking water consumption is Switzerland exceeded 500 litres per person per day. Since then, water consumption has decreased to 325 litres per person per day. In the “households and small businesses” category, drinking water consumption has decreased by 65 litres; today, the average consumption is 194 litres per person per day.

The consumption per person from households in the Case Study area is about 162 l/person/day. Therefore 32 l/person/day are added to a per capita presentation by the consumption of small businesses.



Entwicklung des mittleren (q_m) und des maximalen (q_{max}) Wasserverbrauchs pro Einwohner und Tag (l/E·d) von 1945 bis 2010 *Statistik SVGW*

Figure 31: Development of specific water consumption (average q_m and peak q_{max}) per person per day[29]

The reduced consumption has consequences for the water prices, as the costs for water suppliers' costs consist by 60 to 90% of fixed costs; the share of the variable, quantity-dependent costs is low. The capital of water suppliers lies in the underground pipes, which need to be maintained, regardless of the quantity of water provided. To cover the costs, falling sales volumes have to be compensated through higher prices per unit of provided water. Nevertheless, the biggest part in the revenue of water suppliers is the variable fees for the amount of water provided (see Figure 28).

The Swiss average drinking water price is currently about 1.80 (1.5 Euro) per 1 m^3, which equals to about 30 Rappen (25 Euro cent) per person per day for the 162 l/person/day. The average income in Switzerland lies between 2,000 and 7,000 CHF per month for almost 60% of the population. According to that, the share of income spent for water in Switzerland, lies between 0.45 and 0.13%[30]. Unsurprisingly, a survey (AWEL by DemoSCOPE, 2011) revealed that two thirds of the interwees had difficulties in estimating the price they pay for drinking water. Therefore, it can be concluded that the costs for drinking water are of minor significance for the average household and incentives for any action will hardly be financially motivated. Further below, the costs of drinking water in relation to the disposable income will also be evaluated (basket of goods).

According to Eidgenössisches Volkswirtschaftsdepartement (2006) wastewater price in Zurich is about 3 CHF[31] per m^3.

[29] Source: www.trinkwasser.ch, accessed 08.02.2012
[30] Own calculation based on SFSO (2010): Frequency distribution (net monthly wage), full- and part-time employees by wage-level class. Private and public (Confederation) sectors combined. http://www.bfs.admin.ch/bfs/portal/en/index/themen/03/04/blank/data/01/06_01.Document.100396.xls accessed 13.02.2012.
[31] All water prices in this chapter are without VAT 7.6%

Table 17 depicts the amount of water used and the costs for different sizes of houshold for drinking water and wastewater per person per year in Zurich in 2006.

Table 17: Costs of drinking water and wastewater in CHF per person per year in Zurich 2006[32]

	Water used in m^3	Costs in CHF per person per year	
		Drinking water	Wastewater
1 person household (2 rooms)	60	151	186
3 persons household (4 rooms)	170	123	143
4 persons household (6 rooms)	230	226	253

The prices for drinking water supply and wastewater discharge for households in Waedenswil are composed as follows (Stadt Waedenswil, 2010a; Stadt Waedenswil 2010b):

Drinking water price 1.50 CHF/m^3

Drinking water fix fee 120CHF/year, additionally per entity[33] 30 CHF/year.

Wastewater price 1.80 CHF/m^3

Wastewater fix fee 0.10 CHF/m^2

The prices for drinking water consumption and wastewater discharge for Waedenswil are shown in Figure 32 and Figure 33, in comparison to the Swiss average prices. This comparison shows that the prices in Waedenswil are similar to the average prices in Switzerland.

The money paid per person and day in Waedenswil for drinking and wastewater is approximately 0.66 to 0.8 CHF/(p*day). Considering that the average income of almost the 60% of the Swiss population is between 2,000 and 7,000 CHF per month) the spendings for water and waste water are between 0.3 and 1.2 % of the income.

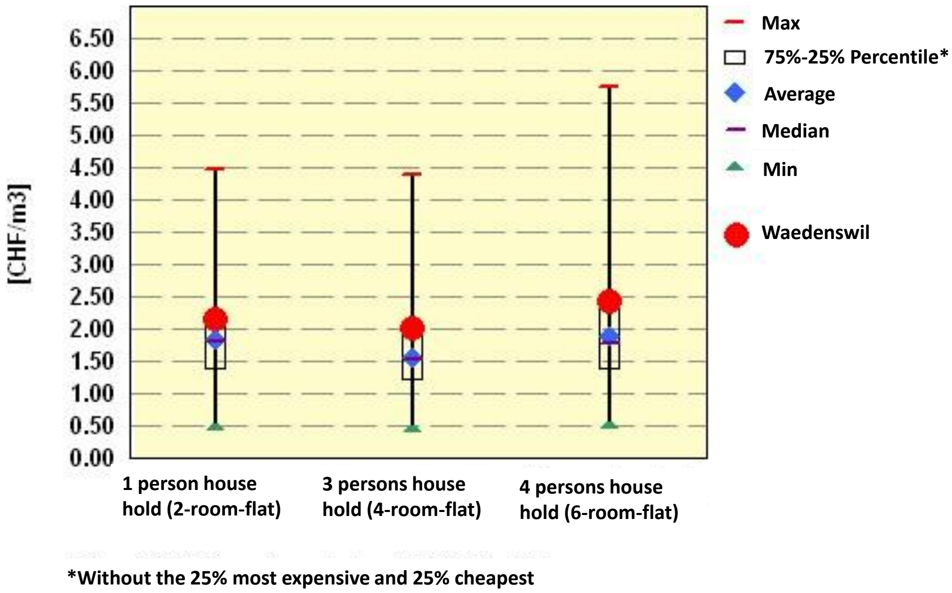


Figure 32: Drinking water prices in Waedenswil in comparison to the Swiss average

32 Source: Eidgenössisches Volkswirtschaftsdepartement (2006)
33 Fix costs for 1 entity = 1 - 2.5 rooms → 150 CHF/year; for 2 entities = 3 - 4.5 rooms → 180 CHF/year; for 3 entities = 5 and more rooms → 210 CHF/year

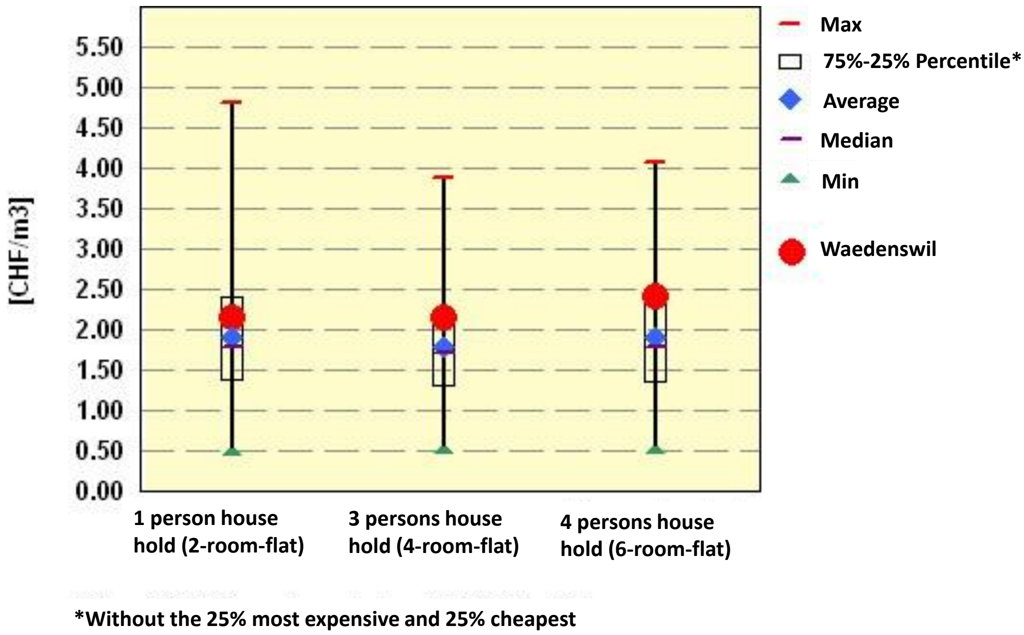


Figure 33: Wastewater prices in Waedenswil in comparison to the Swiss average

The economic benefits of water use for households can be approximated by the analysis of customer satisfaction with the quality of water (Figure 35) and the perception of the appropriatness of water prices (Figure 34). With regard to the latter, most of the interviewees replied to the question (in 2011) ”in your opinion, the water prices in Switzerland are ...?” that the prices are “just right” (green), whereas 19 replied that thet are “too low” (orange).

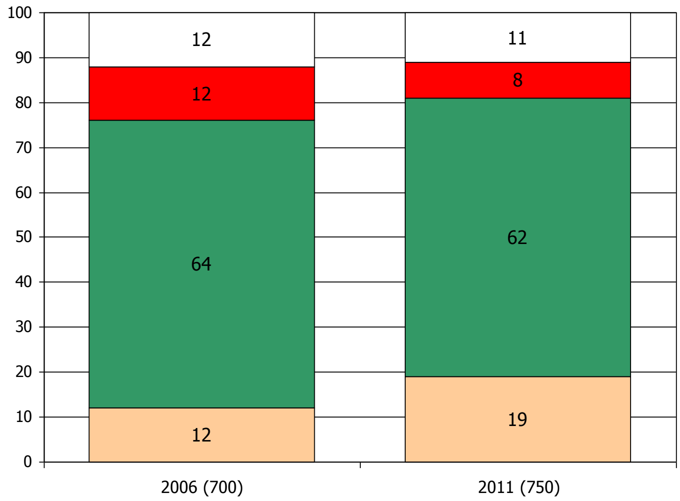


Figure 34: Customer perception of water prices in the Canton of Zurich [34]

[34] Source: AWEL by DemoSCOPE 2011

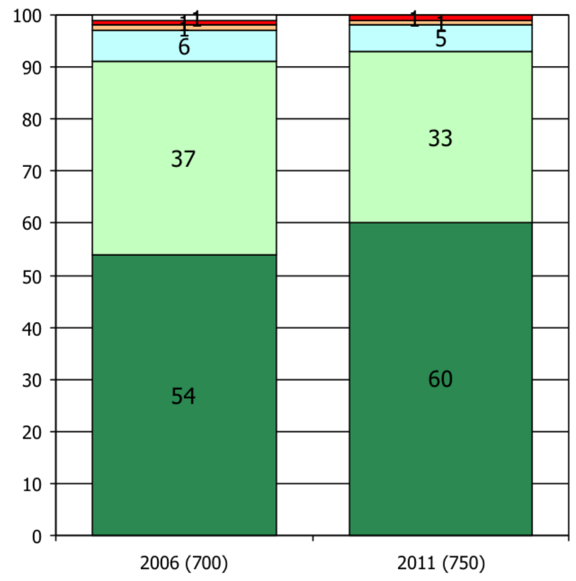


Figure 35: „How do you assess the overall quality of your tap water?“ in 2006 and 2011[35]

The economic value produced by drinking and waste water can be quantified with the highest water price paid in Switzerland as minimum value and the price of percentage given by e.g. the World Bank (3%) as maximum value.

2.6.2.4 Wastewater Disposal System – Treatment and Discharge

Figure 36 depicts the median rebuild value of the wastewater treatment system in the Canton of Zurich. The total median of the rebuild value is about 10,300 CHF (about 8,600 Euro) per inhabitant. The pipe network makes is the major part of the total value by 80% (about 8,271 CHF). The specific length of the canal network is about 4.6 meters per inhabitant[36].

[35] Source: AWEL by DemoSCOPE (2011): Imageanalyse Trinkwasser: http://www.awel.zh.ch/internet/baudirektion/awel/de/wasserwirtschaft/wasserversorgung/imageanalyse.html; assessed 10.02.2012

[36] To compare: in the water supply system the length of the canal network is 7.3 m per inhabitant and the value of the pipeline network is 4`712 CHF per capita. Accordingly, the value of the water supply network is about 34`000 CHF per capita (7.3 * 4`712) and of the wastewater network 38`000 CHF (4.6 * 8`271). So, the sewing water network is nearly twice as large as the water supply network per capita and has a double value per meter and capita. Whether the reason of such value differences is due to the mixed pipe networks (for sewage and rainwater) will have to be analysed.

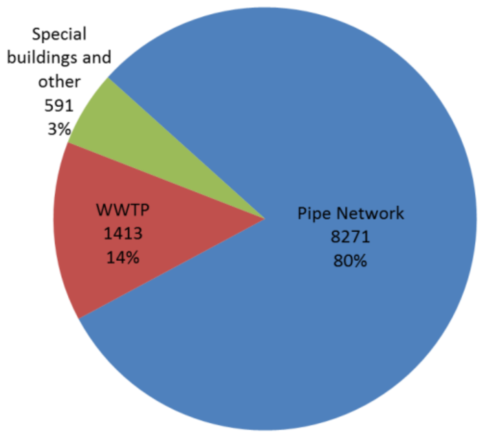


Figure 36: Rebuild value of waste water treatment system in CHF per inhabitant in 2008[37]

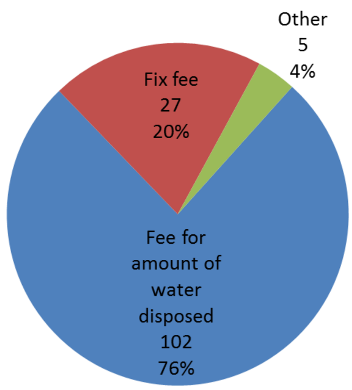


Figure 37: Median revenue of wastewater treatment system in CHF per inhabitant 2008[38]

Figure 38 depicts the median of different types of operating costs. The total operational cost of water suppliers in the Canton of Zurich is 81 CHF (68 Euro) per inhabitant; 68% is generated by the wastewater treatment plant and 32% by the network system. The largest part of the network expenses concerns their maintenance (38%) and the staff-related costs (31%). The main expenses of WWTPs are for staff (35%) and sludge disposal (22%).

[37] Source: AWEL Dezember 2009: Finanzmanagement in der Siedlungswasserwirtschaft Abwasser und Wasserversorgung Kurzbericht zum Normalhaushalt 2008. Table 2.1

[38] Source: AWEL/ Swissplan 2009: Finanzmanagement in der Siedlungswasserwirtschaft. Abwasser und Wasserversorgung. Kurzbericht zum Normalhaushalt 2008. Chapter 2.2

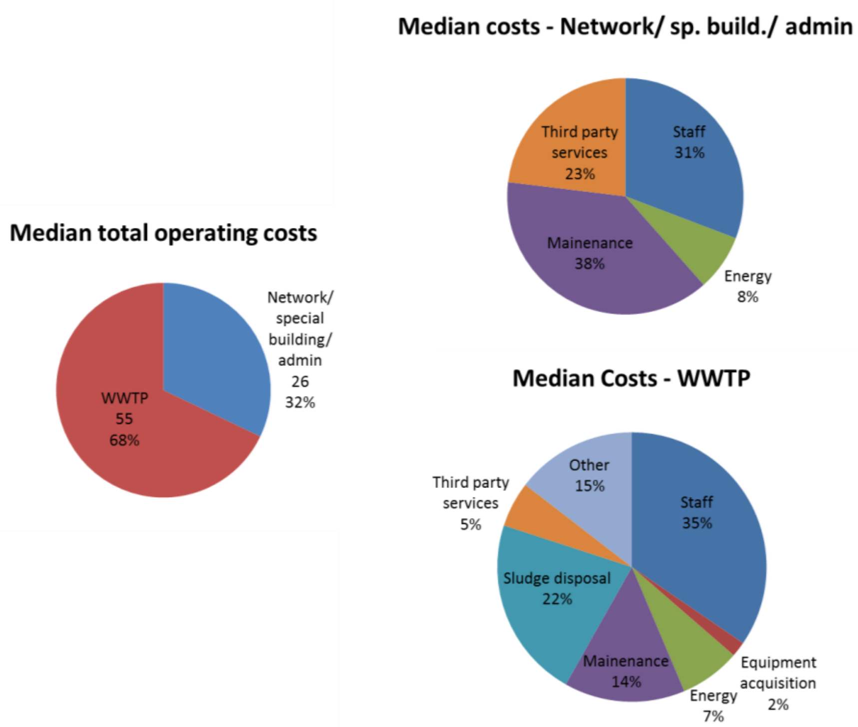


Figure 38: Total operating costs of the wastewater disposal system per type of costs for network and WWTP in CHF per inhabitant in 2008[39]

Costs and benefits of the Waedenswil wastewater treatment plants

In 2011, the total revenue for wastewater discharge and treatment in Waedenswil was about 4 mio CHF. It exceeded the costs of 3 mio CHF and the total net revenue was 1 mio CHF (opex). Accordingly, the revenues to cost ratio was 128%. (Stadt Waedenswil 2012, p. 46).

About 80% of the costs were attributed to by the wastewater treatment plant and 20% to the wastewater network. With regard to the Waedenswil WWTP about 70% of the costs are fixed and 30% variable. As illustrated in Figure 39 the fixed costs are composed of costs for operating material (49%), sludge disposal (28%) and energy (23%). The biggest part of the variable costs concerns the capital costs (50%), followed by personnel costs (29%), maintenance (14%) and administration costs (7%).

[39] Source: AWEL/ Swissplan 2009: Finanzmanagement in der Siedlungswasserwirtschaft. Abwasser und Wasserversorgung. Kurzbericht zum Normalhaushalt 2008. p. 8

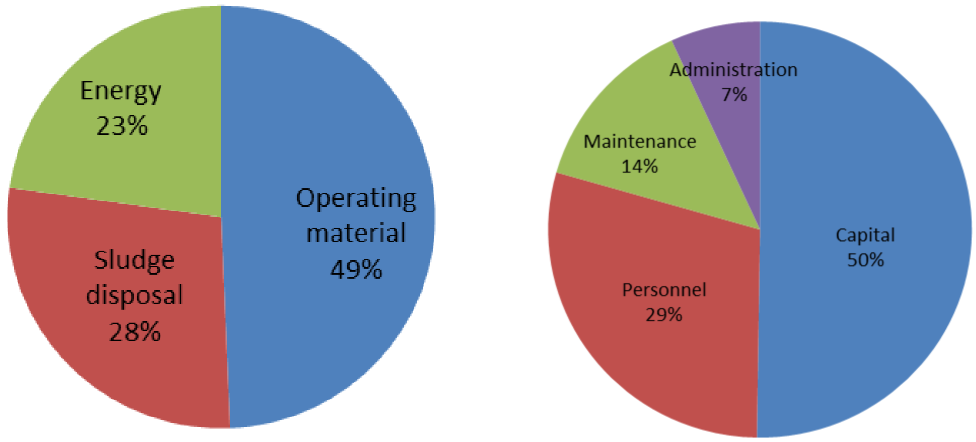


Figure 39: The composition of fixed and variable costs of Waedenswil WWTP

2.7 Preliminary identification of technologies to be assessed

A preliminary list of new technologies, innovations and practices to be applied is presented in Table 18. The list will be finalised after the baseline eco-efficiency assessment (Phase B of the Case Study development) and discussions with local actors.

Table 18 Preliminary list of new technologies to be assessed

Technology name	Short description	Node
BAU0		
BAU1	Groundwater well	Water intake
BAU2	Lake water intakes	Water intake
BAU3	Pre-Oxidation	Pre-Treatment
BAU4	Flocculation and filtration	Filtration
BAU5	Activated carbon filtration	Filtration
BAU6	Ozonation	Disinfection
BAU7	Disinfection by chlorination	Disinfection
BAU8	Pumping stations	Pumping stations
BAU9	Distribution network and reservoirs	Distribution network and reservoirs
BAU10	Production	Production
BAU11	Washing/Cleaning	Washing/Cleaning
BAU12	Cooling	Cooling
BAU13	Irrigation	Irrigation
BAU14	Toilet	Toilet
BAU15	Consumption	Consumption
BAU16	Personal hygiene	Personal hygiene
BAU17	Sewage network and facilities	Sewage network and facilities
BAU18	Primary sedimentation	Primary treatment
BAU19	Membrane bioreactor	Secondary/Tertiary treatment
BAU20	Chemical phosphate elimination	Tertiary treatment
BAU21	Filtration step included in MBR	Filtration
BAU22	Anaerobic sludge treatment	Sludge treatment
BAU23	Biogas usage with block heat and power plant	Energy recovery
BAU24	Incineration	Sludge disposal
T1	New technology T1	
T2	Ultrafiltration membrane filtration	Water treatment (Water Supply)
T3	Elimination of micro pollutants by nano-particles	Water treatment (Water Supply)
T4	Activated carbon	Water treatment (Water Supply)
T5	Ozone treatment	Water treatment (Water Supply)
T6	Advanced phosphorus recovery	Sludge treatment (Wastewater treatment)
T7	Biological phosphorus elimination	Wastewater treatment
T8	Urine separation toilets	Domestic and non-domestic users
T9	Water free toilets in public buildings	Non-domestic users
T10	Water efficient appliances	
T11	Cleaner production innovations for SMEs	Non-domestic users

Seven main water demand management for water saving programs will be examined for the households (Bello-Dambatta et al, 2011):

1. **Household fittings and appliances**

   Assuming a full household retrofit with water efficient fittings and mid-range appliances and average household weekly water use

2a. **Greywater recycling system (residential)**

   Residential greywater recycling system that can be used to supply water for WC flushing for a single household with average household occupancy

2b. **Greywater recycling system (multi-residential)**

   Multi-residential greywater recycling system that can be used to supply water for WC flushing of multiple households with assumed occupancy of about 650.

