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Description of value chains for industrial water use

IVL Swedish Environmental Research Institute

Authors: MITA, DELTARES, IVL, DHI
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IVL Swedish Environmental Research Institute Ltd.,
P.O Box 210 60, S-100 31 Stockholm, Sweden
Phone: +46-8-598 563 00 Fax: +46-8-598 563 90
www.ivl.se

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Persons from IVL involved in EcoWater were:

Åsa Nilsson
Sara Skenhall
Magnus Klingspor
Tomas Rydberg
Uwe Fortkamp
Felipe Oliveira
Lina Danielsson
Elisabeth Hallberg

Contact person: Åsa Nilsson asa.nilsson@ivl.se

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

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Description of value chains for industrial water use

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Abstract

The Deliverable 4.1 presents the results of the first phase of EcoWater Industrial Case Study 5 (Textile Industries in Biella Region in Italy), Case Study 6 (Cogeneration of thermal energy and electricity using water from the Rhine Channel in Netherlands), Case Study 7 (Dairy industry, Denmark) and Case Study 8 (Automotive industry Sweden. The development of all industrial cases followed the same overall methodology for the system mapping; an initial assessment of the system boundary followed by an identification and mapping of the water supply chain with mapping of both the water services and stages and the water uses in the industrial processes and description of existing technologies, value chain mapping and identification of relevant actors.

The methodologies developed for system mapping were applicable in the industrial Case Studies and it was possible to deal with challenges related to the system boundary, what was meant by meso-scale in the industrial cases and the complexity of the interaction between the water system and production system can be reduced. So in general the industry cases have identified the industrial sector level as the meso-scale level.

Up to now only the automotive case has set up their system in the SEAT model-while the other cases plan to do this by January 2013 with assistance from NTUA. This may be the time where options for reducing complexity can be further explored and systems streamlined.

As the document shows, there are still a few gaps in the description of the cases, which are still worked upon by the case leaders. This work will continue until the end of January when the SEAT model will be set up. In January, the phase B activities will continue in each of the cases with inventory of resource flows and stage inputs, which will be followed by assessment of environmental and economic indicators and considerations on normalization/aggregation of indicators. The result of this work will be reported in the Deliverable 4.2 by the end of year two of EcoWater.

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1 Introduction

All four industrial cases presented in this document followed the same overall methodology for the system mapping; an initial assessment of the system boundary followed by an identification and mapping of the water supply chain with mapping of both the water services and stages and the water uses in the industrial processes and description of existing technologies, value chain mapping and identification of relevant actors.

In developing the system mapping the three main methodological challenges were observed. Deciding on the **system boundary** was difficult, in particular for the dairy and automotive industry Case Studies (# 7 and # 8), as there was a need to include more than one industry to give a representative picture of the whole sector. These industries were not in the same basin and hence the water systems were not connected. The solution was to select the industries which were most representative from a sector perspective and then describe the water systems for each of the representative industries. A similar challenge was identified for the Textile case (Case Study # 5). There are more than 2,000 textile units, which are all in the same river basin. However, collecting data from 2,000 units would not be feasible. This has been solved by making the basin the system boundary and then selecting four representative textile production lines and four industries for data collection. The aim will be to aggregate data to represent all 2,000 industries in the same water system and at the same time have a representative picture of the sector.

Another methodological challenge related to the system boundary was to identify what **meso-scale** meant for the industrial Case Studies (was it the basin in which the industries were located or was it the industrial sector to which the industries belonged). As it will be seen from the descriptions in the cases in the document, much emphasis has been put on representativeness from a sector perspective. So in general the industry cases have identified the industrial sector level as the meso-scale level.

A final methodological challenge in the industrial cases has been to reduce the complexity of the water systems and the value chains. While intake and discharge of water in most cases are fairly simple, the interaction of the water system with the production system is not simple, as systems for reuse and recirculation of water are included in the raw material (milk), etc. This complexity will make the following phases of Case Study development even more challenging. Up to now, only the automotive case has set up their system in the SEAT model, while the other cases plan to do this by January 2013 with assistance from NTUA. This may be the time where options for reducing complexity can be further explored and systems streamlined.

As the document shows there are still a few gaps in the description of the cases, which are still worked upon by the case leaders. This work will continue until the end of January, when the SEAT model will be set up. In January, the phase B activities will continue in each of the cases with inventory of resource flows and stage inputs, which will be followed by assessment of environmental and economic indicators and considerations on normalization/aggregation of indicators. The result of this work will be reported in the Deliverable 4.2 by the end of year two of EcoWater.

The present document comprises a description of the four Case Studies (# 5, 6, 7 and 8) in chapters 2, 3, 4 and 5, respectively, each following the same structure. Chapter 6 concludes the results of the work with the industrial cases in phase A of EcoWater and chapter 7 includes a list of references used in developing the Case Studies. Finally, chapter 8 is a glossary of some of the main terms used in this document.

2 System mapping for Case Study #5: Biella, Textile industry.

2.1 Objectives of the Case Study

In Case Study 5, there is a large number of factories which are conducting textile processing, called "wet processes", such as wool washing, dyeing and finishing. For this purpose, the Biella textile industry utilises a large amount of high quality water. In some cases, the water technology is still the same as when the industries were established in the previous century, but in some others it has been refurbished and is technologically modern.

Being a region rich of water resources, the withdrawal of fresh water is not perceived as an environmental problem by the industrial managers. However, there is an insufficient knowledge about water resources sustainable management. One of the objectives of this Project is also to contribute to sustainable water resource management.

In the Case Study, the water provision costs have increased during the last decades and today are considered as a big economic problem (except for the cases of using water from private wells). The water distribution system is managed by the municipalities' consortia. The increased price of water generates additional crisis in the small textile factories and many of these have actually closed their production in the recent years.

The objective of the Case Study is also to provide knowledge on new technologies in the textile industry, which may improve the quality of the industrial wastewater released in the environment. In addition, a positive side effect could be to reduce the quantity of sludge for incineration and increase the quality of sludge for agriculture.

2.2 Overview of the Case Study area / industry

Location and general settings

Biella Province (913.72 km²) is located in the northern East part of Piemonte and is composed by 82 communities, with 187,314 population (205 hab/Km²), The main town is Biella; the second largest town, in terms of inhabitants, is Cossato. In Figure 1, the Region Piemonte is marked with green and the location of Biella is marked with a red bullet. The Biella province is presented at the right side

Figure 1: Case Study 5 location in Piemonte Region

Figure 2: The Biella province - mountains and plane

The Biella Mountains are located in the northern part of the province and are characterized by steep slopes and torrential grooves engraved with very narrow sections, which indicate the particular geomorphologic evolution of the area.

The southern part is composed of alluvial deposits mostly from Pleistocene and just a little Pliocene's deposits in the transition zone between mountains and plane.

Geology

From a geological point of view, the Biella's Alps mountain range is divided in a proper Alpine and in pre-alpine zone, separated by a tectonic line (Insubrica line) that is the biggest tectonic line of the Alps, lying from Piemonte up to Austria (Figure 3). The mountains and hills to the south-east of this line are to be considered geologically foothills, while the other side is part of the main body of the Alps.

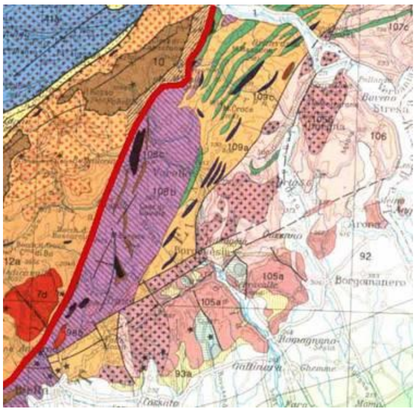


Figure 3: Insubrica line and Cervo Valley Pluton

This fracture marks a distinct change in morphology between the low hills of Biella and Sesia Valley, and the mid-mountain area.

These rocks are metamorphic often with schistose structure. Very interesting is the Cervo Valley Pluton (Figure 3, in red), with excellent quality granites, which are also quarried for decorative uses.

Hydrography

The hydrography of Biella province falls almost entirely in the two basins of Cervo and Sessera, both tributaries of Sesia River that belong to the Po river basin; the longest Italian river that creates a great plain, with important industrial activities and intensive agriculture. It is one of the most fertile areas in Europe, surrounded by the Alps which are acting as barriers, and therefore it delimitates the river basin with very high altitudes.

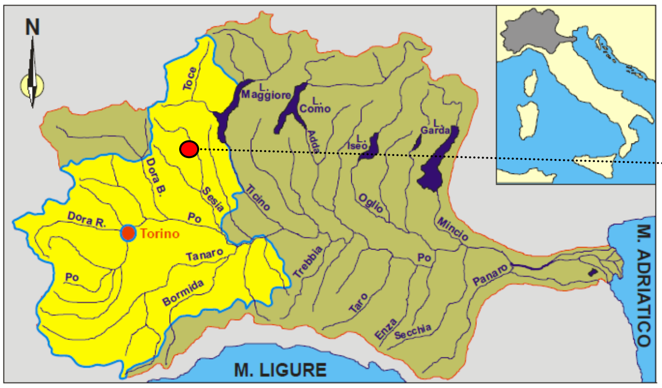


Figure 4: Po river basin (Piemonte region in yellow)

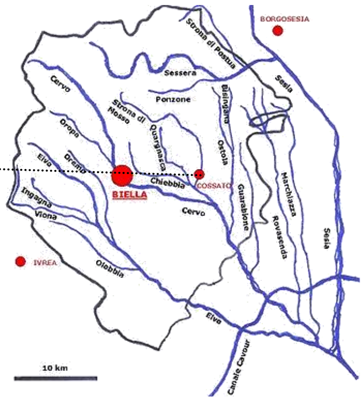


Figure 5: Biella Province and Cervo river basin

Climate

Biella's climate is continental, but it has a diversified climate due to the presence of mountains and plains. The winter is cold and wet, with snowfall and presence of fog in the lowlands. Spring and autumn are the rainy seasons, especially during May, October and November. Summer is often hot and muggy, mainly in the plain, more ventilated in hilly and mountainous areas. This season also has very frequent thunderstorms. In the plains the average annual temperature range is 12-13°C.

Flora and Fauna

The moist, cool climate over most of the Province supports a very dense vegetation cover, especially in medium and low valleys. We can distinguish several groups to "horizons"; a hilly area mostly covered with chestnuts and acacias, the mountains with pine and larch. In the plain, the agricultural activities are located, mainly devoted to cereal (rise, corn).

There is an interesting natural area, the “Baraggia”, which is a sort of savannah. It is composed of Highlands that are the residual of ancient and vast plains of the fluvial deposits accumulated from 750,000 to 135,000 years ago (Middle Pleistocene).

Figure 6: The middle-Pleistocene highland “Baraggia”

The fauna is typical of mountain/hills regions. Among the mammals that are present today, there are species notable for their wide dissemination, i.e. red foxes, hares, squirrels, dormouse, weasels, martens, as well as marmots and ermines. A native of this area is the chamois (*Rupicapra rupicapra*), especially in the Upper Cervo and Sessera Valleys. The Italian name of “deer” is “cervo”; that gives the name to Cervo River.

Water Resources and Major Uses

The natural surface streams of the area are very important and there are also several channels used for irrigation of rice culture, for industry and public distribution of drinking water. With a high population, the groundwater resources are not sufficient to cover the total needs for public water distribution. The streams of the Biellese region are often causing floods and, both in recent and past times, they have resulted in very big damages to industrial and private buildings and killed people too.

With regard to the groundwater resources, Biella can be divided into the mountainous area and the plain zone. Focusing on the former, the rains feed the shallow aquifer that lies just beneath the recent deposits with variable thickness from a few centimetres to several meters or some tens of meters, in the case of deposits of glacial origin. In the plain zone, there are both shallow and deep aquifers, which have their recharge area in the foothills.

Major uses and off-takes of water in the Biella area, mainly for irrigation purposes, are managed by the Consorzio di Bonifica della Baraggia Vercellese, which manages the network of irrigation channels located in Vercelli. For drinking water usage, the reservoirs of Mongrando (Ingagna) and Masserano (Ostola) are managed by the Water Consortium of Biella and Vercelli. Industrial users in the area are listed as major withdrawals; significant is the industrial aqueduct companies of Vallestrona that manage the Camandona multi-purpose reservoir (industrial and irrigation).

With regard to the supply of process water, it is to be noted that Biella, although characterized by a general profile of relative abundance of water resources, has in some specific contexts shortage of supply of special seasonal rain.

Socio-economy aspects of the textile district

The Biella textile district is the centre of the largest and most qualified production of wool fabrics for clothing and fine fibres (cashmere, alpaca, mohair), and produces carded or combed yarns to wool and wool blends for weaving and knitting. There are more than 2,000 production units with a total of 28,000 employees and a turnover of 3 million Euros. The industrial system Biellese is composed of a large number of mid-sized companies.

2.3 Methodology

Usually, the water is drawn from wells that draw from shallow aquifer, from surface water bodies, or aqueducts.

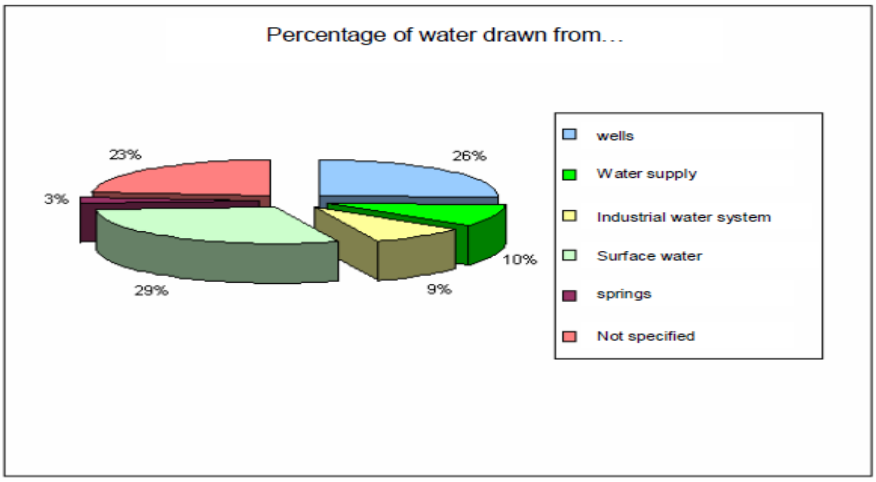


Figure 7: The consumption of water resources by the sector

Water consumption is extremely high, especially for the dyeing and finishing companies.

In a hackling enterprise, the phase that mainly uses water is the washing phase, which also influences the quality of the surface water, because of the use of significant amounts of surfactants.

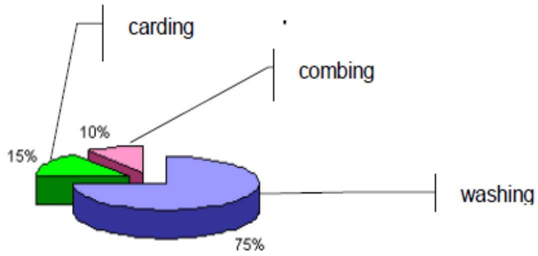


Figure 8: Water consumption in a hackling industry

Water consumption in the dyeing department is also high, since water is the medium through which the dyeing process takes place: it is water that is dissolving and dispersing dyes, chemicals and auxiliaries for dyeing and it is precisely through the water that is the slope of the dye on the fibre.

The main water consumption source in a mill are the dyeing and finishing steps, whereas spinning and weaving have significantly lower water consumption.

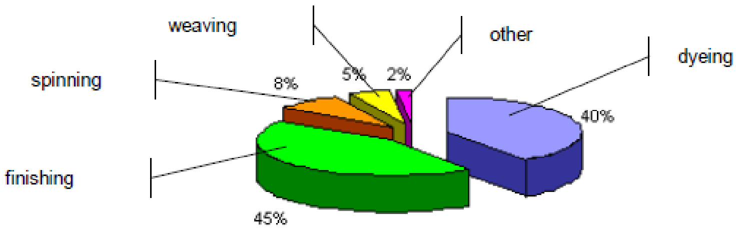


Figure 9: Water consumption in wool mill

Water use is significant even in the finishing department, mainly due to the different washing processes. Further processes that affect consumption and water quality treatment are the bleaching, carbonizing, dry cleaning and the blank, where water is used as a means in the wet scrubber for the removal of pollutants and smell.

Wastewater characterization and treatment

Within the BIELLESE textile district, about one hundred (100) factories conduct ”wet” textile processing, such as wool washing, dyeing and finishing.

The wastewater from the textile district is estimated at about 15-20 million m³/year, which is discharged to the purification systems, to surface waters or to the public sewer systems without final purification. In the case of companies owning wastewater treatment facilities, the process varies from simple pre-treatment and discharge to public service removal and treatment systems, to complete on-site treatment of sewage (which complies with limits for discharge to surface water bodies). In some cases, the treatment allows for recovery and recycling in the production process.

Several studies and a continuous monitoring of the water river parameters is carried by the ARPA (Regional Agency for Environmental Protection of Piedmont that works for the prevention, reduction and elimination of environmental pollution). The wastewater generated from the textile industries is considered to be a problem for the life in the rivers (fauna and flora), but also for the contamination of groundwater

In the province of Biella, the C.O.R.D.A.R. S.p.A. consortium currently operates three WWTPs that treat the most significant quantity of urban wastewater, and a considerable fraction of the wastewater generated from the textile industry (about 6 million cubic meters / year). Industrial discharges to a CORDAR collector or a public sewer connected to a sewage treatment plant of CORDAR are allowed within the limits described in Table 1. These limits are fixed by CORDAR, and established for different types of textile processes.

Table 1: Quality of treated water coming out after depuration[1].

Parameters	Limits of acceptability for the water to be treated	
	Discharges of industrial waste water	**Greasy wool washing industries**
SST mg/l (Total Suspended Solids)	<500	<10000
COD mg/l (Chemical Oxygen Demand)*	<5000	<12000
BODs mg/l	<3000	<8000
Surfactants	<80	<300
Chlorides	<3000	<3000
Sulfates	<3000	<3000

The three (3) plants of the CORDAR Consortium, Cossato, Biella North and Massazza have a total capacity of 650,000 population equivalents. Most of the wastewater discharging into CORDAR treatment plant is of textile type: dyeing, combing, wool mills, finishing, spinning and knitting mills. Table 2 shows the characteristics of industrial wastewater (type, flow, pollution loads) treated in the three treatment plants of the consortium (year 2001).

[1] The Italian law allows the discharge of water sewage systems, whose COD is not greater than 500 mg / L

Table 2: The characteristics of the wastewater treated in the three (3) WWTPs of the CORDAR Consortium per textile industry

Type of textile industry	WWTP Cossato	WWTP Massazza	WWTP Biella Nord
Textile finishing and dyeing	52%	70%	79%
Woolen mill	35%	3%	3%
Combing	10%	11%	15%
Spinning	1%	12%	--
Textile WW (total)	98%	96%	97%
Others	2%	4%	3%
Medium flow (m^3/h)	2.500	700	400
COD (Kg/y)	2.450.000	293.000	695.000
TN (kg/y)	88.000	9.000	2.200
SST (kg/y)	615.000	100.000	135.000

Textile industry processes

The full cycle of wool processing is divided into the washing, carding and combing, spinning and weaving, and finishing operations stages.

- *Washing*: Impurities present on the fleece of the sheep at the time of shearing are eliminated;
- *Combing*: The working cycle of the combing concerns the processing of greasy wool in combed sliver and is placed at the beginning of the textile production chain, making the raw wool available for the subsequent processes. The combing process is a series of activities; the resulting product is the combed wool or wool tops
- *Spinning*: The purpose of spinning is to confer consistency to the wick and to transform an initially disordered mass of textile fibres in an assembly of great length (yarn);
- *Weaving*: A fabric is formed from two or more sets of yarns (warp and weft), crossing each other perpendicularly; and
- *Finishing*: The generic term of finishing operations indicates all chemical, physical and mechanical properties that are made on the tissues, in order to impart them a surface suitable for subsequent uses.

The process flow is presented in Figure 10 below.

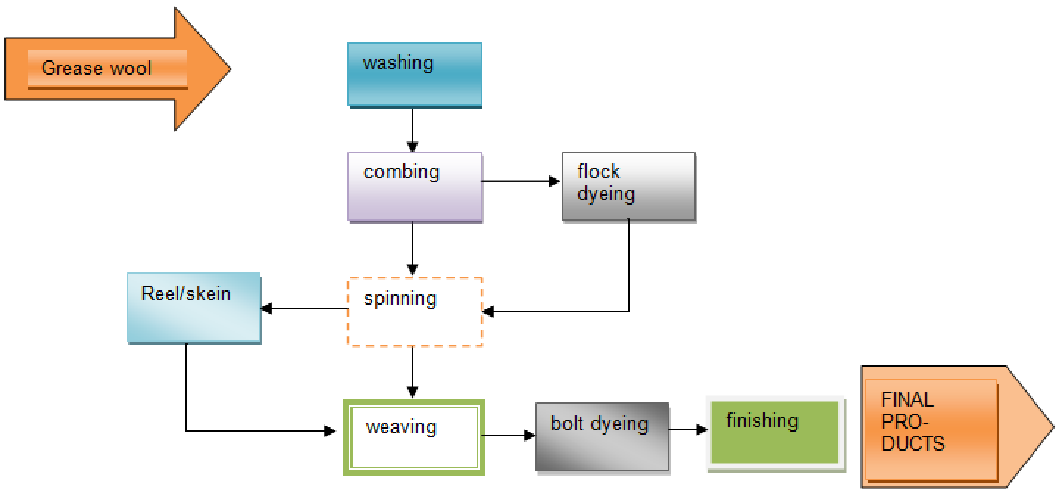


Figure 10: Textile processes

Although there are more than 2,000 textile units in Biella, they fall into a few main types of textile production lines. The first is from the animal fleece to flocks, the second is from the thread up to the fabric, the third is dyeing that covers both flocks either on thread or fabric too. It is thus possible to describe the 2,000 textile units by considering 3 typical production lines/types as outlined in Figures 11-13, which also show the textile industries selected as representative for EcoWater.

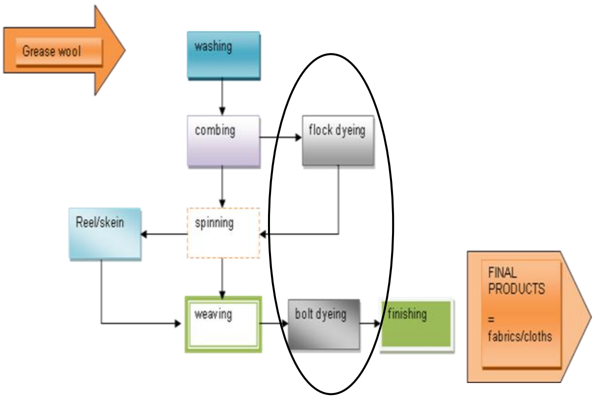


Figure 11: Production line of the Tintoria di Quaregna (TQ) industry for the dyeing type of textile productions in Biella

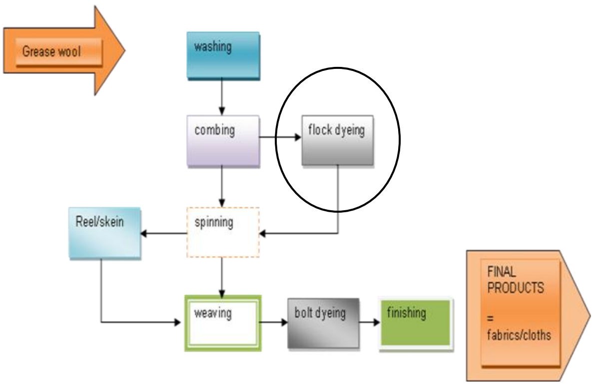


Figure 12: Production line of the Tintoria di Mancini (TM) industry for the dyeing type of textile productions in Biella

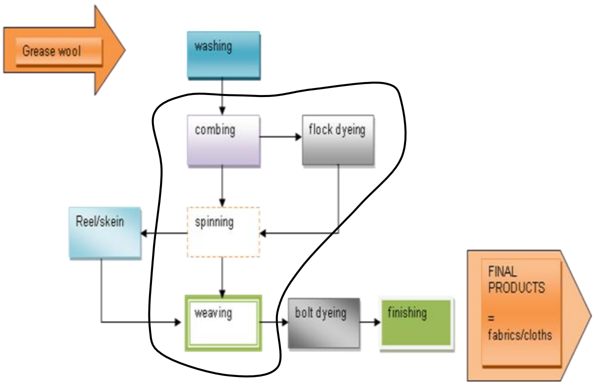


Figure 13: Production line of the Pettinatura Filidea (PF) industry for the Hackling type of textile productions in Biella"

2.4 Water Supply Chain Mapping

2.4.1 System boundary and mapping of the water processes and description of stages

The system boundary is the Biella region. The water source for the industries is either public water supply or own wells, and, in the case of wastewater, the presence/absence of a domestic wastewater treatment system.

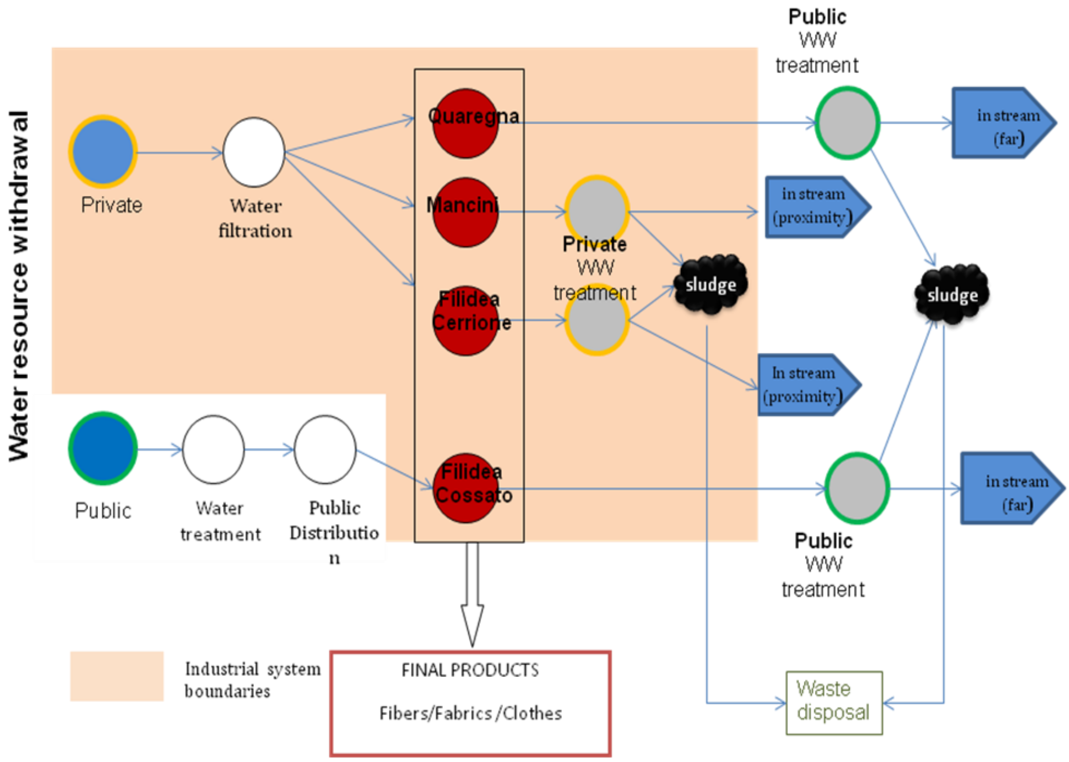


Figure 14: Water system and the typical production lines (system boundaries are marked in pink colour)

2.4.2 Process map description

Water supply can have different origins (either surface water or groundwater). According to Figure 14, some industries are supplied with water from the public distribution system (blue in green circle), after the municipal water treatment and distribution. However, most of the industries have their own wells or withdraw water from streams that flow beside the industrial site along their terrains of property (blue in orange circle). At the end of the textile processes, there are two different situations for water:

i. The industry owns a wastewater treatment plant and releases clean water into the near stream;

ii. The generated wastewater goes into the sewerage network (consortium system CORDAR), is treated in the public WWTP, and subsequently released into the river (sometimes quite much low-stream considering the industries locations).

With regard to the sludge produced, only one final destination exists (i.e. waste disposal). The use of the sludge in agriculture could be considered as an alternative only for the residue coming from innovative methods of dyeing, which will be described in the following chapters.

2.4.3 Mapping of industrial processes

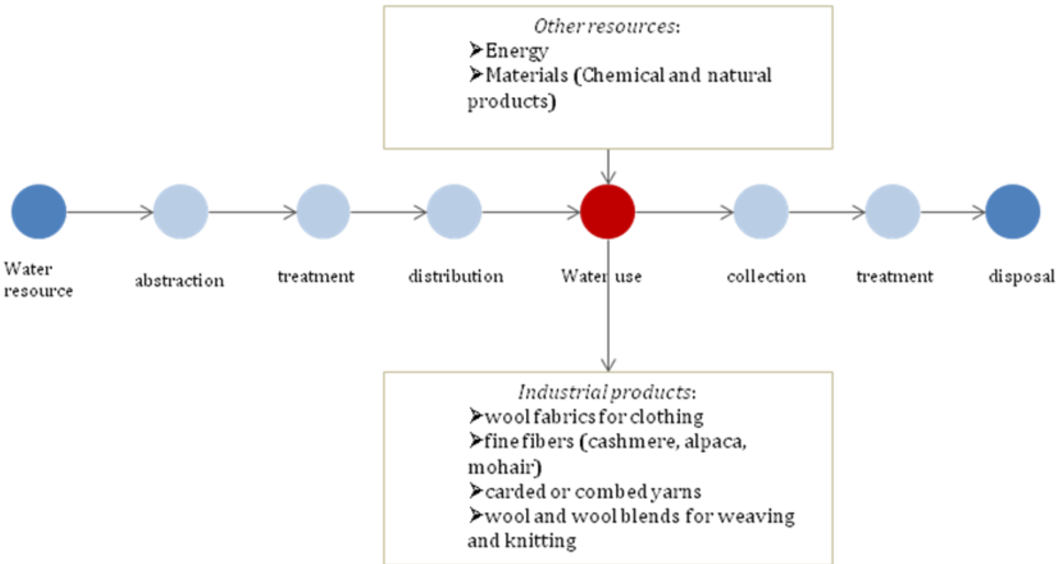


Figure 15: The water supply chain of the system

2.4.4 Description of existing technologies

The description of the technologies included in each process of the system, as well as the problems associated with these, are in progress.

a) Tintoria di Quaregna (dyeing industry)

The buildings of the industry are located along the water stream, and hence 100% of water supply takes place through surface water withdrawal. The quality of the water is good and has a very low pH. Water treatment includes a simple sand filtration; the last sieve gets to 5 μm. On the industrial terrain, there are wells owned by the direction of the dyeing plant, but these are not exploited because the quantity of stream is sufficient. The water supply chain of Tintoria Quaregna is illustrated in Figure 16.

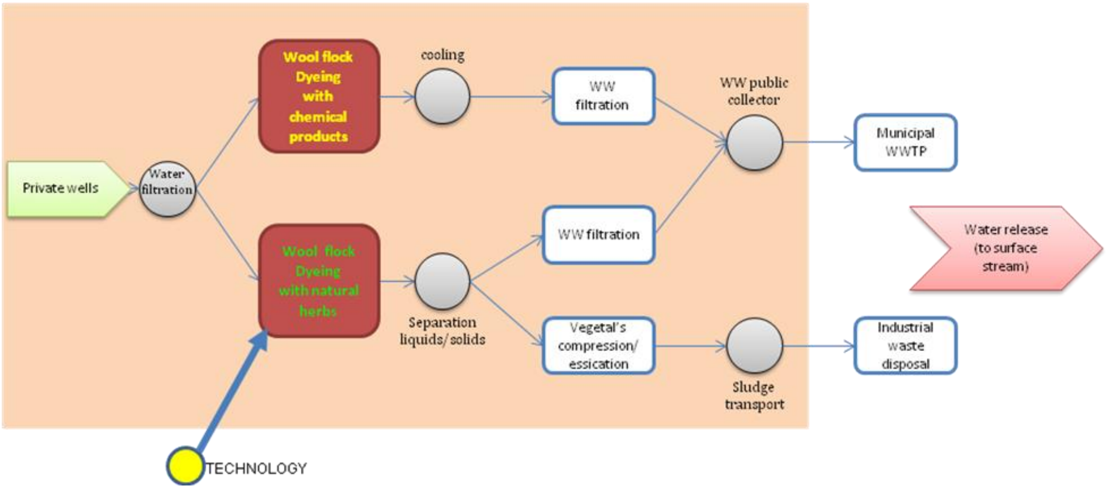


Figure 16: The water supply system of Tintoria Quaregna

Water costs are fixed by a regional grant; the annual costs are 2,000-3,000 Euros. Water losses during processing are not quantifiable because only the released wastewater is measured. Annual withdrawals are approximately 50,000 m³, which correspond to the production of approximately 500,000 kg of finished product.

During the activities, heat is produced, which is recovered for further stages of the technological process. Water processing is used for:

- Cleaning the fiber from oils;
- Rebalancing the pH and removing any residues of previous treatments; and
- Dyeing (coloring); it starts at low temperature, then is increased and gradually is introduced to the dyeing products.

Then comes the cooling phase, where color is fixed and must be done slowly (water is also used for cooling water). In total, there are about 6-7 water withdrawals for the various phases.