3a. **Rainwater harvesting system (residential)**

   Residential RWH for WC flushing and garden irrigation, with average household occupancy, roof area of 70m2 and 500 litre storage tank

3b. **Rainwater harvesting system (multi-residential)**

   Multi-residential RWH that can be used for WC flushing and garden irrigation, with roof area of 10, 800m2, 6000 litre storage tank and assumed occupancy of 650

4a. **Metering with no tariff change**

   Metering program with no tariff change assuming water saving potential of 10 percent

4b. **Metering with tariff change**

   Metering program with tariff changes to incentivise water savings with water saving potential of 16 percent

10 characteristic water demand management options for non-domestic users to be considered in technology assessment (Bello-Dambatta et al, 2011):

WWR 1 Wastewater Recycling / No or low treatment

Water recycling is reusing treated wastewater for beneficial purposes such as agricultural and landscape irrigation, industrial processes, toilet flushing, and replenishing groundwater. (EPA, 2011)

WWR 2 Wastewater Recycling / Medium treatment

Depending on the quality of the wastewater and the requirements of future water use, different type of treatments might be necessary. These have been categorised in 2 ranges. WWR 2 refers to the more extreme cases, for example reusing black water for high quality water needs.

WE 1 Water efficiency improvement / Process change (no recycling)

WWR 1 and WWR 2 concerned water recycling measures. This category considers other types of process changes (e.g. switch from a continuous process to batches or cascading water uses),

WE 2 Water efficiency improvement / Leakage reduction

Leakage reduction concerns only leakages after the point of entry from the public network. Leakages and water losses of the water utility are not taken into consideration in this review.

WE 3 Water efficiency / Monitoring and controlling

RH 1 Rainwater Harvesting /without treatment

This involves using rainwater directly without any treatment

RH 2 Rainwater Harvesting /with treatment

AR Awareness raising and consumer behaviour change

EI Economic instruments - FA Fittings and appliances

Table 19 shows a proposition for stakeholder-technology matrices, which should characterise the decision makers' role in employing new technologies. The first step concerns the identification of the actor relevance to the technology uptake and the second step the definition of the preference structure. This highly depends on who bears the costs and who the benefits. Further questions which could be discussed at this place are.

- Who sells/promotes the technologies?
- Who owns/operates the technologies?
- What are the costs?
- What are the environmental impacts and what are the economic benefits?

Table 19: Technology X uptake and stakeholder involvement

	Stakeholder	Relevant for technology uptake	Preference structure		
		(yes/no)	positive	neutral	negative
1	Zweckverband Seewasserwerk Hirsacker-Appital				
2	Municipality Waedenswil				
3	Municipality Horgen				
4	Municipality Richterswil				
5	Municipality Oberrieden				
6	Canton of Zurich				
7	AWEL (Office of Waste, Water, Energy and Air of Canton of Zurich)				
8	Federation				
9	Environmental organisations				
10	Swiss gas and water industry association svgw.ch				
11	Private persons/households				
12	Private companies using water and discharging waste water				
13	Private companies planning, maintenance, installation of WWTPs				
14	WWTP - Public construction authority (Bauamt), Waedenswil				
15	District heating network (Fernwärmeverbund) ARA Rietliau				
16	Private companies planning, maintenance, installation of plants (e.g. Kuster+Hager)				
17	Research Institutions (Universities etc.)				

3 System mapping of the urban water system of Sofia, Bulgaria

3.1 Objectives of the Case Study

The Case Study deals with the urban water system of the city of Sofia – the capital of Bulgaria. It has been selected due to its importance in four aspects:

1. **The number of the citizens, served by the municipal water system:** Around 17% of the population of Bulgaria lives permanently in Sofia. Taking into account the temporary workers and the students, the city concentrates about 30% of the Bulgarian population.
2. **The contribution to the national GDP**: Sofia contributes to about 50% of the national GDP.
3. **The environmental impact:** Being the biggest city in Bulgaria, Sofia consumes the biggest quantity of fresh water and generates the biggest amount of wastewater, sludge and air emissions. Every step towards the improvement of its eco-efficiency performance will have a positive social, economic and environmental impact.
4. **The ownership of the water infrastructure:** Sofia is currently the only city in Bulgaria where the operation of the water infrastructure was given to a concession. The current legislative basis that concerns the water supply and sewerage infrastructure undergoes significant changes, in the direction of transferring the state public ownership to municipal public ownership. The relationship among the stakeholders in the water service process of Sofia will serve as a model to be followed by other municipalities.

The results, which are expected to be derived with the analysis, will contribute to the:

- Establishment of a set of indicators, which will allow evaluating the eco-efficiency of the urban water system at the meso-level. These indicators will be calibrated for the Sofia Case Study, but they will be applicable for other urban water systems as well;
- Identification of the problematic features of the water use, water supply and sewerage sub-systems; and
- Review of up-to-date technologies and simulation of their implementation for achieving a better eco-efficiency performance of the studied system.

3.2 Overview of the Case Study area

Geo-physical features

Sofia is placed over about 492 square kilometers on four terraces of the Iskar River and its tributaries (Perlovska and Vladayska rivers). Its average altitude is 550 m. There is natural denivelation between the South part (above 900 m) and the North part (around 520 m) of the city. The climate is dry continental and the average annual temperature is 10.5^{o}C.

The main water source of the city of Sofia is the Iskar river (see Figure 44). The treated wastewater of the city is discharged downstream the same river. Iskar River is the longest river in the Bulgarian part of the Danube River Basin, with significant economic and environmental importance. The river begins at Rila Mountain and flows into the Danube River. Sofia is situated in the upper stream of Iskar and it is the second city downstream the river. From a series of water reservoirs, that were built for economic needs, two of them are used for water supply – Iskar (the biggest water reservoir in the country) and Beli Iskar. The water resources in the upper basin are used for domestic water supply (54.6% of the abstracted water), industrial water supply (44.9% of the abstracted water), irrigation (0.5% of the abstracted water), electro-power production and for recreation (Ribarova, 2009). There are 43 thermal water sources in Sofia with a total capacity of about 262 l/s.

Population

Sofia is the biggest city in Bulgaria. During the last years it has turned to be an attractive destination for people from over the country due to the favorable employment conditions and the high level of the service sector. This has led to high population density. According to 2005 data, the average population density for the Sofia municipality is 13 times higher (913 inh./km^2) than the country average (69,9 inh./km^2). This has reflected in a sharp increase of the number of dwellings in Sofia during the last decade (Figure 40).

In general, in Bulgaria there is a tendency for decrease of population. However, Sofia is one of the few settlements where the statistical data show that population is gradually increasing during the last decade and that this tendency will continue in the future (Figure 41).

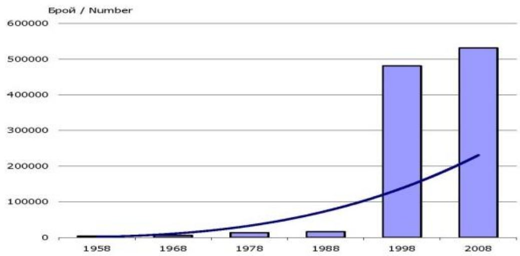


Figure 40: Increase of the dwellings in Sofia in the last decades

[Source: National Statistical Institute (NSI), 2009]

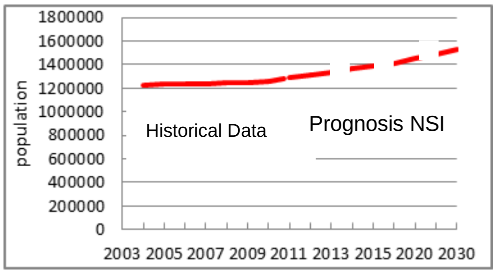


Figure 41: Prognosis for the development of the population in Sofia

[Source: National Statistical Institute (NSI), 2009]

Table 20 presents information on the utility services that are provided for the dwellings in Sofia.

Table 20: Number of dwellings provided with different type of utility services

	2003	2004	2005	2006	2007	2008	2009	2010
Total capital town	485158	486878	488796	490265	493500	497144	500186	502111
Electricity, water, sewer, central heating	306887	30825	309296	310213	312108	314428	316685	317731
	63.26 %	*63.31%*	*63.28%*	*63.27%*	*63.24%*	*63.25%*	*63,13%*	*63,23%*
Electricity, water, sewer, local heating	11115	11277	11879	12087	1275	13355	13940	14290
	2.29%	*2.32%*	*2.43%*	*2.47%*	*2.59%*	*2.69%*	*2,77%*	*2,84%*
Electricity, water, sewer	158009	158218	158504	158879	159571	160310	160542	161097
	32.57%	*32.50%*	*32.43%*	*32.41%*	*32.33%*	*32.25%*	*32,10%*	*32,08%*
Electricity, water	4166	4160	4156	4151	4145	4139	4133	4127
	0.86%	*0.85%*	*0.85%*	*0.85%*	*0.84%*	*0.83%*	*0,83%*	*0,82%*
Electricity	3477	3476	3476	3475	3471	3471	3469	3468
	0.72%	*0.71%*	*0.71%*	*0.71%*	*0.70%*	*0.70%*	*0,69*	*0,69*
water, sewer	263	262	262	262	262	262	262	262
	0.05%	*0.05%*	*0.05%*	*0.05%*	*0.05%*	*0.05%*	*0,05%*	*0,05%*
water	106	106	106	106	106	106	105	105
	0.02%	*0.02%*	*0.02%*	*0.02%*	*0.02%*	*0.02%*	*0,02%*	*0,02%*
Without facilities	1135	1128	1117	1092	1080	1073	1050	1031
	0.23%	*0.23%*	*0.23%*	*0.22%*	*0.22%*	*0.22%*	*0,21%*	*0,20%*
Total surroundings	34268	34311	34345	34372	34416	34451	34486	34518
Electricity, water, sewer, central heating	111	111	111	111	111	111	111	111
	0.32%	*0.32%*	*0.32%*	*0.32%*	*0.32%*	*0.32%*	*0,32%*	*0,32%*
Electricity, water, sewer, local heating	3222	3222	3222	3223	3224	3226	3235	3247
	9.40%	*9.39%*	*9.38%*	*9.38%*	*9.37%*	*9.36%*	*9,38%*	*9,41%*
Electricity, water, sewer	23712	23755	23789	23815	23858	23891	23917	23937
	69.20%	*69.23%*	*69.26%*	*69.29%*	*69.32%*	*69.35%*	*69,35%*	*69,35%*
Electricity, water	2010	2010	2010	2010	2010	2010	2010	2010
	5.87%	*5.86%*	*5.85%*	*5.85%*	*5.84%*	*5.83%*	*5.83%*	*5,82%*
Electricity	3813	3813	3813	3813	3813	3813	3813	3813
	11.13%	*11.11%*	*11.10%*	*11.09%*	*11.08%*	*11.07%*	*11,05%*	*11,05%*
Water, sewer	38	38	38	38	38	38	38	38
	0.11%	*0.11%*	*0.11%*	*0.11%*	*0.11%*	*0.11%*	*0.11%*	*0.11%*
Water	7	7	7	7	7	7	7	7
	0.02%	*0.02%*	*0.02%*	*0.02%*	*0.02%*	*0.02%*	*0.02%*	*0.02%*
Without facilities	1355	1355	1355	1355	1355	1355	1355	1355
	3.95%	*3.95%*	*3.95%*	*3.94%*	*3.94%*	*3.93%*	*3.93%*	*3,92%*

[Source: National Statistical Institute]

The dwellings that are provided with electricity, water, sewer and central heating installations are dominating in the city of Sofia and represent around 63% of all dwellings, followed by those dwellings provided with electricity, water and sewer which represent around 32% of the total. These two categories represent around 95% of all dwellings and are also dominating in the surroundings of Sofia, representing around 78%.Nonetheless, the dominating category is the dwellings with electricity, water, sewer but without heating installation.

Economic context

Sofia is the biggest industrial center of Bulgaria contributing with around 50% to the national GDP. The number of the enterprises of the employed people according to the size of the enterprise is given in Table 21. The data show that micro enterprises prevail considerably (91% of all enterprises) in terms of their number. In terms of the employed people, the distribution among the 4 categories of enterprises is almost equal (around 20-30% for each category).

Table 21: Number of enterprises and employed people according to the size (in Sofia in the year 2010)

Size	Number of enterprises	%	Number of people	%
Micro (up to 9 employees)	91,878	91,4	171,564	26
Small (10 to 49 employees)	7,029	7,0	136,947	21
Medium (50-249 employees)	1,372	1,4	133,743	20
Big (above 250 employees)	257	0,3	219,951	33
Total number	100,536	100	662,205	100

[Source: National Statistical Institute (NSI), requested data]

Table 22 provides further information about the number of the small and medium enterprises in Sofia in the last years.

Table 22: Number of micro, small and medium size enterprises in Sofia

	up to 9 employees		10 to 49 employees		50-249 employees		Total	
	No. of enterprises	No. of employed	No. of enterprises	No. of employed	No. of enterprises	No. of employed	No. of enterprises	No. of employed
2003	42,265	105,952	4331	91692	949	97482	47545	295126
2004	40,735	96,638	5064	99530	979	99296	46778	295464
2005	41,122	97,314	5420	106986	1089	109838	47631	314138
2006	41,320	100,830	6033	120095	1240	126050	48593	346975
2007	56,246	126,567	6672	133135	1404	140559	64322	400261
2009	89,721	172,088	7620	150486	1496	147480	99097	694565
2010	91,878	171,564	7029	136947	1372	133743	100 536	662205

[Source: National Statistical Institute (NSI), 2009 and 2010 NSI requested data]

The categorization of the SMEs according to economic activities (Table 23) shows that the branch "*trade, repairing activities, wholesale and retail trade, repair of motor vehicles*" has the biggest share, followed by the branch *"real estate, renting and business activities*". However, these two branches do not have any specific requirements towards water needs and their needs and "attitude" towards water consumption is similar to those of the domestic users. Big factories for motor vehicles repair might have specific industrial flows, containing mostly oils. However, the case here is small workshops that change tires or motor oils or fix vehicle problems. In the case of oil changing the oil is collected in special tubes and the same applies for the accumulators. There is actually no use of water in these activities except for the daily needs of the personnel.

Table 23: Review of SME in Sofia according to the economic activities by 31.12.2010

Economic activities	Legend	up to 9 employees	10 to 49 employees	50-249 employees	Total
Agriculture, hunting,forestry and fishing	Activity 1	405	44	….	454
Mining and quarrying	Activity 2	64	…	….	79
Manufacturing	Activity 3	4,432	841	235	5,508
Electr., gas and water supply	Activity 4	339	19	5	363
Construction	Activity 5	6,439	908	184	7,531
Trade, repairing activities, wholesale and retail trade, repair of motor vehicles	Activity 6	30,025	2,168	366	32,559
Hotels and restaurants	Activity 7	4,026	569	76	4,671
Transport, storage and communication	Activity 8	4,098	304	67	4,469
Real estate, renting and business activities	Activity 9	7,468	207	31	7,706
Education	Activity 10	966	66	11	1,043
Health and social work	Activity 11	2,516	166	40	2,722
Other services	Activity 12	4,264	….	….	4,375
Total		**65,042**	**5,292**	**1,015**	**71,480**
Total activity 6 +7+9+10+11		**45,001**	**3,176**	**524**	**48,701**

[Source: National Statistical Institute own request]

The manufacturing activities that usually have specific water needs and contribute to water pollution are ranked on the 4th place in terms of the number of SMEs (5508), coming after the "trade, repairing etc." activities (32559), "construction" (7531) and "real estate, renting and business" activities (7706); micro size enterprises are prevailing again as shown in Table 23.

The enterprises, whose water needs are similar to the ones of the domestic user are summarized on the last row of Table 23 (Total activity 6+7+9+10+11). They represent 69% of all enterprises (e.g. only 31% of all enterprises in Sofia use the water and generate industrial wastewater in terms of the Directive 91/271).

General environmental issues

The biggest environmental problems resulting from the exploitation of the urban water system of Sofia are: (i) the high rate of the water leakages and (ii) the pollution from the sewerage system. With regard to the former the water leakages are currently estimated at 59% of the abstracted water. They are considered as an environmental problem, because of the:

- Increased volume of water abstracted; and
- Resources (such as energy and reagents) needed for water treatment and delivery, which result in increased emissions, (e.g. GHG emissions).

The pollution coming from the sewerage system is due to the following facts:

- Most of the pipes are in very bad structural condition, with cracks and not water tight joints, and hence they allow both infiltration of foreign waters and exfiltration of waste water;
- 70% of the existing 170 Combined Sewer Overflows (CSO) do not cover the EU standards;
- Not all citizens are connected to the centralized sewerage system. Although they are obliged by the Law to have individual septic tanks or to use machines for removing wastewater from their houses, in many cases there is uncontrolled wastewater discharge to rivers or dry rivers;
- Side products from the wastewater treatment, such as sludge, which cannot be disposed any more on solid waste landfills and should be accommodated according to the recent EU requirements.

3.3 Methodology and data availability

Considering that, in principal, in Bulgaria limited data is publicly available, the following methodological approach for data collection is applied:

1. Identification of the relevant stakeholders (SH);
2. Signing of a protocol of cooperation with them;
3. Discussion with the SHs about their vision of the system – current state and environmental impact and interest in investing in new technologies which will improve their eco-efficiency performance;
4. Collection of data;
5. Processing of the data;
6. Collection of additional data, in case that gaps are noticed;
7. Provision of the processed data, results and conclusions to the SH for their feedback.

Thanks to the kind contribution and involvement of the urban water operator utility ("Sofyiska voda") and three enterprises (AD "Aroma", "Sopharma" AD and “Panteley Toshev LTD”), the data that were collected for a period of five years, from 2007 to 2011, are presented in Figure 42 and described below.

3.3.1 Technical data:

Water intake

Total amount of abstracted water from all sources for water supply in Sofia.

Water treatment plants

There are three water treatment plants – “Bistritsa”, “Pancharevo” and “Mala Tsarkva”. For each of them the following data was provided:

- Treated water quantity;
- Consumed electricity;
- Chlorine for disinfection; and
- Reagents added to water ($Al_2(SO_4)_3$, NaOH, $Na_2S_2O_3$; Cl_2);

Urban water supply system and sewerage network:

- Total length of the water supply network;
- Number of DMA's;
- Chlorine gas for disinfection in tanks;
- Number of building connections;
- Total length of sewerage network; and
- Consumed electricity.

Water supply and sewerage in buildings (water use):

1. Buildings connected to the sewerage network
    - Number of consumers;
    - Number of consumers connected to Central Heating;
    - Billed metered water consumption (cold water);
    - Billed metered water consumption (warm water); and
    - Billed unmetered water consumption.
2. Buildings not connected to the sewerage network
    - Number of consumers;
    - Number of consumers connected to Central Heating;
    - Billed metered water consumption (cold water);
    - Billed metered water consumption (warm water); and
    - Billed unmetered water consumption.

Waste water treatment – WWTP "Kubratovo"

- Waste water quantity;
- Reagents;
- Total electricity consumed;
- Electricity for aeration;
- Produced gas methane;
- Produced electricity from co-generators;
- Produced heat from co-generators;
- Produced sludge for using as fertilizer in agriculture; and
- Treated wastewater discharged to the Iskar River.

3.3.2 Economic data:

Water treatment plants

- Costs for consumed electricity;
- Costs for reagents added to water; and
- Costs for chlorine disinfection.

Urban water supply system and sewerage network:

- Costs for consumed electricity;

- Costs for elimination of leaks and breakdowns;
- Costs for chlorine disinfection in tanks;
- Costs for sewage network cleaning;
- Profit from water supply (water bills); and
- Profit from waste water discharge (water bills).

Waste water treatment – "Kubratovo" WWTP

- Costs for electricity consumed;
- Profit from green energy produced;
- Profit from reduced CO_2 emissions; and
- Profit from waste water treatment (water bills).