With regard to the wastewater quality, Tintoria di Quaregna runs natural dyes, using an infusion of herbs, instead of chemical compounds, in contrast to the classic chemical residues produced by a traditional dyeing industry. This infusion, due to its concentration could be polluting for the environment, sometimes can also be toxic (as some herbs are), but definitely no stranger to the natural environment. The point is the concentration.

It is interesting for the Tintoria di Quaregna to move further into research knowledge in this field of natural herbs. Actually, they just provide a filtration of the solid residues before the release of wastewater into the sewerage system. The net system is managed by CORDAR and it costs 0.90€/m³ of water. Afterwards, the net system is mixing urban and industrial wastewater; the total volume of wastewater goes to the WWTP.

From the point of view of the dyeing owners, this kind of treatment is too extreme and not needed, but up today it is compulsory due to the lack of legislation (there is no distinction among the different types of products used for dyeing), so is not classifiable and considered as traditional dyeing.

KEY POINT: Increase the dialogue with public services to optimize and ecologize the water treatment considering the real needs of treatment and diversifying practices in chemistry (i.e. the wastewater generated by Tintoria di Quaregna is a sort of "tea", with very high concentration of herbs).

b) Tintoria Mancini

The Tintoria Mancini is a traditional dyeing industry, using chemical components to prepare the dyeing baths. They extract water from their own well (80 -150m) and the corresponding pH is 7.

This dyeing industry uses formulas of chemicals to produce dyeing baths of 1:10; this means 1 liter of solution into 10 liters of water. Each bath contains 300 liters of water and the fraction is 100 liters to produce 1kg of wool flock. Considering this, it is evident that a great quantity of water is contaminated with chemical components, and some of them are very polluting.

The industry owner has considered the idea of reusing industrial wastewater but the appropriate technology is currently too expensive. In addition, the generated wastewater cannot be used for all processes.

This industry has internal wastewater treatment facilities and the treated water is released into the surface natural water network. The main technology used for the depuration processes is a "bio-treatment" using micro-organisms, bacteria and protozoa (fanghi attivi). These organisms eat the pollution and generate CO_2+H_2O.

These waters are regularly checked by the hygiene public national service and up to today they never surpass the threshold of pollutant. The sludge coming from the wastewater treatment is pressed in form of bricks, which are sent to the municipal collector as urban solid waste twice a year. The water supply chain of Tintoria Mancini is illustrated in Figure 17.

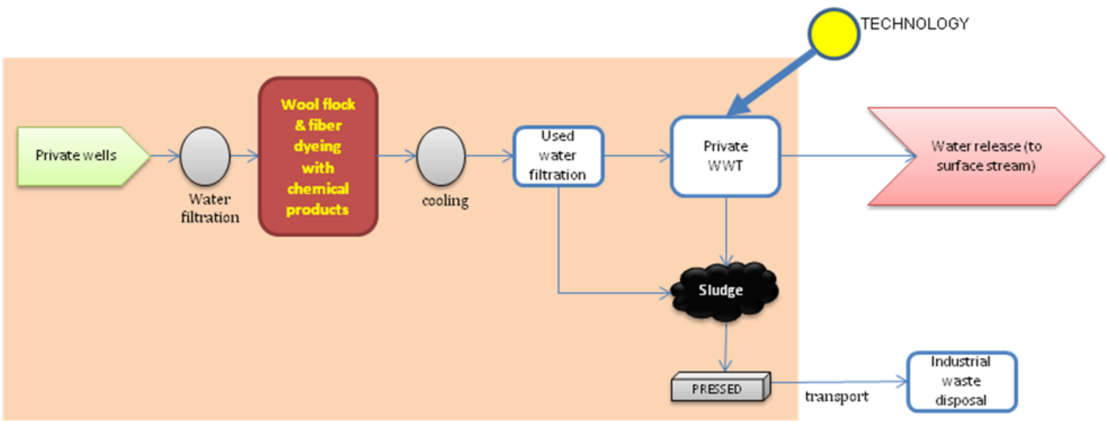


Figure 17: The water supply chain of Tintoria Mancini

KEY POINT: This site is an example of industrial investment. They have made an initial investment for internal wastewater treatment facilities, resulting in "no additional costs" for municipalized WWT. They would like to promote the reuse of sludge bricks for building/ construction.

c) FILIDEA (old name "Filatura Barberis")

Filidea is a quite old industry, which is actually in a restructuring phase. In the recent past, the industry (originally named Filatura Barberis) is moving from Cerrione (South of Biella) to Cossato (East of Biella). The water supply chains of these two sites are presented in Figure 18 and Figure 19 respectively. The textile activities mainly concern spinning and yarn dyeing.

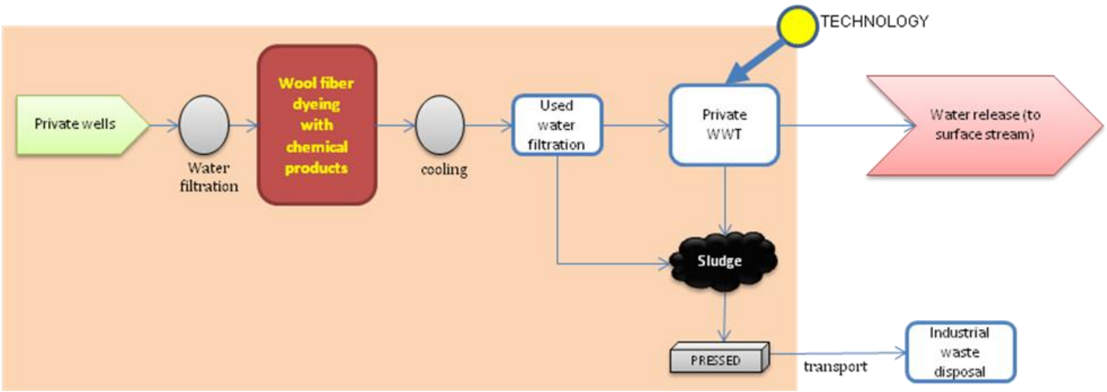


Figure 18: The water supply chain of FILIDEA Cerrionesite

The description begins from the first location in Cerrione. In that site, water is withdrawn from four (4) deep wells located inside the area of the industry; the abstracted water is just filtrated as it is of adequate quality. After the dyeing and washing processes, the generated wastewater undergoes biological treatment (bacteria). This process is using a blow of air that gives oxygen to the bacteria that eat the dirt present in wastewater. Taking into account that they use also a lot of tensioactives and they treat more than 1 million liters of wastewater, they can also produce a lot of good families of bacteria, which are sold to other industries. At present, the old location in Cerrione is gradually transforming into a laboratory for research and development. It is part of a research project managed by the Politecnico of Turin. This is a pilot site in which all the discharge phases are analysed in the scope of studying the recycling of water for dyeing purposes with good quality standards and not only for rinsing processes.

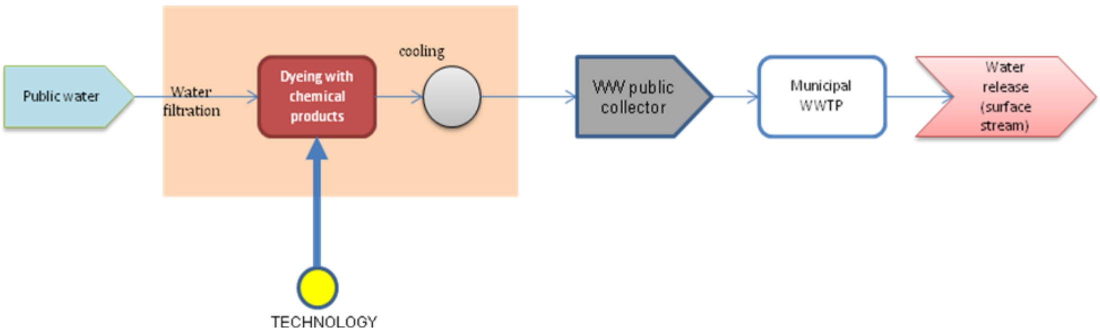


Figure 19: FILIDEA Cossato site

As already mentioned, most of the dyeing activities of FILIDEA are transferred to Cossato. In this new location the water provision and release is not private as in the previous conditions, but completely public. Therefore, water withdrawal services are provided from CORDAR, distributing the water coming from the Piancone Dam.

Wastewater is also released into the collectors of the consortium CORDAR and is treated in the Spolina WWTP.

KEY POINT: The cost of water, which used to be near to null, is now increased, but is compensated by the new technology of machineries, which have a better performance. Specifically, 4-5 liters of water are currently required for the production of 1 kg of wool, in contrast to the 12 liters required with the previous technology.

Although water management is also more expensive than previously, it is compensated by the energy savings and the reduction of the quantities of salt used for the solutions of baths (that are very expensive). On the other hand, reducing the quantity of salts means reduction of the quantity of pollutant in the wastewater streams as well; this has to be considered as relevant for environmental impacts.

2.5 Value Chain Mapping

The Actors in the system are the textile industries, the water supply companies CORDAR, the river basin authority, the municipalities, the electric companies for energy provision, wastewater treatment plants (CORDAR), transport companies for sludge transfer, incinerators, farmer organizations and farmers. Other actors are also local public/private authorities as water quality control supervisors, technology providers, technicians and researchers, consumers and laboratories (inside or outside the factories). The mapping of the interactions among the actors directly involved (Value Chain Mapping) is illustrated in Figure 20. The relevance of the actors to technology uptake is presented in Table 3.

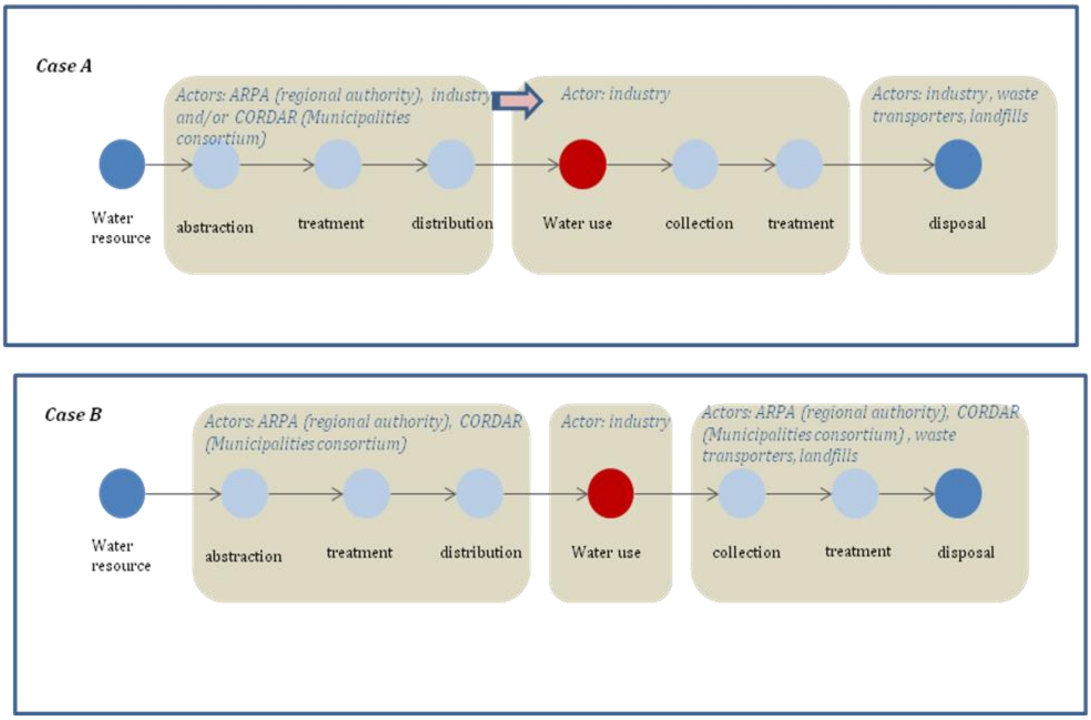


Figure 20: Value chain mapping of the system

Table 3: Actors directly involved

Actors	Relevant for technology uptake?	Impact		
Commercial enterprises	**Yes / No**	**Pos.**	**Neutr.**	**Neg.**
Textile industries	**Y**	x		
Water supply companies (CORDAR)	**Y**		x	
Electric companies for energy provision	**Y**		x	
Wastewater treatment plants (CORDAR)	**Y**	x		
Transport companies for sludge transfer	**N**		x	
Laboratories	**N**		x	
Technology providers	**Y**	x		
Technicians and researchers	**N**		x	
Incinerators	**N**	x		
Governmental institutions				
Water quality control supervisors	**N**		x	
River basin authority	**N**		x	
Municipalities	**Y**		x	
Non Governmental Organisations				
Farmer organizations	**Y**	x		
Consumers	**N**		x	

2.6 Selection of eco-efficiency indicators

2.6.1 Environmental impacts

The textile industry uses a great volume of water, and hence creates a big impact on the water supply chain, mostly on groundwater but also on stream flows, depending on the means of withdrawal utilised by each single industry unit. In addition, treated wastewater is quite often not immediately released after the industrial sites, creating a gap in streams and impacting on the stream “minimum vital flow” and on river life eco-system.

These are due mostly to the quality of wastewater generated by any textile process, which is much polluted and needs to be treated carefully. To that end, the stages where innovative technologies will be introduced are illustrated in Figure 21, while a list of indicators to be used in presented in Table 4.

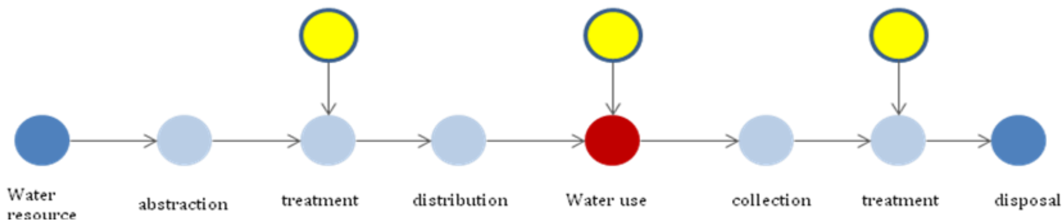


Figure 21: Eco-innovative technologies possible intersections

Table 4: A list of indicators to be used in the analysis

Indicator	Importance	Indicator Parameters
Climate Change/ global warming	Important	Evaporation, sludge
Water quality	Important	Chemical pollutant
Water quantity	Important	Quantity gap (abstracted- re-leased)
Biodiversity	Very Important	Difference in QUANTITY up-downstream the industry Difference in QUALITY up-downstream the industry
Resource use	Important	Surface Water , ground water Electricity, Oil/Gas, chemical components

2.6.2 Economic costs and benefits

The economic costs and benefits in the water system are presented in Table 5.

Table 5: Economic costs and benefits in the water system

Economic costs and benefits of the meso-level system	
Costs	**Benefits**
Water supply	Reduction
Energy provision	Reduction
Wastewater treatment	To be defined
Transport of sludge	Reduction
Laboratories	Not sure
Technology providers	Improve Economy
Technicians and researchers	Improve Economy
Incinerators	Reduction

2.7 Preliminary identification of technologies to be assessed

The development of this activity is in progress.

3 System mapping for Case Study #6: Cogeneration of thermal energy and electricity

3.1 Objectives of the Case Study

The Case Study addresses a system that consists of (i) a river water system, which provides supply and discharge of cooling water used by local energy plants for electricity and thermal energy production, (ii) the local energy plant, (iii) the storage and distribution network, and finally (iv) the houses and industries where the energy is used.

It will assess the wider environmental impacts and improvements and the added economic (service/product) value that will arise from the implementation of innovative technologies in water-related processes. The assessment will be executed by means of an indicator approach. The eco-indicators that will be applied to this case will also be applied to the other 7 cases, creating the possibility to make comparisons.

The three (3) main objectives of the Case Study are:

1. *Finding the most effective ways to* ***improve the water quality of the Amsterdam-Rhine Channel*** *by reducing (the impact of) thermal discharges.*

   The ecological impact of the energy production depends on (i) the increase/decrease in temperature averaged over the cross section, (ii) the temperature difference between cooling water and ARC water, and (iii) the percentage of the flow through the ARC used as cooling water. As a consequence of these impacts, biodiversity can either increase or decrease.

2. *Finding the most effective ways* ***to improve sustainability in the energy sector*** *by better accommodating electrical and thermal demands, leading to reduction of fossil fuel based heating.*

   The sustainability can be defined by the efficiency of energy production and by the effectiveness of the energy produced. The efficiency is determined by the ratio between the intrinsic energy content of the gas (energy source of the power plants) and the supplied energy content of the distributed electrical and thermal energy. The effectiveness can be determined by the ratio between the electrical and thermal energy produced and the electrical and thermal energy demand.

3. *Finding the best sustainable ways* ***to improve the robustness of the energy sector****, by reducing the dependence on the availability of cooling water.*

   Dutch legislation limits the allowed (relative) temperature rise due to cooling water discharges; limitations concern both the maximum allowed absolute temperature and the maximum temperature that may be discharged. This, in combination with (i) a limited water flow through the ARC (with temperature fluctuations due to climatological influences) and (ii) a series of energy plants operational along the ARC, sets constraints to the allowed thermal discharges. Especially when the water in the ARC is warm, trips (shut downs) of energy plants are a real fear. The robustness of the energy sector can be improved if the dependency of energy plants on cooling water is reduced.