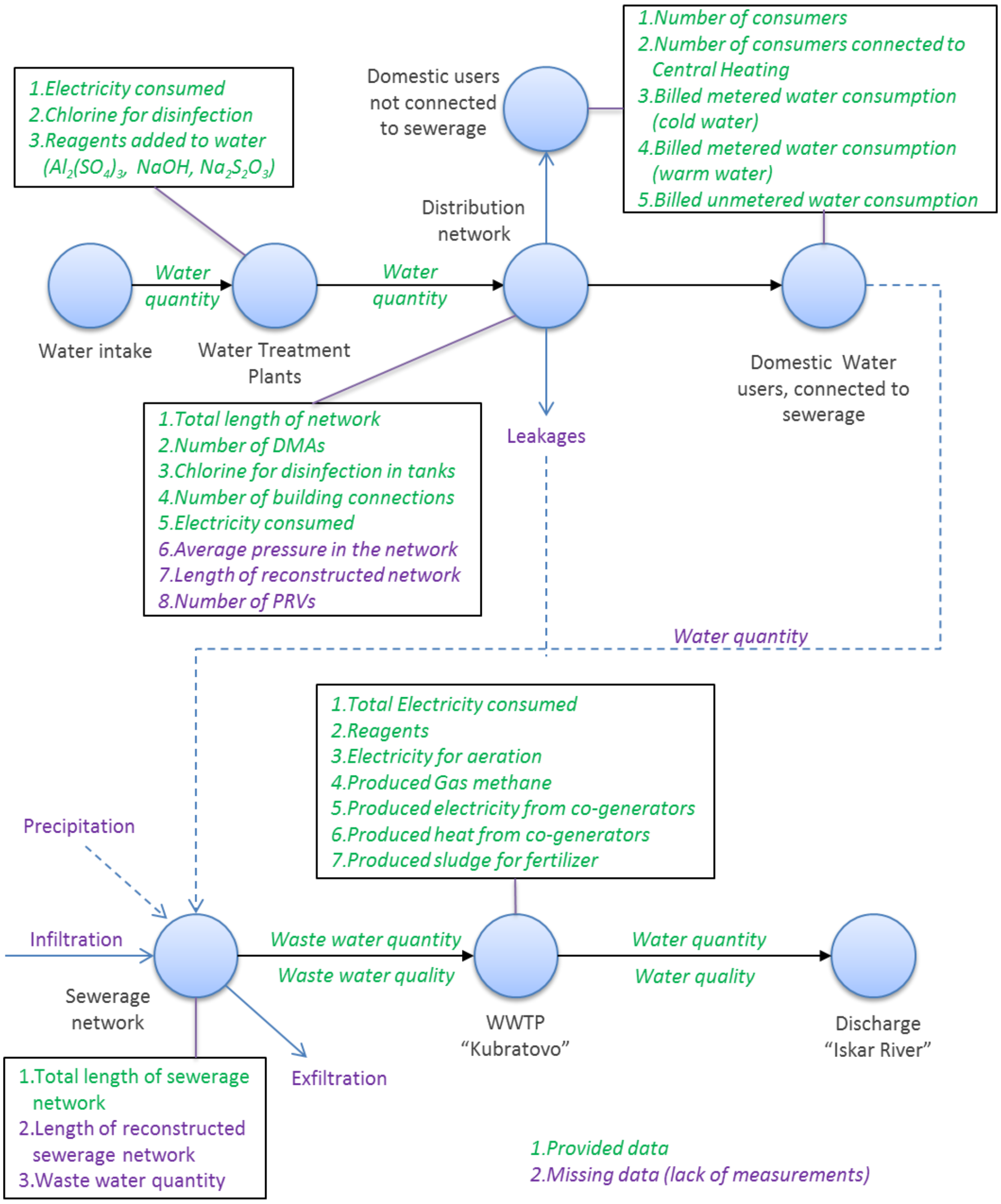


Figure 42: Data availability in the Sofia Case Study (yearly basis, from 2007 to 2011)

The investigated non-domestic users (“Aroma”, "Sopharma", “Panteley Toshev LTD”) have provided information both about the technological processes and the water sources and water utilization within the factory. They will be discussed in the next chapters and cannot be included in Figure 42, because of the specificity of each of them.

For detailed investigation of the WWTP, additional data was requested and provided. These concern the:

- Hourly water quantity rates for 6 months;
- Daily and monthly measurements of suspended solids, BOD, COD, nitrogen, phosphorus and moisture content in sludge sludge in different points of the WWTP
- Monthly rates:
- Sludge quantity from primary clarifier;
- Sludge quantity from secondary clarifier;
- Flocculant for mechanical thickening;
- Activated sludge recirculation quantity;
- Produced gas methane;
- Produced electricity and heat from co-generators; and
- Sludge quantity after dewatering.

3.4 Water Supply Chain Mapping

3.4.1 System boundaries

The Upper Iskar sub catchment (from springs to Sofia city) delineates the spatial system boundaries (Figure 44). In order to determine the functional system boundaries, relevant to this study, two issues were considered; i.e. the sewerage system and the type of water users, Figure 43 illustrates the volume of the water used per sector in Sofia in the last 5 years.

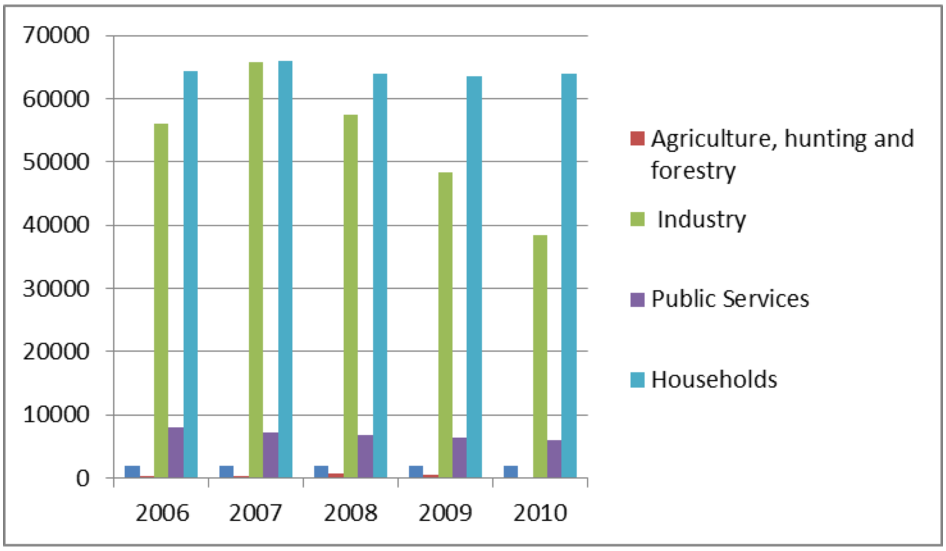


Figure 43: The volume (x1000 m^3) of the water used per sector in Sofia in the last 5 years

Table 24: Consumed water by sectors and years (x1000 m^3)

	2006		2007		2008		2009		2010	
Total*	128 726	%	139 398	%	128 750	%	118 760	%	108 420	%
Agriculture, hunting and forestry	305	0,2	346	0,2	660	0,5	480	0,4	230	0,6
Industry	56 029	43,5	65 805	47,2	57 420	44,6	48 280	40,6	38 330	35,4
Public Services	8 005	6,2	7 214	5,2	6 800	5,3	6 390	5,4	5 930	5,5
Households	64 387	50,0	66 033	47,4	63 870	48,6	63 610	54,6	63 930	58,9

[Source: National Statistical Institute]

**The total water consumption is sum of the delivered water and own water sources*

In the last 5 years, a trend for considerably reducing water use in the industrial sector and in the public services can be notices. The reason for this reduction lies to the economic crisis, rather than to undertaken water saving measures. The agriculture and household consumption show relatively constant rate. These data reveal that the two biggest consumers are the households (58.9% in 2010) and the industry (35.4% in 2010). Public services consume only 5.5% of the total water consumption and the smallest share, below 1%, belongs to the sector "Agriculture, hunting and forestry".

Table 24 is based on the data supplied by the NSI and presents the total volume of water, supplied to the users belonging to the "industry" category. This category includes all the registered companies that are water users, even those that operate in the sector of services, which are prevailing (Table 23). As mentioned above the rough estimation shows that around 31% of all industrial units use water for industrial needs like manufacturing (Table 23). This means that the expected share of water used for industrial purposes, different in nature than that of the domestic types uses , is approximately no more than 10% of the total supplied water, as the share of every individual industrial entity to the total water/wastewater system is too small. Nevertheless some of the biggest industrial entities in Sofia are also discussed below, for study completeness.

While around 100% of the population of Sofia is connected to the water supply system, only 94% are connected to the sewerage system (Table 25). The rest use septic tanks.

Table 25: Accessibility of the water supply and sewer service in Sofia

	2006	2007	2008	2009	2010
Share of population served by public water supply - %	100.0	99.9	100.0	100.0	100.0
Share of population serviced by drinking water purification plants - %	99.9	99.9	99.9	99.9	99.9
Share of population served by public sewage - %	93.0	93.5	-	-	94.3
Share of population serviced by WWTP - %	93.2	93.2	-	-	93.3

[Source: National Statistical Institute]

According to the data provided by "Sofiyska voda" only a small part of the industrial units were connected to the municipal sewerage system in 2011. With regard to the quantity of the wastewater discharged, the industrial units have a share of only 12% and the rest 88% belong to the domestic users.

In order to estimate the eco-efficiency performance of the entire system, including the water supply and sewerage sides, the functional system boundaries start from the water abstraction and end to the treated water discharged to the water bodies (after wastewater treatment in the WWTP). The study will focus on both types of water use – domestic and non-domestic water uses.

3.4.2 Mapping of the water service system and description of stages

Figure 44 presents a geographical and a schematic map of the urban water system of the City of Sofia and Table 26 summarizes the system's stages.

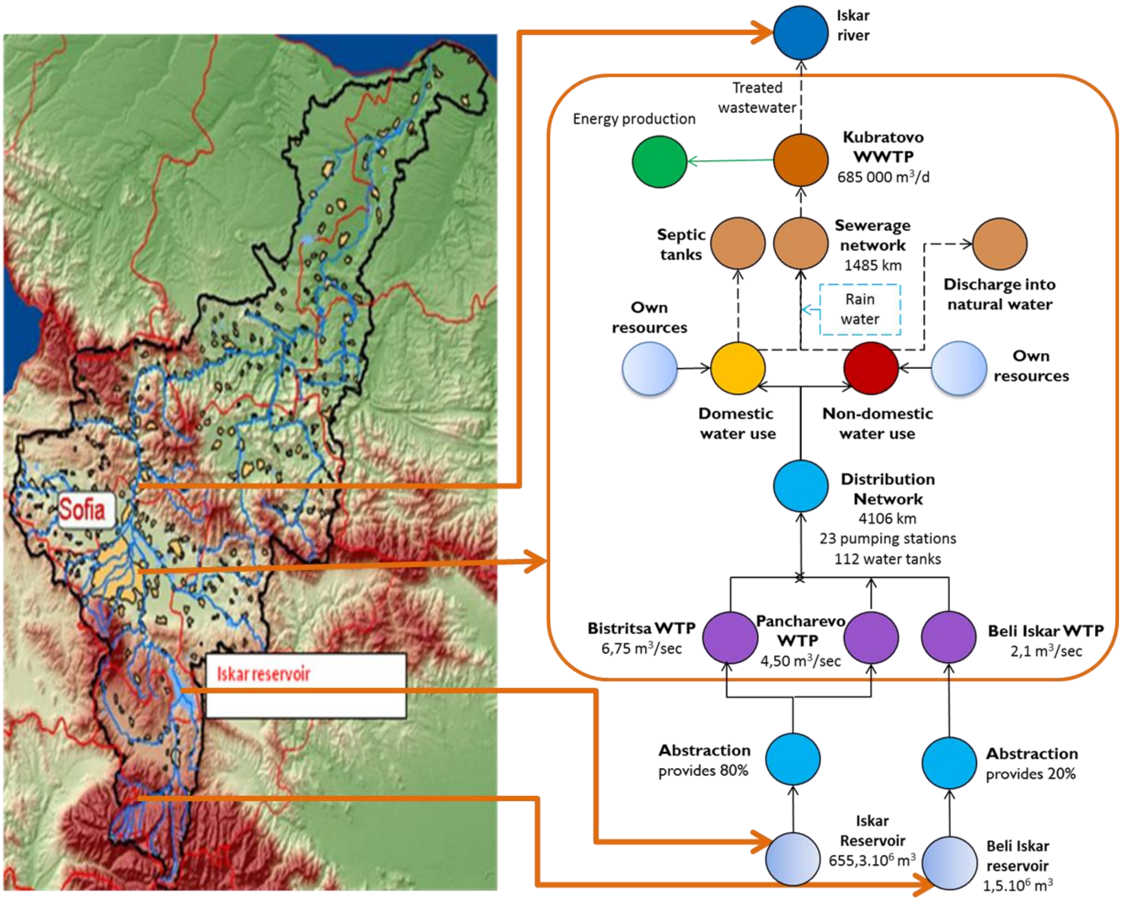


Figure 44: Geographic and water supply chain map of the Sofia case study

Table 26: The stages of the system

	Stage number	Stage name
Water supply system	1	Water intake
	2	Water purification
	3	Distribution network and reservoirs
Water uses	4a	Non-domestic
	4b	Domestic
Sewerage system	5	Sewage network and facilities
	6	WWTP
	7	Water Discharge

3.4.2.1 Water supply system

The water supply system consists of 2 main water sources, 3 water treatment plants, 23 pumping stations (3 major and 20 in the surrounding areas), 112 water tanks and the pipeline network.

Stage 1. Water intake

Water is abstracted from three water sources - Iskar reservoir, Beli Iskar reservoir and spring catchments. The biggest source is Iskar reservoir, which has a capacity of 655.3×10^6 m^3 and provides about 80% of the consumed water in Sofia. The Beli Iskar reservoir has a capacity of 1.5×10^6 m^3 and provides about 20% of the consumed water. Less than 1% of the city's water consumption is supplied by other rivers and spring catchments.

Stage 2. Water purification

The water abstracted from Iskar reservoir is treated in two water treatment plants (WTP) – Pancharevo and Bistritsa. The water abstracted from Beli Iskar reservoir is treated in the Mala Tsurkva WTP.

Pancharevo WTP

Pancharevo purification plant is the oldest one as it has been operating since 1968. It has a capacity of 4.50 m^3/sec. The water purification is realised through the so called “two-stage treatment”, which includes the following processes:

- Pre-treatment with chlorine and aluminum sulphate;
- Coagulation and Sedimentation (Sludge blanket clarifier);
- Sand filtration type “Akvasur 1”; and
- Disinfection with chlorine.

Bistritsa WTP

Bistritsa water purification plant has been operating since 1999. It has a capacity of 6.75 m^3/sec. The technological scheme of the plant is presented in Figure 45.

The water purification is realised through the following processes:

- Pre-treatment with chlorine and aluminum sulphate;
- Contact coagulation and sand filtration; and
- Disinfection with chlorine.

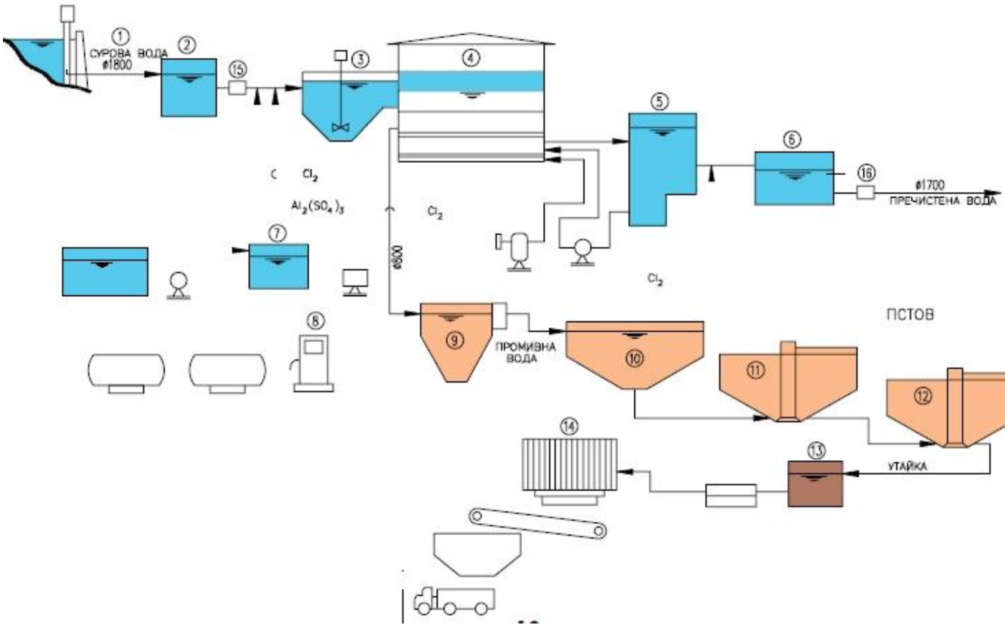


Figure 45: Drinking water purification scheme in the Bistrtitsa WTP

Legend: 1 – Iskar reservoir, 2 – Inlet chamber; 3 – Mixing of water with reagents (aluminum sulphate and chlorine); 4 – Sand filters; 5 – Reservoir for the purified water; 6 – Outlet chamber; 7 – Flow measuring; 8 – Reagents' stock; 9 – 13 – treatment of the processed waters.

[Source: Sofiyska voda]

Mala Tsurkva WTP

This is the newest water purification plant, in operation since 2010. Its capacity is 2.1 m^3/sec. Its technology scheme includes only two macro strainers, four micro strainers and disinfection, because the quality of the raw water is quite good.

Stage 3. Distribution network and reservoirs

Figure 46 presents a schematic map of the water supply system in the city of Sofia. There are two mains – "Pasarel" (19.4 km long), coming from Iskar reservoir and "Rila" (67.5 km long), coming from Beli Iskar reservoir. As shown in Figure 46, two potable water treatment plants are built on the line coming from Iskar reservoir (i.e. Pancharevo WTP and Bistritsa WTP, marked in red). The new WTP on the line coming from Beli Iskar reservoir is not marked on Figure 46. The WWTP of Sofia is also marked in yellow on the same figure. The water treated in Pancharevo and Bistritsa WTPs is collected in a "gravity channel", which delivers it either to five main water tanks – "Losenets", "Iskar", "Dragalevtsi", "Bukston" and "Koniovitsa" or directly to the consumers. From these main water tanks, water is distributed to the water distribution network and the other tanks. In total, there are 14 bigger water tanks.

Figure 46: Map of Sofia water supply system (Sofiyska voda, 2007)

The overall length of the distribution network is 4106 km. The pipes were installed in different years and hence different materials were used. Figure 47 shows the percentage distribution of the different materials. In total, 90% of the pipes were installed before 1990. All asbestos-cement (ethernit) pipes were installed in the period 1957-1977 and 97% of the CT pipes were installed in the period 1911-1990.

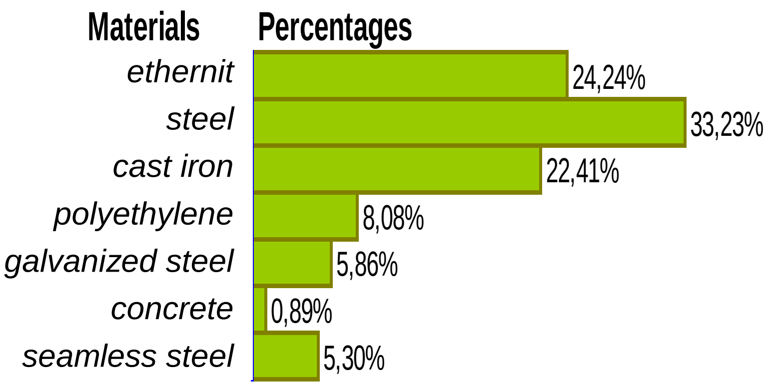


Figure 47: Types and % share of the materials of the pipes in Sofia water supply system in 2009

[Source: Sofyiska voda]

The average flow rate of the water, delivered to Sofia is 7.9 to 8 m^3/s. The maximum hourly consumption in the city is around 10 m^3/s, while the minimum hourly consumption is around 6.5 m^3/s. The specific feature of the system is that only a part of the consumers are supplied with water directly from the transport mains; the other part is supplied indirectly, after the water tanks from the distribution network. This complicated scheme of usage requires smart management and internal distribution of the water among the existing tanks. A high volume of water losses is detected in the system, which is attributed both to the fact that pipes are quite old and to the high water pressure.

Table 27 provides an overview of the abstracted water, delivered water and the water losses from 2006 to 2010.

Table 27: Water losses in Sofia water system delivery network

Year	Abstracted water	Delivered water	Losses during transportation	% of the losses
	$10^6 m^3$/year	$10^6 m^3$/year	$10^6 m^3$/year	
2006	239.53	91.82	147.72	61.7
2007	242.02	93.11	148.92	61.5
2008	224.66	91.46	133.21	59.3
2009	214.96	89.51	125.45	58.4
2010	206.63	89.15	117.47	56.9
Average	225.56	91.01	134.554	59.56
% reduction in 2010 in relation to the average	8.4	2.1	12.7	4.5

[Source: National Statistical Institute]

The information provided in Table 27 reveals that the volume of water abstracted in 2010 was 8.4% less than the average water abstracted in the last 5 years. The delivered water also was reduced by 2.1%. Reduction in terms of the water losses was registered as well (Table 27). 12.7% less water was lost in 2010 comparing with the average value for the last 5 years. The main reasons for this reduction are the measures undertaken by the water operator, mainly change of old pipes and improved management.