3.2 Overview of the Case Study area / industry

The assessed river water system is actually a channelled river water system, since the Amsterdam-Rhine Channel (ARC) is a 72 km long man-made connection between the Rhine River and the IJ-bay near Amsterdam. The water then flows into the North Sea Channel, where it is discharged near IJmuiden into the North Sea.

The ARC has a South to North orientation and is heavily used for navigation, which is the most important goal of this channel. Two other important goals are the fresh water supply and discharge of water surplus in the area and to keep the ecological conditions healthy. The ARC goal in focus of the research is the supply and discharge of cooling water. It is one of the three sub-goals of “Water supply and discharge”; the other two are the water supply for drinking water and the fresh water supply for water boards.

Several energy plants are installed along the ARC (and also the North Sea channel) and contribute - amongst others - to the thermal conditions of these channels. The total installed capacity lies somewhere around 1.5 GW of electrical energy and 1 GW of thermal energy.

3.3 Methodology

The methodology used in this case is to describe the supply and value chain using a basin approach similar to the one used for the EcoWater cases 1 and 2. This Case Study views the system that consists of a river water system, which provides in supply and discharge of cooling water used by local energy plants for electricity and thermal energy production. It also consists of the local energy plant and the storage and distribution network and finally the houses and industries where the energy is used.

3.4 Water Supply Chain Mapping

3.4.1 System boundaries

The system boundaries of the meso-level system are a challenge to define. From the perspective of this research the next argumentation is applied.

The system boundaries of the meso-level system are “from the inside” defined in such a way that the boundaries enclose an “area” in which multiple sectors are involved, multiple actors interact and and multiple services and/or tasks are delivered, and for which an area-specific approach is required. And above that, the meso-level system has to be representative for other than this specific area. From the outside, the system is checked and approved when neither a micro-level nor a macro-level approach is applicable.

From a more political level a more soft approach to the system boundaries is applied:

Meso-level indicators are for meso-level managers and meso-level decision makers that make meso-level decisions and take meso-level measures. The search for meso-level indicators implies that we need to seek such a level for the indicators, and subsequently for the system, that the inherent indicators can be applied to other meso-level systems and are representative for the whole range of eco-efficiency.

Given the above assumptions, the meso-level system for the Case Study consists of four parts, representing four different sectors (Figure 22):

Part 1. Water system (water sector)

Part 2. Energy plant (energy sector)

Part 3. Network for energy storage and distribution (energy sector)

Part 4. Domestic and industrial energy usage (housing sector and industrial sector)

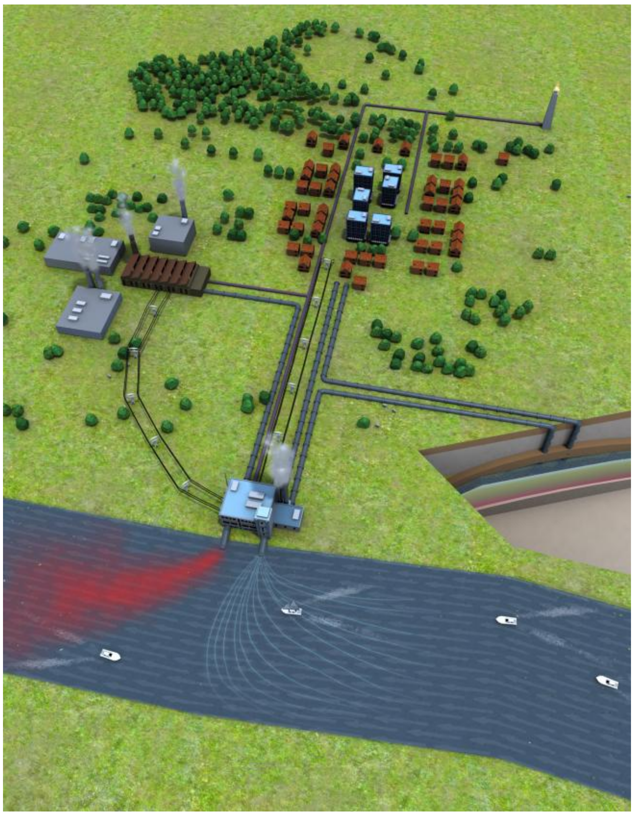
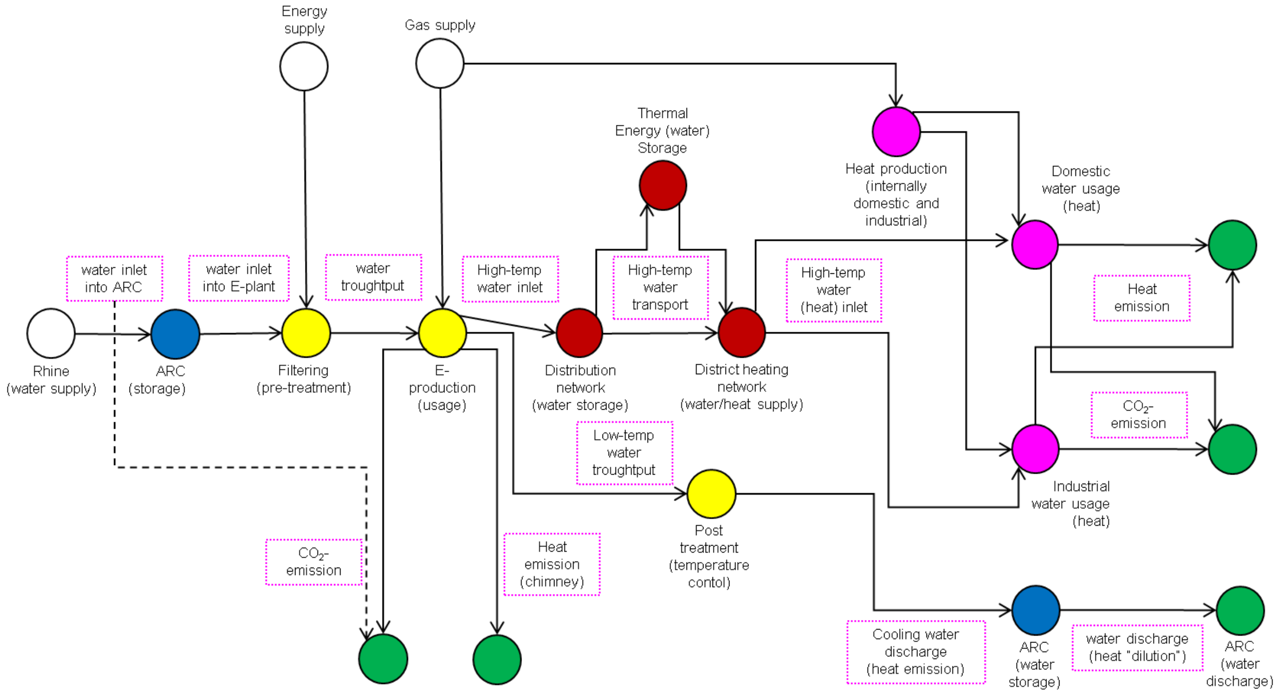


Figure 22: Sketch of the meso-level water-energy system

The product of this meso-level system is the production, storage and distribution of thermal and electrical energy for usage in households and industries.

3.4.2 Mapping of the water supply chain, water service system and description of stages

The stages that are included in the water supply chain of the system are illustrated in Figure 23, whereas the corresponding processes are presented in Table 6.



Stage	Name system	Part	Stage	Name system	Stage
(blue)	Water system	1	(magenta)	Users & consumers	4
(yellow)	Energy plant	2	(green)	Output system	External
(red)	Distribution & storage	3	(white)	Input system	External

Figure 23: Mapping of the water service system

Table 6: Water system and processes

Stages	Processes
Part 1: Water System	
Abstraction	Water inlet into the ARC
Storage	Water remaining in ARC
Uptake	Water inlet into E-plant
Pre-treatment	Filtering
Part 2: Energy plant	
Electrical energy production	Cooling process (production hi & lo temp water)
Thermal energy production	Throughput high temperature water to network
Treatment	Post treatment (temperature control)
Disposal	Low temperature water discharge to the ARC
Part 3: Storage & Distribution Network	
Thermal energy distribution from the energy plant (closed circuit)	Thermal Energy (water) Storage Distribution of high temperature water through the district heating network to households and industry
Part 4: Energy Usage	
Thermal Energy Use	Domestic heat (water) usage Industrial heat (water) usage
External: Thermal Energy production and Supply	
Domestic & Industrial heat production	Fossil fuelled heat production and supply for direct domestic and industrial usage

3.4.3 Description of existing technologies

The technologies of each of the stages are described in Table 7.

Table 7: Stages and technologies

Stages	Technology
Part 1: Water System	
Abstraction	Pumping station
Storage	-
Uptake	Pumping
Pre-treatment	Filtering
Part 2: Energy plant	
Electrical energy production	Condenser and heat exchanger
Thermal energy production	Heat exchanger
Treatment	Pumping water (pre-discharge mixing)
Disposal	Pumping
Part 3: Storage & Distribution Network	
Thermal energy distribution from the energy plant (closed circuit)	Pumping
Part 4: Energy Usage	
Thermal Energy Use	Pumping
External: Thermal Energy production and supply	
Domestic & Industrial heat production	None relevant

3.5 Actors in the Value Chain

3.5.1 Actors (direct and indirect)

A list of the directly and indirectly involved actors is presented below. For each actor, the role, stake(s), possible measures and an insight on the magnitude of influence are listed.

Governmental institutions

Actor: Ministry of Infrastructure & Environment (I&M) – Rijkswaterstaat

Role: Permitting office for water extraction and thermal discharge

Stake: Responsible for maintaining good water quality and good ecological conditions

Measure: Granting permit

Influence: Large

<u>Actor:</u> <u>Ministry of Economics, Agriculture and Innovation (EL&I)</u>

Role: Financier

Stake: Responsible for sustainable energy production and usage

Responsible for economic growth and activities

Responsible for innovation

Measure: Granting subsidies
Influence: Medium

Actor: Province of Utrecht
Role: Development planning agency for the area of Utrecht
Stake: Improving employment and sustainability
Measure: Granting subsidies
Provincial support
Lobbyist
Influence: Medium

Actor: Community of Utrecht
Role: Permitting office for construction
Stake: Creating best value for the limited available area by regulating urban developments
Measure: Granting permits
Influence: Large

Commercial enterprises

Actor: Energy companies
Role: Energy supplier and distributor
Stake: Economical profit through production, storage and distribution of electrical and thermal energy
Measure: Investing
Exploiting energy resources
Exploiting energy distribution network
Influence: Large

Actor: Financial institutions
Role: Financier
Stake: Economical profit by investing in new business
Measure: Granting financial contribution
Influence: Small

Actor: Technology suppliers
Role: Developer and supplier of custom made technologies
Stake: Economical profit by developing and supplying technological solutions
Measure: Showing technological solutions and possibilities
Influence: Medium

Actor: Housing company
Role: Provider of housing
Stake: Economic profit through letting and selling houses
Measure: Investing
Influence: Large

Actor: Thermal energy requiring industries
Role: Industry specific
Stake: Economic profit through selling service and/or product value
Measure: Investing
Settling in meso-level system area
Influence: Large

Non Governmental Organisations

Actor: Environment federation (Milieufederatie NL)
Role: Defender of environmental values
Stake: Clean environment, vital nature and diversity in landscape
Measure: Lobby
Public action
Influence: Small

Actor: Fishery Organization (Sportvisserij NL)
Role: Defender of fishing conditions
Stake: Sustainable fish population and good fishing locations
Measure: Lobby
Public action
Influence: Medium

Actor: Local Industry Association
Role: Defender of commercial values and necessities focussed to a specific area/location
Stake: No hindrance for local economic growth and commercial activities (think of: good transportation routes, good facilities, expanding possibilities etc)
Measure: Migrating to other industrial locations/sites
Influence: Small

Actor: Association for Energy, Environment and Water (VEMW NL)
Role: Defender of stakes of commercial energy and water users

Stake: Reduction CO_2-emissions

Enlarging energy efficiency

Production of sustainable energy

Measure: Networking platform

Lobby

Knowledge supply

Influence: Medium

The preference structure of the relevant actors is presented in Table 8. The list of the directly involved actors is presented in Table 9.

Table 8: Preference structure of the actors

Actors	Relevant for technology uptake?	Preference structure of actors		
Commercial enterprises	**Yes / No**	**Pos.**	**Neutr.**	**Neg.**
Energy Companies	**Yes (primary)**		X	X
Technology Suppliers	Yes (secondary)	X		
Housing Company	**Yes (primary)**	X	X	
Financial Institution (Venture Capitalist)	Yes (tertiary)	X		
Thermal Energy requiring industries	**Yes (primary)**	X		
Governmental institutions				
Ministry of Infrastructure and Environment – Rijkswaterstaat	**Yes (primary)**	X		
Ministry of Economics, Agriculture and Innovation	Yes (secondary)	X		
Province of Utrecht	Yes (secondary)	X		
Community of Utrecht	**Yes (primary)**	X	X	
Non Governmental Organisations				
Fishery org. (Sportvisserij NL)	Yes (secondary)	X		
Local Industry Association	Yes (tertiary)	X		
Association for Energy, Environment and Water (VEMW NL)	Yes (secondary)	X	X	
Environment Federation (Milieufederatie NL)	Yes (tertiary)	X	X	X

Table 9: The directly involved actors

Direct actors (subset of the above)	
Supply	
Governmental institution for surface water management (national water authority)	Ministry of Infrastructure and Environment – Rijkswaterstaat
Production	
Energy company	NUON
Demand	
Domestic use – Housing company	Eneco Warmte & NUON ET&W
Industrial use – Specific industry	Eneco Warmte & NUON ET&W
Overall	
Branche organization	VEMW NL
Governmental institution for local spatial development	Community of Utrecht

3.5.2 Communication strategy

The communication strategy per actor depends on the gravity of the corresponding stakes and the magnitude of the influence that can be executed. Some actors only have to be informed, some have to be made partners in this co-production and others need to be approached in a way somewhere in between. To make the strategy clear, a quadrant method is applied to this theory as illustrated in Figure 24.

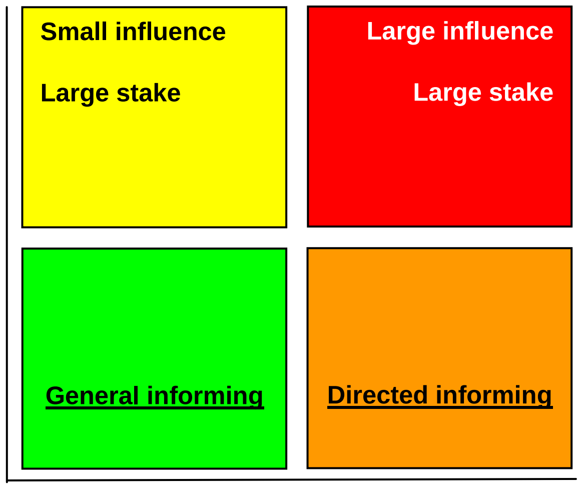


Figure 24: The communication strategy quadrant

3.5.3 Visualisation of actor interaction

Figure 25 below shows a visualisation of all actor relations and interactions. The primary (or large influence) relations are marked in red, the secondary (medium influence) relations in blue and the tertiary (small influence) relations in green. The listing of all actors in the previous paragraph shows the kind of influence that is actuated; it can be of a financial (positive/negative) kind, lobby kind, permitting kind and so forth (see the “measures” bullet in the listing).