3.4.2.2 Water users

Stage 4a. Non-domestic users

The share of non-domestic users in the Sofia water system was 40.9% in 2010, with a tendency of decrease (Table 24). This category encompasses public buildings and industrial enterprises; the share of the latter in the water consumption is about 35.5%. The biggest part of the industrial enterprises (more than 91%) (see Table 21 on page 69) are actually “micro industries” with up to 9 employees. These enterprises are mostly involved in the services sector, rather than actually producing any type of goods.

The contribution of the industrial sector to the municipal sewer network is a bit bigger since some of the industries use industrial water either from the industrial network or from own water sources located within the industrial site e.g. wells).

Within the industrial sector, seventeen of the industrial enterprises generate wastewater flows bigger than 1% of the total industrial flow. Four of them were initially selected for detailed investigation: a pharmaceutical enterprise, a milk products enterprise, a chocolate factory and a cosmetic factory, contributing to the total wastewater flow by 5.4%, 2.13%, 1.76% and 1.21% respectively.

The discussions held with the managing personnel of these industrial enterprises revealed some typical problems concerning utilization of water and energy sources in Bulgaria (e.g. lack of detailed monitoring on water use; lack of any metering on the wastewater quantities; prejudice that the data might be used by the competitors). Some of the managers emphasized that water utilization is not the main cost for their industrial activities and therefore they were reluctant to cooperate with the team within the EcoWater framework. As a result of all these, two of the factories (the chocolate factory and the milk products factory) were not willing to cooperate.

The survey, held in the other two factories is presented below. In addition to these two relatively big factories, an SME was included as a representative example of the micro industries.

Cosmetic factory – "Aroma" AD

"Aroma" AD is a factory with over 85 years of history in the production of personal care products (tooth paste, shampoos, cosmetic products, hair dyes and soaps). The factory is situated in the North-Eastern part of Sofia and occupies an area of 8.5 ha. The main production lines are the workshops for the production of:

- Toothpastes;
- Cosmetics products;
- Shampoos and balsams;
- Hair dyes;
- Soaps; and
- Packaging materials – tubes

In addition to the main production lines, "Aroma" AD has a number of subsidiary processes and premises (potable water treatment plant, steam production plant, storage of products, etc.). In 2011 the company built a new production line for toothpastes and currently the company is about to finalize a new production building for personal care products, whose equipment is in compliance with the latest corresponding European requirements .

Water Use in "Aroma" AD

The company uses potable water from the public network. The water is used for:

- Daily life needs of the personnel;
- Preparation of products;
- Cleaning of the technological vessels and premises;
- Preparation of hot water and steam for the process requirements;
- Heating of premises during the winter; and
- Seasonal irrigation of the green areas in the campus of the factory.

The potable water that is used for the technological processes undergoes additional treatment in order to meet the EU standards for water implementation in personal care products. At present there are two old potable water treatment plants in the old production building. The water treatment process consists of several steps: (i) Disinfection with Cl_2; (ii) Dechlorination; (iii) Deionisation of water (ion-exchange process); (iv) Ultrafiltration; (v) Reverse Osmosis; (vi) UV disinfection. Figure 48 presents a general diagram of the water utilization within the factory in question.

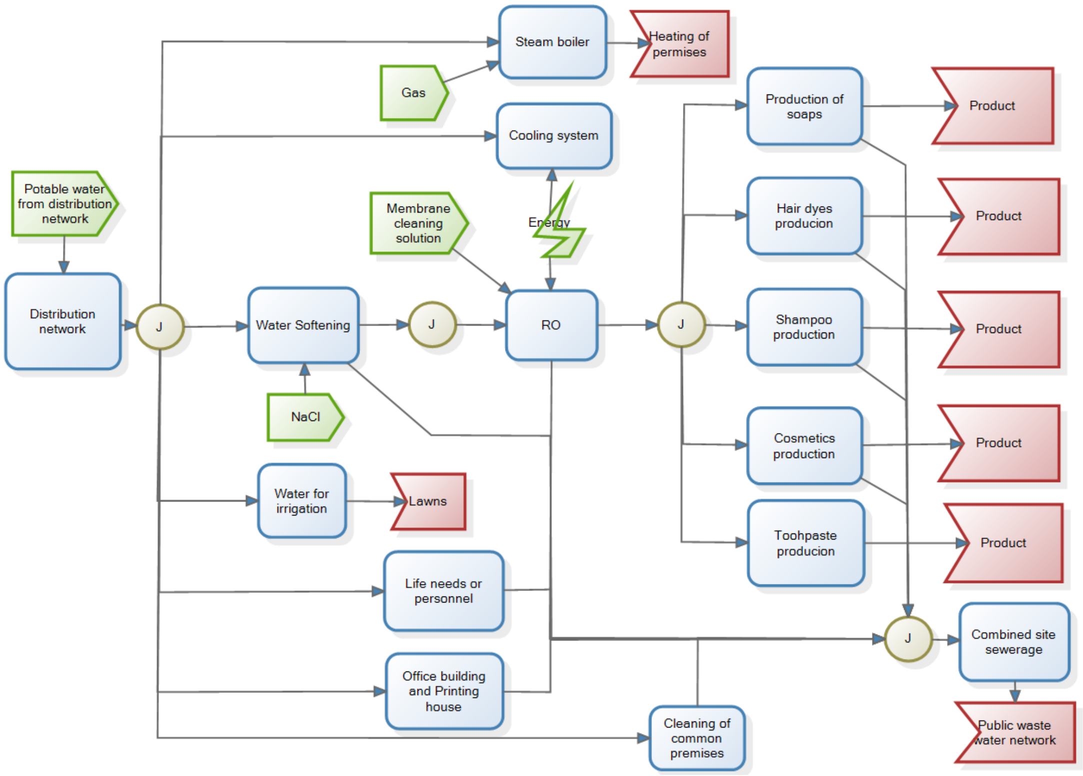


Figure 48: General scheme of water utilization in Aroma, AD

The site potable water distribution network is about 2.5 km long, steel pipes with DN 150. About 40% of the network was built more than 25 years ago, which is the reason for frequent accidents and significant water leakages. To that end, the managing body of the factory has started an investment program for replacing the old network. The plant is equipped with a large number of water meters, which makes possible the establishment of water balance for the whole factory and for the different internal technological processes.

The managing staff of "Aroma" AD has kindly provided data about:

- Technological processes within the factory;
- Total water consumption;
- Water consumption for different technological units;
- Gas consumption for heating water; and
- Monthly production of specific goods.

The main results and conclusions on the water use that have been elaborated based on data provided by the operational staff of "Aroma" are presented below. Figure 49 (focusing only on the first six months of each year, because for year 2012 data were collected only for the first six months) and Figure 50 (annual data) present the water use in "Aroma" for 2010, 2011 and 2012, according to four categories: (i) main production; (ii) other (not main) activities; (iii) leakages and (iv) irrigation. The water use for daily life needs of the personnel is included within the categories "main production" and "others". There are not measurements of the water used for domestic purposes within the factory and these figures should be estimated.

It appears that the water not accounted is the second “bigger water consumer” within the factory. This can be attributed to leakages within the site distribution network, as water meters are installed at the entrance of almost each premise. The specific assumption was proven by a detailed survey on the monthly water consumption and records on the accidents diary. Rehabilitation measures were executed recently on the distribution network and their effect is visible on the amount of leakages which has been reduced almost by double for the first six months.

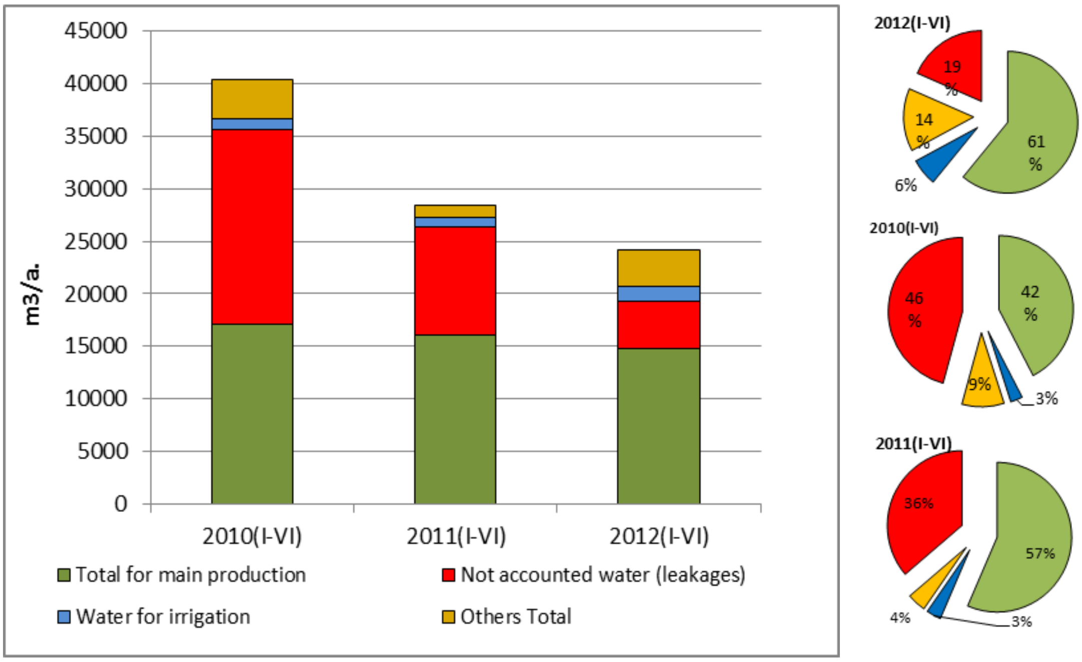


Figure 49: First six months use of potable water in “Aroma” AD, in absolute values and as percentage share

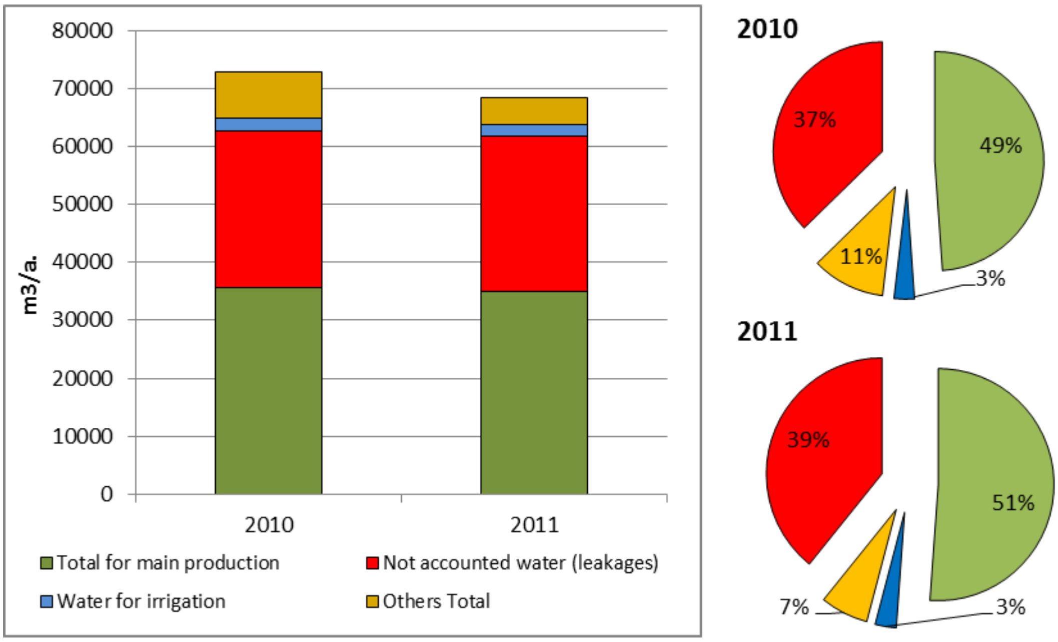


Figure 50: Annual use of potable water in “Aroma” AD in absolute values and as percentage share

Figure 51 and Figure 52 present a more detailed view on water use according to different technological processes.

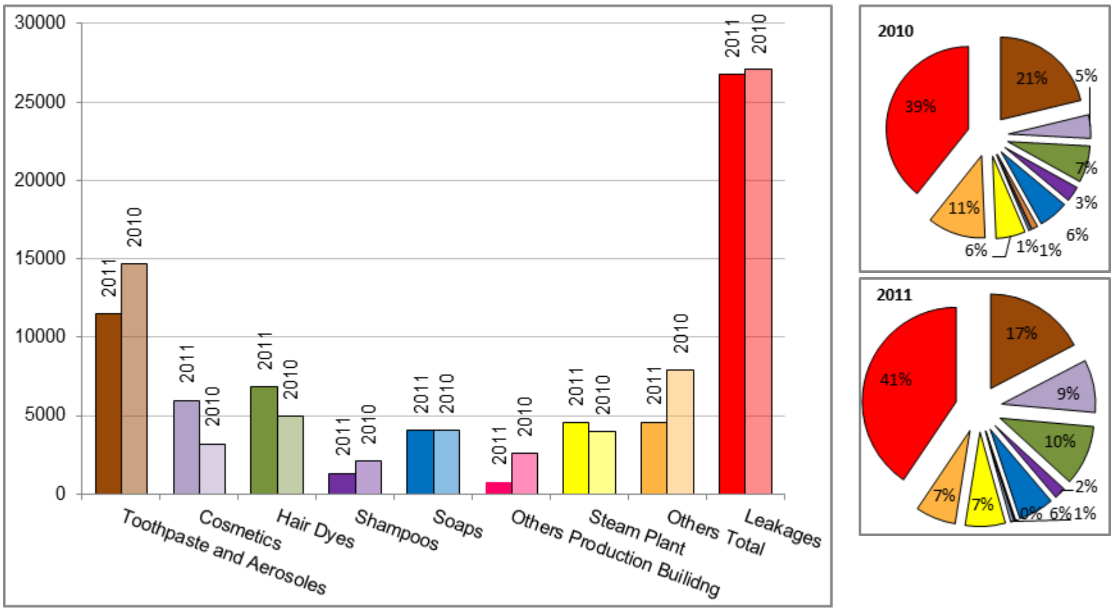


Figure 51: Annual use of potable water in "Aroma" AD according to the main technological processes

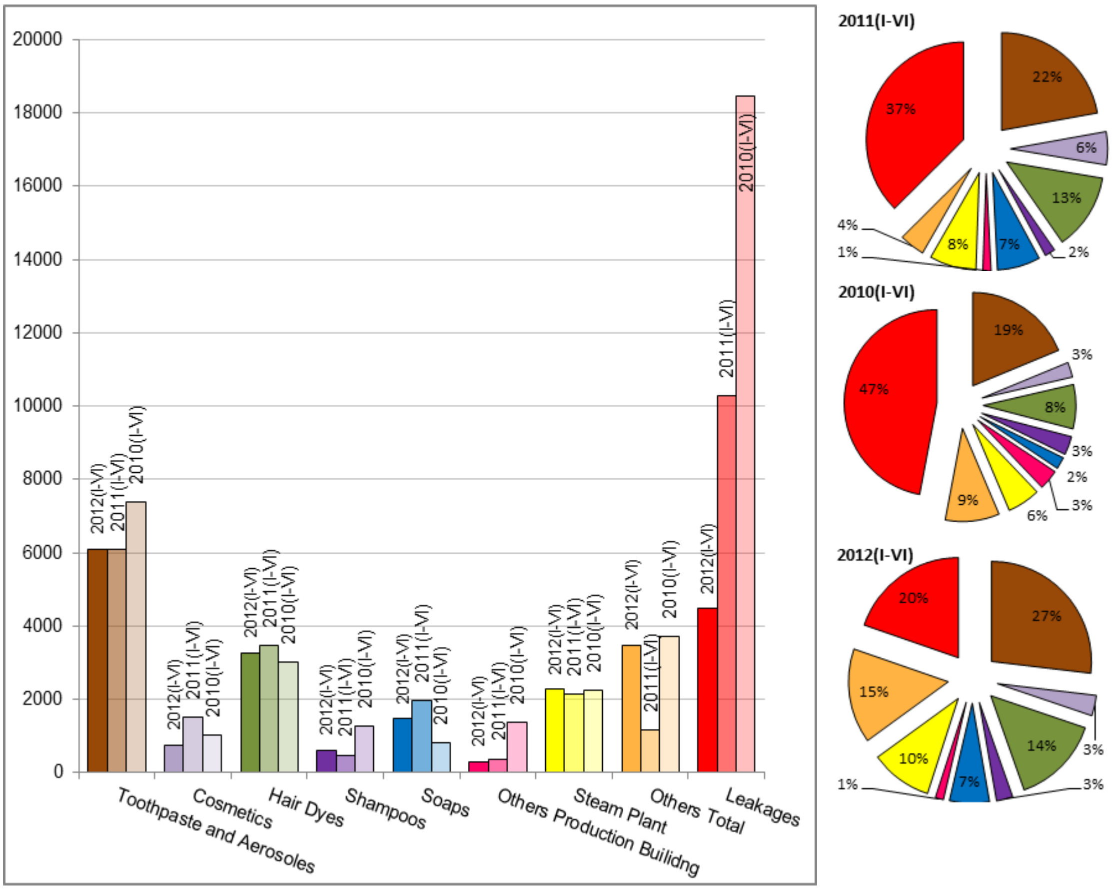


Figure 52: Potable water use in "Aroma" AD according to the main technological processes, during the first six months of the year.

The presented volumes account for the water:

- Implemented in the product;
- Used for washing of the technological premises (predominant figure); and
- Used for the needs of the personal.

The biggest water consumer is the production of toothpaste, followed by the production of hair dyes and steam plant. The rest of the production lines have relatively small share (less than 10%). It can also be concluded that the water use for the different processes is relatively constant, except for the production of toothpaste, which shows a decrease. This is mostly attributed to the changing of the technological equipment. As mentioned above, the toothpaste production was shifted to a new modern technological line in March 2011. The effect of the new equipment is illustrated in Figure 53 and Figure 54.

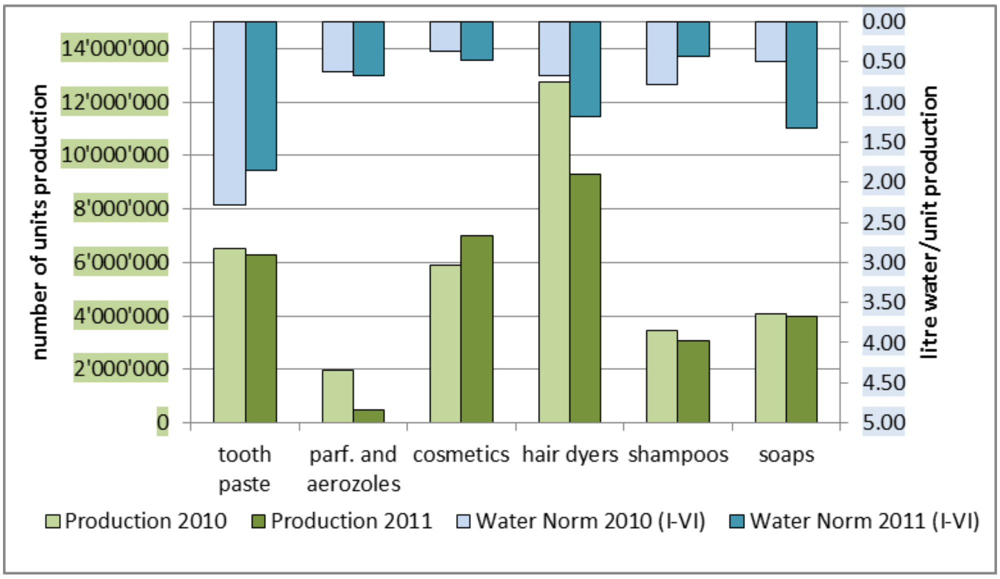


Figure 53: Annual production of goods and water norm per unit product

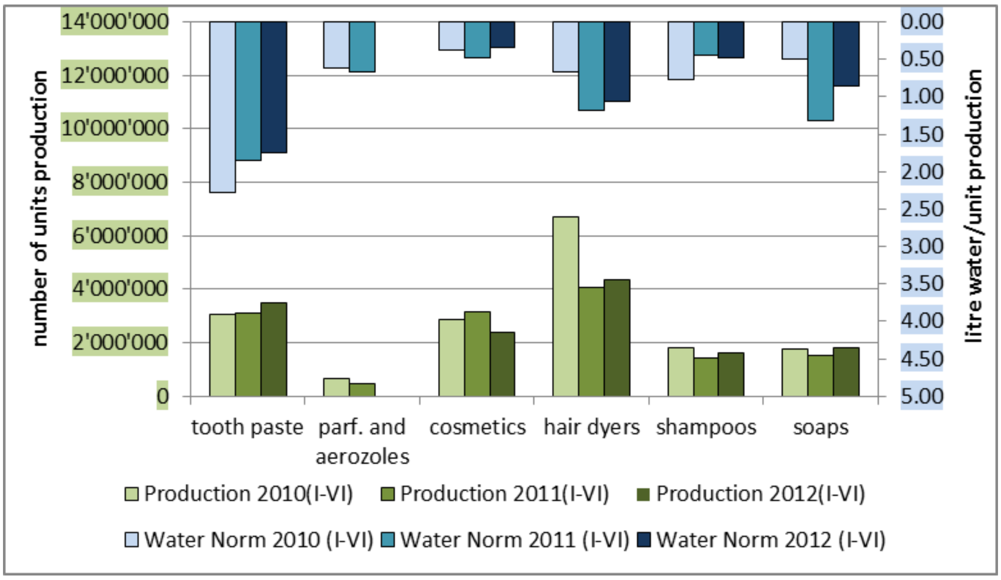


Figure 54: Six months production and water norm per unit product

The amount of production of different products is relatively stable in the investigated period except for the production of hair dyes, which had a significant peak in 2010. The water used per toothpaste tube has decreased from 2.1-2.3 l/tube to about 1.7 l/tube. Significant reduction in water use is also noticeable in the production of shampoos. The water use per unit production of soaps ranges from 0.50 l/unit to 1.85 l/unit without any explainable tendency.