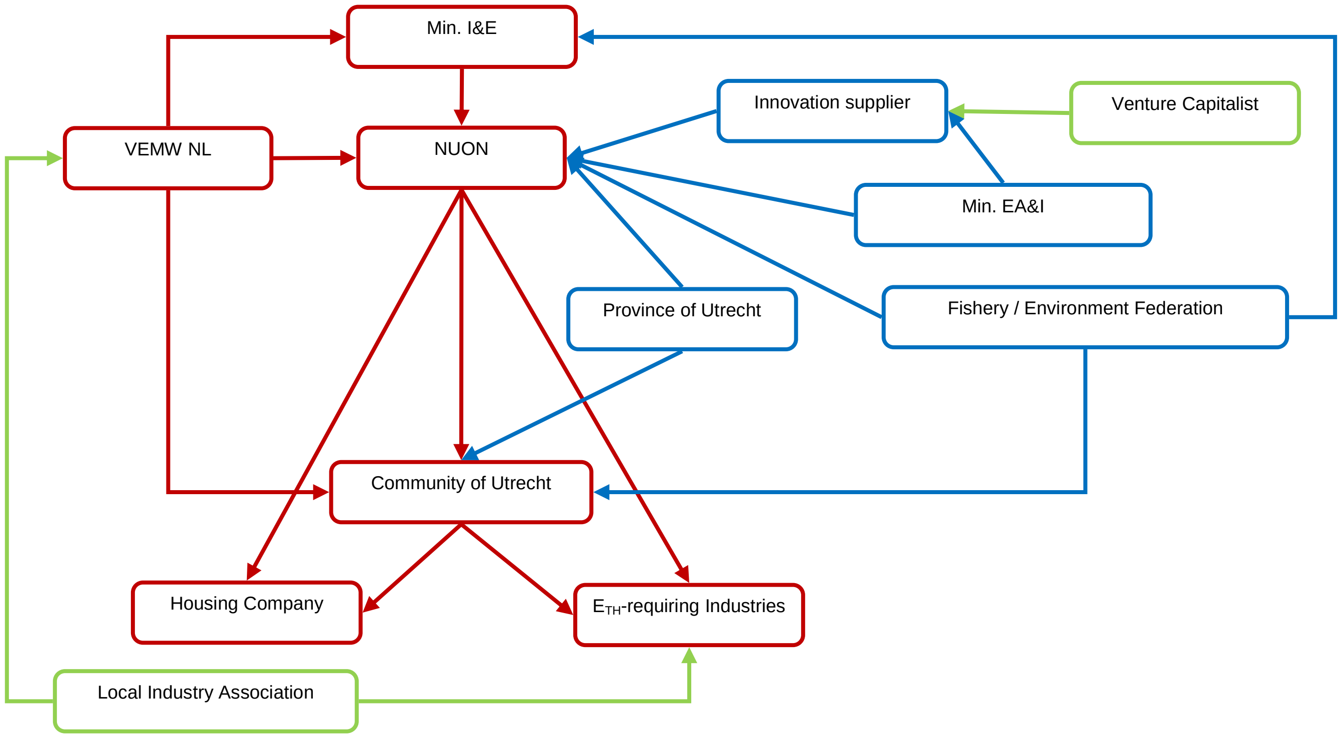


Figure 25: Interaction among actors

3.6 Selection of eco-efficiency indicators

3.6.1 Environmental impacts

Indicators for input to and output from each stage and system part are presented in Table 10. A list of the most important indicators for the system is provided in Table 11.

Table 10: Input and output indicators

Input to & output from meso-level system		
Input	**Related stage**	**System Part**
Fresh water	Amsterdam-Rhine Channel	Part 1. Water system
Electrical energy	Filtering (pre-treatment)	Part 2. Energy plant
Natural Gas	Energy production	Part 2. Energy Plant
Natural Gas	Domestic and Industrial thermal energy production	Part 4. Energy Usage
Output	**Related stage**	**System Part**
CO_2	Energy production	Part 2. Energy Plant
Heat emission	Energy production	Part 2. Energy Plant
CO_2	Domestic and Industrial thermal energy production	Part 4. Energy Usage
Heat emission	Domestic and Industrial thermal energy production	Part 4. Energy Usage
Thermal discharge (cooling water)	Amsterdam-Rhine Channel	Part 1. Water system

Table 11: Importance of the overall indicators

Indicator	Importance of indicator	Indicator Parameters
Climate Change/ global warming	Possibly important	CO_2 emissions to air
Water quality	Important	Temperature (gradient)
Water quantity	Important	Quantity of water abstracted for cooling
Tropospheric ozone formation / depletion (emissions to air)	Possibly important	CO
Biodiversity	Important	Habitat variety
Resource use	Important	Electricity, Oil/Gas, Surface Water

3.6.2 Economic costs and benefits

The economic costs and benefits for the meso-level system are presented in Table 12.

Table 12: Economic costs and benefits in the water value chain

Economic costs and benefits of the meso-level system	
Costs	**Benefits**
Purchase of Natural Gas	Thermal energy sale
Purchase of CO_2-emission rights	Electrical energy sale
	Energy transport fee

3.7 Preliminary identification of technologies to be assessed

A preliminary list and short description of the technologies to be assessed for their eco-efficiency in the system is provided in Table 13.

Table 13: New technologies / innovations to be introduced and the the corresponding processes

Technology/Innovation	Related Process
Part 1: Water System	
RTC Inlet: Real Time Controlled inlet of water into the Amsterdam Rhine Channel to provide the required energy capacity in the ARC	Water inlet into ARC
Mixture Device: A mixture device (using jets, bubbles or blades) forces the mixture of cooling water with ARC water so that the temperature gradient is as small and local as possible	Storage in the ARC **and** Post treatment – temperature control
Smart Cooling: Bubble screens which stimulate water mixture and with that efficient water to air heat transfer.	
Smart Pumping: Efficiency improvement through smart pumping i.e. operating the pumps at optimal Q-H working point.	Water inlet into E-plant
Clever inlet design to reduce intakes of animals, larvae, debris	
Energy efficient **dimensioning** of water inlet system (fewest friction losses)	
Part 2: Energy plant	
Adaptive ratio Elecrtical/Thermal: Energy plants often have electricity production as its main goal. When adapting the ratio between El and Th energy production the demands can be met more accurately	Cogeneration
Pre-discharge mixture of cooling water with ARC water	Post treatment – temperature control
Application of **Decision Support Systems** for real time controlling the thermal conditions of ARC water by adjusting energy production or addressing thermal energy to other uses	Post treatment – temperature control
Part 3: Storage and Distribution Network	
Connection of adjacent district heating systems	Distribution of high temperature water through the district heating network
Extension of the coverage of district heating system	Domestic heat (water) usage Industrial heat (water) usage

Part 4: Energy Usage	
Development of uses for otherwise wasted thermal energy *INFRASTRUCTURE* I. Ice prevention roads, landing strips and industrial areas II. Conditioning of roads (tracking, cracks) III. Conditioning of bridges (expanding and shrinking) IV. Ice prevention of railway crossings *RECREATIONAL INDUSTRY* V. Indoor swimming pools VI. Ice tracks VII. Botanical gardens VIII. Ice prevention and conditioning of sporting fields IX. Boulevard heating *PRODUCTION INDUSTRY* X. Growing algae and tropical plants XI. Breeding shrimps and tropical fish XII. River sludge drying *PROVISION OF MUNICIPAL SERVICES* XIII. Gasification of biomass (producing gas) XIV. Biological soil cleaning XV. Heating of houses and buildings XVI. Biological drinking water treatment	Domestic heat usage Industrial heat usage

4 System mapping for Case Study #7: Arla, Dairy Industry

4.1 Objectives of the Case Study

The dairy sector is unique by having two water sources – groundwater and milk. The objectives of this study, focusing on two (2) very different but representative dairies as examples, are to (i) identify technologies and/or the use of them, which can help switching from groundwater supply to use of surplus water from milk treatment, and (ii) reduce the outlet of treated wastewater to the end recipient (fresh water streams or the sea). The eco-efficiency for different solutions will be documented.

4.2 Overview of the Case Study area / industry

The dairy industry in Denmark is highly dominated by the approximately 27 dairies of Arla, which is about 40% of the Danish dairies by number. Most farms with milk cattle are placed on Jutland and Fynen, and hence the Arla diaries are almost all placed there, in order to be close to the farmers and for logistic reasons (exports to Germany and the UK).

Today the Arla dairies are almost all highly specialized, each dairy producing few product categories. Technological innovations on unit operations, such as CIP of filtration unit and change of pumps with single mechanical seal ring, can add to the overall goal for Arla, i.e. to reduce water and energy consumption by 3% per year.

4.3 Methodology

The dairy sector in Denmark can roughly be divided into the highly specialized but integrated dairies as those of Arla and some mostly individually owned dairies producing either several product categories or a few dairies producing one or few product categories.

In addition to the generic methodology outlined, the methodology for the dairy sector will be to analyse the potential for reducing the water footprint from the dairy sector by focusing on new technologies for treatment and disposal on the wastewater side.

4.4 Water Supply Chain Mapping

4.4.1 System boundaries

The focus of the dairy case will be Arla DK production sites at the Rødkærsbro Dairy (RD), Rødkærsbro and the HOCO Holstebro. At Rødkærsbro Dairy, the production is specialized to Mozzarella and shredded cheese. The HOCO site is one of the Arla milk powder plants, receiving milk from farmers and producing caseinates, hydrolysates and milk minerals.

The dairies are linked with other Arla dairies mostly by the transport of whey and cream to other dairies. The dairies are chosen, so as to cover the different situations for public management for wastewater outlet. The system under the responsibility of the dairies and the corresponding processes are shown is Table 14.

Table 14: System stages and corresponding processes

Stages	Processes	RD	HOCO
Water Supply Side			
Abstraction	Groundwater pumping	X	No
Treatment	Water conditioning	X	X
Dairy production (water use side)			
Dairy production, process water	CIP, Cleaning and Steam	X	X
Dairy production, sanitary water	Cheese / powder production	X	X
Wastewater Side			
Wastewater Treatment	Primary treatment Secondary treatment Tertiary treatment	X	No
Wastewater Disposal	Discharge to the water envi-ronment	X	No
Sludge Disposal	Biogas production	X	X

4.4.2 Mapping of industrial processes

The water and milk processes for the two dairies are drawn individually in each box of Figure 26. The white space between the dairies indicates the common links for the dairy sector; on the water side, the link is groundwater and recipients (dark blue dots), on the milk side, milk from farmers and surplus streams (whey, cream) to be delivered to other dairies.

When modelling the water streams, the respective groundwater sources and recipients for each of the two dairies will be handled individually. For HOCO, the groundwater is abstracted, treated and delivered by Vestforsyningen A/S. The company also runs the WWTP to which HOCO delivers the wastewater generated from the dairy. Rødkærsbro Dairy monitors the whole water chain from abstraction and treatment to wastewater treatment and outlet to the recipient (see also Table 14). The water use and re-use processes in Figure 26 will be later split up into single operation units for the actual processes, where the assessment of new technologies is going to take place.

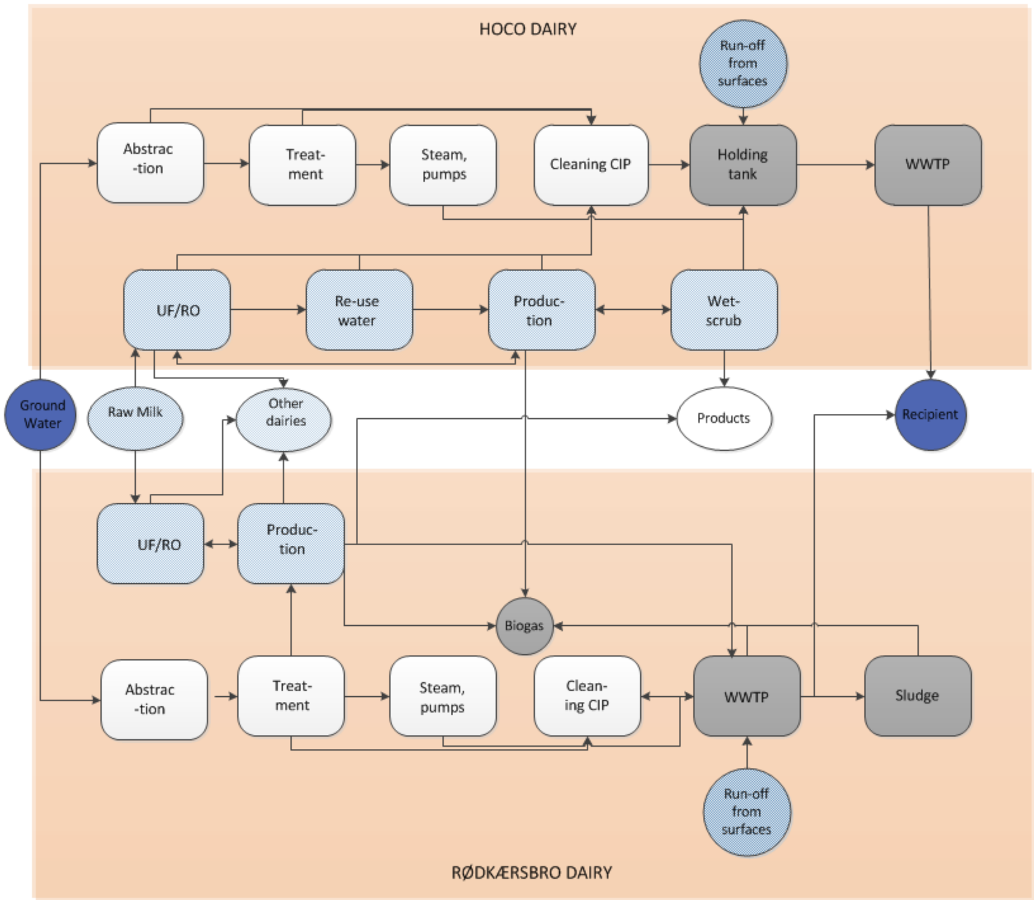


Figure 26: Mapping of the processes at the dairies HOCO and Rødkærsbro

Note: Light-blue boxes are milk-streams and processing, grey boxes are waste and wastewater, white dots are areas where drinking water quality is in place (water for cooling and cleaning) or is being established (abstraction and treatment). Sanitary waste, hazardous waste and rain water going into the rain water system is not included in the system.

4.4.3 Description of existing technologies

An overview of the existing technologies is presented in Table 15. The innovation potential areas identified at this point are the use of CIP-fluids for cleaning membranes and the water use stage, e.g. pumps with single-mechanical seal rings.

Table 15: List of existing technologies – Rødkærsbro Dairy and HOCO

Technology	Related Process	RD	HOCO
Water Supply Side			
Ion exchanger for preparation of softened water	Water conditioning	X	X
Membrane filtration (RO) for production of boiler feed water		X	X
Dairy production (Water use side)			
Boiler for Steam production	Production of cheese and powders CIP, cleaning, cooling, pumps and steam	X	X
Cooling system based on water		X	X
Process water, cheese, caseinates		X	X
Technology for automated equipment cleaning based on CIP (Cleaning in place)		X	X
Water applied for cleaning of manufacturing equipment COP (Cleaning out of place), e.g. milk tank cars.		X	X
Water applied for sealing of vacuum pumps		X	X
Re-use	Polishing	X	X
Wastewater Side			
Holding tank, grease trap, P-removal bio, activated sludge, separation tank, SS filter-ing, dewatering of sludge, sludge buffer	Pretreatment	X	Buffer tanks only
Settling tanks, holding tank, grease trap, aerated grease chamber, dissolved air flo-tation, chemical coagulation/flocculation, sand filter	Primary treatment	X	No
Activated sludge, bio filters, anaerobic treatment	Secondary treatment	X	No

4.5 Value Chain Mapping

The directly and indirectly involved actors for both dairies are presented in Table 16.

Table 16: Directly and indirectly involved actors

Directly Involved actors	Indirectly Involved actors
Water works. Vestforsyningen, Nupark 51, 7500 Holstebro Waste water treatment Plant. Vestforsyningen, Nupark 51, 8500 Holstebro Biogas plant. Maarbjerg, Nupark 51, 7500 Holstebro Biogas plant. Lemvig Biogasanlæg A.m.b.a., Pillevej 12, 7620 Lemvig Biogasplant Thorsø, Kongensbro vej 10, 8881 Thorsø Viborg Municipality, Prinsens Alle 5, 8800 Viborg Farmers Other Arla dairies,	Food safety authority. Fødevareafdeling Herning, Rosenholmvej 15, 7400 Herning Holstebro Municipality. Rådhuset, Kirkestræde 11, 7500 Holstebro Regional environmental protection agency. Miljøstyrelsen Århus, Lyseng Alle 1, 8270 Højbjerg Environmental Protection Agency, Strandgade 29, 1401 København K Danish Nature Agency (Water plans). Naturstyrelsen, Haraldsgade 53, 2100 København Ø Energi

Figure 27 and Figure 28 below show the interactions of the directly and indirectly involved actors with the Rødkærsbro Dairy and HOCO respectively, focusing on the water, product and money flows. The directly involved actors are shown below the blue line; blue arrows represent the product flow and red arrows the money flow. The major indirectly involved actors, regulating water supply and use and some of the directly involved actors, are presented above the blue line. White arrows illustrate the interaction of the public actors related to the water use (and water quality).

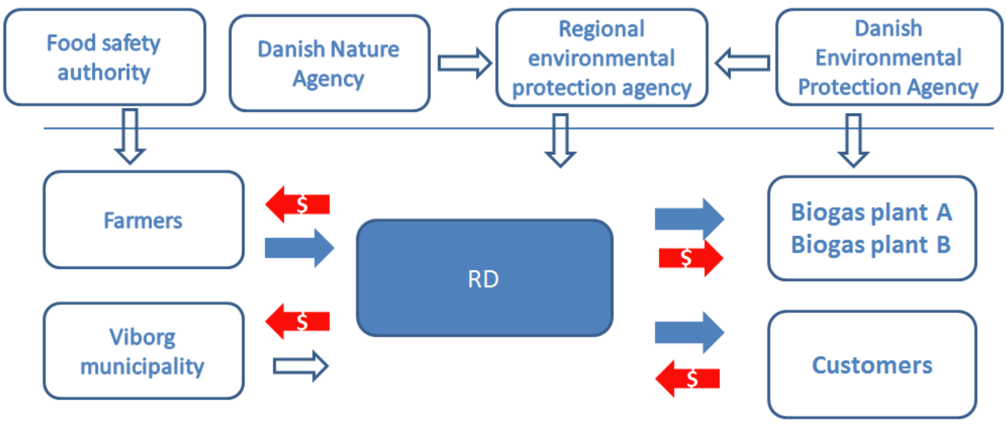


Figure 27: Visualization of the interactions action between Rødkærsbro Dairy and its actors

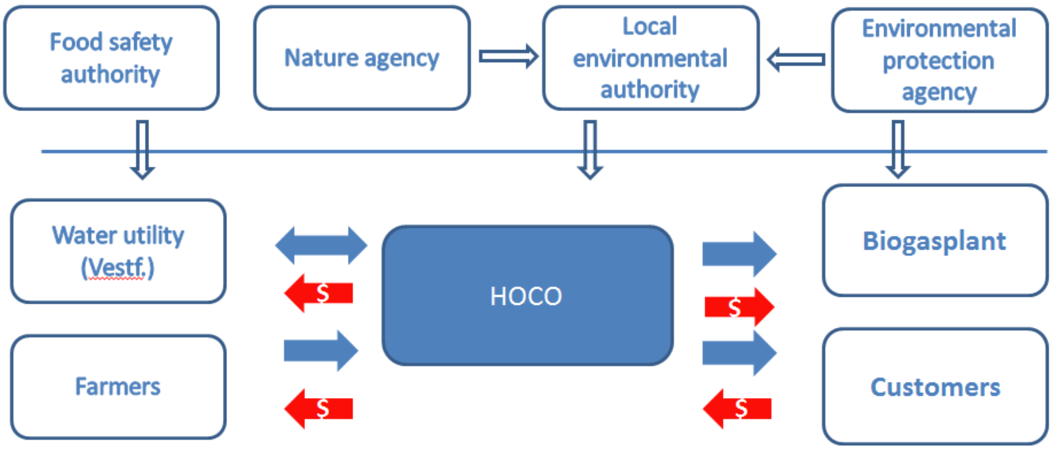


Figure 28: Visualization of the interactions between HOCO and its actors

4.6 Selection of eco-efficiency indicators

4.6.1 Environmental impacts

A preliminary list of environmental impact indicators is shown in Table 17.

Table 17: Preliminary list of environmental impact indicators to be assessed

Indicator	Importance of indicator	Indicator Parameters
Climate Change/ global warming	Possibly important	CH_4
Waste water quality	Important	NO_3, N Total,PO_4, P Total, BOD, COD. Inhibition of nitrification. Quantity.
Water quantity	Possibly important	Total volume of water abstracted including water from milk
Biodiversity	Possibly important (at RD)	Habitat variety, Inventory flora variety, Inventory fauna variety
Air Quality	Possibly important	Number of days of pollution, Milk powder dust, Refrigerants (ammonia)
Resource use	Important	Electricity, Oil/Gas, Transport Fuels, Detergents, Sanitizers, Refrigerants (ammonia).

4.6.2 Economic costs and benefits

Rødkærsbro Dairy manages the water supply chain from abstraction to WWTP and the outlet to the stream Gudenåen, and hence the costs related to water and wastewater are defined by the investment costs and the maintenance and operational costs. A fee of 3.80 DKR/m^3 is paid to the Municipality for the wastewater.

For HOCO the fee paid in 2012 to Vestforsyningen for raw water was 4.52 DKR/m^3 (approx. 0.61 Euro) and for wastewater 19.47 DKR/m^3 (approx. 2.61 Euro). By-products for biogas production are delivered free of charge to the biogas plant; expenses for transport are approximately 50 DKR/t.

4.7 Preliminary identification of technologies to be assessed

A list of potential technologies/innovations to be assessed is presented in Table 18.The list is preliminary, as it covers the dairy sector in general; each of the two (2) dairies will evaluate and indicate the most promising technologies.

Table 18: List of new technologies / innovations

Technology	Related Process
Production Side - Recirculation / re-use	
UV-treatment of water	Cheese washing
Osmosis (FO/RO)	Concentration of water
Electrolytic production of NaOH and hypochlorite on-site	Treatment of production water streams
Pumps, single-mechanical seal rings.	In production: process and CIP
Wastewater Side	
Membrane bioreactors (Removal of particulate and dissolved pol-lutants in membrane bioreactor based WWTP)	Secondary / Tertiary Treatment
Ultra filtration (Polishing of treated wastewater by filtration through Ultrafiltration unit)	Tertiary Treatment
Reverse osmosis (Polishing of tertiary treated wastewater by fil-tration through reverse osmosis unit)	
Ozonation (Disinfection of treated wastewater by addition of ozone)	
Microfiltration (cheramical filtration system for CIP-fluids)	Secondary / Tertiary Treatment
UV-treatment (Disinfection of secondary/tertiary treated wastewater by irradiation with UV-light)	Secondary / Tertiary Treatment
Biofuel waste water treatment, closed system	Secondary / Tertiary Treatment
Lagoons for collecting for irradiation	Secondary / Tertiary Treatment
Seepage	Tertiary Treatment
Ground water reservoirs	Outlet
Drainage water treatment before outlet	RO water and Tertiary treatment

The potential innovation areas identified at this stage are:

- Water use side: Use of CIP-fluids when cleaning membranes, reduction of water use – pumps with e.g. single-mechanical seal rings, technologies for re-use of dairy-water as drinking water quality.
- Wastewater side: Technologies and systems for treatment of lightly loaded wastewater streams.

5 System mapping for Case Study #8: Meso-level eco-efficiency indicators for technology assessment in water use in the automotive industry

5.1 Objectives of the Case Study

The focus of this Case Study will be on innovative technologies and concepts for improving the eco-efficiency in water use in the automotive industry. The Case Study will assess the wider environmental impacts/ improvements and the added economic value that would arise from the implementation of innovative technologies in all relevant stages, including technologies for input water treatment, wastewater handling, recycling, energy recovery and closed-loop processes. Impacts will include environmental effects and cost aspects of water and energy usage, but also other impact categories including waste and greenhouse gas emissions, reliability of technologies etc.

5.2 Overview of the Case Study area / industry

The stages with the largest share of water consumption in the automotive industry are the metal surface treatment (for corrosion protection) and the painting lines (except for painting lines using powder coatings).

New technologies for metal surface treatment have emerged, which exchange the heavy metals zinc, nickel and manganese as active components into other components (silane or zirconium fluoride). Suppliers of these technologies also claim the benefit of reduced water quantity used in the process and a reduction of the amount of generated sludge.

5.3 Methodology

As a complement to the generic methodology for all Case Studies that was outlined in the Deliverable 1.8 “Roadmap for Case Study Development”, an additional assessment of technologies in CS # 8 will be made. In that assessment, cradle-to-gate LCI data for commodities (e.g. electricity, chemicals) used in the system will be included. The results of this additional assessment will show whether the same conclusions can be drawn when the environmental impacts of using a new technology is put in a wider perspective.

5.4 Water Supply Chain Mapping

5.4.1 System boundaries

The Case Study concerns the Volvo Group, Sweden, and will focus on the two (2) manufacturing sites of Volvo Trucks and their respective water supply chain. The sites are located in Umeå, northeast of Sweden, and Gothenburg, southwest of Sweden. Volvo Trucks Umeå is a producer of truck cabins, while Volvo Trucks Tuve produces frame beams and has a vehicle assembly line. There is neither a common water resource nor a common wastewater treatment facility between the two sites of

Volvo Trucks. Instead they are linked together by the delivery of produced cabins from the Umeå site to the Tuve site, where the cabins are used in the assembly line. All of the cabins used in the Tuve assembly line come from the Umeå site. The Umeå site also delivers truck cabins to other Volvo Trucks facilities, outside Sweden. These are not further studied within this Project. The final product of the system is trucks.

5.4.2 Mapping of the water service system and description of stages

An overview of the system and its stages is given in Figure 29. The water supply side includes the Abstraction and Treatment stages. The water use stages are those of the industrial water use at the two Volvo Trucks production sites. The wastewater treatment side includes the Collection, WW Treatment and Disposal stages.

Both the water supply side and the wastewater treatment side involve several different actors. For future model calculation purposes, stages are assigned to involve only one individual actor. Hence, the system includes more than one stage of Abstraction, Treatment, Collection, WW Treatment and Disposal.

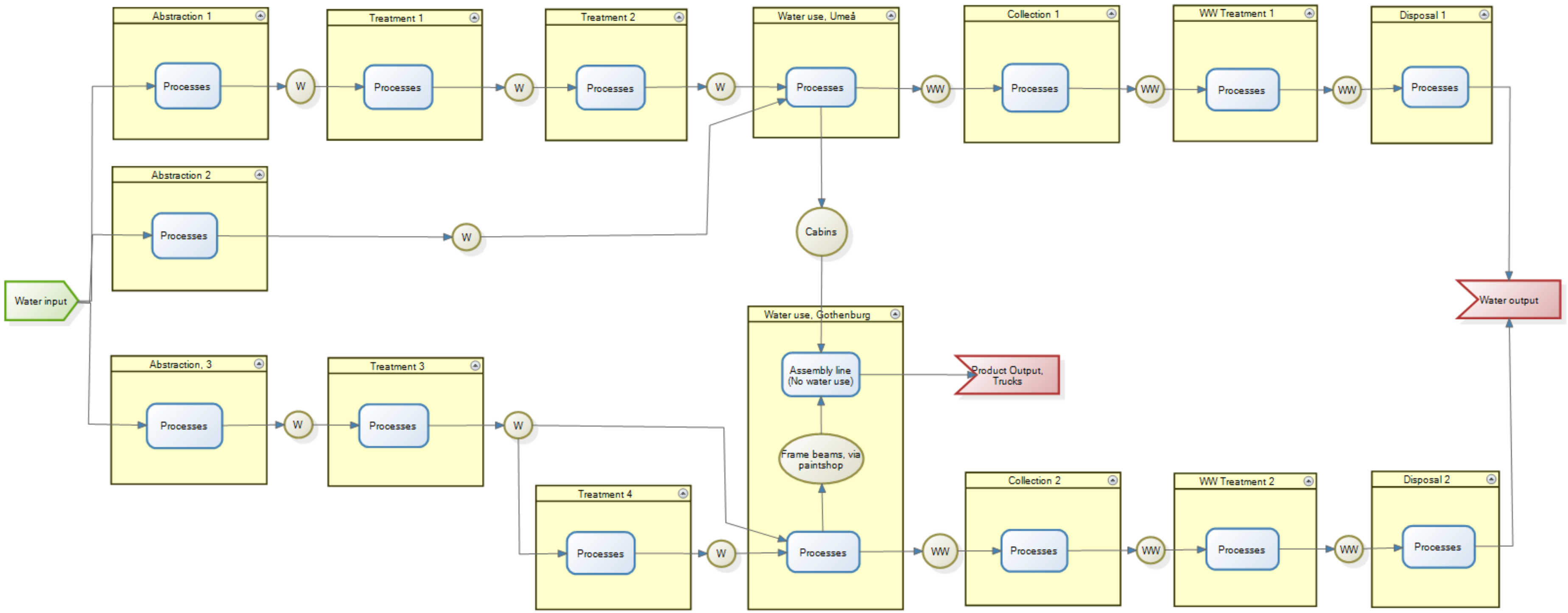


Figure 29: Overview of stages in CS#8 from the SEAT modelling tool.

Note: the system holds two separate water supply chains (upper and lower part of the figure). Water input comes from separate water sources and water output goes to separate recipients.

5.4.3 Process map description

The processes included in each stage are presented in Table 19, Table 20, Table 21 and Table 22.

Table 19: The stages and corresponding processes in the water supply side

Stages	Processes
Water Supply Side, Umeå site	
Abstraction 1	River water extraction and infiltration on top of ridge to produce artificial groundwater.
	Extraction of artificial ground water mixed with natural ground water at the base of the ridge.
Abstraction 2	River water extraction.
	Extraction of sub-terrain water (ice rivers).
Treatment 1	Municipal water treatment plant.
Treatment 2	Water purification at Volvo Trucks, Umeå.
Water Supply Side, Gothenburg site	
Abstraction 3	Extraction of river water.
Treatment 3	Municipal water treatment plant.
Treatment 4	Water purification at Volvo Trucks, Gothenburg.

Table 20: Processes in the water use stage at Volvo Trucks, Umeå

Water use process	Description
Pre-treatment, degreasing	Degreasing of truck cabins in a series of steps.
Water Recycling, degreasing bath	Water from 1st spray degreasing is treated and recycled to 2nd spray degreasing.
Pre-treatment, phosphating	Phosphating for corrosion protection of truck cabins in a series of steps.
Water Recycling, final dip rinse	Water from final dip rinse is treated and recycled to final dip rinse.
Cataphoresis (Electrophoresis)	Electro dip painting in a waterborne colour bath.
Powerwash	Washing of plastic components before painting.
Painting lines	Combined painting of truck cabins and plastic components.
Water for Cooling	Cooling of processes.

Table 21: Processes in the water use stage at Volvo Trucks, Gothenburg

Water use process	Description
Pre-treatment, degreasing	Degreasing of frame beams in a series of steps.
Pre-treatment, phosphating	Phosphating for corrosion protection of frame beams in a series of steps.

Table 22: Stages and corresponding processes in the wastewater side

Stages	Processes
Wastewater Side, Umeå site	
Collection 1	Wastewater in tanks.
WW Treatment 1	Wastewater treatment at Volvo Trucks, Umeå
Disposal 1	Water discharge to effluent point in Ume river, 90 m off-shore.
	Metal hydroxide sludge as hazardous waste to closed landfill.
Wastewater Side, Gothenburg site	
Collection 2	Wastewater collected in tank.
WW Treatment 2	Hazardous liquid waste treatment.
Disposal 2	Discharge to Göta river.

5.4.4 Mapping of industrial processes

The water using processes of Volvo Trucks, Umeå are mapped in Figure 30. Water input is (from top to bottom) (i) municipal water that has been purified by Volvo Trucks, (ii) river water extracted by Volvo Trucks, and (iii) ice river water extracted by Volvo trucks. All wastewater is collected in tanks and treated on site. Sludge from painting lines is sent to incineration. Metal hydroxide sludge is sent to landfill.

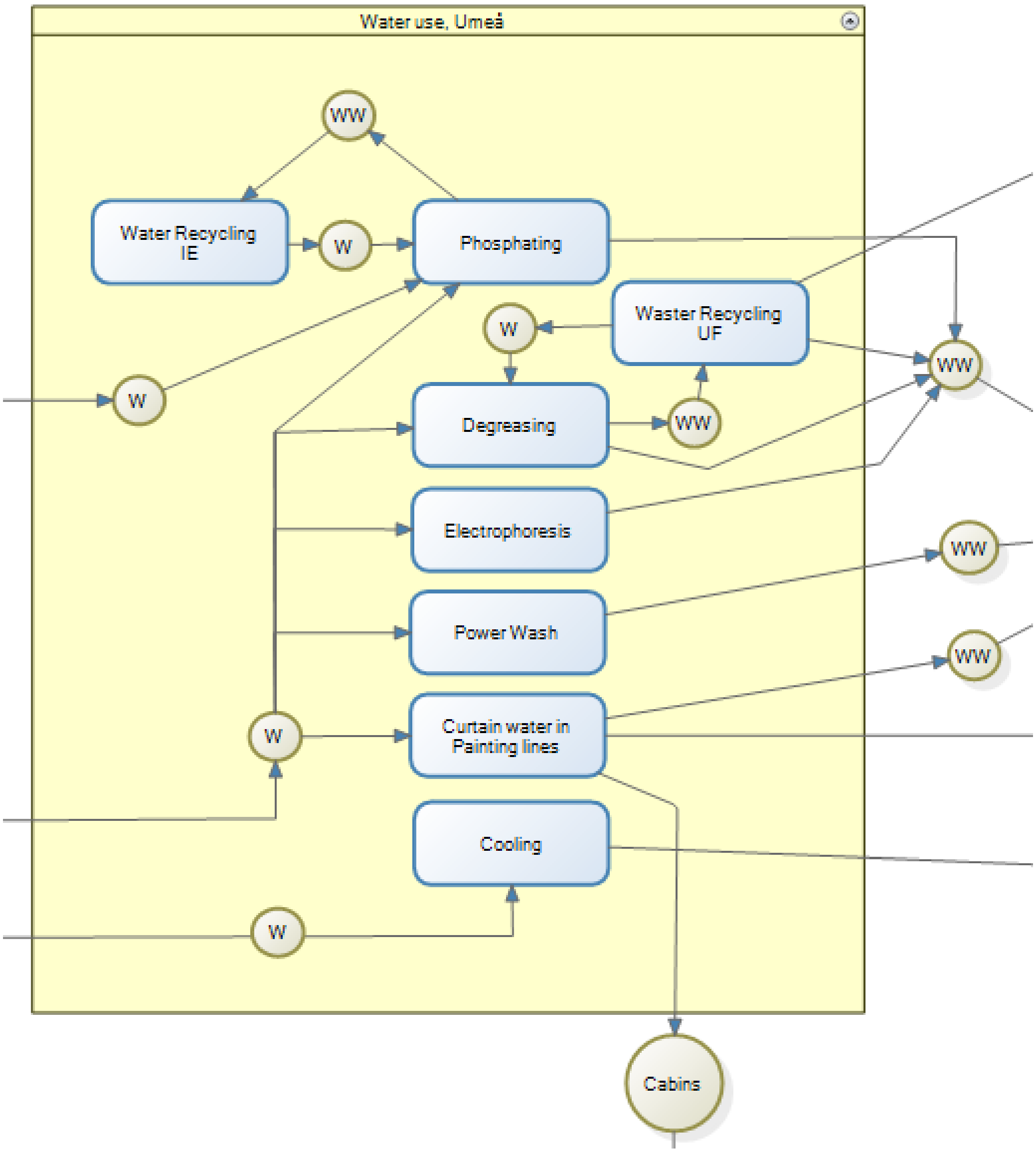


Figure 30: Map of the water using industrial processes at Volvo Trucks, Umeå, from the SEAT modelling tool.