Waste Water

The sewer network of the complex is combined. “Aroma” AD does not own a wastewater treatment plant. The generated wastewater is conveyed through the municipal sewer network to the WWTP of the city of Sofia. The wastewater that is discharged to the sewer network is not measured, but it is accounted by the regional operator “Sofiyska Voda” as 100% of the supplied potable water.

Utilization of Energy Resources

The expenses for electrical energy are measured for the complex as a whole. Therefore it is not possible to make any evaluation concerning the energy expenses of the different technological lines. Similarly, the expenses for gas are measured for the whole campus. Gas is mostly used for the steam plant. Gas expenses per m^3 of hot water during the summer period (April-September) are evaluated to be 6.5-7 nm^3 gas/m^3 hot water. During the rest of the year however the gas use is increased by 3 to 5 times due to the necessity of energy for heating the premises.

Financial data

The financial data were retrieved from the annual financial balance of the company and the relevant costs for the water supply and sewerage service provided by the regional operator. Based on these data, the price for buying potable water from the public network and discharging wastewater to the public sewer network is less than 1% of the total expenses of the enterprise. Table 28 presents the percentage of the expenses for water resources paid by “Aroma” AD to (i) the total expenses, and (ii) the total expenses paid for materials.

Table 28: Total expenses for buying potable water and discharging wastewater to the public sewer network in Aroma

Expenses for water resource	2010	2011
as % of total expenses for materials	0.73	0.64
as % of total expenses	0.36	0.33

Conclusion

The “Aroma” AD factory has a satisfactory database, with regard to the utilization of water and energy sources within the production cycle. Concerning the utilization of electrical and gas energy however there are no sound data on the share of energy for water treatment and distribution within the factory. A rough estimation can be possible on the basis of technical data about the power consumption of the corresponding equipment. As a result, the eco-efficiency performance of the factory concerning water utilization could be evaluated.

Pharmaceutical enterprise – “Sopharma”

Sopharma, AD is a pharmaceutical factory with more than 75 years history. It is the biggest pharmaceutical factory in the Balkan Peninsula, producing ampoules, tablets, extracts, chemical products, hygienic products, etc.

The production activities of Sopharma, AD are concentrated on the following sites:

- Ampoule Plant, situated in Sofia;
- Tablet Plant, situated in Sofia;
- Suppositories Plant, situated in Sofia;
- Vrabevo Plant, situated in Vrabevo village, Troyan; and
- Pharmaceutical Substance Plant, situated in Kazanlak.

Detailed information about the Ampoule and Tablet Plant, which are situated on the so called site “B” in Sofia, is presented below.

The Ampoule Plant is the only plant of its kind for the production of ampoule forms of humanitarian medicine in Bulgaria. The product portfolio includes solutions for injection of the major pharmacotherapeutic groups - gastroenterology, cardiology, pulmonology, allergic, analgesic and anti-pyretic.

In 2007, a complete reconstruction of the ampoule production was undertaken, doubling its capacity. A new production line for dosing with a capacity of 24 thousand ampoules/hour was introduced, enabling to ensure a high level of sterility of the product and and minimizing the influence of the human factor. The new equipment allows for full automation and 100% quality control of the production. The state-of-the-art air conditioning system maintains the parameters of the environment as required by the production of sterile products.

The Tablet Plant produces pharmaceutical products in all main pharmacological groups (gastroenterology, cardiology, pulmonology, allergy, analgesics, antipyretic, psychopharmacological and chemotherapeutic). The capacity of the plant is about 2.5 billion tablets annually.

A *laboratory for pharmacological and clinical tests* is also situated at site B.

<u>Water Use in “Sopharma” AD, site B</u>

“Sopharma” AD uses three types of water sources, as shown on Figure 55.

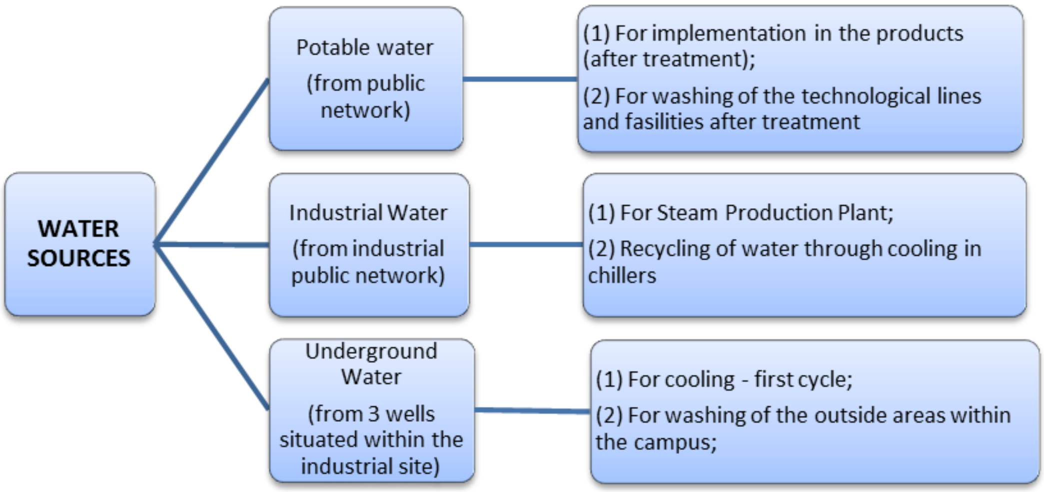


Figure 55: Water Sources in "Sopharma" AD

Figure 56 presents the general scheme of water utilization in "Sopharma" AD.

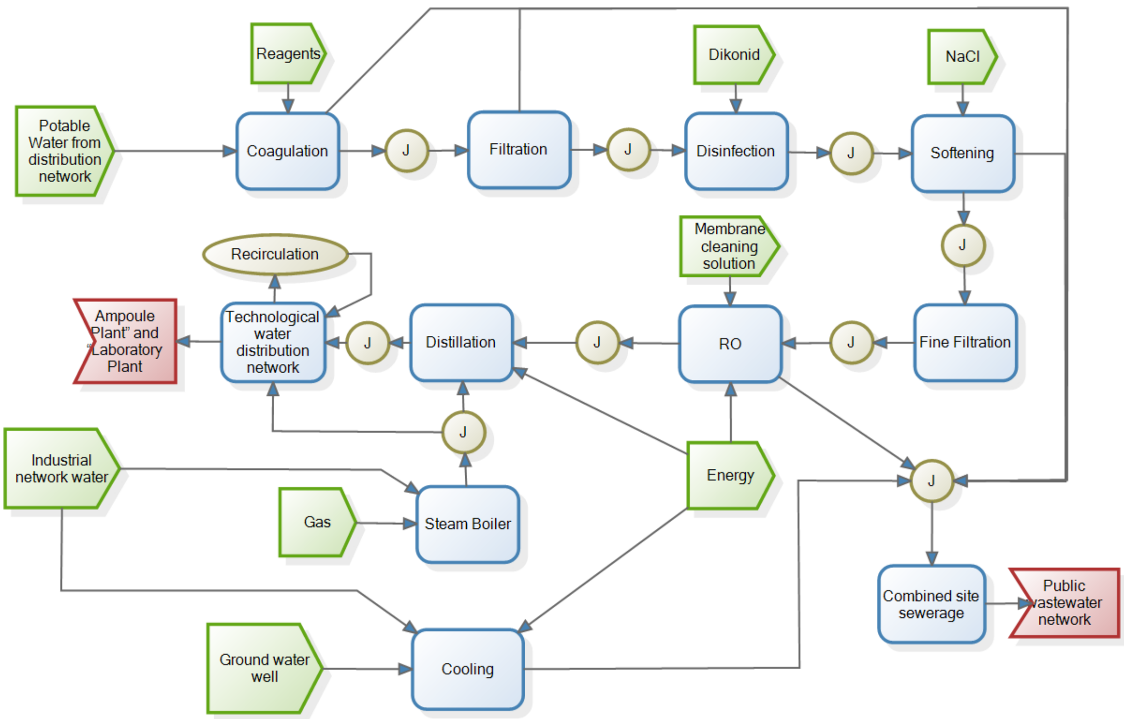


Figure 56: General scheme of water utilization, with regard to the technological process in "Sopharma" AD

The potable water that is directly used for the products preparation undergoes several treatment stages according to the European GMP requirements. Figure 57 outlines the processes involved in the treatment plant. The treated water is being continuously circulated in the technological water supply system, as the maintained temperature in the pipes is between 80°C and 90°C. The RO system has an internal recirculation (the concentrate is returned for second pass through the membrane) for achieving better efficiency. In t his way the final concentrate is reduced to 50% of the feed water and it is drained to the sewerage system. Only about 30% of the treated water is used in the ampoule production. The rest of it (70%) is utilized for washing the premises and machines for preparation of the medicaments.

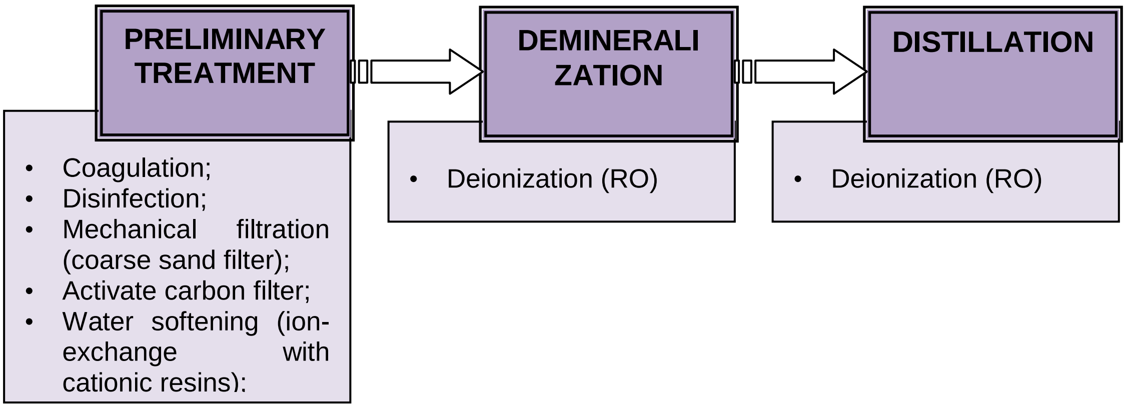


Figure 57: Main stages of potable water treatment

The managing staff of “Sopharma” AD has provided Information about the technological processes for producing water for ampoules and the total water consumption on the site and in the Ampoule Plant for the period June 2011-June 2012.

Figure 58 presents data on the utilization of potable water from the public network for the above mentioned period. The Ampoule Workshop accounts for 65-70% of the total water used on the site. Except for the Ampoule Workshop other consumers on the site that have not been separately measured are: (i) the pharmaceutical laboratory and (ii) the construction activities for building a new “Tablets Plant” on the site. The data presented also include the water required for the daily life needs of the personnel. Measurements of the water, used for domestic purposes within the factory, are not available and these quantities should be estimated.

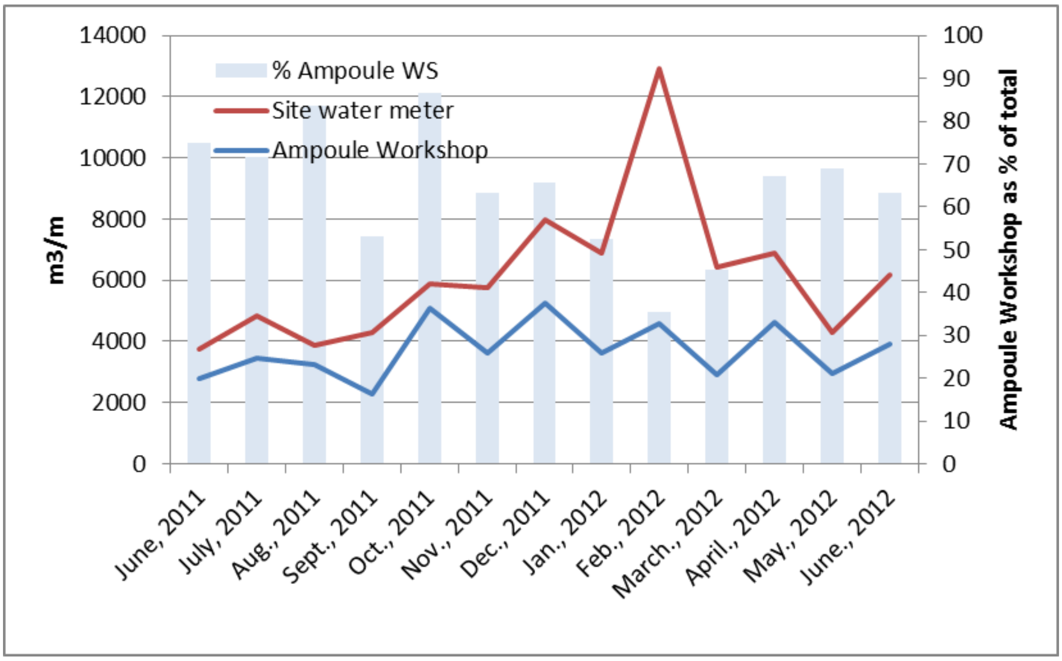


Figure 58: Use of potable water on site B of “Sopharma”, AD

Wastewater

The campus of production site B is equipped with a combined sewer network for wastewater from the industrial premises and rain water. The wastewater is conveyed through the municipal sewer network to the WWTP of the city of Sofia. The wastewater that is discharged to the sewer network is not measured, but it is accounted as 100% of the supplied potable water, industrial and well water.

For the financial estimation, data, provided both by the staff of Sopharma and their Financial Report (FR) were used. The percentage of the total expenses for buying water from the public network and discharging wastewater to the public sewer network is less than 1% of the total expenses of the enterprise. The other water-use related expenses, such as: expenses for operation and maintenance of the potable water treatment plant and for electricity required for groundwater intake, have not been provided as a separate item. They are, however, included in the general expenses. Data about electricity consumption of the water related facilities are most probably not available separately, due to the lack of separate measurement of the electrical energy required for the potable water treatment plant.

Table 29: Percentage of the expenses for water resources to the total expenses and the total expenses for material for "Sopharma" AD (estimation based on the provided data for water for the period June 2011-June 2012

Expenses for water resource	06/2011-06/2012
as % of total expenses for materials	0.34
as % of total expenses	0.05

Conclusion

"Sopharma" AD does not have reliable data on water and energy utilization within the factory. The argument of the managing staff is that water as a resource has a negligible share of costs (below 1%) compared with the other expenses of the factory. To that end, development of relevant eco-efficiency indicators requires further investigation and measurements.

"Panteley Toshev LTD"

"Panteley Toshev LTD" is a rapidly growing company specialized in the development and production of beverage and food ingredients. From a state-of-the-art production center located in Sofia, "Panteley Toshev LTD". markets about 1,500 standard products to more than 1,200 customers, spreading in 17 countries.

The enterprise is being supplied water from the urban water supply network. The water is used for (i) cooling, washing and cleaning purposes, (ii) use in production line (iii) personal hygiene, and (iv) consumption by workers. The quality of the water from the supply network is good enough for being appliedin the products, so there is no need for future treatment. The wastewater is discharged directly into the sewerage network without treatment. The cooling system is once-through and after the cooling process the heated water is also discharged into the urban sewerage network. The water supply chain of the this enterprise is presented on Figure 59.

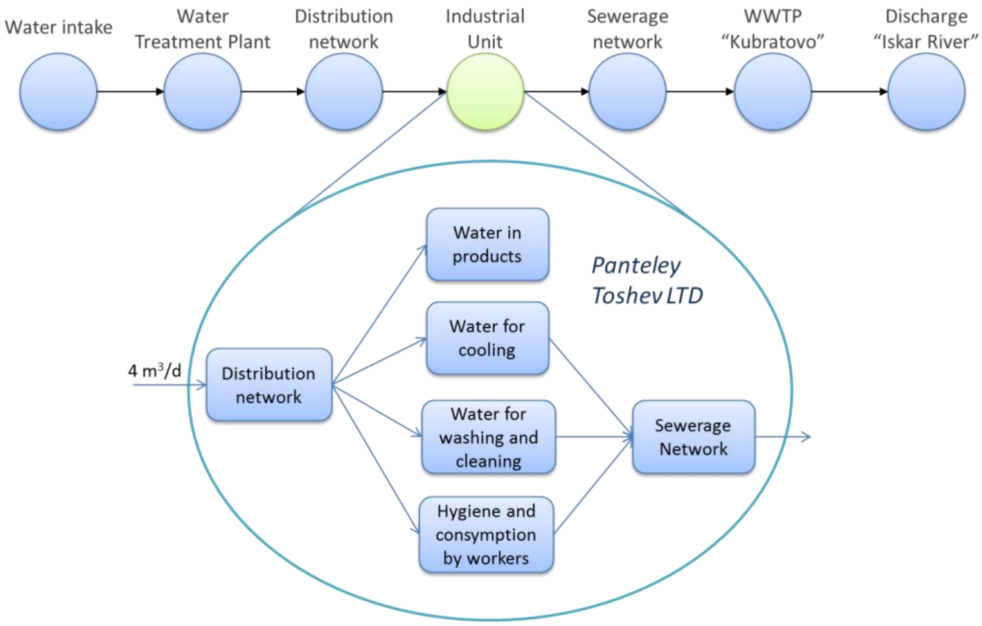


Figure 59: Water supply chain map of "Panteley Toshev LTD".

The factory purchases drinking water from "Sofiyska voda" and pays for discharge and water treatment depending on contamination of wastewater, measured with regular samplings. The quantity of consumed water could be reduced and the value added could be increased either by using own sources of groundwater for cooling or by recycling the water used in thecooling system.

Since the potable water from the municipal network does not undergo specific treatment for the purpose of production, there are no measurements on the water quantity utilized for production purposes. The information available is only based on the water use and the water approximately consumed on a daily basis.

<u>Conclusion</u>

The factory does not have reliable data on water and energy utilization. Development of eco-efficiency indicators for water and energy utilization within the factory requires further investigation and measurements.

Stage 4b. Domestic users

As shown in Table 24, domestic users are the predominant water consumer within the municipal water distribution network. Therefore, improving the eco-efficiency performance of the domestic water consumption would have a significant impact over the whole urban water system. The socio-economic development of Sofia indicates that in the future the potable water needs in Sofia will increase; on the other hand there is significant potential for water saving in the households. An appropriate management of the water supply system in the future should provide water for all. Table 30 presents the average daily water consumption per person for the last 5 years.

Table 30: The average domestic water consumption in Sofia for the period 2006-2010 (liters per capita per day)

	2006	2007	2008	2009	2010
Water used by population per capita - (l/ca/day)	143.0	146.1	141	140	140

[Source: National Statistical Institute]

Although there is a trend for decreasing of daily water consumption per capita day in Sofia, it is still higher (with about 40%) than the country's average.

For modeling reasons, it is assumed that the central provision of hot water and heating increase domestic water use, which is why the modeling of water consumption between dwellings with central heating system and without differs.

Figure 60 presents the distribution of the supplied water for the last 5 years among the users without and with central sewerage system (CSS). Some of them are connected to centralized heating systems (CHS) as well.

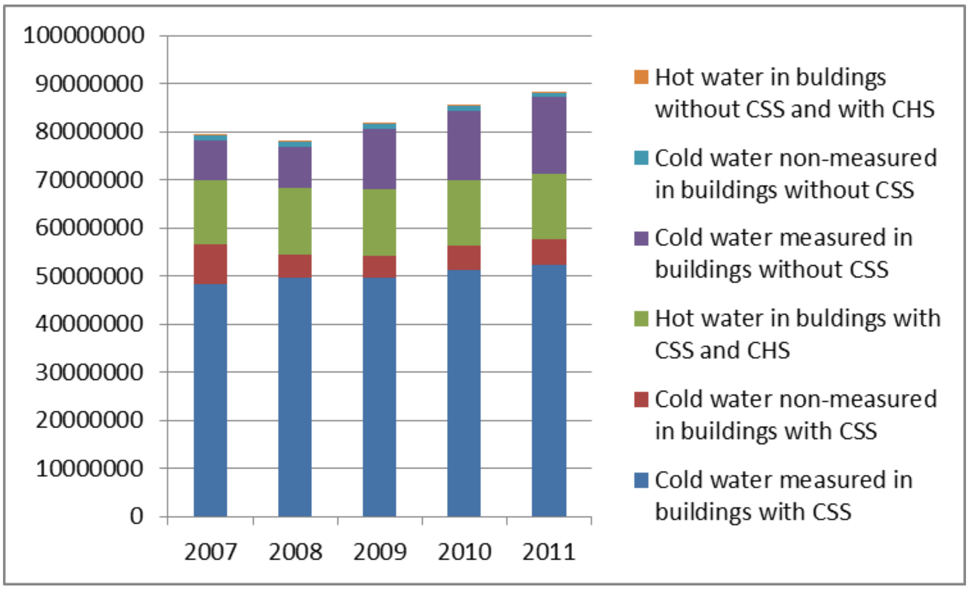


Figure 60: Water in m3/year, supplied to different types of users [Sofiyska voda, requested data]

**CSS – centralized sewerage system, CHS – centralized heating system*

A previous research performed by the "Water Supply, Sewerage, Water and Wastewater Treatment" Department at the UACEG, BG and the University of Cranfield, UK focused on the analysis of the state of water supply in Sofia and the attitude of the population towards water saving. The project was financed by the EC through the international scientific project AquaStress, realized in 2005-2009. 640 households were interviewed, according to income and spatial (districts in Sofia) criteria. The interviews comprise of 43 questions, distributed in 4 categories (Tsanov et al, 2011):

- *Category 1: Intention* – the wish of the citizens to invest money and time in order to decrease the water consumption;
- *Category 2: Possibility* – the possibility to decrease water consumptions, to pay in order to decrease water consumption and easy opportunity for getting appliances for consumption decrease;

- *<u>Category 3: Attitude</u>* – the attitude towards water saving (good/bad);
- *<u>Category 4: Motives</u>* - the motives of the citizens for water saving (ecological reasons, financial, raised public awareness)

Figure 61 illustrates a part of the achieved results through the replies to three (3) questions from different categories. The figure shows that the residents of Sofia are not positive towards water saving. The possible explanations are:

- Lack of appropriate education on environmental significance of water;
- The major economic problems in the conditions of the transitional period – low incomes, uncertainty concerning the employment –that make people concentrate the finance on short term rather that long term household issues;
- Lack of appropriate dialog between the regional water company and the citizens – the water supply systems has leakages within the distribution pipes over 50% and this demotivates the people to save water in the household;
- The relatively low price of the water service.

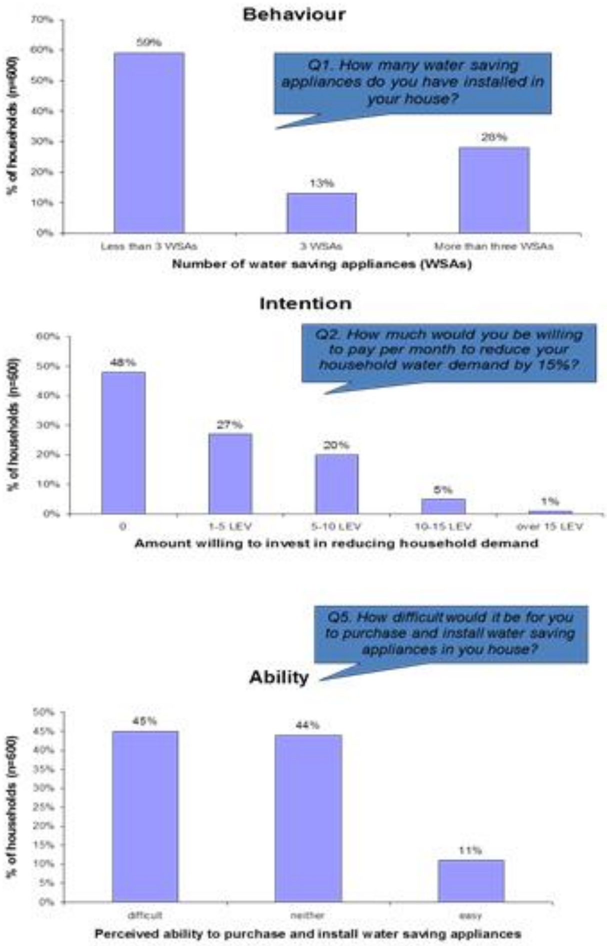


Figure 61: Indicative results of the interviews in Sofia

Stage 5. Sewerage system and facilities

The sewerage system in Sofia is combined type. It was designed and built in stages, in parallel with the development of the city; with different drainage coefficients and overflow period. The sewer system has no storm water retention tanks but in some areas it has been designed to collect underground water with the purpose to drain foundations of some buildings or basement storey. In older sections of the network, the concrete pipes are in very bad condition and allow infiltration of extraneous water and/or exfiltration of wastewater into the ground.

The sewage system is a gravity one and conveys the wastewater to “Kubratovo” WWTP. The total length is 1485 km, whereas the length of the main sewerage pipelines in the area of Sofia is 426 km. There are 11 pipeline networks, whose route is along the banks of the rivers flowing through the city of Sofia. Recently the sewerage system was modeled using the DHI Mouse software.

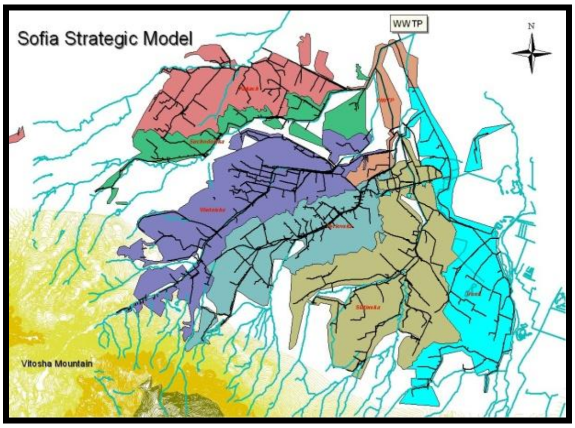


Figure 62: A map of Sofia sewerage system (Lichev, A)

Stage 6. WWTP

The WWTP of Sofia has been operating since 1984. The initial technological scheme is of conventional type, including: (i) mechanical and biological treatment (only BOD removal), (ii) disinfection and (iii) sludge treatment. The design parameters of the system were:

- Average daily flow rate 480 000 m^3/d; and
- BOD_5 - 220 mg /l; TSS – 315 mg/l.

The treated wastewater is discharged into Iskar River. Since then, the WWTP has undergone three significant reconstructions.

In 2004 the water line was fully reconstructed in order to allow bigger quantity to be treated and the treatment performance to meet the requirements of Directive 91/271. After this reconstruction the average treated daily flow rate was increased to 685,000 m^3/d. The nitrogen and phosphorus removal was included in the reconstruction of the biological stage. The project was funded under the PHARE program and amounted to EUR 17 million.

In 2006, a project for rehabilitation and upgrade of sludge digesters was completed; the project amounted to over BGN 10 million.

Currently, the technological scheme of Sofia WWTP includes: (Figure 63):

- Mechanical treatment (screens, grid chambers and primary clarifiers);
- Biological treatment (completely mixed bioreactors, pre-denitrification and chemical phosphorus removal); and
- Chlorination;

The sludge treatment line includes:

- Gravity thickeners;
- Anaerobic digestors;
- Gravity post thickeners;
- Dewatering.

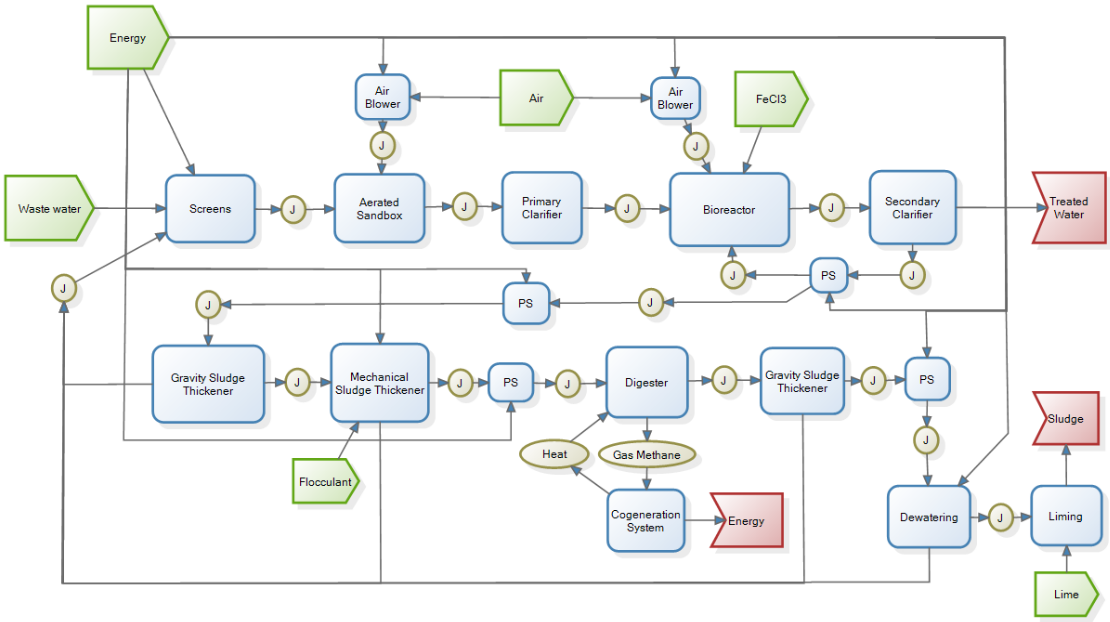


Figure 63: General scheme of Sofia WWTP

In 2009, "Sofiyska Voda" put in operation a cogeneration installation for combined production of electricity and heat, in order to reduce CO_2 emissions in the atmosphere and use a more sustainable energy source. Prior to commissioning the facility, biogas, which is released during the decay of the sludge, was burned without being utilized. Its composition is about 68% methane, 30% carbon dioxide and 2% other gases.

The reconstruction of the sludge line allowed to produce sludge that could be used in agriculture as fertilizer; 68,028 tons were sold in 2010.

Detailed data were requested and kindly provided by “Sofiyska voda”. Some data are at an annual basis, whereas other - at monthly, daily, or even hourly basis. Some of these data are presented below.

<u>Inflow to the Sofia WWTP</u>

Figure 64 presents the inflow to the Sofia WWTP from January 2012 to July 2012 at an hourly basis.

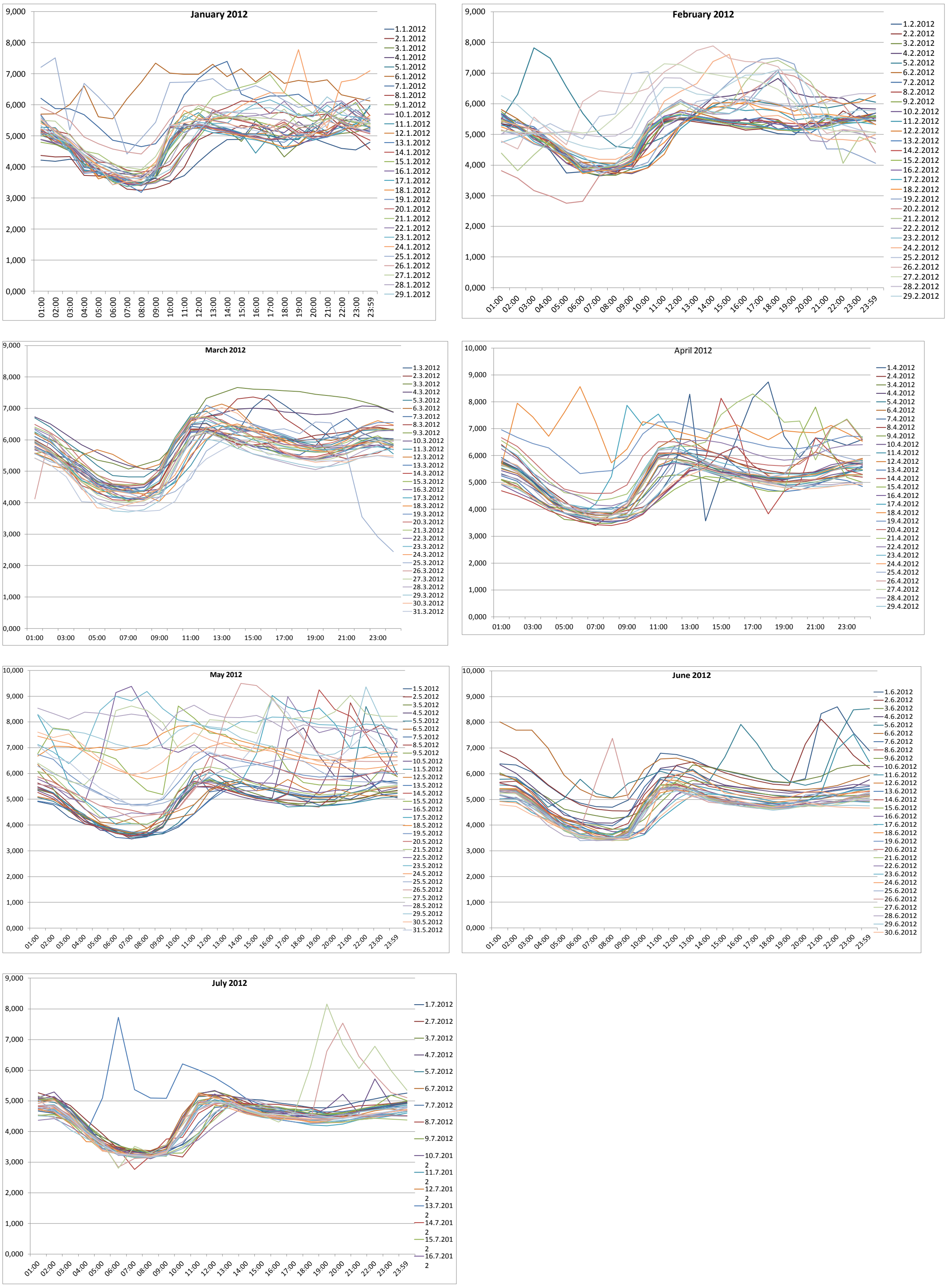


Figure 64: Inflow to the Sofia WWTP

Legend: horizontal axes – 24 hours, vertical axis – flow magnitude, each line presents one day

These figures clearly indicate that the inflow of wastewater varies due to the combined sewerage system. The highest variations can be observed in the wet months (i.e. January-February and April-May). On the other hand, the flow is relatively constant during the dry months (i.e. June and July). However, a high infiltration rate is observed in the dry months and even in the “dead hours” (in the late night) the flow is very high.

<u>The reduced load</u>

Another important aspect for the WWTP’s performance concerns the treatment effectiveness expressed through the removed load of BOD, TSS, TKN and TP. Figure 65 present the removed load of BOD and TKN.

The data show that the daily average BOD removal load is between 20,000 kg and 60,000 kg (the maximum value for the period is 80,000 kg/d). The corresponding average value for TSS removal is 50,000 kg TSS/day (the maximum value is 200,000 kg). The daily average loads of phosphorus and nitrogen removed are 1,000 kg (the maximum value is 1,700 kg) and 5,000 kg (the maximum value is 15,000 kg) respectively.

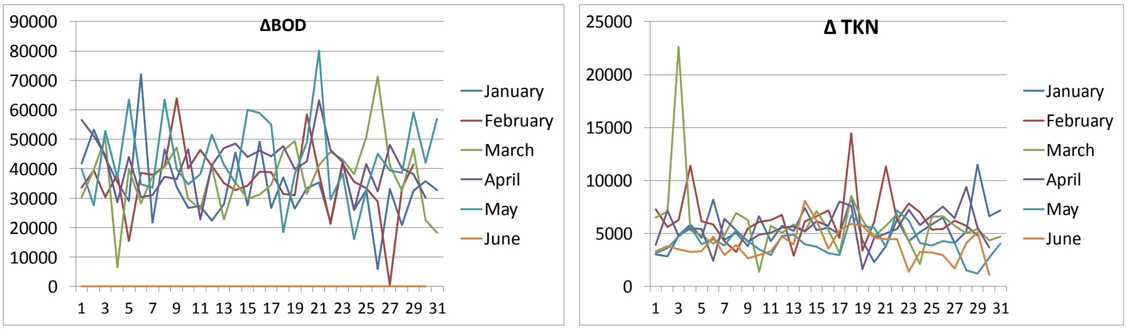


Figure 65: BOD and TKN removed in the Sofia WWTP (kg/d)

Stage 7. Wastewater Discharge

In Sofia, wastewater is discharged into Iskar River. The controlled wastewater discharge concerns both the treated effluent of the Sofia WWTP and the treated or non-treated effluents of the industrial units.

There are also uncontrolled discharges from the CSOs and from septic tanks of the domestic water users.

3.4.3 Process map description

Table 31 summarizes the information about the processes in each stage of the system.

Table 31: Summary overview on the processes of the system

	Stage number	Stage name	Processes
Water supply system	1	Water intake	Two similar mountain reservoirs; Iskar and Beli Iskar
	2	Water purification	Pre-Treatment (chlorination and aluminum sulphate), sand filtration and disinfection (chlorination); treatment of technological waters;
	3	Distribution network and reservoirs	Transportation and in some cases pumping
Water uses	4a	Non-domestic	Production, washing/cleaning, cooling
	4b	Domestic	Consumption, personal hygiene, toilet
Sewerage system	5	Sewage network and facilities	Transportation, overflowing (CSOs)
	6	WWTP	Screening, Sand removal, Primary sedimentation, Biological treatment (completey mixed reactor), pre-denitrification, Chemical phosphorus removal, Thickening, Stabilization (anaerobic), Dewatering, Biogas usage with co-generation
	7	Water discharge	N.A.

3.4.4 Description of existing technologies

Table 32 summarizes the information about the technologies in each stage of the system.

Table 32: Summary overview on the existing technologies

	Stage number	Stage name	Technologies
Water supply system	1	Water intake	N.A.
	2	Water purification	Mechanical mixers, sand filters, installations for reagents dosing and preparation; installation for disinfection through Cl_2 , lime saturator, SCADA system; treatment of technological water: grit removal, sedimentation, thickening, chamber filter press for sludge dewatering,
	3	Distribution network and reservoirs	SCADA system, DMA managing. maintaining pressure with PRVs, innovation methods for finding covered leakages, trenchless technologies.
Water uses	4a	Non-domestic	Open/closed cooling systems, steam plants/heating water systems, water treatment technologies where necessary (softening with ion-exchange cationic resins, reverse osmosis, distillation)
	4b	Domestic	Low-flush toilets, water saving taps and appliances
Sewerage system	5	Sewage network and facilities	Technologies for cleaning sewerage pipes and monitoring of the structural condition of the pipe.
	6	WWTP	Smart pumping, screens, grit removal, sedimentation tanks, bioreactors, digestors, gravity sludge thickeners, mechanical sludge thickeners, belt filter press, co-generators, SCADA system for monitoring and management,, etc.
	7	Water intake	N.A.

3.5 Value Chain Mapping

The most important stakeholder, who will assist in the realization of EcoWater Project, is the water and sewerage system operator, i.e. **"Sofiyska voda"**. The company was established in October 2000 by a 25-year Concession Agreement. According to the agreement, the Municipality of Sofia grants to the Company the operation and maintenance of Sofia's WSS system. The shareholding capital is divided between the Municipality of Sofia (22.9 %) and the French company Veolia Water (77.1 %).

- At the state level, there are four (4) important institutions which should be accounted for as stakeholders (further on, the first three will be referred as

"Ministries"). These are the:**Ministry of Environment and Waters (MOEW) -** Determines the water and environment policy in Bulgaria**;**

- **Danube Basin Directorate (DBD), subordinated to MOEW** - Controls the execution of the water law in the Iskar catchment;
- **Ministry of Regional Development and Public works (MRDPW)** - Manages the water supply and sewerage networks at the national level; and
- **State Commission for energy and water management (SCEWM)** – Controls the water and energy tariffs and services under the Law for regulation of the water supplying and sewerage services.

Further important actors are the:

- Water users, including both the citizens and the industrial enterprises;
- "CHEZ" AD company, producing electricity and providing it to Sofiyska voda and to all other water users; and
- Companies that supply "Sofiyska voda" with the reagents required for water purification and wastewater treatment.

The interactions among the aforementioned stakeholders (SH) are summarized in Table 33.