Note: W = water, WW = Wastewater

The water using processes of Volvo Trucks, Gothenburg are mapped in Figure 31. Water input is (from top to bottom) municipal water and municipal water that has been purified by Volvo Trucks. Wastewater is treated by a private company, Stena Recycling.

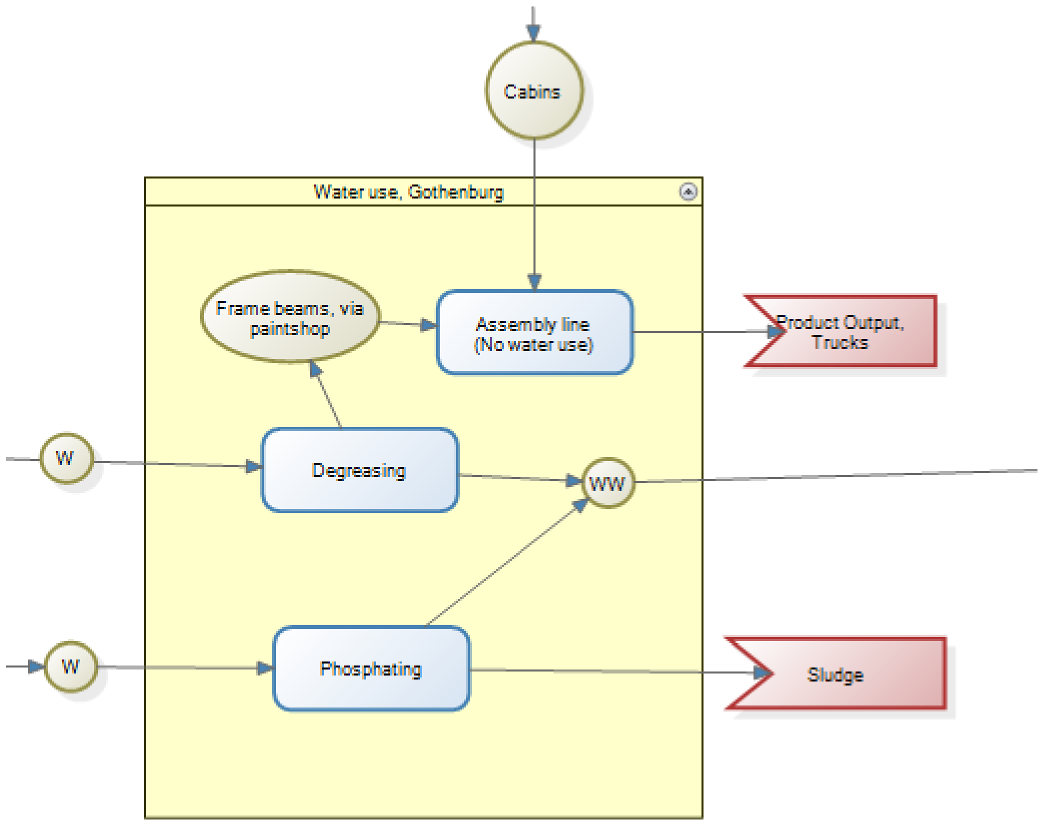


Figure 31. Map of the water using industrial processes at Volvo Trucks, Gothenburg, and of the assembly to a final product based on intermediate products of the two sites. The map is from the SEAT modelling tool

Note: W = water, WW = Wastewater

5.4.5 Description of existing technologies

The existing technologies for the corresponding processes are listed in Table 23, Table 24, Table 25 and Table 26. The phosphating technology for metal surface treatment is particularly interesting from an environmental perspective. Traditional technology uses the heavy metals Zn, Ni and Mn, and hence the sludge from the process is rich in heavy metals.

Table 23: Technologies in the processes of the water supply side

Processes	Current technology
Water Supply Side, Umeå site	
River water extraction and infiltration on top of ridge to produce artificial groundwater.	Pump
Extraction of artificial ground water mixed with natural ground water at the base of the ridge.	Pump from gravel filter
River water extraction.	Pump station at riverside. 2 hydrophores.
Extraction of sub-terrain water (ice rivers).	Pump
Municipal water treatment plant.	A series of 4 steps: • Aeration • Sand filtration • Carbonation • Alcaline filtration.
Water purification at Volvo Trucks, Umeå.	Reverse osmosis
Water Supply Side, Gothenburg site	
Extraction of river water.	Pump
Municipal water treatment plant.	A series of 4 steps: • Settler • Activated carbon filtra-tion • pH adjustment • Chlorination
Water purification at Volvo Trucks, Gothenburg.	Reverse osmosis

Table 24: Technologies in the processes of the water use stage at Volvo Trucks, Umeå

Water use process	Technology used
Pre-treatment, de-greasing	2 spray degreasing, 1 dip degreasing, 1 spray rinse and 1 dip rinse. Counter current flows to minimise water use (and chemical use).
Water Recycling, degreasing bath	Ultra filtration
Pre-treatment, phos-phating	1 activation bath, 1 Zn/Mn phosphating bath, 1 spray rinse, 1 dip rinse, 1 passivation bath and 1 dip rinse. Counter current flows to minimise water use.
Water Recycling, final dip rinse	Ion exchange
Cataphoresis (Electrophoresis)	Electrophoresis followed by a closed system of 3 rinse steps. Rinse water is recirculated to the rinse steps after ultrafiltration. (All excess colour is recovered and re-used)
Powerwash	Using surfactant free degreasing agent followed by rinsing in deion-ized water.

Water use process	Technology used
Painting lines	A total of 5 lines of spray booths. 2 parallel lines for priming, 1 line for waterborne basic colour and 2 lines for solvent borne colour. Venturie system, circulating water system, for recovery of paint missing the cabins when sprayed. 5 venturie systems, 3 separate flocculation/flotation tanks (chemical use) and 1 centrifuge for dewatering the sludge. Clear water is re-circulated to the venturie systems. The sludge is sent to Umeå Energi for incineration. Venturie water is dumped 1 time / yr.
Water for Cooling	Pump

Table 25: Technologies in the processes of the water use stage at Volvo Trucks, Gothenburg

Water use process	Technology used
Pre-treatment, degreasing	2 spray degreasing, 1 spray rinse and 1 combined spray rinse / spray activation step. Counter current flows to minimise water use (and chemical use).
Pre-treatment, phosphating	1 phosphating spray step and 4 spray rinse steps. Counter current flows to minimise water use.

Table 26: Technologies in the processes of the wastewater side

Processes	Current technology
Wastewater Side, Umeå site	
Wastewater in tanks.	Pump and/or free-fall
Wastewater treatment at Volvo Trucks, Umeå	A series of 5 steps: • pH adjustment with $FeCl_3$ • pH adjustment with $Ca(OH)_2$ • Flocculation using polymer • Lamella settler • Sludge compression.
Water discharge to effluent point in Ume river, 90 m off-shore.	Pump
Metal hydroxide sludge as hazardous waste to closed landfill.	Shipment by truck
Wastewater Side, Gothenburg site	
Wastewater collected in tank.	Pump and/or free-fall to collection tank. Shipped by truck to treatment on regular basis.
Hazardous liquid waste treatment.	Biological and chemical treatment.
Discharge to Göta river.	Pump

5.5 Value Chain Mapping

The directly and indirectly involved actors are presented in Table 27. The information provided for the indirectly involved actors shows their relation to the industrial sites of Volvo Trucks, Umeå and Gothenburg. Table 28 and Table 29 present a more complete overview of the interactions between the directly and indirectly involved actors of the system, and among the indirect actors. Figure 32 shows the mapping of the directly involved actors in the different stages of the system (Volvo Trucks is regarded as one actor because the two sites are part of the same corporation).

Table 27: The directly and indirectly involved actors

Actor role/function	Umeå site	Gothenburg site
Directly involved actors		
Municipal water supply	UMEVA, municipal corporation	Göteborg Vatten, administration within Gothenburg municipality
Automotive industry	Volvo Trucks Umeå	Volvo Trucks Tuve
Wastewater treatment	(On-site wastewater treatment at Volvo Trucks)	Stena Recycling, Gothenburg
Indirectly involved actors		
County administrative board (for issuing limits on emissions)	Länsstyrelsen Västerbotten	Länsstyrelsen Västra Götaland
Municipal environmental authority (supervisory authority)	Samhällsbyggnadskontoret, Miljö- och hälsoskyddsnämnden, Umeå kommun	Miljöförvaltningen, Göteborgs stad
Water management authorities (regional decisions and co-ordination)	Vattenmyndigheten i Bottenviken (Länsstyrelsen Norrbotten)	Vattenmyndigheten i Västerhavet (Länsstyrelsen Västra Götaland)
National water management authority	Havs- och Vattenmyndigheten (very high level, do not deal with specific issues of the industrial sites.)	
Environmental court (appealing instance)	Mark- och miljödomstolen	
Suppliers of treatment technologies	Specific suppliers cannot be named due to Volvo Trucks company policy.	
Non-profit organisations	Ume- och Vindelälvens vattenvårdsförbund, Coordinated recipient control.	Göta älvs vattenvårdsförbund.
Consumers	Automotive consumers for trucks	

Table 28. Summary of interactions between actors for the Umeå site.

UMEÅ SITE	UMEVA **(municipal water supply corporation)**	Volvo Trucks Umeå	Suppliers of treatment technologies	Mark- och miljödomstolen **(land and environment courts)**	Länsstyrelsen Västerbotten **(county administrative board)**	Samhällsbyggnadskontoret, Miljö- och hälsoskyddsnämnden, Umeå kommun **(municipal environmental authority)**	Vattenmyndigheten i Bottenviken **(regional water management authorities)** including the Water delegation	Havs- och vattenmyndigheten **(national water management authority)**	Naturvårdsverket **(Swedish EPA)**	Ume- och Vindelälvens vattenvårdsförbund **(Ume and Vindel River Water Conservation Society)**	Svenska Sportfiskeförbundet **(Swedish Sports Fishing Society)**
UMEVA **(municipal water supply corporation)**		Water supply to site.	Buy technologies.	Appeal, e.g. against decisions by county administrative board.	Environmental reporting. Permit application. Appeal, e.g. against decisions by municipal environmental authority.	Notification of minor changes within current permit.	-	-	-	Inform publically in connection to larger permit process	Inform publically in connection to larger permit process
Volvo Trucks Umeå	Pay for service of water supply.		Buy technologies.	Appeal, e.g. against decisions by county administrative board.	Permit application (at MPD, an independent delegation of the county administrative board). Appeal, e.g. against decisions by municipal environmental authority.	Environmental reporting. Notification of minor changes within current permit.	-	-	-	Inform publically in connection to larger permit process	Inform publically in connection to larger permit process
Suppliers of treatment technologies	Sell technologies.	Sell technologies.									
Mark- och miljödomstolen **(land and environment courts)**	Decides permits.	Appealing instance.	-		-	-	-	-	-	-	-
Länsstyrelsen Västerbotten **(county administrative board)**	New permits: Decide permits. Issues limits on emissions. Appealing instance. Consequently: Review environmental report. Appealing instance.	New permits: Decide permits. Issues limits on emissions. Appealing instance. Consequently: Appealing instance.	-	-		Supervisory guidance.	-	-	-	Inform in connection to decisions process.	Inform in connection to decisions process.
Samhällsbyggnadskontoret, Miljö- och hälsoskyddsnämnden, Umeå kommun **(municipal environmental authority)**	Approval/disapproval of notifications.	Supervision of emissions limits. Review environmental report. Approval/disapproval of notifications.	-	-	Annual reports of selected activities (e.g. supervision activities)		-	-	-	Inform in connection to decisions process.	Inform in connection to decisions process.
Vattenmyndigheten i Bottenviken **(regional water management authorities)** including the Water delegation		*Decides environmental quality standards.*	-	-	Regional decision and coordination.	Regional decision and coordination.		Regional decision and coordination.	Regional decision and coordination.	*Regional decision and coordination.*	*Regional decision and coordination.*
Havs- och vattenmyndigheten **(national water management authority)**	*Issues guidelines and regulations.*	*Issues guidelines and regulations.*	-	-	High-level policy for good environmental status, based on Water Framework Directive. Issues guidelines.	High-level policy for good environmental status, based on Water Framework Directive. Issues guidelines.	High-level policy for good environmental status, based on Water Framework Directive. Issues guidelines.		High-level policy for good environmental status, based on Environmental Act in particular, but also Water Framework Directive, Marine framework Directive.	-	-
Naturvårdsverket **(Swedish EPA)**	*Issues guidelines and regulations.*	*Issues guidelines and regulations.*	-	-	Harmful substances regulation. Issues guidelines (general and/or specific)	Harmful substances regulation. Issues guidelines (general and/or specific)	Harmful substances regulation. Issues guidelines (general and/or specific)	-		-	-
Ume- och Vindelälvens vattenvårdsförbund **(Ume and Vindel River Water Conservation Society)**	Look for public interest. Reviewing instance in permit application.	Look for public interest. Reviewing instance in permit application.	-	Appeal, e.g. against decisions by county administrative board	Appeal, e.g. against decisions by municipal environmental authority.	Report, e.g if actors do not follow permit conditions.	Look for public interest. Reviewing instance in regulation process.	Look for public interest. Reviewing instance in regulation process.	Look for public interest. Reviewing instance in regulation process.		-
Svenska Sportfiskeförbundet **(Swedish Sports Fishing Society)**	Look for public interest. Reviewing instance in permit application.	Look for public interest. Reviewing instance in permit application.	-	Appeal, e.g. against decisions by county administrative board	Appeal, e.g. against decisions by municipal environmental authority.	Report, e.g if actors do not follow permit conditions.	Look for public interest. Reviewing instance in regulation process.	Look for public interest. Reviewing instance in regulation process.	Look for public interest. Reviewing instance in regulation process.	-	

Note: Read table from left to right to find what one actor does for another actor

Table 29. Summary of interactions between actors for the Gothenburg site.

GBG SITE	Göteborg Vatten **(water supply administration within Gothenburg municipality)**	Volvo Trucks Tuve (represented by Volvo Technology)	Stena Recycling **(wastewater treatment company)**	Suppliers of treatment technologies (including chemical suppliers)	Mark- och miljödomstolen **(land and environment courts)**	Länsstyrelsen Västra Götaland **(county administrative board)**	Miljöförvaltningen, Göteborgs stad **(municipal environmental authority)**	Vattenmyndigheten i Västerhavet **(regional water management authorities)** including the Water delegation	Havs- och vattenmyndigheten **(national water management authority)**	Naturvårdsverket **(Swedish EPA)**	Göta älvs vattenvårdsförbund **(Göta River Water Conservation Society)**	Svenska Sportfiskeförbundet **(Swedish Sports Fishing Society)**
Göteborg Vatten **(water supply administration within Gothenburg municipality)**		Water supply to site.	Water supply to site.	Buy technologies.	Appeal, e.g. against decisions by county administrative board.	Environmental reporting. Permit application. Appeal, e.g. against decisions by municipal environmental authority.	Notification of minor changes within current permit.	-	-	-	Inform publically in connection to larger permit process	Inform publically in connection to larger permit process
Volvo Trucks Tuve	Pay for service of water supply.		Pay for service of wastewater treatment.	Buy technologies.	Appeal, e.g. against decisions by county administrative board.	Permit application (at MPD, an independent delegation of the county administrative board). Appeal, e.g. against decisions by municipal environmental authority.	Environmental reporting. Notification of minor changes within current permit.	-	-	-	Inform publically in connection to larger permit process	Inform publically in connection to larger permit process
Stena Recycling **(wastewater treatment company)**	Pay for service of water supply.	Treatment of process wastewater.		Buy technologies.	Appeal, e.g. against decisions by county administrative board.	Environmental reporting. Permit application. Appeal, e.g. against decisions by municipal environmental authority.	Notification of minor changes within current permit.	-	-	-	Inform publically in connection to larger permit process	Inform publically in connection to larger permit process
Suppliers of treatment technologies (including chemical suppliers)	Sell technologies.	Sell technologies.	Sell technologies.									
Mark- och miljödomstolen **(land and environment courts)**	Decides permits.	Appealing instance.	Decides permits.	-		-	-	-	-	-	-	-
Länsstyrelsen Västra Götaland **(county administrative board)**	New permits: Decide permits. Issues limits on emissions. Appealing instance. Consequently: Review environmental report. Appealing instance.	Appealing instance on decicions from Miljöförvaltningen. MPD, an independent delegation of the county administrative board, decides on new permit applications. Issues limits on emissions.	New permits: Decide permits. Issues limits on emissions. Appealing instance. Consequently: Supervision of emissions limits. Review environmental report. Appealing instance.	-	-		Supervisory guidance.	-	-	-	Inform in connection to decisions process.	Inform in connection to decisions process.
Miljöförvaltningen, Göteborgs stad **(municipal environmental authority)**	Approval/disapproval of notifications.	Supervision of emissions limits. Review environmental report. Approval/disapproval of notifications.	Approval/disapproval of notifications.	-	-	Annual reports of selected activities (e.g. supervision activities)		-	-	-	Inform in connection to decisions process.	Inform in connection to decisions process.
Vattenmyndigheten i Västerhavet **(regional water management authorities)** including the Water delegation		*Decides environmental quality standards.*	Decides environmental quality standards.	-	-	Regional decision and coordination.	Regional decision and coordination.		Regional decision and coordination.	Regional decision and coordination.	*Regional decision and coordination.*	*Regional decision and coordination.*
Havs- och vattenmyndigheten **(national water management authority)**	*Issues guidelines and regulations.*	*Issues guidelines and regulations.*	*Issues guidelines and regulations.*	-	-	High-level policy for good environmental status, based on Water Framework Directive. Issues guidelines.	High-level policy for good environmental status, based on Water Framework Directive. Issues guidelines.	High-level policy for good environmental status, based on Water Framework Directive. Issues guidelines.		High-level policy for good environmental status, based on Environmental Act in particular, but also Water Framework Directive, Marine framework Directive.	-	-
Naturvårdsverket **(Swedish EPA)**	*Issues guidelines and regulations.*	*Issues guidelines and regulations.*	*Issues guidelines and regulations.*	-	-	Harmful substances regulation. Issues guidelines (general and/or specific)	Harmful substances regulation. Issues guidelines (general and/or specific)	Harmful substances regulation. Issues guidelines (general and/or specific)	-		-	-
Göta älvs vattenvårdsförbund **(Göta River Water Conservation Society)**	Look for public interest. Reviewing instance in permit application.	Look for public interest. Reviewing instance in permit application.	Look for public interest. Reviewing instance in permit application.	-	Appeal, e.g. against decisions by county administrative board	Appeal, e.g. against decisions by municipal environmental authority.	Report, e.g if actors do not follow permit conditions.	Look for public interest. Reviewing instance in regulation process.	Look for public interest. Reviewing instance in regulation process.	Look for public interest. Reviewing instance in regulation process.		-
Svenska Sportfiskeförbundet **(Swedish Sports Fishing Society)**	Look for public interest. Reviewing instance in permit application.	Look for public interest. Reviewing instance in permit application.	Look for public interest. Reviewing instance in permit application.	-	Appeal, e.g. against decisions by county administrative board	Appeal, e.g. against decisions by municipal environmental authority.	Report, e.g if actors do not follow permit conditions.	Look for public interest. Reviewing instance in regulation process.	Look for public interest. Reviewing instance in regulation process.	Look for public interest. Reviewing instance in regulation process.	-	

Note: Read table from left to right to find what one actor does for another actor

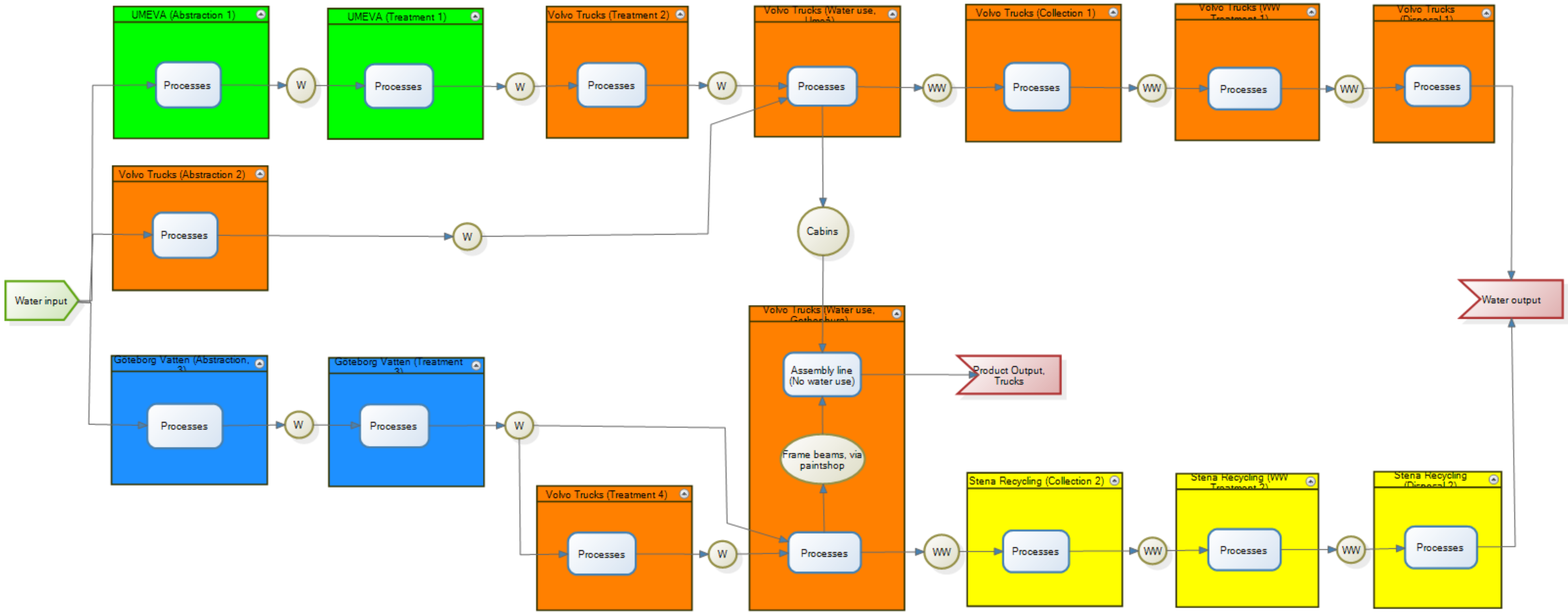


Figure 32: Colour coded stages according to the operating actor, from the EVAT modelling tool

Note: Green = UMEVA, Blue = Göteborg Vatten, Orange = Volvo Trucks, Yellow = Stena Recycling

The interactions among the directly involved actors are illustrated in Figure 33. Volvo Trucks purchase municipal water from UMEVA and Göteborg Vatten. The internal product of truck cabins is transferred from the Umeå site to the Gothenburg site. The Umeå site treats its own wastewater, whereas the Gothenburg site pays Stena Recycling for treatment of the generated wastewater. Income is generated by Volvo Trucks, Gothenburg (aka Tuve) by the final sales of assembled trucks.

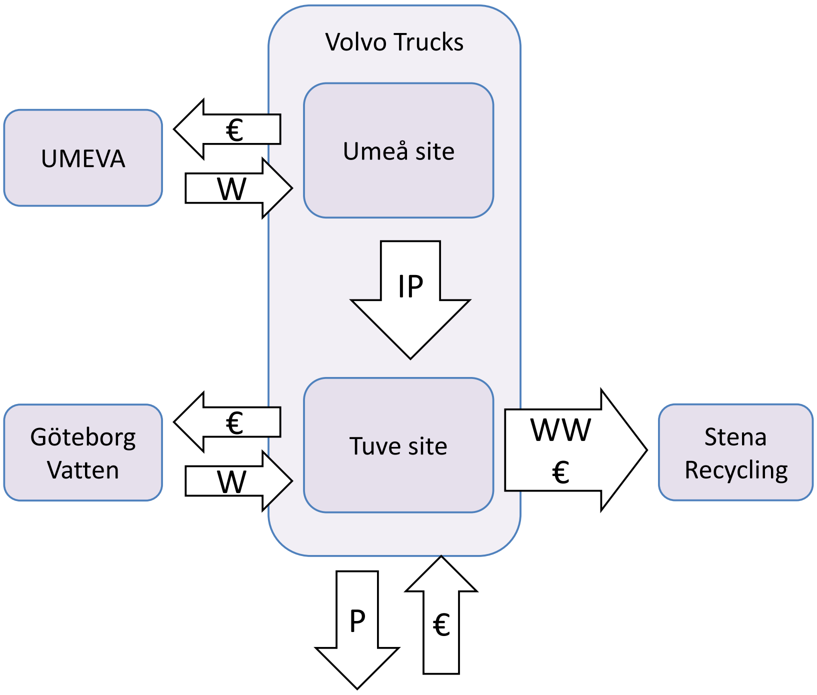


Figure 33: Interactions among the directly involved actors

Note: Arrows indicate the transfer of money (€), water (W), internal product (IP) and wastewater (WW). The final product (P) of Volvo Trucks is trucks

5.6 Selection of eco-efficiency indicators

5.6.1 Environmental impacts

A number of environmental impacts, which differ in relevance for the stages of the system, are important. The screening of environmental impacts per stage, which was performed in Task 1.1, provided the results presented in Table 30.

Table 30: Relevance of environmental impacts per stage

Stage	Indicators of importance, (Possibly important)
Abstraction	Water quantity, Resource use
Treatment	Water quality, Resource use, (Solid waste)
Water use	Water quality, Ecotoxicity, Resource use, (Solid waste)
Collection	(Resource use)
WW Treatment	Water Quality, Ecotoxicity, Resource use, Solid waste
Disposal	Water quality

Table 31 summarises the environmental indicators that could form the environmental part of eco-efficiency indicators.

Table 31: List of environmental impact indicators to be used primarily for Case Study # 8

Indicator	Importance of indicator	Indicator Parameters
Water quality	Important	PO_4, P Total, BOD (Biological oxygen demand), COD (Chemical oxygen demand), Temperature, Mineral oil
Water quantity	Important to the industry even though it is not located in an area of water scarcity.	Quantity of water used
Ecotoxicity	Important	Nickel (Ni), Zinc (Zn), TEH (Total Extractable Hydrocarbons
Resource use*	Important	Electricity, Transport fuels, Surface Water, Groundwater, Other water, Chemicals, Dolomite (crushed), Sand
Solid waste	Important	Waste to landfill, Waste to incineration plant, Waste to recycling plants

***Note:** An additional analysis will be performed on resources used, see the Methodology description in Section 5.3.

5.6.2 Economic costs and benefits

For the Umeå site, UMEVA bears the cost of water abstraction, purification and distribution of municipal water. They charge Volvo Trucks Umeå for the supplied water at a set tariff of 7.89 SEK/m^3. Additional costs endured by Volvo Trucks are their own water abstraction and purification, production costs other than water and the cost of treating wastewater on-site. There is no fee for releasing the treated wastewater to the recipient, Ume River. However, Volvo trucks Umeå is charged a wastewater fee of 7.43 SEK/m^3 by UMEVA, which corresponds to the volume of freshwater purchased.

Similarly for the Gothenburg site, the municipal administration Göteborg Vatten abstracts, purifies and distributes the municipal water. Volvo Trucks Gothenburg are charged according to a set tariff of 5.98 SEK/m^3. Additional costs endured by Volvo Trucks are their own water purification, production costs other than water and the cost of treating wastewater externally. Process wastewater is collected and shipped by truck for treatment at Stena Recycling; this service is paid by Volvo Trucks. Stena Recycling treats different kinds of liquid wastes and the corresponding costs for this operation are recovered from the fee charged to customers, including a net profit. Income is generated by Volvo Trucks by the final sales of assembled trucks.

5.7 Preliminary identification of technologies to be assessed

Table 32 holds the current list of technologies to be assessed. The list is preliminary, and will be finalized during Task 4.3 "Identification of technologies for eco-efficiency improvement", following discussions with local actors/stakeholders.

Table 32: Preliminary list of technologies to be assessed

Technology	Related Process
Water Supply Side	
Carbon filtration	Water purification
Zeolite or membrane softening	
Micro-filtration	
Reverse osmosis	
Ion exchange	
Water Use Side	
Separation technologies & configurations for internal recycling (e.g. ultra filtration, precipitation, flotation, centrifugation, counter current flows)	Pre-treatment, degreasing Pre-treatment, phosphating
"Traditional" phosphating technology	Pre-treatment, phosphating
Oxilan® (Phosphating technology which uses silane instead of Zn, Ni and Mn)	
Closed-loop processes (e.g. venturie system)	Painting lines
Energy recovery	Water use processes
Wastewater Side	
Metals' treatment (chemical precipitation)	Wastewater treatment
Clarification	
Oils/water separation	
Handling of wastewater streams from painting processes (chemical precipitation)	

6 Concluding remarks

In Case Study # 5, the industries are interested to identify key technologies that can reduce the use of water, as the prices for water supply and wastewater treatment have gradually increased over the recent years. The introduction of new technologies may also lead to the reduction of the impacts on surface water and groundwater quality. Improved quality of sludge from treatment plants can lead to increased use of sludge in agriculture, which can subsequently reduce the use of chemical fertilizers.

In Case Study # 6, there is a possibility to further analyse technologies that can decrease the impact of thermal discharges to surface water and reduce the dependency of energy plants on the availability of cooling water. The solutions require a strong interaction with key stakeholders, as the water system has strong interactions with the energy system.

For Case Study # 7, the environment strategy and plans of the industry have a clear focus to reduce the use of resources in the production and use new, key technologies to reach this goal. A better understanding of the water system and how it interacts with the production process and how the water which is in the raw material may replace some of the water abstracted is seen as a way both to decrease the environmental impact and increase the economic outputs. The long-term goal (20-30 years perspective) may be to use water only from the milk. The industry is committed to comply with the Water Framework Directive, the Habitat Directive and the Groundwater Directive. Nonetheless, it is also interested in having a dialogue with the local and national Danish authorities, in order to identify more eco-efficient ways than those currently implemented for complying with the aforementioned Directives.

For Case Study # 8, it is clear that the industry is very well-aware of environmental demands from customers, as well as pre-requisites for natural resources, which are reflected in legislation and policies. A current trend for the products of the automotive industry is to move away from the dependency on petroleum products, such as fuel, and towards a larger use of renewable fuels. The demand for hybrid cars and pure electrical cars has increased over the years. The environmental awareness is also reflected in the industry's ambition to making improvements in its manufacturing processes. The goal is both to reduce the use of water and energy and shift from the surface treatment technology (using heavy metals) to more environmentally friendly alternatives.

The Water Framework Directive is naturally of importance for the automotive industry, which is a water using sector.

7 References

7.1 References on methodologies

EcoWater Website (http://environ.chemeng.ntua.gr/ecowater)

7.2 References for Case Study # 7

Indicators template for CS#7 (version No.1, April 2012, uploaded at the EcoWater website on 28/08/2012)

Arla, www.arla.com / www.arla.dk

Danish Ministry of the Environment, www.mst.dk

Danish Nature Agency, www.naturstyrelsen.dk

7.3 References for Case Study # 8

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8 Glossary

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 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

Environmental indicators

Environmental Indicators cover all environmental pressures other than direct resource-use, and ideally include all emissions from the production and consumption of goods and services, and waste generation.

Source: UN/ESCAP, 2009

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

Water services

Water services include all services which provide water for households, public institutions or any economic activity:

1. Abstraction, impoundment, storage, treatment and distribution of surface water or groundwater,
2. Waste-water collection and treatment facilities which subsequently discharge into surface water.

Source: EC/Water Framework Directive

Water service system (or system of water use)

A system, which provides water suitable (in terms of quantity and quality) to meet the requirements of specific activities, or, in other terms, a system which includes the entire range of water services required to render water suitable for a specific water use purpose, and safely discharging it to the water environment. This system also includes water using processes/economic activities (see water use stage).

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

CIP – Cleaning in Place

When production equipment or pipings are cleaned without opening and with scarce manual operations. Mostly CIP is done by high velocity circulation of water, cleaning agents and disinfectants through pipes, heat exchangers and tanks. Used in dairies, breweries, juice production etc.

IVL Swedish Environmental Research Institute Ltd., P.O. Box 210 60,
S-100 31 Stockholm, Sweden
Phone: +46-8-598 563 00 Fax: +46-8-598 563 90
www.ivl.se