Table 33: The interactions among the most important actors

With:	Sofijska voda and Sofia municipality	The energy supplier	The reagent suppliers	Ministries	SCEWM	Domestic users	Non-domestic users
Sofijska voda and Sofia municipality		buys energy	buys reagents	has to respect the law	the suggested water tariffs are controlled by SCEWM	sell water and water services to them	sell water and water services to them
The energy supplier			sells energy	neutral for this case	the suggested energy tariffs are controlled by SCEWM	sells energy	sells energy
The reagent suppliers				neutral for this case	neutral	indirect on the water price	indirect on the water price or direct when supplies them
Ministries					neutral	neutral	neutral

SCEWM						defends their interest	defends their interest
Domestic users							competition for the water as resource

A scheme of the value chain for the Sofia urban system at meso-level is provided in Figure 66.

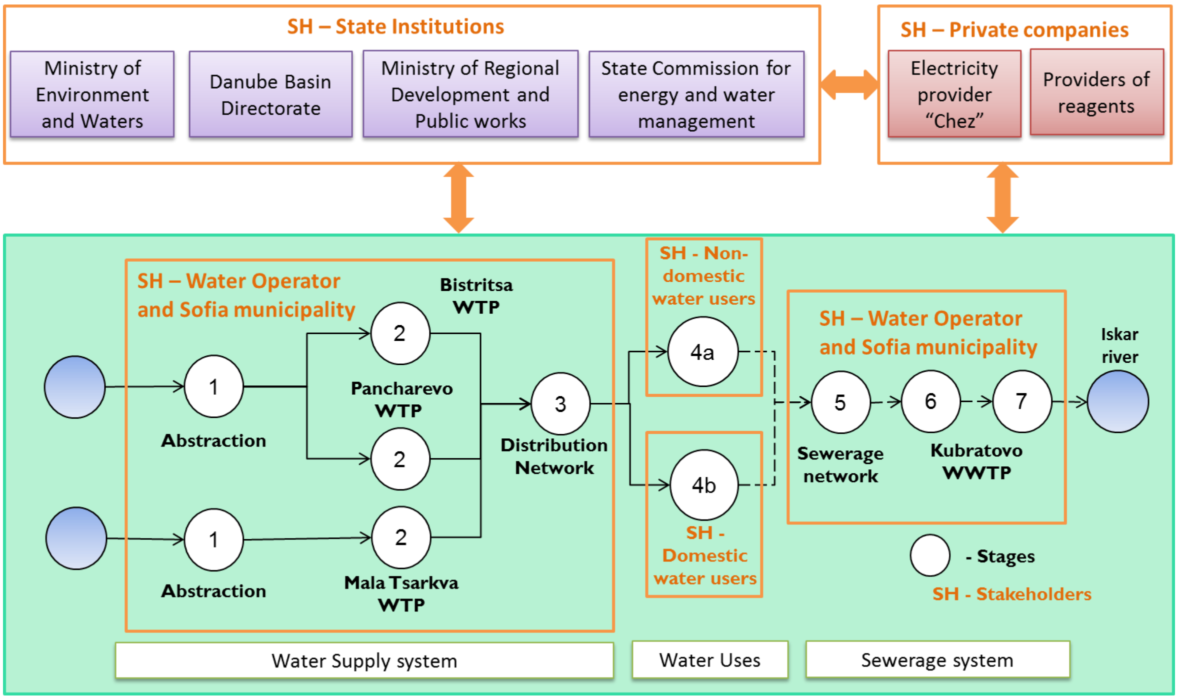


Figure 66: Meso-level value chain mapping of Sofia urban system

3.6 Selection of eco-efficiency indicators

The term eco-efficiency was introduced in the late 1980s (Schaltegger and Sturm, 1989) and appears in academic literature for the first time in 1990 (Schaltegger and Sturm, 1990). Eco-efficiency is seen both as a concept and as a tool and the basic idea is to produce more with less impact on nature, which can be measured as reduced emissions and/or reduced raw material consumption,(Schaltegger and Burrit 2000).

Eco-efficiency indicators link the environmental with the economic performance and they are expressed as the ratio of (economic) output per environmental influence (Figure 67).

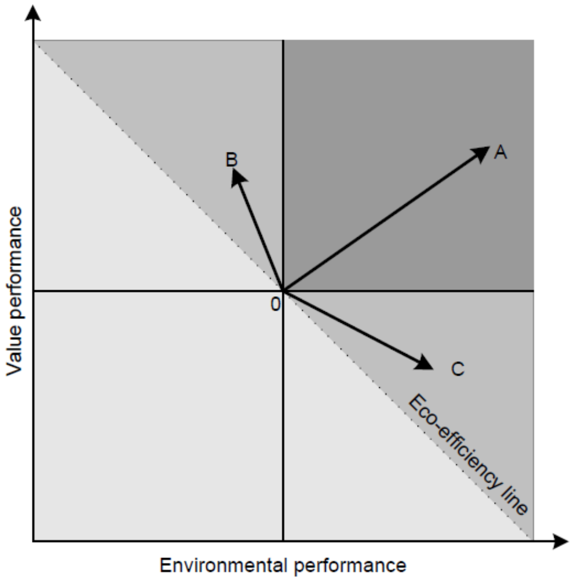


Figure 67: Eco-Efficiency Performance Comparison (taken from Schaltegger and Burritt 2000)

In order for the eco-efficiency to be assessed, both the value performance and the environmental performance must be calculated (These two categories are discussed below.

3.6.1 Environmental impacts

Urban water systems have direct impact on the:

- Water (amount of the abstracted water; quality of the discharged wastewater; exfiltrated wastewater from malfunctioning sewerage pipes; polluted groundwater through infiltration into the sewer pipes). The variation of the water quality and the water quantity along the water supply chain is illustrated in Figure 68;
- Soil (land used for building the necessary facilities such as water intake structures, pumping station, water treatment station, tanks and reservoirs, wastewater treatments plant; generation of sludge during the water and wastewater treatment process, which has to be deposited afterwards);
- Air (GHG emissions due to the energy used; gas emissions from the water and wastewater treatment processes).

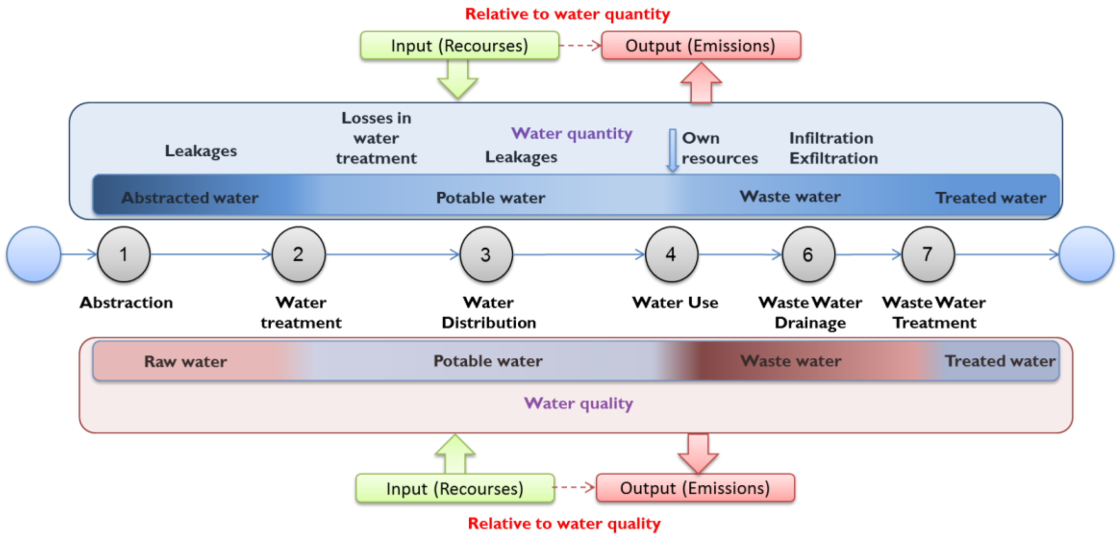


Figure 68: Water quantity and water quality variations along the water chain

The environmental indicators can be classified into two main categories, i.e. those related with the resources needed ("input indicators") and those related with the environmental emissions ("output indicators") (Figure 68):

An input indicator indicates that the environmental impact (of the underlying parameters) is associated with the resources needed within the water service system. The corresponding equation is

$$EII = \frac{Resources\ on\ input}{Delivered\ water} \qquad eq.1$$

The most important resources for the Sofia urban water supply systems are:

- Water, abstracted from nature;
- Reagents; and
- Energy.

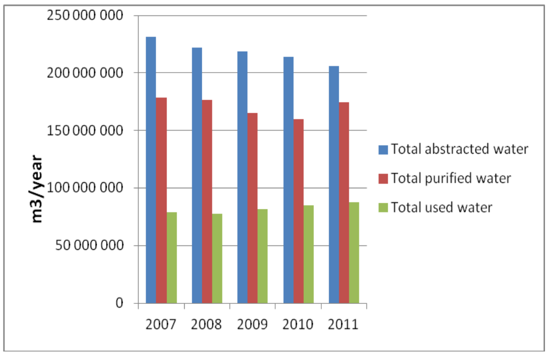
The total amount of each resource used will be divided with the total volume of the delivered water in order to calculate the indicator. A preliminary estimation of an input indicator for the water supply stage is presented below.

The environmental impact related to the amount of the abstracted natural water is given by the following equation:

$$EII - W = \frac{Abstracted\ water}{Delivered\ water}$$

One of the most important environmental problems of the urban water system of Sofia is the loss of water both through the transfer mains and through the water distribution system (Figure 69).

Figure 70 illustrates the application of this indicator in the water supply stage. A clear tendency of reducing the environmental impact can be observed. This can be most probably attributed to the measures taken, such as the replacement of the pipes, better management of the water tanks, pressure management, etc.



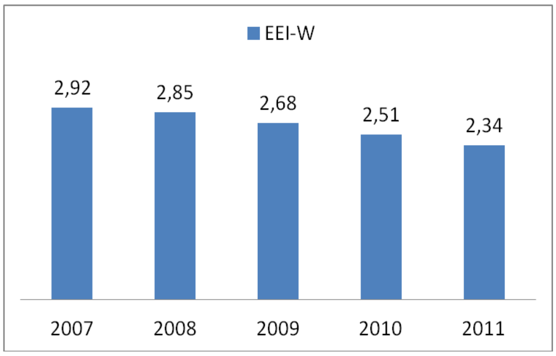


Figure 69: Volumes of abstracted, treated and delivered water in Sofia from 2007 to 2011 [Sofiyska voda, requested data]

Figure 70: The EEI-W indicator for the Sofia urban water system

On the other hand, an output indicator shows that the emissions of the water service systems emissions (CO_2, BOD, N and P) exert pressure on the environment. The corresponding formula is:

$$EII = \frac{Parameter\ (BOD, N, P \dots)[\frac{kg}{year}]}{Delivered\, water\ [\frac{m3}{year}]}\ [\frac{kg}{m3}] \qquad \textit{eq.2}$$

The relevance and importance of a set of environmental parameters and indicators was assessed for each stage of the system. Table 34 presents a list of indicators relevant to the Sofia urban water service system; the importance of each parameter is ranked from “not important” to “possibly important” and “important” for each stage. .

According to the expert estimation, the most important environmental impacts related to the system mainly concern the (i) quantity of abstracted water, (ii) quality of the discharged treated water (load of pollutants), (iii) CO_2 released to the air due to energy use, and (iv) indirect impact from the use of other resources in the water-related processes.

Table 34: Ranking of the indicator's parameters for the Sofia urban water system

Stages		Water Supply system			Water use		Sewerage system	
Nodes		Water intake	Water purification	Distribution network	Non-domestic	Domestic	Sewage network and facilities	Waste water treatment
Indicator	**Parameter**	1	2	3	4	5	6	7
Water Quantity	Abstracted water	Important	Important	Important	Important	Important	Not imp.	Not imp.
(Input) Resources	Energy - Electricity	Not imp.	Important	Important	Possibly imp.	Possibly imp.	Not imp.	Important
Climate Change	CO2 to air emission	Not imp.	Important	Important	Possibly imp.	Possibly imp.	Not imp.	Important
Water quality	BOD	Not imp.	Not imp.	Not imp.	Important	Important	Possibly imp.	Important
Water quality	COD	Not imp.	Not imp.	Not imp.	Important	Important	Possibly imp.	Important
Water quality	P Total	Not imp.	Not imp.	Not imp.	Important	Important	Possibly imp.	Important
Water quality	N Total	Not imp.	Not imp.	Not imp.	Important	Important	Possibly imp.	Important
Water quality	TSS	Not imp.	Not imp.	Not imp.	Important	Important	Possibly imp.	Important
(Input) Resources	Energy - Transport fuels	Not imp.	Important	Possibly imp.	Not imp.	Not imp.	Not imp.	Important
Water Quantity	Re-used water	Not imp.	Possibly imp.	Not imp.	Important	Important	Not imp.	Not imp.
Water Quantity	Infiltration	Not imp.	Not imp.	Not imp.	Not imp.	Not imp.	Important	Important
Climate Change	CH4	Not imp.	Not imp.	Not imp.	Not imp.	Not imp.	Possibly imp.	Important
Water Quantity	Leackages	Not imp.	Not imp.	Important	Not imp.	Not imp.	Not imp.	Not imp.

3.6.2 Economic costs and benefits

The second component of the eco-efficiency indicators concerns the value performance (Figure 67), expressed through the Total Value Added (TVA). The TVA can be calculated, using the following formula:

$$EII = \frac{Parameter\ (BOD, N, P \ldots)[\frac{kg}{year}]}{Delivered\ water\ [\frac{m3}{year}]}\ [\frac{kg}{m3}]$$

where:

1. Income generated from water use (value added in products / services as a result of water use); this is the **economic value of water use**;
2. Financial costs incurred for rendering the water suitable for the specific use purpose;
3. Financial costs incurred for meeting applicable standards for effluent discharge; and
4. Income generated from potential by-products of the water system.

Figure 71 and Figure 72 illustrate some of the data collected for the calculation of the TVA for the system (for the last three years). More specifically, Figure 71 presents the most significant costs in the provision of urban water services; the costs for chlorination and for reagents in the WWTP are not included, due to currently missing data. Figure 72 illustrates the total income of the water operator (Sofiyska voda), as well as the corresponding primary sources.

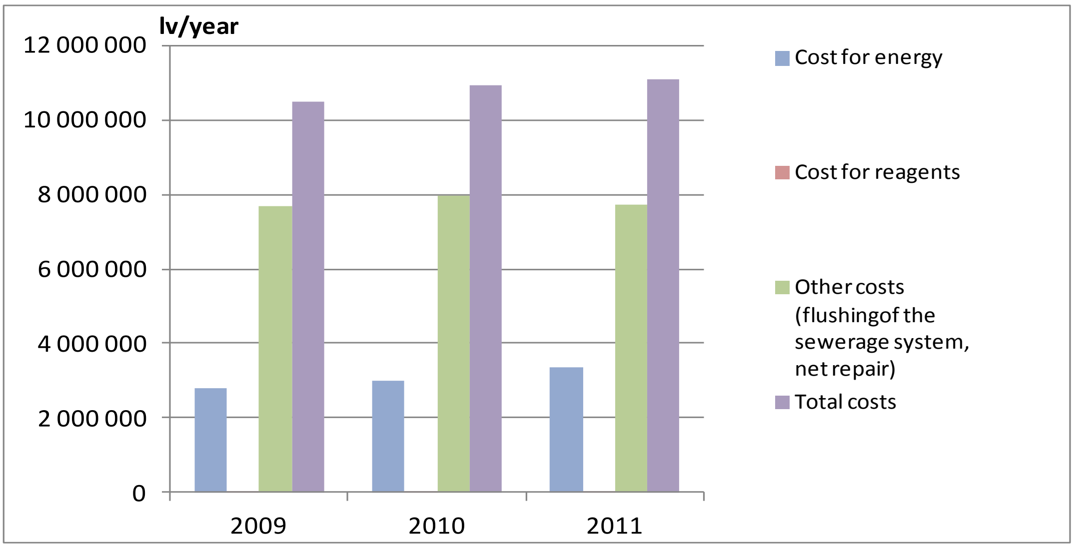


Figure 71: Some of the major costs in Sofia urban system (reagents in the WWTP as well as chlorine are not included)

Figure 72: Some of the major incomes of the Sofia water operator

The Sofia WWTP has installed a Combined Heat and Power (CHP) installation, which produces heating and electric power simultaneously, in a combined process with a higher efficiency and a lower cost compared to the conventional methods. The efficiency of a CHP plant reaches about 82%, which is about twice that of conventional plants. The CHP allows the full utilization of the biogas produced from the digesters and its transformation into heat and electric power. This reduces the amount of electricity required from the National Electrical Company. 100% of the heat produced by the CHP is used for heating the digestion plant and the surrounding buildings of the plant. Figure 73 presents the quantitative trends in energy use and recovery in Sofia WWTP from 2008 to 2011.

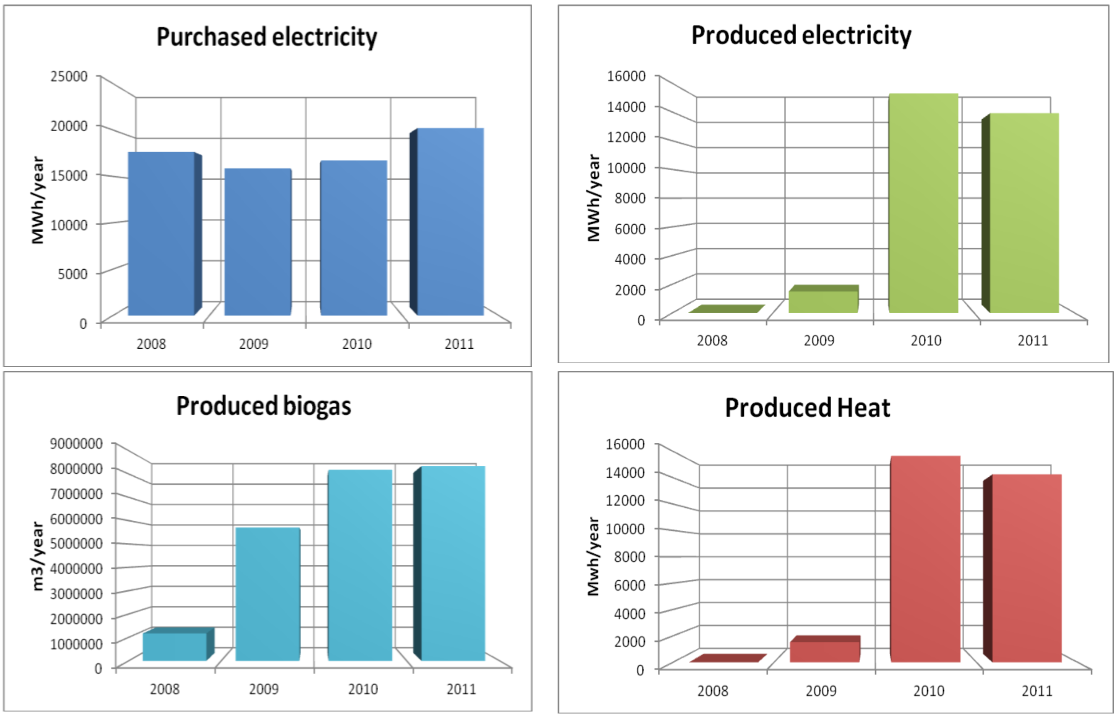


Figure 73: Quantitative trends in energy use and recovery in the Sofia WWTP

The prices of the water services in Sofia are determined according to the Act for regulation of the water supplying and sewerage services (ViK), in force since January 2005. The ViK includes the services of treatment and supply of water for drinking, industrial and other needs as well as of sewerage and treatment of wastewaters and stormwater.

Table 35: The current water tariffs in Sofia

Item	Price[40], BGN per m³
Domestic and equivalent commercial and budgetary consumers:	
Potable water supply	0.94
Sewerage	0.18
Wastewater treatment	0.28
Total (water supply, sewerage and wastewater treatment)	1.40
Industrial and other commercial consumers	
Potable water supply	0.94
Sewerage	
Pollution level I (up to 200 mg BOD/l)	0.28
Pollution level II (from 200 mg BOD/l up to 600 mg BOD/l)	0.36
Pollution level III (above 600 mg BOD/l)	0.42
Wastewater treatment	
Pollution level I (up to 200 mg BOD/l)	0.43
Pollution level II (from 200 mg BOD/l up to 400 mg BOD/l)	0.55
Pollution level III (above 600 mg BOD/l)	0.65
Total (water supply, sewerage and wastewater treatment)	
Pollution level I (up to 200 mg BOD/l)	1.65
Pollution level II (from 200 mg/l up to 400 mg BOD/l)	1.85
Pollution level III (above 600 mg BOD/l)	2.01

Under the terms of the Act the prices are controlled by the State Commission for energy and water management (SCEWM). The methodologies for price control, the principles of price formation reflecting the structure of the expenses, the order of making proposals for the prices and their approval are all defined by a Regulation of the Council of Ministers.

When regulating the prices of the ViK services the SCEWM is guided by the business plan of the operator, the economic well-grounded expenditures, the compliance among the prices for the different populated areas and the actual expenses, the social acceptability of the ViK prices, avoiding of cross subsidies among the consumers, encouraging the purposeful and effective planning of the investments in time, encouraging the water loss decrease, environment protection, prevention of misuse with monopoly and others.

The Act for regulation of water supply and sewerage services stipulates that the water for drinking and life needs is a basic life necessity, in the sense of the Act for social support.

According to the Act, the social acceptability of the water price is actual in these cases, when its value formed on the basis of the minimum monthly water consumption for drinking and life needs (2.8 m^3 per person) is not higher than 4% of the average monthly income of the households in the corresponding region.

The water tariff, set by SCEWM comprises of the: (i) price for the supply of potable water, (ii) price for the sewerage, and (iii) price for wastewater treatment. The tariffs presented in Table 10 have been used for Sofia as of February 2011 according to

[40] Prices without VAT (VAT is 20%); 1 Euro=1,95583 BGN

Decision No. Ц-04 on January 31, 2011 by the SCEWM. According to the same Decision, the social endurance of the water service is 5.90 BGL/m^3 for the city of Sofia; therefore the currently (2012) charged price of 1.40 BGL/m^3 by the water service is significantly below this limiting level.

Considering the requirements of the Water Supply and Sewerage Services Regulation Act, the water operator must develop a 5-year Business Plan, which has to be approved by the SCEWM. The water operator of Sofia is the private company "Sofiyska Voda" which in 2000 has signed a concession contract with the Municipality for 25 years period.

3.7 Preliminary identification of technologies to be assessed

Sofiyska Voda is currently implementing its investment programme which amounts to BGN 240 million for the period 2009-2013. The investment priorities of this programme are:

- Extension of the Water and Sewerage network, following the model settled in the City Development Plan of Sofia Municipality;
- Provision of high quality of services including the discharge and treatment of wastewater according to the EU standards;
- Well-developed sewerage infrastructure according to the EU standards;
- Implementation of the requirements regarding the quality standards for wastewater and sludge treatment; and
- Preservation and improvement of the environment.

A preliminary list of new technologies/innovations/practices that could be applied in the system of Sofia has been formed and is briefly presented below. The list will be finalized after the baseline eco-efficiency assessment and discussions with local stakeholders.

Water saving appliances

As already described in the previous chapters, there is good potential in Sofia for implementing water saving appliances. The EEA prompts that the reduction of water consumption in showers, dishwashers and washing machines is crucial for reducing the carbon footprint associated with water. Heating water at the spot, when the households are not supplied with central hot water, accounts for 25% of the total energy household consumption and for 89% of CO_2 emissions associated with water (Water Protocol).

With respect to this measure, attention should be paid on the so called Rebound Effect, i.e. an increase in consumption which may occur as an unintended side-effect of the introduction of policies, as well as of market and/or technology interventions aimed at environmental efficiency improvements (Maxwell et al., 2011).

Pressure management - Pressure Reducing Valves (PRV) combined with electricity generator

This technology combines the pressure control from chokes with electricity generation from hydroturbines, in order to generate pure power at no extra operating cost. The benefits of this technology are that it:

- Generates power
  - Supplies electricity to the plant
  - Sells electricity to the grid
- Has no operating cost
  - Replaces pressure chokes and valves
  - Utilizes excess pressure
- Reduces carbon footprint
  - Increases energy efficiency
  - Improves leakage management in water grids
- Creates a predictable production
  - Correlates with energy demand/price
- Utilizes existing plants
  - Has no added envirnmental impact

System for producing O_2 and H_2

Hydrogen plays an important role as a renewable energy source. The new concepts do not consider the wastewater treatment plants only as industrial facilities with certain potential to increase its energy efficiency, but also as producers of renewable energy and suppliers of hydrogen.

The WWTP has all the necessary requirements to produce hydrogen and oxygen, such as availability of space to obtain renewable energy, plenty of water and strategic geographical position. Hydrogen and oxygen can be produced via an electrolysis process with water after additional treatment. Hydrogen can be used for producing back energy or charging hybrid vehicles, whereas oxygen can be used for a more effective low aeration in the bioreactor.

Sludge Drying with Solar and Renewable Energy

Dried sludge is a natural fertilizer, which interacts with the environment less (if at all) than artificial fertilizers. Until recently, it was avoided in the WWTPs because of the high energy requirements for drying. However, innovative drying facilities using solar or thermal energy have already been identified. Their implementation in the WWTPs will solve the problem of the increasing amount of unwanted sludge and, at the same time, provide environmentally friendly soil fertilizer.

Phosphorus recovery from sludge

Contrary to the fossil fuels, which can be substituted by renewable energy sources, phosphorus is a non-renewable resource, which cannot be substituted. Considering that the WWTPs are a significant source for phosphorus recovery, the Case Study will also focus on the assessment of the eco-efficiency improvement, resulting from the implementation of new technologies for phosphorus recovery from sludge.

Low energy aeration

Considering that the highest amount of energy in a WWTP is consumed for the aeration of the bioreactors, measures towards reducing it will be apparently eco-efficient. A new generation of low-energy aerators is available in the market.

Reducing sludge generation

Nowadays, the classical wastewater treatment is being replaced by new technologies, which produce less or even a negligible small quantity of sludge. Bearing in mind that half of the operational costs of a WWTP are for sludge treatment, the implementation of such a technology will reduce considerably the required resources in the wastewater treatment processes.

4 Concluding remarks

This report presents the results of a comprehensive system mapping of the urban water system in the Canton of Zurich and in the city of Sofia. These form the basis for the elaboration of a set of meso-level indicators to quantify the eco-efficiency of the whole investigated system, which will be performed in the next steps of the project.

4.1 Concluding remarks for the case study of Zurich

The mapping of the system includes the technical descriptions of the relevant stages of the water supply chain in the commune Waedenswil, i.e the water supply side, the water use (domestic and non-domestic) and the waste water discharge system. Relevant contacts with the stakeholders groups were established during the mapping of the system. Part of the dataset had already been developed since part of the data is public; the rest of the data were provided by the stakeholders. In addition, site visits to most of the important installations were done.

With regard to the mapping of the SMEs, only a few among the 190+ companies could be visited and analysed in deep. In the next steps of the Project, it has to be discussed how the non-domestic users as a whole can be included in the analysis.

An analysis of the interactions between the actors was performed, accompanied by a preliminary identification of relevant environmental impact indicators and indicators for the economic benefit and the costs.

4.2 Concluding remarks for the case study of Sofia

During the first year of the Case Study development, work undertaken was directed towards: i) mapping of the system boundaries and system's meso-level; ii) data collection and iii) preparation of the next project phases, e.g. clarifying the terminology and the methodology.

In principal, data collection in Bulgaria is not an easy task, because in most cases data are not publicly available. To that end, UACEG signed protocols of cooperation with the most important actors. The dataset collected so far facilitated the mapping of the system boundaries. This provided a solid base for the calculation of the environmental indicators and the Total Value Added in the selected stages of the system.

The survey about non-domestic users revealed that in most enterprises in Sofia the information about the water use could not be obtained because there is lack of measurements. Only one out of five visited factories have sufficient data, which will allow estimation of its eco-efficiency. At this stage of understanding, two approaches seem to be applicable for non-domestic users: 1) estimating the eco-efficiency of one single industrial user ("Aroma" AD); 2) estimating eco-efficiency of the non-domestic users as a multitude.

There are several issues, which have to be clarified in the next Project stages. Among them are, the most significant are the:

a. Selection of a representative year as the baseline scenario. The system is dynamic and it is modified every year while its performance depends on different factors – climate, social, economic. In case of consecutive years with no significant modifications in the system, the average performance will be accounted for. However, a solution must be found for the case that significant modifications are observed.

b. Assessment of the influence of a new technology on the system. This is important as the corresponding systems are quite complex, and hence the impacts from the introduction of new technologies cannot be studied without a simulation model of the system performance in different circumstances.

5 References

A. Bello-Dambatta, Z. Kapelan, D. Butler, E. Oertlé, C.Hugi , Z. Jelinkova, N. Becker, R. Hochstrat, E. Rozos, C. Makropoulos and T. Wintgens (2011): Work Package: Urban Water Demand Management. Milestone: Priorities of Current and Emerging Water Demand Management Technologies and Approaches. Internal Report TRUST Project, not published.

AWEL & Basler & Hofmann AG (2007): Massnahmenblätter – Einzugsgebiet Furtbach. http://www.awel.zh.ch/internet/baudirektion/awel/de/wasserwirtschaft/massnahmenplan/furtbach.html accessed: 15.02.2012

AWEL & Ernst Basler + Partner (2002a): Massnahmenblätter – Einzugsgebiet der Glatt. http://www.awel.zh.ch/internet/baudirektion/awel/de/wasserwirtschaft/massnahmenplan/glatt.html accessed 15.02.2012

AWEL & Ernst Basler + Partner (2002b): Massnahmenplan Wasser Kurzfassung. http://www.awel.zh.ch/internet/baudirektion/awel/de/wasserwirtschaft/massnahmenplan/_jcr_content/contentPar/downloadlist_1283409115977/downloaditems/schlussbericht_phase.spooler.download.1284733457738.pdf/Schlussbericht_Phase1_Massnahmenplan+Wasser_Kurzfassung.pdf accessed 08.02.2012

AWEL & Ernst Basler + Partner (2005): Massnahmenblätter – Einzugsgebiet der Limmat und Reppisch http://www.awel.zh.ch/internet/baudirektion/awel/de/wasserwirtschaft/massnahmenplan/limmat_reppisch.html accessed 15.02.2012

AWEL (2009): Finanzmanagement in der Siedlungswasserwirtschaft Abwasser und Wasserversorgung. Kurzbericht zum Normalhaushalt 2008

AWEL by DemoSCOPE (2011): Imageanalyse Trinkwasser: http://www.awel.zh.ch/internet/baudirektion/awel/de/wasserwirtschaft/wasserversorgung/imageanalyse.html; assessed 10.02.2012

BAFU (2012): Drinking water. http://www.bafu.admin.ch/wassernutzung/02792/02796/index.html?lang=en accessed 08.02.2012

DVGW W217: Technische Regel Arbeitsblatt W217: Flockung in der Wasseraufbereitung – Teil 1: Grundlagen, DVGW Regelwerk, September 1987; ISSN 0176-3504

DVGW W213-3: Technische Regel Arbeitsblatt W213-3: Filtrationsverfahren zur Partikelentfernung; Teil 3: Schnellfiltration, DVGW Regelwerk, Juni 2005; ISSN 0176-3504

DVGW W225: Technische Regel Arbeitsblatt W225: Ozon in der Wasseraufbereitung, DVGW Regelwerk, Mai 2002; ISSN 0176-3490

DVGW W239: Technische Regel Arbeitsblatt W239: Planung und Betrieb von Aktivkohlefiltern für die Wasseraufbereitung, DVGW Regelwerk, Juli 1991; ISSN 0176-3504

DVGW W240: Technische Regel Arbeitsblatt W240: Beurteilung von Aktivkohlen zur Wasseraufbereitung, DVGW Regelwerk, Dezember 1987; ISSN 0176-3504

DVGW W294: Technische Regel Arbeitsblatt W294: UV-Desinfektionsanlagen für die Trinkwasserversorgung – Anforderungen und Prüfung, DVGW Regelwerk, Oktober 1997; ISSN 0176-3490

Eidgenössisches Volkswirtschaftsdepartement, Preisüberwachung (2006): Gebührenvergleich für Wasser, Abwasser und Abfall für die 30 grössten Städte der Schweiz. www.preisueberwacher.admin.ch accessed 15.02.2012

Federal Statistical Office / Bundesamt für Statistik (2011): Bevölkerungsstand http://www.bfs.admin.ch/bfs/portal/de/index/themen/01/02/blank/key/bevoelkerungsstand/02.html accessed 08.02.2012

http://www.awel.zh.ch/internet/baudirektion/awel/de/wasserwirtschaft/massnahmenplan/greifensee.html accessed: 15.02.2012

Kaspar, H., Winter, D., AWEL & Basler & Hofmann AG (2006): Massnahmenblätter – Einzugsgebiet Greifensee

Koehler, A. (2008): Water use in LCA: managing the planet's freshwater resources, In: Int. J Life Cycle Assess 13, p. 451-455

Lichev, A., Modeling of the sewerage system – a new approach for successful investment planning, Sofiyska voda

Maxwell, D., Owen, P., McAndrew. L, Muehmel, K., Neubauer, A., Addressing the Rebound Effect, a report for the European Commission DG Environment, 26 April 2011

National Statistical Institute, Regional Statistical Office Sofia, (2009) Sofia in Figures

Ribarova, I., Sharing water under conditions of scarcity and stress, in "Water stress mitigation: the Aquastress case studies", ed. D. Assimacopoulos, 2009

Schaltegger S and Burritt R. 2000. Contemporary environmental accounting. Issues, concepts and practice. Greenleaf Publishing, Sheffield

Schaltegger S and Sturm A. 1989. Oekologieinduzierte Entscheidungsprobleme des Managements. Ansatzpunkte zur Ausgestaltung von Instrumenten. WWZ Discussion Paper Nr 8914. Wirtschaftswissenschaftliches Zentrum der Universität Basel, Basel

Schaltegger S and Sturm A. 1990. Ökologische Rationalität: Ansatzpunkte zur Ausgestaltung von ökologieorientierten Managementinstrumenten. Die Unternehmung 4: 273-90

Sofiyska voda, Serving customers, Delivering water and wastewater services in Sofia and its surroundings, leaflet, 2007

Sofiyska voda, Strategy for sludge management in Sofia WWTP till 2025. report, 2011

Stadt Waedenswil (2010a): Tarifordnung der Wasserversorgung.

Stadt Waedenswil (2010b): Tarife für die Siedlungsentwässerung (ehemals Abwassergebühren).

Stadt Waedenswil (2012): Rechnung 2011. Mit NPM Berichten.

Stadtrat Waedenswil (2012): Geschäftsbericht des Stadtrates Waedenswil 2011.

State Commission for energy and water management (SCEWM), http://www.dker.bg/

Tsanov E., I. Ribarova, D. Alichkov (2011). Reducing the water consumption in the households, Facilities, 12 (40), 22-25 (in Bulgarian)

Van de Worp, J. (2002): Sustainable water management in industry in: Water Recycling and Resource Recovery in Industry, p. 3-28

Zweckverband (2012): Jahresrechnung 2011.

6 Glossary

Stakeholder

Stage-relevant actors who can affect or be affected by the water system.

Eco-efficiency

Eco-efficiency refers to the delivery of competitively-priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life-cycle to a level at least in line with the earth's estimated carrying capacity.

Critical aspects of eco-efficiency are: (a) a reduction in the material intensity of goods or services; (b) a reduction in the energy intensity of goods or services; (c) reduced dispersion of toxic materials; (d) improved recyclability; (e) maximum use of renewable resources; (f) greater durability of products; (g) increased service intensity of goods and services.

In short, the term refers to creating more value with less impact or doing more with less. **Source: WBCSD, 2000**

Micro-level (eco-efficiency) assessment

It concerns the measurement of (economic and environmental) performance for an individual product, service, process or company. It is considered an important tool for tracking and improving performance at the firm level or for comparing the eco-efficiency of similar products and processes. **Sources: Reid and Miedzinski, 2008, Saling et al., 2002; Michelsen, 2006; Huppes, 2007**

Macro-level (eco-efficiency) assessment

Macro-level analyses refer to the national level as a whole, focusing on cycles of activity that economies go through and economic sectors of a country's economy. Macro-level eco-efficiency assessments are used to offer evidence of general trends towards the decoupling (relative or absolute) of economic growth from environmental deterioration and resource depletion. These assessments are most often based on aggregate data from the various sectors and individual companies. **Sources: Sloman and Hinde, 2007; WBCSD, 2000**

Meso-level (eco-efficiency) assessment

The meso-level involves the coupling of individual technologies and groups of actors, resulting in interdependencies and regimes (Schenk, 2006). The meso-level is wedged between the micro- and macro- levels and can refer to a sector, supply chain, region, product/service system.

Coupling should not be confused with aggregation, as meso-level assessment focuses on the dynamic behaviour of the interdependencies of individual system elements, rather than on their aggregation (it is often the case that interdependencies of individual elements result in a complex behavior of the overall system). Meso-level assessments are associated with so-called systems-analysis, and depend on data acquired from both bottom-up and top-down approaches. **Sources: Schenk, 2006; Reid and Miedzinski, 2008; Dopfer et al., 2004; Battjes 1999**

Eco-efficiency metrics

Sets of indicators to measure the eco-efficiency performance of products, services, businesses, systems, etc. By definition, eco-efficiency metrics focus on the environmental and the economic component (i.e. the social component is not included – Figure 1).

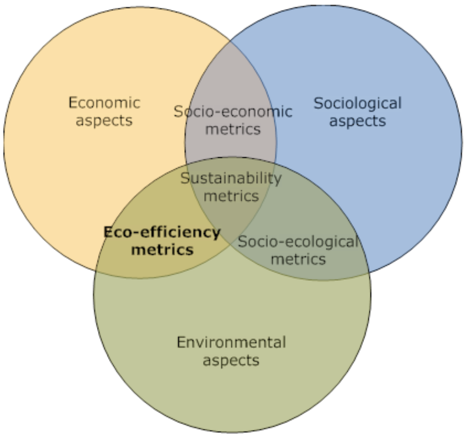


Figure 74: Sustainability and eco-efficiency metrics

Eco-efficiency indicators

Eco-efficiency indicators link environmental and economic performance. They are expressed as the ratio of (economic) output per environmental influence.

At the company level, eco-efficiency indicators can be used to provide a measure of a business's resource efficiency (i.e. how efficiently resources such as energy, water and key materials are transformed into saleable products). **Sources: UN/ESCAP, 2009; Ellipson AG., 2001; WBCSD**

Value chain

At the firm level, the term value chain refers to the chain of activities for a firm operating in a specific industry. This sequence refers to all activities concerning the way that that a firm undertakes to create value (primary activities), but also to additional activities (support activities), such as marketing, sales and service.

At the **industry** level, the term value chain refers to a string of companies or players working together to satisfy market demands for a particular product. The term is a superset of the **"supply chain"**. The latter refers to the sequence of steps, often done in different firms and/or locations, and needed to produce a final good, starting with processing of raw materials, continuing with production, and ending with final assembly and distribution. Otherwise stated, the term "value chain" concerns the network of organisations that are involved, through upstream and downstream linkages, in the different processes and activities, in order to produce value in the form of products and services in the hand of the ultimate consumer. **Sources: Porter, 1985; Michelsen et.al., 2006**

Stages and water use stage

In the EcoWater concept, the distinct stages refer to the water supply side (abstraction, storage, treatment, and distribution), water use stage, and the wastewater side (collection, treatment, disposal or re-use).

The "water use stage" in particular refers to the final use of the water provided, either as an intermediate good in a production process (agriculture and industry) or as a final good, which provides direct utility to consumers (households).

(Total) Economic value of water

The Total Economic Value of water comprises both use and non-use values.

Use values relate to current or future uses of a resource. Direct use values may be 'consumptive' (e.g. irrigation for agriculture) or 'non-consumptive' (e.g. many water-based recreational activities), while indirect use values encompass the role of water in the provision of key ecosystem services (e.g. provision of habitats, flood protection, etc.). Non-use values are not related to current or future use but are derived from knowledge that natural resources continue to exist (existence value), or are available for others to use now (altruistic value) or in the future (bequest value). **Source: CCME, 2010**

(Economic) Value of water to users

The assessment of the economic component of eco-efficiency indicators in the EcoWater Case Studies implies the assessment of the economic value of water to users, which according to what is described above, is a direct use value, associated with consumptive use (agriculture, industry, urban).

Typically, for industrial and agricultural uses, the economic value to users is at least as large as the marginal value of product. For domestic use, the willingness to pay for water represents a lower bound on its value, as there is additional value to the water. **Sources: Rogers et al., 1997**

Residual value method

The residual value method is often used for practical, non-market valuation of producers' or intermediate goods. The method is one of the most frequently used to approximate the net rent or value marginal product of a non-priced (or under-priced) productive input, by subtracting all other estimated costs of production from the total forecasted value of output. The remaining (residual) value is assigned to the non-priced input (water). **Source: Young, 2005**

Watershed management

Integrated management of water in the catchment area – watershed management for short – is an intersectoral approach to management of water resources, water bodies and water infrastructures. It is based on long-term goals and proceeds in a continuous cycle of planning, implementation and monitoring processes. The reference area is the watershed. **Source: Water Agenda 21 (2011)**

Willingness-to-pay

The amount an individual is willing to pay to acquire some good or service. This amount can be elicited from the individual's stated or revealed preferences. **Source: OECD, Sustainable Development's Glossary**